Mississippi Valley Division,
Regional Planning and Environment Division South

St. Tammany Parish, Louisiana Feasibility Study

Appendix C – Annex E - Endangered Species Act

July 2023

Fish and Wildlife Service general information and guidance for FEMA projects regarding the proposed alligator snapping turtle

Louisiana Ecological Services Office

Areas and Habitat Conditions likely to host AST

The alligator snapping turtle (AST) has a wide geographic range and occurs in bayous, rivers, streams, swamps, and lakes in Texas, Louisiana, Oklahoma, Arkansas, Missouri, Illinois, Kentucky, Tennessee, Mississippi, Alabama, Georgia, and Florida. They prefer water bodies (small streams [perennial], bayous, canals, swamps, lakes, reservoirs, ponds, and oxbows) with overhang banks and adjacent riparian forest, especially bald cypress bordered banks. Sections of waterways with steep-sloped banks, or those lined with concrete, stone, etc. are likely avoided, especially when there are no trees on the bank. However, relatively short sections of non-preferred bank composition do not necessarily preclude occupation of the entire waterway. They may venture onto the adjacent floodplain during high water events. Although they have been found at the edge of the Gulf of Mexico, coastal marshes and saline water are not their preferred habitat type. They also prefer waterbodies with snags and submerged logs, tree root masses, or other debris in the water. Adults generally stick to deeper water (enough to cover their body to deeper than 20ft), but in areas with deep, loose mud, they have been found in 10 inches of water with a mud layer of several feet. Juveniles can be found in shallow streams less than 1 foot deep. AST are sensitive to water temperature and will change locations as needed to thermoregulate. AST generally stay on the water bottom, but they do move along the bottom, and can travel considerable distances (miles) in just days or weeks. Trapping surveys are generally effective at locating AST, but lack of capture, especially during short-term limited area survey efforts, does not confirm absence.

AST rarely leave the water except for nesting females generally from April to early July (typically April-May in southern parts of the range including Louisiana and May-July in north/western portion of the range). Egg incubation time is generally between 96 and 143 days. Nesting areas may have varying amounts of canopy cover. Nests are generally located between 4 and 656 feet from the water line, and more likely less than 300 feet from the water line.

Potential project effects on the species

<u>Individuals</u>

Adults, juveniles, and hatchlings could be killed, injured, or stressed by instream operation of heavy equipment (e.g., excavator, bucket dredge, hydraulic dredge, shallow water watercraft, etc.)

Nesting females, eggs, and hatchlings could be killed, injured, or stressed by operation of heavy equipment or other disturbance in the riparian zone adjacent to waterbodies during the nesting/hatching season.

<u>Habitat</u>

Removal of snags, submerged logs, and other debris would decrease the value of or eliminate aquatic habitat.

Removal of trees at the bank and adjacent forest could degrade nesting habitat and would likely decrease the use of adjacent aquatic habitat.

Bank hardening and change of bank incline would likely eliminate nesting in the area, and significant use of the adjacent aquatic habitat.

Conservation Recommendations

To minimize effect on AST habitat:

Limit work to deepest part of channels

Limit work to areas previously disturbed or lacking snags, submerged logs or other cover used by AST

Use floating work platform instead of ground-based equipment

Relocate woody debris to streamside instead of removing completely

Minimize removal of trees and brush on bank adjacent to waterbodies

Avoid the use of concrete or other bank hardening methods

To minimize effect on individuals:

Limit work to areas unlikely to be occupied by adult or juvenile AST or live AST nests

Use floating work platform instead of ground-based equipment

If removing snags is necessary, pull up from above water instead of digging out

Avoid work on streamside from the water's edge to 200 meters away during times of the year when nesting/hatching are occurring

Limit work to deepest part of main channels except during the hottest times of the year

Conferencing with Fish and Wildlife Service

Because the AST is proposed, the only requirement for federal agencies is to "confer" (rather than consult) with the Service if any proposed actions are determined by them to be likely to jeopardize the existence of a proposed species or result in destruction or adverse modification of critical habitat. There is currently no critical habitat designated, or proposed, for the AST, so the focus would be mostly on the species itself. Note that regardless of critical habitat, effects on habitat are still considered when analyzing effects on species. (Note: *In certain circumstances, emergency actions in presidentially declared disaster areas can be exempted from the requirements of consultation under sec 7(a)(2) of the Endangered Species Act*.).

Project actions that "may affect" the species do not necessarily make the action, "likely to jeopardize the existence of a proposed species". Actions that kill an individual or even multiple individuals also may not necessarily result in a likely jeopardy determination. The AST has a large multistate range, and the

species is estimated to be comprised of many thousands of individuals. Any effects determination should consider the spatial extent of project effects when analyzing effects on populations and ultimately the species as a whole.

It is the policy of the Service to conduct conferencing if the lead federal agency requests a conference. The Service would require all the same types of information about the project(s) including project timing, specific work, equipment, and expected effects on the species, as when conducting a consultation for a listed species. The Service's practice is to conduct and conclude conferencing in the same manner and time frame as consultations which require variable amounts of time to complete depending on complexity and whether the conference is informal or formal.

Appendix: Project Description for the Optimized Tentatively Selected Plan
St. Tammany Parish Louisiana Feasibility Study

SUMMARY

PROJECT DESCRIPTION
for the
Optimized Tentatively Selected Plan
St Tammany Parish Louisiana Feasibility Study

1.0 INTRODUCTION

Subsequent to the release of the June 2021 Draft Integrated Feasibility Report and Draft Environmental Impact Statement (DIFR and DEIS), the Project Delivery Team (PDT) conducted additional engineering, economic, and environmental investigations on the individual features of the Optimized Tentatively Selected Plan (TSP) which is comprised of a structural plan and a non-structural plan. Information gathered by the PDT through these additional investigations, together with the consideration of comments received from the public, stakeholders, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service assisted the PDT in further refining the design of the Draft TSP. This document is a summary project description of the proposed Optimized TSP. Refer to Appendix F and H for the full description of the non-structural plan and Appendix D for full description of the structural plan.

1.1 SCOPE OF WORK

The Optimized TSP includes a non-structural plan and a structural plan. For planning purposes, the 50-yr period of analysis for the study was estimated to be from the year 2032 to 2082. Project authorization would occur in the year 2024 and kick-off planning, engineering, and design (PED). PED was originally estimated to be complete by the year 2027. Initial construction of the project would begin 2027 and conclude by the year 2032 (base year). These original assumptions will be revised once the construction schedule is prepared by the Cost team in MVN Engineering. Figure 1-1 illustrates the optimized TSP including a non-structural and a structural plan.

<u>Non-Structural Plan</u>:

Insert summary of the non-structural plan from Economics.

<u>Structural Plan</u>:

The structural plan consists of construction of a levee and floodwall system along an alignment in South and West Slidell and channelization of a portion of the Mile Branch in Covington.

1.2 **Mile Branch Channel Improvement:** This measure consists of channel improvements on the lower 2.15 miles (11,341 ft channel) of Mile Branch in Covington, Louisiana. The proposed work would consist of approximately 20 acres of channel that would be cleared and grubbed prior to mechanical dredging.

The mechanical dredging would consist of a maximum of 130,000 cubic yards of fill dredged from the channel. There are no surveys available for this area for this study, and no surveys will be conducted during the study phase. The existing elevations used for the hydraulic analysis and design of the Optimized TSP were obtained from the LIDAR raster dataset. Designs are based on existing information gathered from reports provided by the non-Federal sponsors as shown on Table 1.2 in the main report.

Design refinements would occur during PED based on field data collections. Based on data collected, the design would be refined to minimize impacts to aquatic and riparian habitat and real estate. Riparian Zone bioengineering techniques and nature-based-solutions (NBS) would be incorporated as appropriate during PED in coordination with the NFS and resource agencies. A backwater area has been incorporated in the design of Mile Branch.

Table 1.1 lists the Mile Branch attributes of the TSP for the 50-year period of analysis.

Table 1.1 Summary Table of TSP for Mile Branch

Attribute	**Mile Branch Channel Improvements**
Total Length of improvements	2.15 miles (11,341 feet)
Material to be Mechanically Dredged	130,000 cubic yards
Access Roads for both clearing and for bridge replacement?	0 acres
Number of staging areas for clearing and grubbing and mechanical dredging and for culvert/bridge replacement	19 (7 for culvert/bridge replacements, 11 for clear and grubbing and mechanical dredging and one that becomes a backwater area)
Number of Bridge Replacements of Culverts	7
Temporary ROW	7.3 acres (2.2 acres for culvert/bridge replacements and 5.1 acres for clear and grubbing and mechanical dredging)
Permanent ROW	38.5 acres (34 acres for clear and grubbing and mechanical dredging and 4.5 acres for one staging area that becomes a backwater area)

The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and end at the intersection of Mile Branch and the Tchefuncte River. Assumptions for channel improvements included a 65-ft from the centerline of each side of the channel for ROW as a general guideline (total width of 130 ft).

The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel would be widened as well as deepened. The channel bottom would be lowered by 5 ft. All work would be performed from the bank. The trees located close to the bank would be removed. The banks would be stabilized and seeded and fertilized to have a grass cover. Work would be done by excavators or small skid steers.

Material removed may include sediment, trees, debris, or other obstructions within the waterway. Removed material would be trucked off-site and disposed at a facility licensed to handle the material. Site access to Mile Branch would be via public roads and public rights of way.

For the channel improvements, approximately 34 acres of permanent ROW would be needed. This area would include 25 ft on each side of the Mile Branch channel. Within the 34 acres, approximately 21 acres of channel would be cleared and grubbed prior to mechanical dredging. An assumed maximum of 130,000 cubic yards of material may be mechanically dredged from the channel.

Mile Branch improvements may include bridge replacements or culverts. Approximately 2.2 acres would be required for staging along the various areas of the bridge/culvert replacements.

1.3 <u>South and West Slidell Levee and Floodwall Alignment:</u> The levee and floodwall system would consist of a total of approximately 18.4 miles (96,950 feet) of earthen levee and floodwall which includes approximately 15 miles (79,100 feet) of levees constructed in separate (non-continuous) segments, and 3.4 miles (17,850 feet) of separate (non-continuous) segments of a floodwall. Construction of the levee alignment would impact approximately 520.7 acres of permanent ROW and it would require approximately 7,069,000 cubic yards of fill, including fill material required for future levee lifts (estimates include a 30 percent contingency). Table 1.2 provides a summary of the attributes of the South and West Slidell Levee and Floodwall System. Table 1.3 is a summary of the levee quantities required for the initial construction.

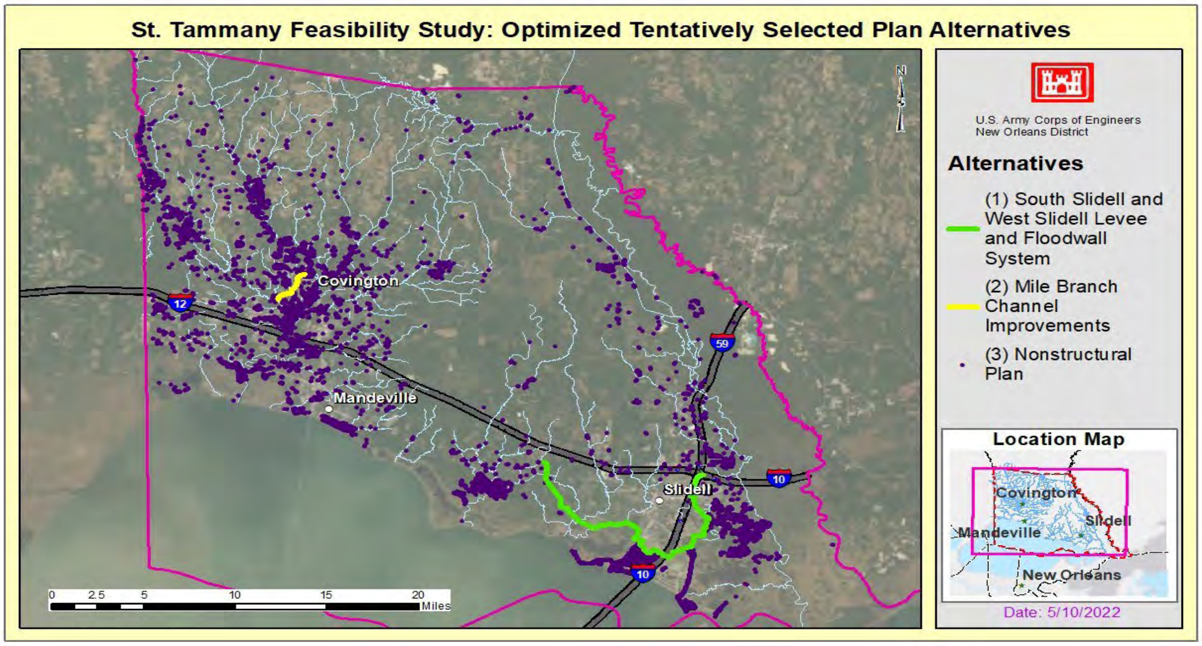

Figure 1-1. Optimized Tentatively Selected Plan

Table 1.2 Summary Table of South Slidell and West Slidell Levee and Floodwall System

Attribute	**South Slidell and West Slidell Levee and Floodwall System**
Total Length of alignment	18.4 miles (96,950 feet)
Length of Floodwall	3.4 miles (17,850 feet)
Length of earthen Levee	15 miles (79,100 feet)
Temporary Acres of Construction for Levee and Floodwall system	109 acres
Permanent Acres for Levee and Floodwall system	521 acres
Hydraulic Design Elevation Range (Dependent on location)	13.5 to 16 (year 2032) 17.5 to 20 (year 2082)
Pump Stations	8
Sluice Gates/Lift Gates	13
Number of Vehicular Floodgates	16
Number of Pedestrian Floodgates	1
Number of Railroad Gates	1
Number of Road Ramps	11
Fill (Borrow Material) Required	7,069,000 cubic yards

The existing elevations utilized were obtained from the LIDAR raster dataset. No survey data was obtained at this stage of the study; therefore, a 30% contingency was

used for the calculation of the borrow quantities for the South Slidell and West Slidell levee alignment.

Table 1.3 Summary Table: TSP Levee Quantities for Initial Construction

Levee Alignment ROW and Levee Quantities Initial Construction (Year 2032)	
WEST SLIDELL	
Permanent ROW	240 acres
Fill Material (includes 30% contingency)	2,007,000 cubic yards
SOUTH SLIDELL	
Permanent ROW	120 acres
Fill Material (includes 30 %contingency)	825,000 cubic yards**
TOTAL	
Permanent ROW	360 acres
Fill Material (includes 30 % contingency)	2,832,000 cubic yards

**includes quantities for I-10 portion of the alignment.

Levee lifts would be required over the 50-yr period of analysis. The levee lift schedule would follow the hydraulic design elevation requirements and thus were divided into 3 geotechnical reaches: Oak Harbor South; I-10 Crossing and Slidell East/Northeast as illustrated in Table 1-4. The fourth lift (final lift for the 50-year period of analysis), projected to occur in year 2076 would elevate the levee to a construction elevation of 19 ft. It is during the scheduled 4th lift that construction of the Western High Ground Tie-in would be necessary for year 2082. The fill quantities listed for the 4th lift, include quantities for the construction of the Western High Ground Tie-In.

Table 1.4. Future Levee Lifts

	Construction Lift (year)	**Construction Elevation (feet)**	**Permanent ROW (acres)**	**Fill Material (+30% contingency; cubic yards)**
WEST SLIDELL				
First lift	2033	16	N/A	771,000
Second lift	2038	17.5	N/A	901,000
Third lift	2051	19	N/A	685,000
Fourth lift	2076	19	30 *	709,000 *
SOUTH SLIDELL				
Oak Harbor South				
First Lift	2035	17	N/A	106,000
Second Lift	2048	18	N/A	120,000
Third Lift	2064	19	N/A	115,000
I-10 Crossing**				
Slidell East / Northeast				

First Lift	2034	19	N/A	271,000
Second Lift	2047	20.5	N/A	295,000
Third Lift	2064	21.5	N/A	264,000
Total For Future Lifts				
			30	4,237,000
Total for Life of the Project (initial construction + lifts)				
			390	**7,069,000**

***** Includes the levee quantities (192,000 cubic yards) for the Western High Ground Tie-in for Year 2082.

** I-10 Crossing features would be constructed to the 2082 elevation and therefore would not require additional lifts.

2 LEVEE AND FLOODWALL SYSTEM DESCRIPTION

The levee and floodwall system consists of a combination of portions of the West Slidell levee alignment and the South Slidell levee alignment. The two alignments would be connected by a new railroad gate across the existing Norfolk Southern Railway Corp. railroad tracks. The alignment is shown in lime green in Figure 1-2.

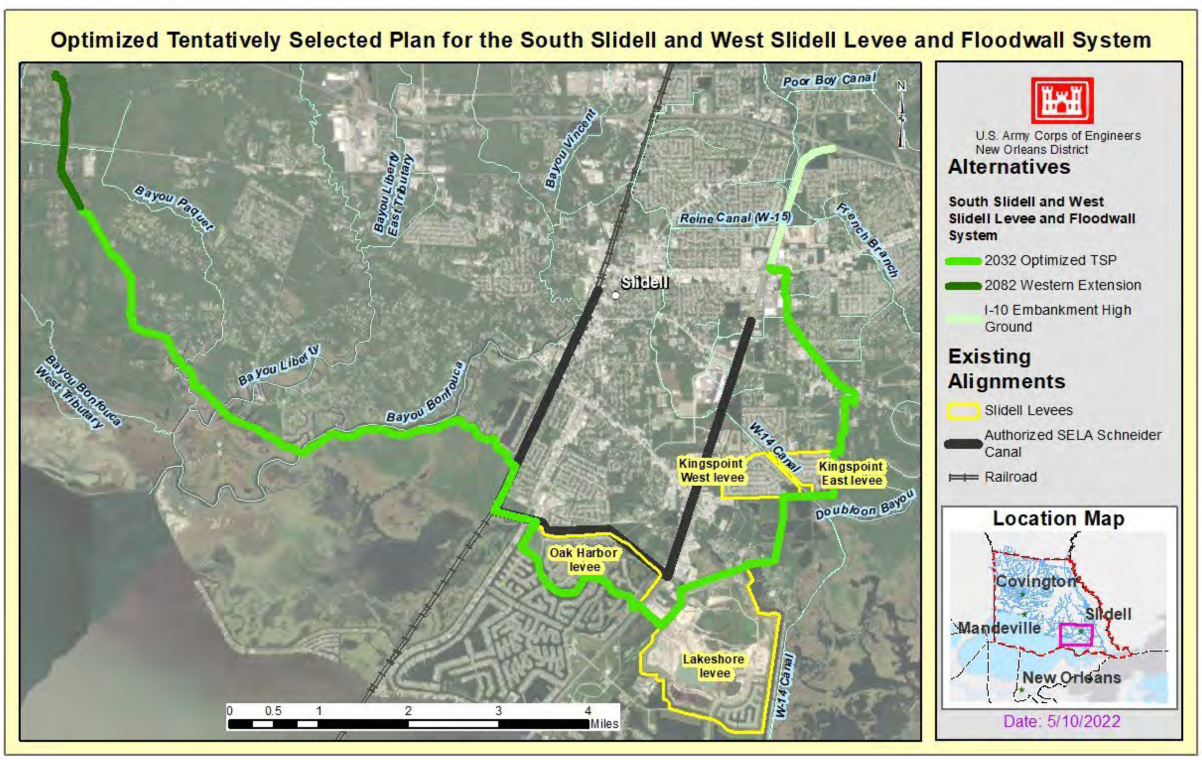

Figure 2-2. Optimized TSP for the West Slidell and the South Slidell Levee and Floodwall System

2.2 LEVEE AND FLOODWALL ALIGNMENT AND STRUCTURES

This section describes the alignment starting on the northwest end and continuing east. For floodwall segments refer to table 2.4, for pump stations refer to Table 2.9, for sluice, lift and sector gates refer to table 2.7, and for vehicular, pedestrian, and railroad floodgates refer to Table 2.8. All structural components would be constructed during initial construction.

2.2.1 WESTERN EXTENTION

Western Terminus: The intermediate scenario of relative sea level change between years 2032 and 2082 was used to develop the 2082 hydraulic design elevations. Based on that analysis, the levee was extended to the west to maintain a 1% risk reduction. The Western High Ground Tie-in for Year 2082 is shown in dark green in Figures 1-3 and 1-4. Based on modeling, the western extension would not be necessary until the year 2076 when the risk reduction would be needed. It is anticipated that this levee segment would be constructed during the fourth levee lift of the West Slidell alignment.

The alignment would commence north of US Highway 190 in the neighborhood near the intersection of North Tranquility Road and Shannon Drive between two properties. The alignment would be a berm with hydraulic design elevation of 17.5 ft for year 2082. The alignment would switch to levee (hydraulic design elevation of 17.5 ft (Year 2082)) and would continue south on the edge of the properties and cross US Highway 190, the Tammany Trace Bike Trail and South Tranquility Road on the eastern side of Pineridge Road. The alignment would run south southeast an additional 890 feet past the intersection with South Tranquility Road and tie with the existing year 2032 alignment for West Slidell.

2.2.2 WEST SLIDELL ALIGNMENT

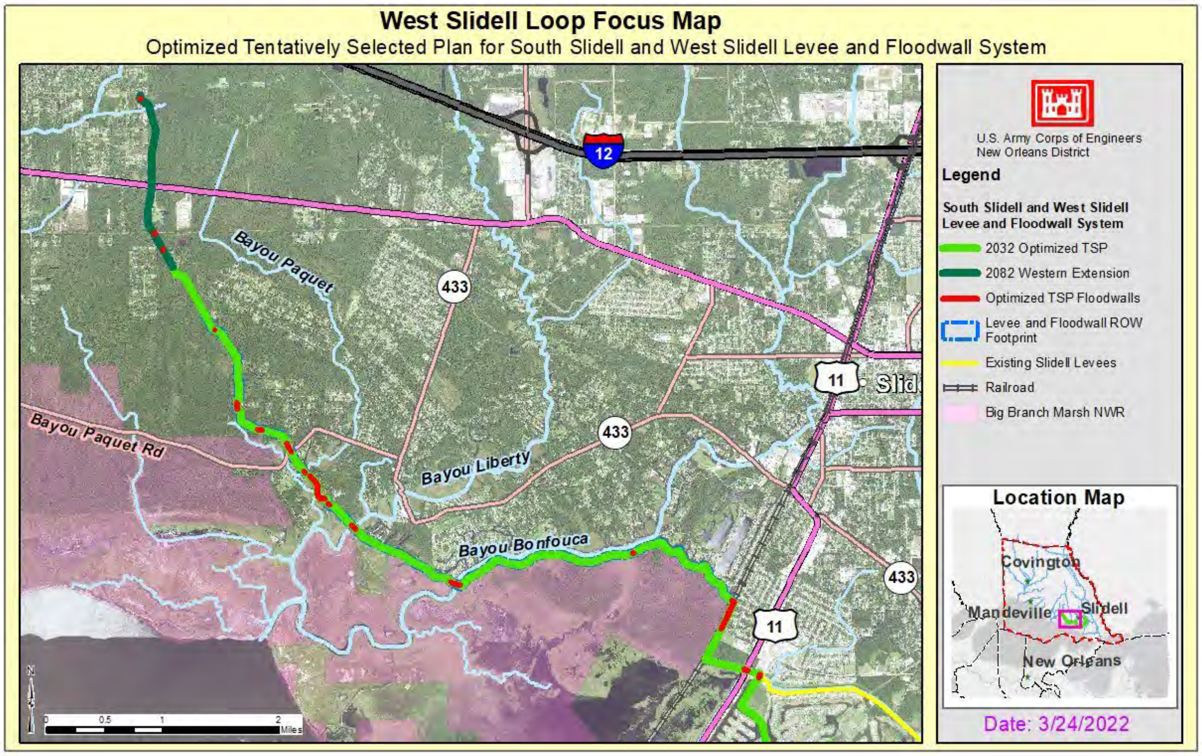

Figure 1-3. West Slidell Levee and Floodwall System- Optimized Tentatively Selected Plan Focus with Floodwall Segments

West Slidell Levee Segment: Levee construction would commence on the south side of US Highway 190 and South Tranquility Road, and on the eastern side of Pineridge Road. For the West Slidell portion of the alignment, the levee segments would have a hydraulic design elevation of 13.5 ft (Year 2032).

The alignment would run southward and would run on the west side of Tranquility Road (CC Road) and then it would turn in the southeast direction crossing Bayou Paquet Road and would stay on the east side of Bayou Paquet Channel to avoid impact to the Big Branch Marsh National Wildlife Refuge (NWR). The alignment would cross Bayou Paquet and Bayou Liberty and would continue eastward on the northside of the Big Branch Marsh NWR. The alignment would cross Bayou Bonfouca and would continue on the south bank of the bayou (northern side of the refuge) until reaching the Norfolk Southern Railway Corp. railroad tracks west of US Highway 11 in the vicinity of Dellwood Pump Station in Slidell.

2.2.3 SOUTH SLIDELL ALIGNMENT

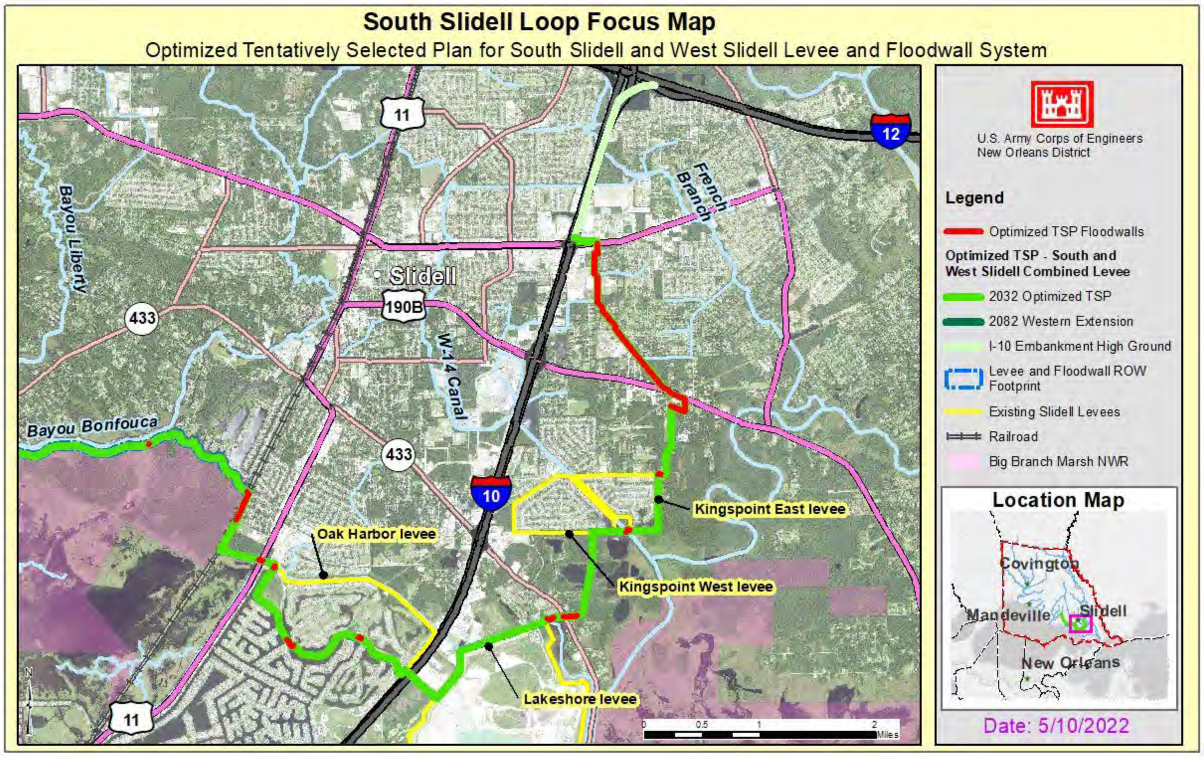

Figure 1-4. South Slidell Levee and Floodwall System- Optimized Tentatively Selected Plan Focus

<u>South Slidell Levee Segment</u>: The levee and floodwall system alignment from West Slidell would continue to South Slidell. From the railroad gate connecting West Slidell with South Slidell, the alignment would transition to a floodwall running parallel along the east side of the railroad tracks. The floodwall by the railroad tracks would have a hydraulic design elevation of 16.5 ft for year 2082.

The alignment would transition to levee when it turned east toward Highway 11. The alignment would cross Highway 11 and would turn south in the vicinity of the existing Schneider Canal Pump Station and then turn east (on a portion of the existing Oak Harbor ring levee). The alignment would run on the south side of Oak Harbor Boulevard and would cross to the north side immediately past Mariners Cove Boulevard. The levee along the south side of the Oak Harbor would have a hydraulic design elevation of 14 ft for year 2032.

The alignment would run on a portion of the existing Oak Harbor ring levee. The alignment would turn north and then east in the vicinity of the I-10. The I-10 would be raised to ramp over the new levee section (hydraulic design elevation of 18.5 ft for year 2082).

The alignment would continue southeast and would tie to an existing portion of the Lakeshore Estates ring levee. The alignment then would turn north and then east and cross Old Spanish Trail/Highway 433. The alignment would continue north and tie to a portion of the existing King's Point west levee. The section of levee would have a hydraulic design elevation of 16 ft for year 2032.

The alignment would cross the W-14 Canal and would tie to a portion of the existing King's Point east levee and would turn north. The levee would have a hydraulic design elevation of 16 ft for year 2032. The levee would turn east and then north. Immediately south of Highway 190 Business the alignment would turn from levee to floodwall to provide risk reduction to the existing Hardin Road power substation. The floodwall would have a hydraulic design elevation of 18.5 ft for year 2082.

The alignment would cross Highway 190 Business and continue northwest on the west side of the existing CLECO Corporate Holdings, LLC utility corridor. The alignment would cross South Holiday Drive and continue north. The alignment would turn east on Manzella Drive and turn north in the middle of the block between Yaupon Drive and Malbrough Drive.

The alignment would cross Gause Boulevard as a ramp crossing and would turn west and tie to high ground (hydraulic design elevation of 18.5 ft for year 2082) in the vicinity of the I-10. There would be additional road ramps for businesses on the north side of Gause Boulevard, the I-10 Service Road and the I-10 on-ramp for the I-10 eastbound at Gause Boulevard.

The existing highway embankment would serve as the means of risk reduction in order for the project to form a continuous system up to the elevation required in 2082. Refer to light green portion of the alignment in Figure 1-5.

CLECO Corporate Holdings, LLC has right-of-way use requirements pertaining to USACE work around their existing utility lines on the northeast corner of the floodwall alignment that would have to be met to provide clearance for construction activities (i.e., pile driving).

INTERSTATE 10 ELEVATION

The I-10 road surface would be raised to construction elevation 21.5 ft to ramp over the new levee section to stay above the hydraulic design elevation for year 2082, to ensure the entire pavement section remains above the hydraulic design elevation across the interstate. The hydraulic design elevation at this location for year 2082 is 18.5 ft. The pavement section was assumed to have a thickness of 2.5 ft.

The existing elevation of the I-10 at the proposed location is approximately 12.8 feet as per LIDAR raster dataset. This proposed location is the highest elevation of the I-10 in the vicinity of the proposed alignment. The I-10 elevation is lower (approximately 10 feet) on the adjacent areas.

The levee and the Interstate 10 would be lifted during initial construction in year 2032 to construction elevation of 21.5 ft to avoid future disruptions to the traffic on the interstate.

2.3 TYPICAL SECTION AND ELEVATIONS

2.3.1 WEST SLIDELL LEVEE DIMENSIONS AND QUANTITIES

The dimensions for the new West Slidell levee may be found in Table 2.1 and Figure 1-5.

Geotextile would be placed for West Slidell during initial construction under the levee. Geotextile would be placed 70 ft from the centerline of the levee on the floodside and 40 ft from the centerline of the levee on the land side for a total of 110 ft.

Table 2.1. West Slidell Levee

West Slidell Levee **Initial Construction**	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Floodside Berm Slope	1V:42H
Landside Berm Slope	1V:33H
Construction Elevation	14.5 ft
Geotextile	13,200 lbs/ft

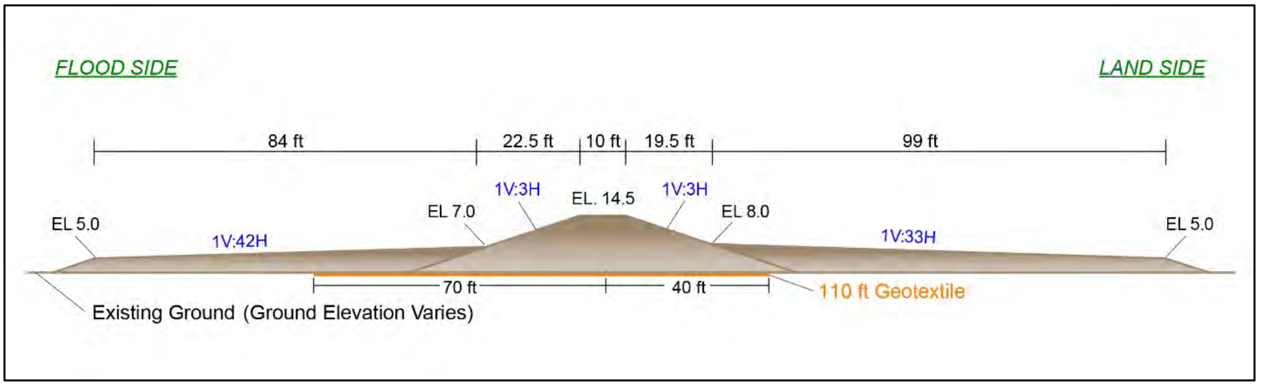

Figure 1-5. Typical Cross-Section with Berms for West Slidell

The hydraulic design elevations of the new West Slidell levee would be 13.5 feet (year 2032) and the 17.5 ft (year 2082). Right of way for the levee was assumed to be 300 ft wide.

2.3.2 SOUTH SLIDELL DIMENSIONS QUANTITIES

The dimensions for the new South Slidell levee may be found in Table 2.2 and Figure 1-6. The construction elevation for the first lift would vary depending on location. This portion of the alignment would not have berms or geotextile.

Table 2.2. South Slidell Levee

South Slidell Levee **Initial Construction**	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Construction Elevation	Varies

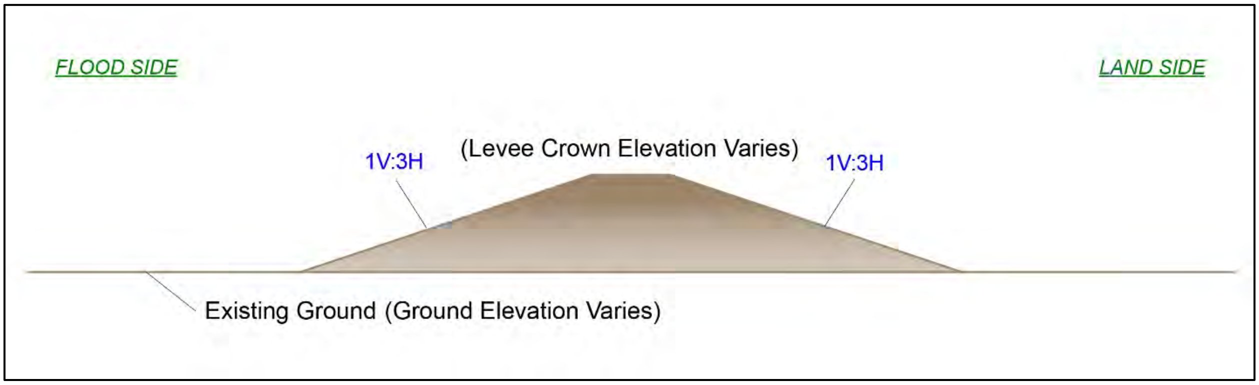

Figure 1-6. Typical Cross-section for South Slidell

The hydraulic design elevation of the new South Slidell levee would vary between 14 ft and 16 ft (year 2032) depending on the location.

2.4 FUTURE LEVEE LIFTS

To maintain the levee crown at or above the base year (2032) and future year (2082) design elevations while accounting for levee settlement and relative sea level rise, levees would be constructed in multiple lifts over the period of analysis. Both the design elevations and constructed "top of levee" elevations vary by location. Design elevations vary by levee location because of surge and wave differences due to storm path, wind speeds and direction, etc.

Levee portions of the Optimized TSP would require future lifts to bring the levees to hydraulic design elevations for year 2082.

For West Slidell, four future levee lifts are projected to be needed. The assumed cross-section for these lifts would have a 10 ft wide levee crown and side slopes of 1V:3H.

Existing berm sections from initial construction would be in place on both sides of the levee.

For the first lift (Year 2033) and the second lift (Year 2038), it was assumed that in addition to elevating the levee, the berm previously built during initial construction would settle 25 percent. Additional material would be placed on the berms during these two lifts.

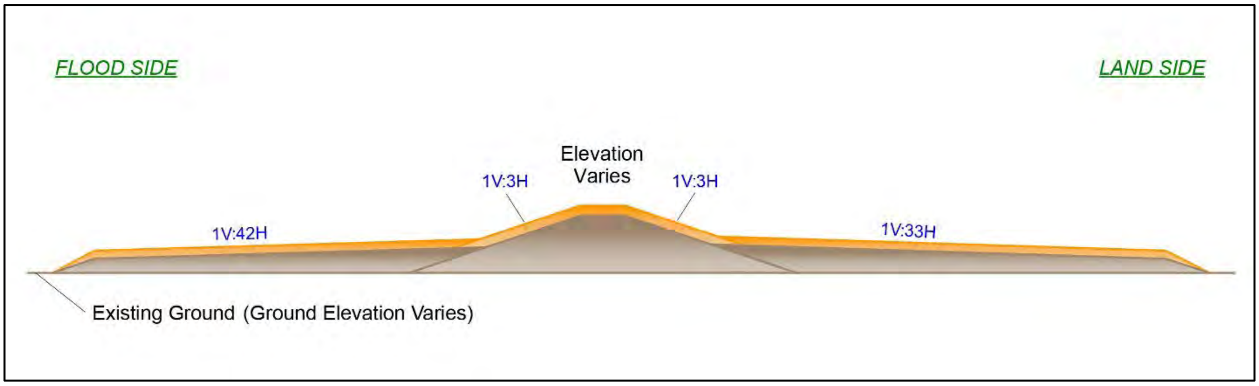

Figure 1-7. Typical Cross-section with berms for First and Second Lifts for West Slidell

For the third lift (Year 2051) and the fourth lift (Year 2076), it was assumed that no additional material would be placed on the berms.

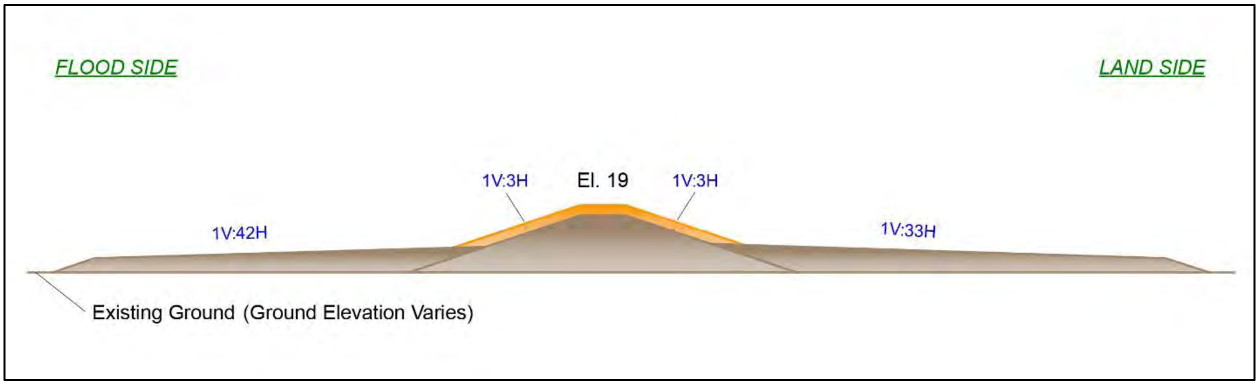

Figure 1-8. Typical Cross-section with berms for Third and Fourth Lifts for West Slidell

2.4.1 WESTERN HIGH GROUND TIE-IN LEVEE CONSTRUCTION

The construction of the Western High Ground Tie-In would be performed during the fourth lift for West Slidell which is projected for year 2076. The dimensions for the Western High Ground Tie-In may be found in Table 2.3 and Figure 1-9. This portion of the alignment would not have berms or geotextile.

Table 2.3. Western High Ground Tie-In *Levee*

Western High Ground Tie-In	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Construction Elevation	19 ft

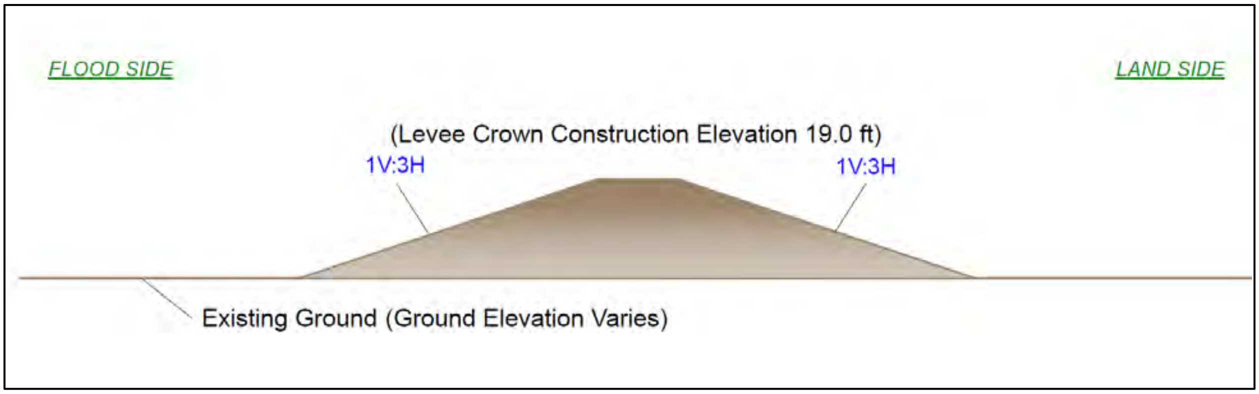

Figure 1-9. Typical Cross-section for the Western High Ground Tie-in for Year 2082

The lift schedules for West Slidell consisted of one geotechnical reach as shown in Figure 1-9. The hydraulic design elevation is 13.5 ft for year 2032 and 17.5 ft for year 2082 are shown in the design line in blue. The red lines represent the projected lifts.

2.4.2 SOUTH SLIDELL LEVEE TYPICAL CROSS SECTION FOR FUTURE LIFTS

The future lifts for South Slidell levee would have a 10 feet wide levee crown and side slopes of 1V:3H.

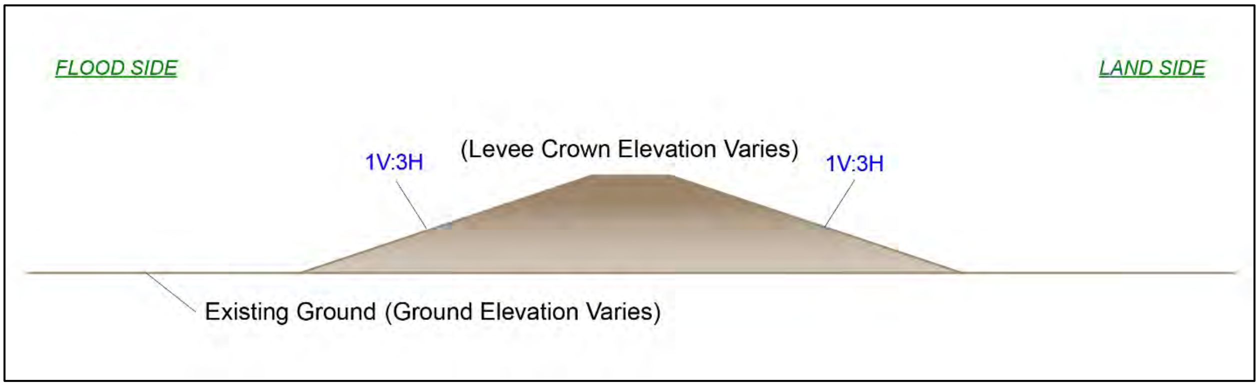

Figure 1-10. Typical Cross-section for South Slidell for Future Lifts

2.5 Typical Floodwall Section and Elevations

The T-wall sections would vary based on location. Table 2.4 lists the floodwall segment and the various dimensions for each floodwall segment.

Table 2.4. Floodwall Segment dimensions

Description of Floodwall Segment	Length of Floodwall Segment (ft)	Base of Slab BOS (ft)	Base of Wall BOW (ft)	Top of Wall TOW (ft)	Stem Height (ft)	Wall Thick (ft)	Slab Width (ft)	Number of piles per row
Western High Ground Tie-in for Year 2082								
N/A								
West Slidell								
Properties at the end of West Doucette	350	1.5	4.5	17.5	**13**	2	15	3
North Side Bayou Paquet Dr.	250	-1.5	1.5	16.5	**15**	2.5	20	4
Bayou Paquet/Mayer Dr.	1400	-1.5	1.5	16	**14.5**	2.5	20	4
South Slidell								
Front Street/ Railroad	1375	-0.5	2.5	16.5	**14**	2.5	20	4
Old Spanish Trail	300	-2.5	0.5	18.5	**18**	2.5	20	4
Esprit du Lac Street	450	1	4	18.5	**14.5**	2.5	20	4
Substation Floodwall	1950	4.5	7.5	18.5	**11**	2	15	3
Highway 190 Business	430	5	8	18.5	**10.5**	2	15	3
Utility Corridor	3530	5	8	18.5	**10.5**	2	15	3
Hollywood Dr. to Yaupon	3700	9	12	18.5	**6.5**	1.5	10	2
Manzella Dr. to Gause	650	10.5	13.5	18.5	5	1.5	10	2

2.6 CONCRETE AND PILE QUANTITIES FOR FLOODWALL SEGMENTS

The floodwall segments would require the following concrete quantities during initial construction as shown on Table 2.5.

Table 2.5: Concrete Quantities for Floodwall Segments

CONCRETE FLOODWALL SEGMENTS	
Total Concrete Quantities	36,200 cubic yards
Total Sheetpile Quantities	451,400 square feet
Total Length of Piles	887,000 linear feet

Total Slope Paving for floodwall/levees tie-ins	7,000 square feet

Table 2.6: Pile Quantities for Floodwall Segments

PILES FOR FLOODWALL SEGMENTS	
Type of pile	18-inch pipe
Configuration	1H:2V battered
Length of each pile	101 feet
Total Length of Piles	26,300 linear feet

2.7 FLOODGATES DESIGN INFORMATION

The Optimized TSP would include a total of 13 gates. Three (3) gates would be lift gates and one gate would be a sector gate. These gates would allow navigation of recreational vessels. There are nine (9) sluice gates which would be control structures (non-navigable).

During construction of the gated structures, temporary bypass channels would be constructed for recreational vessels in Bayous Paquet, Bonfouca, and Liberty.

Table 2.7: Floodgate Dimensions

Description of the Floodgate	Type of Gate	Width of Opening of the Gate (ft)	Ground/ Sill Elevation (ft)	Structural Height of Drainage Gate (ft)
Western High Ground Tie-in for Year 2082				
Sluice gate near Shannon Drive	Sluice	4	15.5	2.0
Tammany Trace Sluice Gate	Sluice	15	12	5.5
West Slidell				
Sluice Gate # 7 (Near CC Road)	Sluice	25	8.6	8.9
Sluice Gate # 6 (Bayou Paquet North Tributary)	Sluice	75	0.8	15.2
Bayou Paquet Gate Nav. Gate	Lift	90	-0.5	16.5
Bayou Liberty Nav. Gate	Lift	80	-6.8	22.8
Bayou Bonfouca Nav. Gate	Lift	110	-9	25.0
Sluice Gate # 2 (Bayou Bonfouca Sluice Gate)	Sluice	50	0.4	15.6
South Slidell				
W-14 Canal Nav. Gate	Sector	90	0.1	18.4
Sluice Gate # 8 (Kings Point East)	Sluice	90	4.4	14.1

Sluice Gate # 10 (Near Eastern Terminus)	Sluice	20	10.5	8.0
Reine Canal	Sluice	30	7.5	11.0
French Branch at I-10	Sluice	25	8.3	10.2

The floodgate locations and minimum sizes above are an estimate. A detailed interior drainage design would be provided during PED.

Limited information and estimates of channel depths and widths has been considered in estimates of the minimum gated opening dimensions. An increase in the size of the gated openings would likely benefit environmental conditions and would provide additional flood flow conveyance. Any channel constriction such as a gate has the potential to locally increase velocities, which could erode natural channels.

It is assumed that most of these floodgate locations would need to retain some flood conveyance capacity during construction. During PED, bypass channels would be considered as part of the design.

Temporary Bypass Channel

Temporary bypass channels would be constructed at locations where a pump station or floodgate is proposed within the limits of a channel. The temporary bypass channel would route water around the structure in order for the construction to be done in dewatered conditions.

In order to maintain pre-construction flow conditions and minimize environmental impacts during construction, the temporary bypass channels would be similarly sized to the channels being impacted. After construction, the bypass channel is assumed to be included in the footprint of the structure site and the channel flow would be rerouted through the new structure feature. Navigation of common local vessels would be considered for the bypass channels, and design features of a navigable bypass channel would be developed during PED.

Temporary Retaining Structures (TRS)

Temporary Retaining Structures (cofferdams) are temporary features that facilitate the construction of major structures. Cofferdams allow water or other materials to be removed inside the TRS in order to work in an excavated and/or dewatered condition.

Cofferdams would be required during the construction of the pump stations and floodgates. Qualified designers employed or sub-contracted by the construction contractors would design the TRS for this project.

2.8 TYPES OF FLOODGATES

2.8.1 FISH-FRIENDLY LIFT GATE

For Bayou Paquet, Bayou Bonfouca and Bayou Liberty, the proposed navigable gates would be designed to have a small amount of restriction and a gradual slope so that fish and larvae may traverse the structures. The navigable gates would consist of a lift gate which would be raised during open mode to let water and recreational vessels traverse. This design would include smaller sluice gates on both sides of the lift gate to simulate the natural opening of the bayous.

During PED, the PDT would consider additional fish-friendly studies and input provided by the NFS, USFWS and National Marine Fisheries Service criteria, including the rock arch and rock ramp designs.

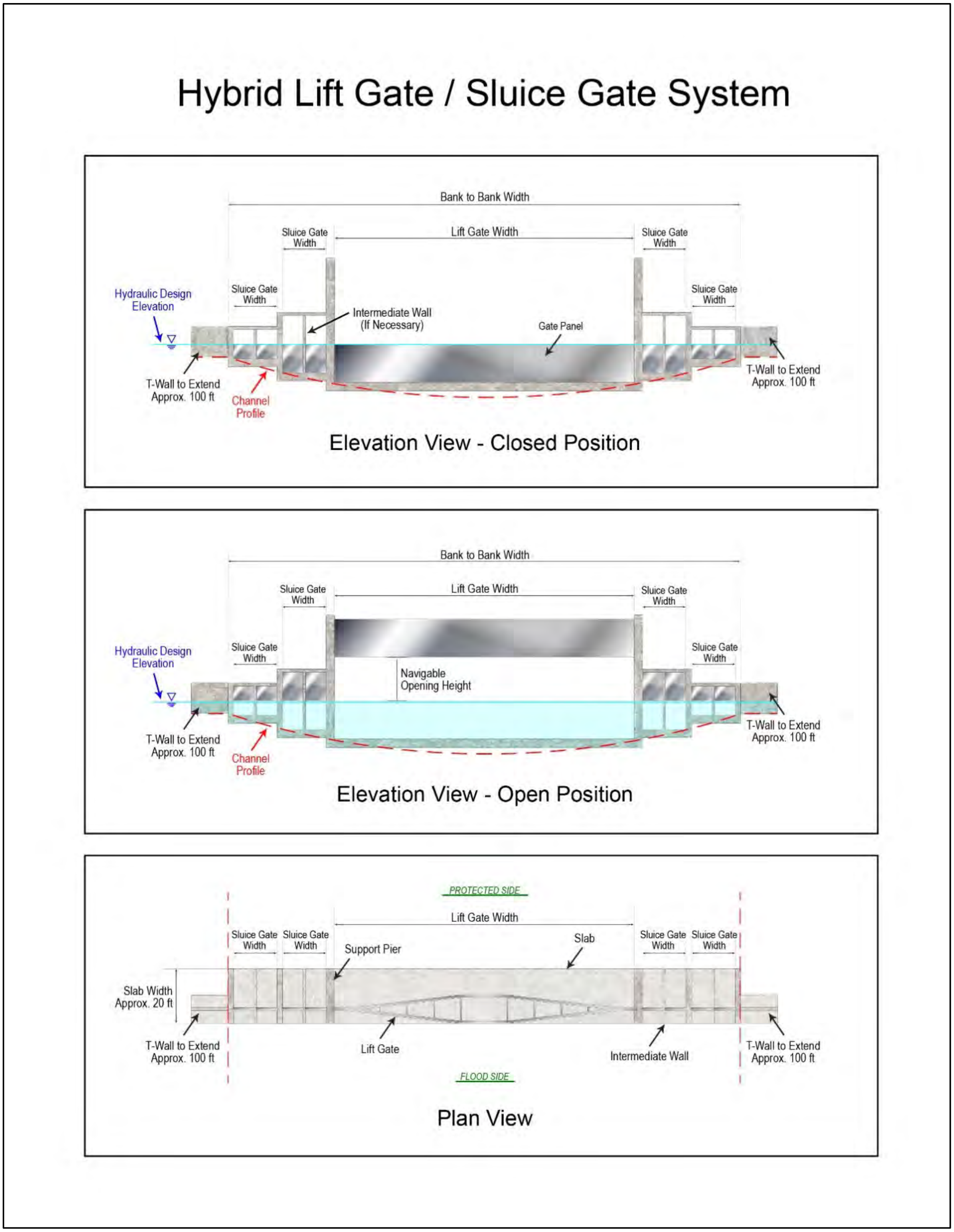

Figure 1.11. Typical Fish-Friendly Gate - Elevation and Plan Views

2.8.2 SLUICE GATE

A sluice gate is a structure that contains a movable gate or series of movable gates that, when lifted, allow material and water to flow under it. Generally, sluice gates are not navigable as they do not raise high enough, or they have fixed components that do not allow vessels to pass through."

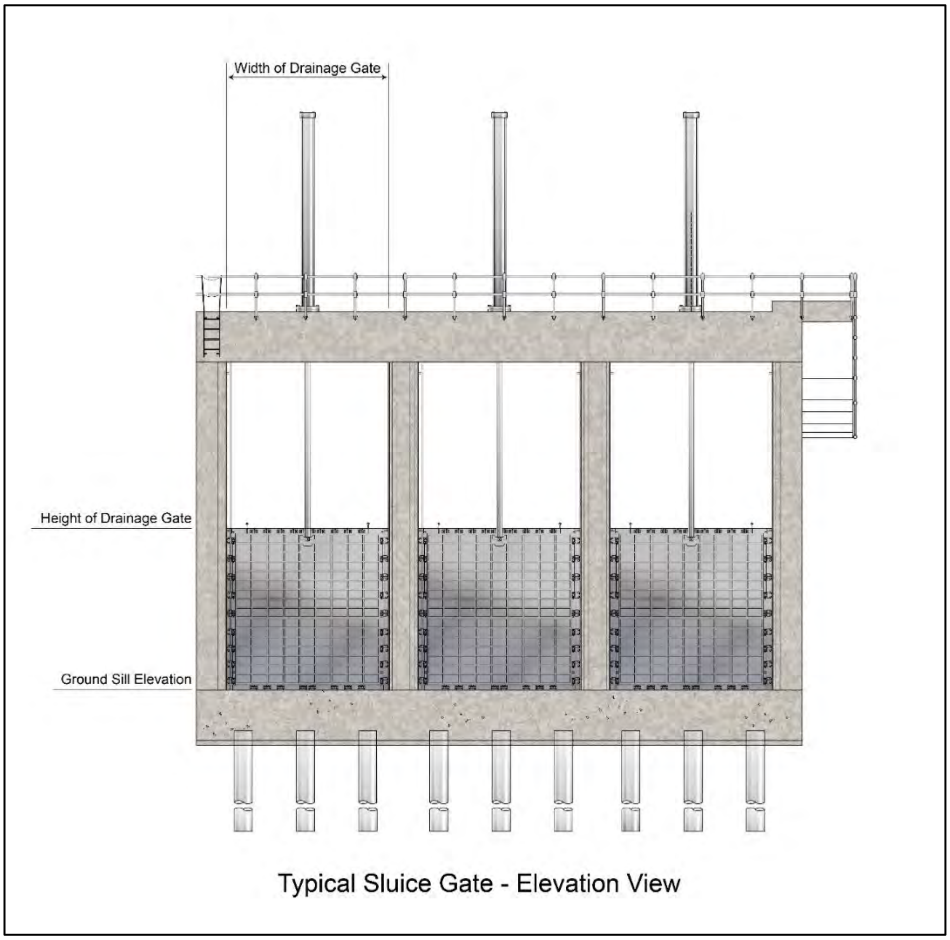

Figure 1-12. Sluice Gate - Elevation View

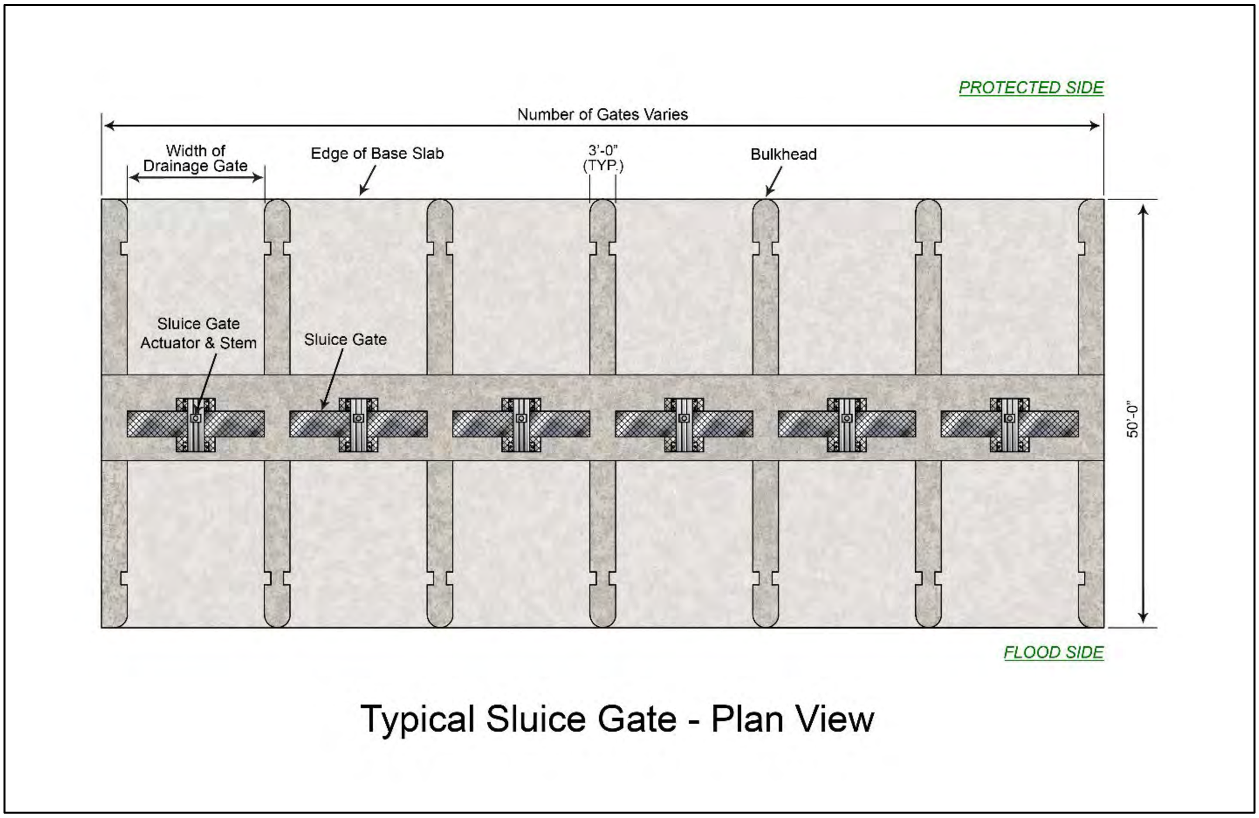

Figure 1-13. Sluice Gate - Plan View

2.8.3 SECTOR GATE

A sector gate is a pie-slice structure that allows navigation to get through when in the open position.

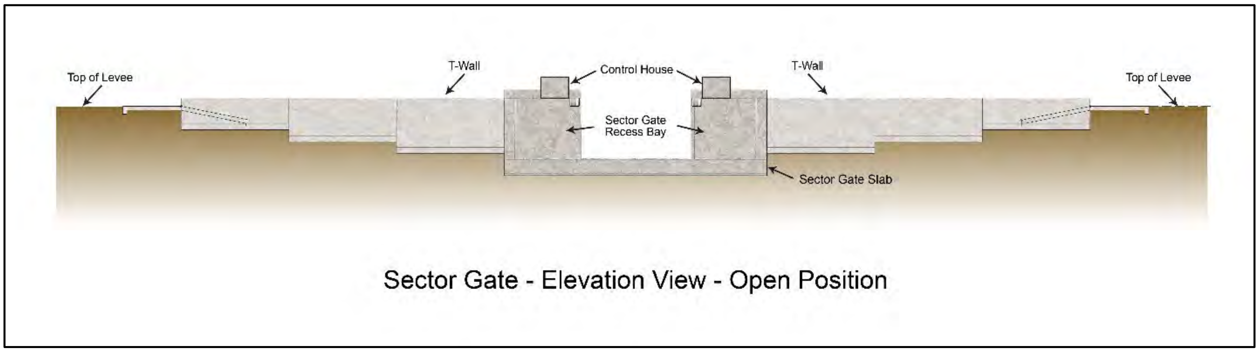

Figure 1-14. Sector Gate - Elevation View with Gates in Open Position

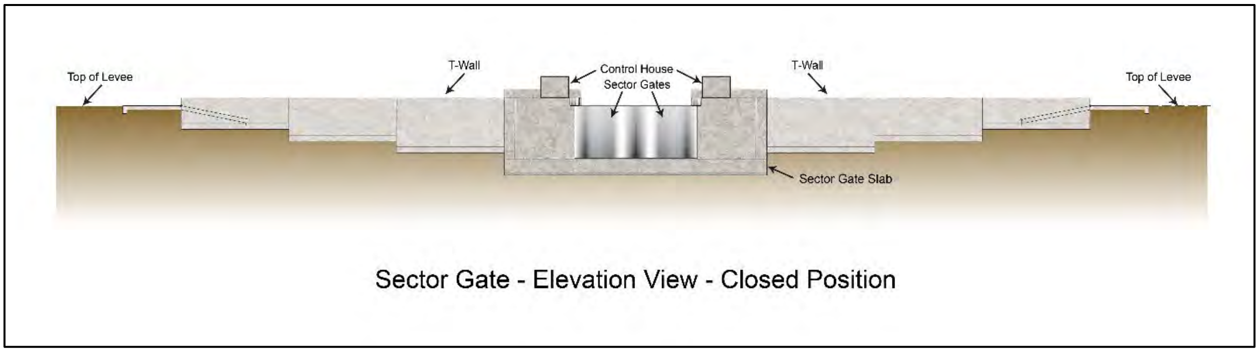

Figure 1-15. Sector Gate - Elevation View with Gates in Closed Position

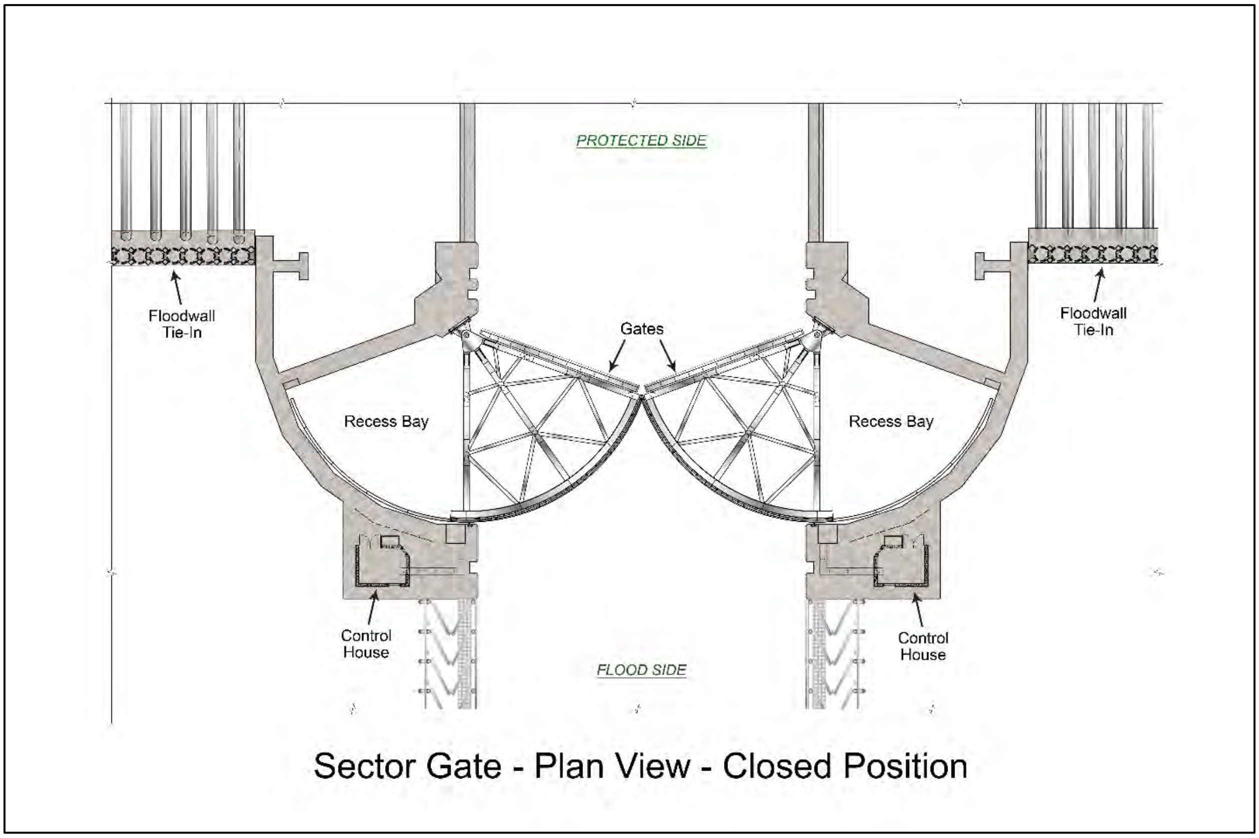

Figure 1-16. Sector Gate - Plan View

2.8.4 ROLLER GATE

A roller gate is a structure that uses rollers for the gate to open and close. The operating motion of the gate is typically parallel to the skin plate face of the gate.

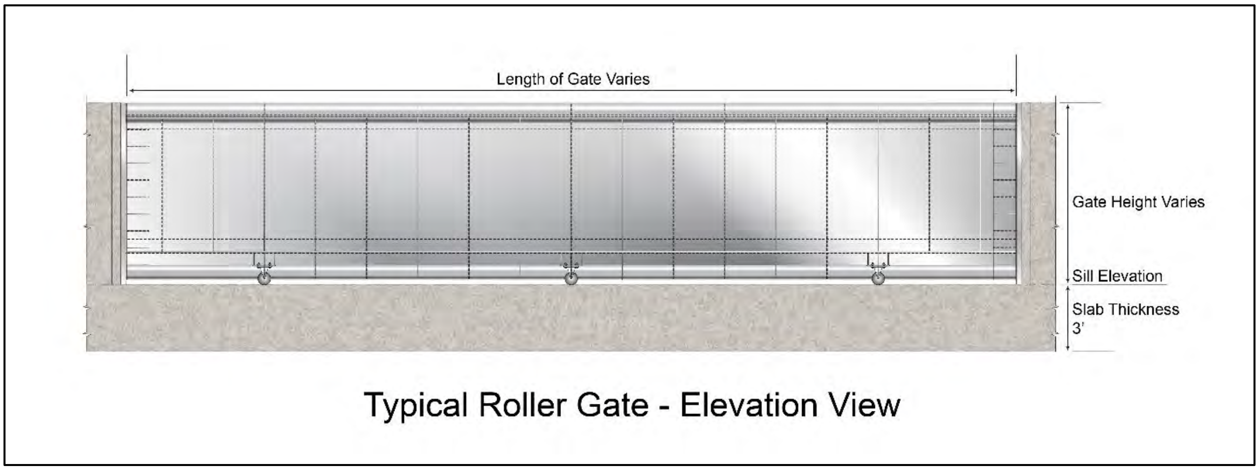

Figure 1-17. Roller Gate - Elevation View

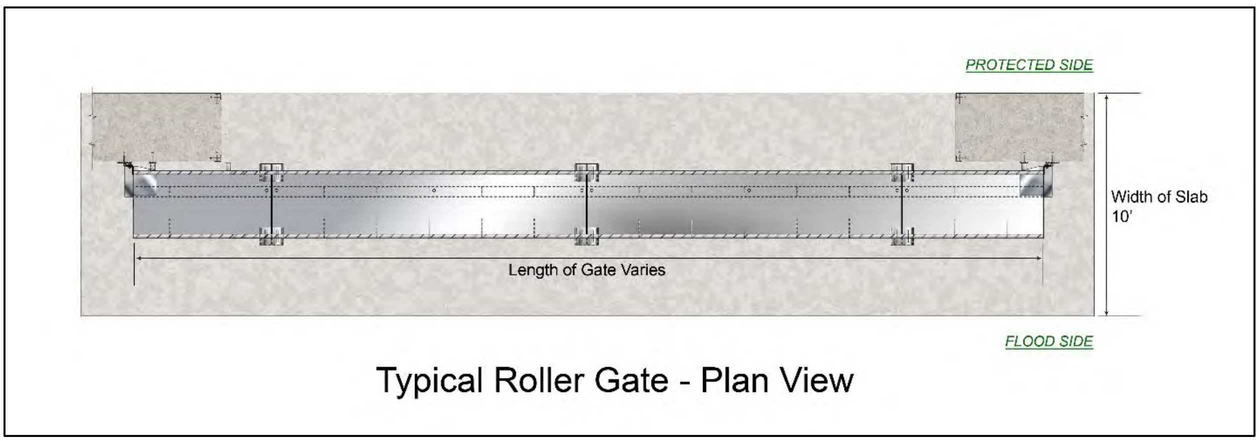

Figure 1-18. Roller Gate - Plan View

2.8.5 SWING GATE

A swing gate is a structure that uses a hinge system to open horizontally. The gate can be actuated through automated mechanical means such as hydraulic arm or manually.

It was assumed that a swing gate would be constructed where the alignment crosses the Southern Railway Corp. railroad tracks. (The analysis for this gate was based on Mississippi River Levee (MRL) Carrollton Railroad Gate.)

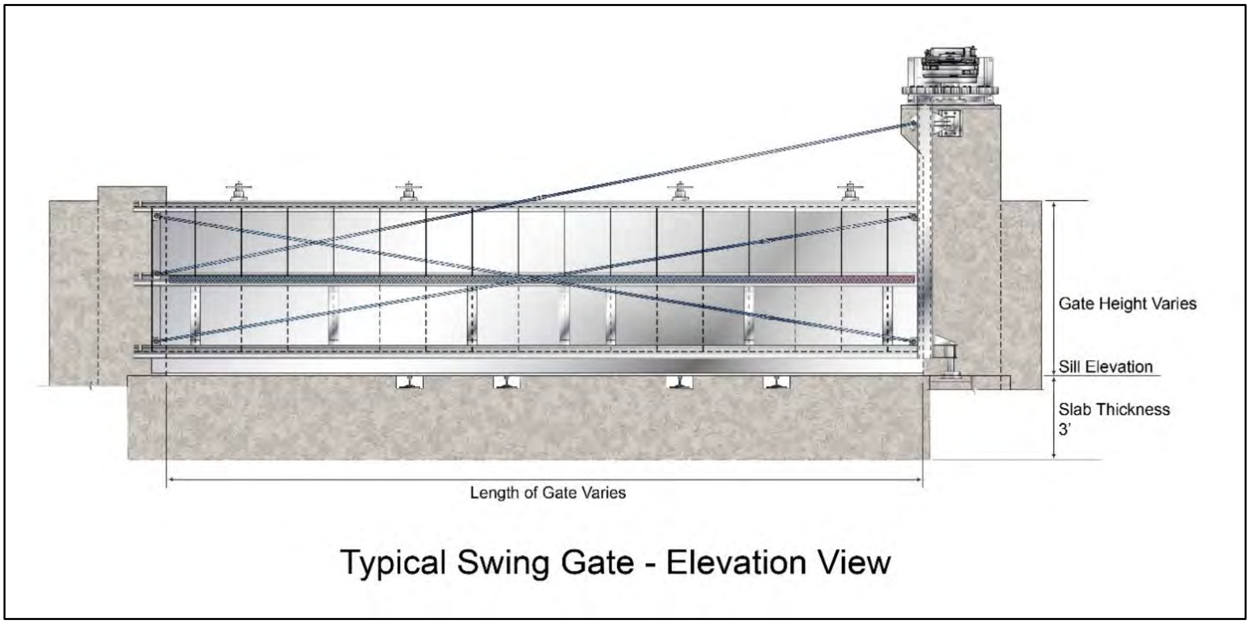

Figure 1-19. Swing Gate - Elevation View

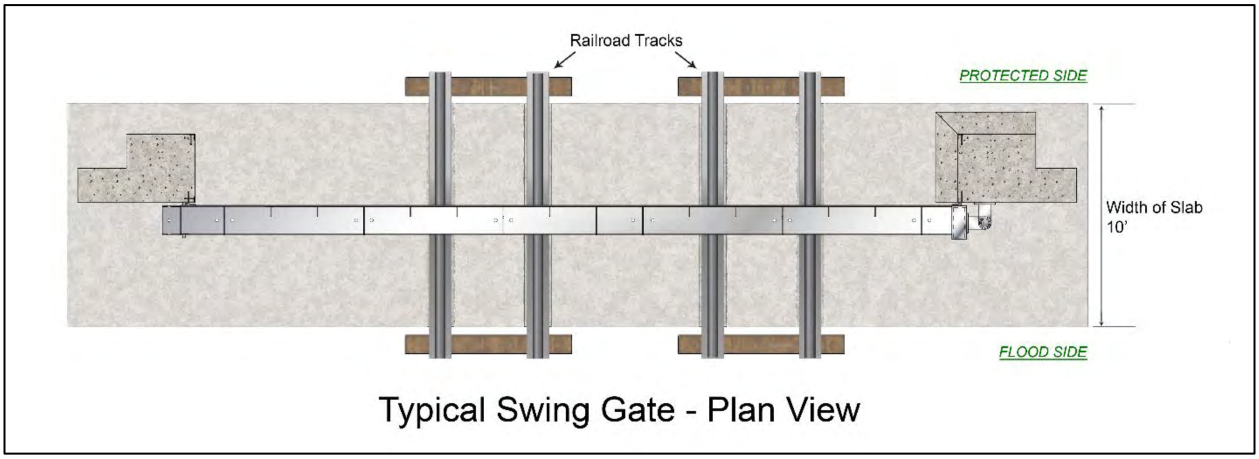

Figure 1-20. Typical Swing Gate - Plan View

2.9 VEHICULAR, PEDESTRIAN AND RAILROAD GATES DESIGN INFORMATION

Table 2.8 contains the design information for the vehicular, pedestrian and railroad gates for the Optimized TSP.

Table 2.8: Vehicular, Pedestrian and Railroad Gates

Name	Description	Type	Mode	Width	Ground/ Sill Elevation (ft)	Design Height (ft)	Height of Gate (ft)
Western High Ground Tie-in for 2082							
Tammany Trace Pedestrian Gate and Culvert	10-ft Pedestrian Gate at Tammany Trace with Lift Gate for Culvert on south side	Swing	Pedestrian	10	13	17.5	3.5
Tranquility Road Vehicular Gate	20-ft Vehicular Gate at Tranquility Road	Roller	Vehicle	20	12	17.5	4.5
West Slidell							
Bayou Paquet Road Floodgate # 2	60-ft Floodgate at Bayou Paquet Road	Roller	Vehicle	60	3	16	13
Mayer Drive Vehicular Gate	20-ft Vehicular Gate at Mayer Road	Roller	Vehicle	20	2.5	16	13.5
Railroad Floodgate	60-foot floodgate for Railroad	Swing	Railroad	60	0.5	16.5	16
South Slidell							
Hwy 11 Vehicular Gate	75-ft Roller Gate at Hwy 11 (Pontchartrain Drive)	Roller	Vehicle	75	4	16.5	12.5
Mariners Cove Floodwall and Vehicular Gate	500 Linear feet of floodwall for narrow section of Oak Harbor levee at Mariners Cove Blvd	Roller	Vehicle	50	10.5	16.5	6
Oak Harbor Vehicular Gate	Floodwall and 20-foot Vehicular Gate for Oak Harbor	Roller	Vehicle	20	11.5	16.5	5
Oak Harbor Country Club Vehicular Gate	Floodwall and 20-foot Vehicular Gate for access to Oak Harbor Country Club	Roller	Vehicle	20	11.5	16.5	
Old Spanish Trail Floodgate (Hwy 433)	30-foot roller gate at Hwy 433 east crossing (Old Spanish Trail)	Roller	Vehicle	30	3.5	18.5	15

Hardin Rd Substation Gate	20-foot roller gate for access from Hardin Road to power substation	Roller	Vehicle	20	8	18.5	10.5
Hwy 190-B Floodgate (East Floodwall)	50-foot roller gate at Hwy 190-B east crossing (Fremaux Road)	Roller	Vehicle	50	9	18.5	9.5
South Holiday Drive Vehicular Gate	20-foot roller gate at South Holiday Drive	Roller	Vehicle	20	14	18.5	4.5
Jaguar Drive Vehicular Gate	20-foot roller gate at Jaguar Avenue	Roller	Vehicle	20	12	18.5	6.5
Natchez Drive Vehicular Gate	20-foot roller gate at Natchez Avenue	Roller	Vehicle	20	12	18.5	6.5
Kisatchie Drive Vehicular Gate	20-foot roller gate at Kisatchie Avenue	Roller	Vehicle	20	14	18.5	4.5
Manzella Drive Vehicular Gate	20-foot roller gate at Manzella Drive (Added to extend floodwall to 18.5 ft ground elevation south of Hwy 190)	Roller	Vehicle	20	15	18.5	3.5

2.10 PUMP STATIONS DESIGN INFORMATION

The Optimized TSP would include a total of eight (8) pump stations. These pump stations are divided into large pumping capacity and small pumping capacity.

In West Slidell there would be two (2) pump stations with large pumping capacity and two (2) pump stations with small pumping capacity. In South Slidell there would be four (4) pump stations with small pumping capacity.

Table 2.9: Pump Stations

Pump Station Location	**Pump Station Capacity**
Western High Ground Tie-in for 2082	
N/A	
West Slidell	
Bayou Liberty	1,800 cfs

Bayou Bonfouca	2,000 cfs
Bayou Paquet North Tributary	300 cfs
Bayou Paquet	500 cfs
South Slidell	
W-14 Canal	1,000 cfs
Kings Point	200 cfs
Reine Canal	200 cfs
French Branch at the I-10	450 cfs

The Optimized TSP would include two (2) pump stations with large pumping capacity at Bayou Liberty (1,800 cfs) and Bayou Bonfouca (2,000 cfs). These pump stations were assumed to have similar components and configuration as the USACE West Shore Lake Pontchartrain Reserve Relief Canal Pump Station (WSLP Pump Station). The structural quantities from the Reserve Relief Canal Pump Station were scaled accordingly to reflect the size of the pump stations for this study.

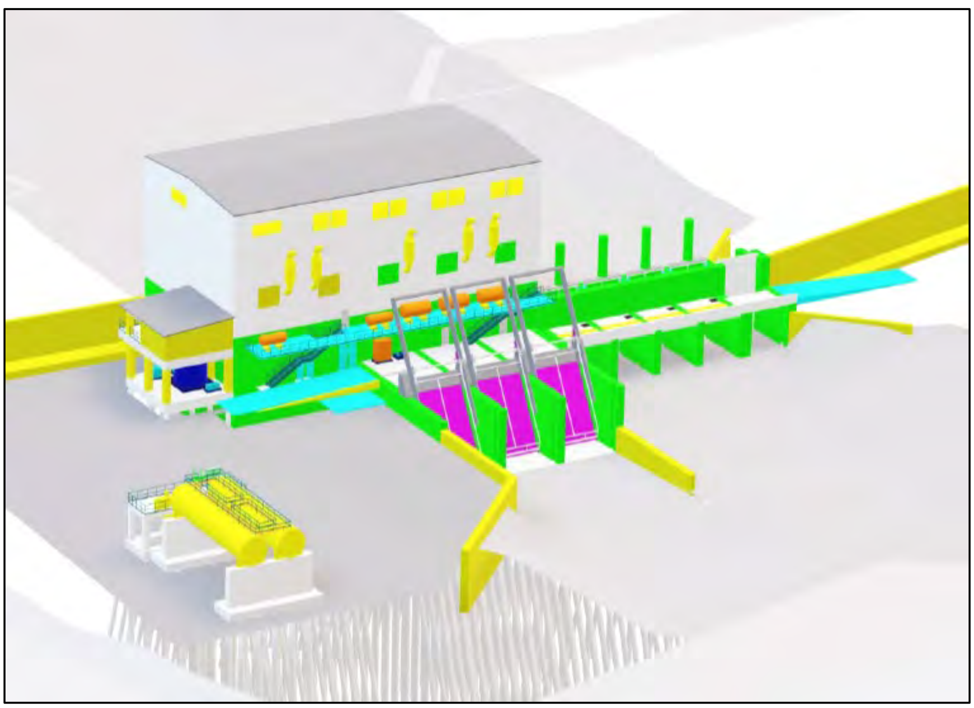

Figure 1-21. Typical Site Plan of a Pump Station with Large Pumping Capacity

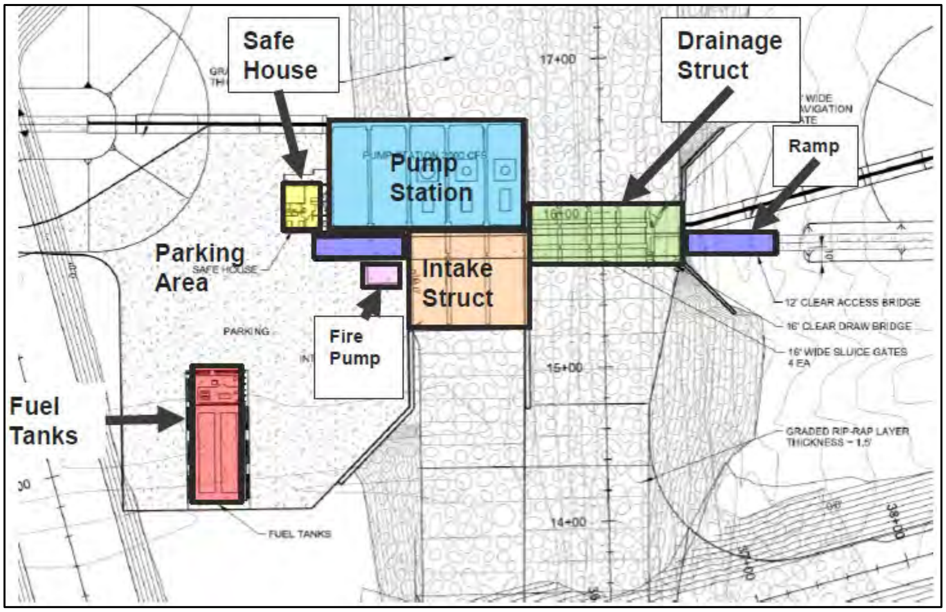

Figure 1-22. Typical Layout of a Pump Station with Large Pumping Capacity

The TSP would include six (6) pump stations with small pumping capacity at sluice gate #6 on the Bayou Paquet North Tributary (300 cfs), Bayou Paquet lift gate (500 cfs), W-14 Canal (1,000 cfs), sluice gate # 8 at Kings Point (200 cfs), Reine Canal (200 cfs) and at French Branch at the I-10 (450 cfs).

These pump stations would have similar pumping capacities to the Prescott Road Pump Station for the Lake Pontchartrain Lakeshore study. The structural quantities from the Prescott Road Pump Station were scaled accordingly to reflect the size of the pump stations for this study.

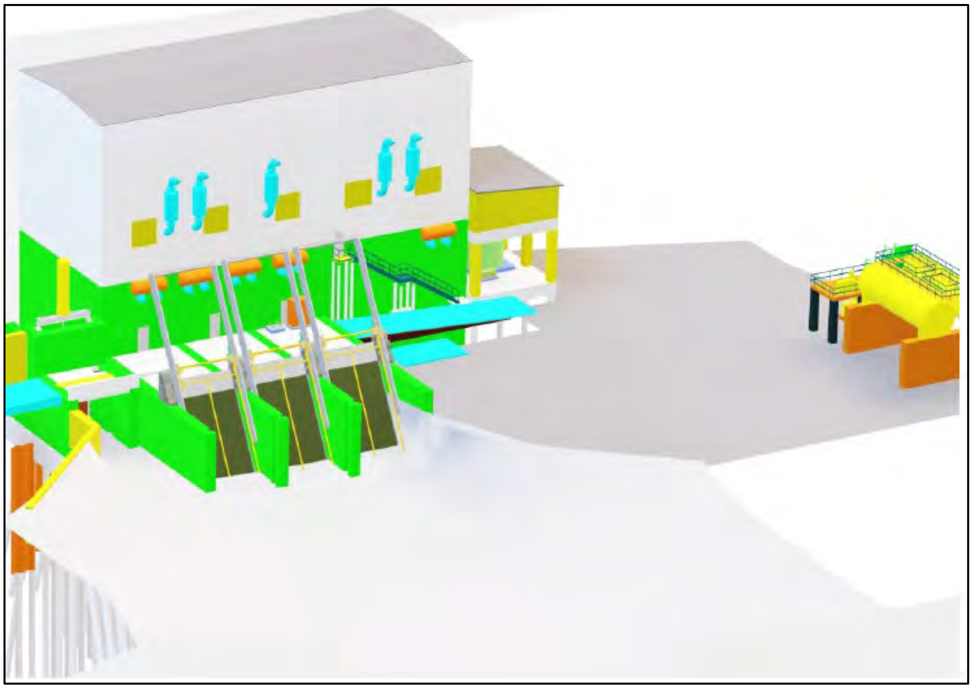

Figure 1-23. Typical Site Plan of a Pump Station with Small Pumping Capacity

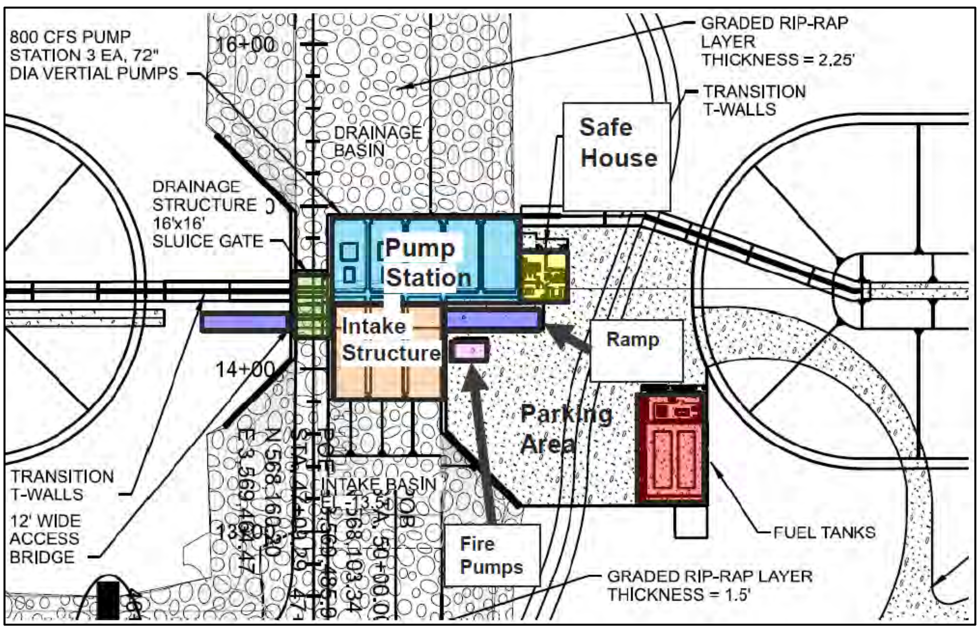

Figure 1-24. Typical Layout of a Pump Station with Small Pumping Capacity

Note: the schematics on this section were obtained from a presentation prepared by Stantec.

3 ACCESS ROUTES AND STAGING AREAS REQUIRED

Table 3.1 provides a summary of the necessary staging areas and permanent ROW required for construction of the levee and floodwall segments for the 50-yr period of analysis. The staging areas required during initial construction of the levee alignment would be the same staging areas required for construction of future levee lifts.

Table 3.1 Summary of Staging Areas and Permanent ROW

SUMMARY of STAGING AREAS AND PERMANENT ROW		
Levees	**Staging Areas (Acres)**	**Permanent ROW (Acres)**
Western High Ground Tie In	2	30
West Slidell	8	270
South Slidell (includes 23 acres for I-10)	29	120
Sub-Total for Levees	**39**	**420**
Floodwall Segments		
Western High Ground Tie In	NA	NA
West Slidell	0	3.7
South Slidell	0	22.7
Sub-Total for Floodwall Segments	**0 ***	**26.4**
Floodgates and Pump Stations		
Western High Ground Tie In	1.5	2.5
West Slidell	11	21
South Slidell	3.75	6.25
Sub-Total for Floodgates and Pump Stations	**16.25**	**29.75**
Vehicular, Pedestrian, and Railroad Gates		
Western High Ground Tie In	1.5	1.25
West Slidell	1.25	0
South Slidell	9	0
Sub-Total for Vehicular, Pedestrian, and Railroad Gates	**11.75**	**1.25**
Road Ramps		
Western High Ground Tie In	0.5	0
West Slidell	0	0
South Slidell	5	0
Sub-Total for Road Ramps	**5.5**	**0**
Access Roads - New		
Western High Ground Tie In	0.1	0.1
West Slidell	0.45	0.45
South Slidell	2.75	2.75
Access Roads - Existing		
Western High Ground Tie In	0	0
West Slidell	15.8	0
South Slidell	9.9	0
Sub-Total for Access Roads	**29**	**3.3**
Mile Branch Channel Improvements	7.3	38.5

Sub-Total for Mile Branch Channel Improvements	**7.3**	**38.5**
Total Acres for 50-year Period of Analysis	**109**	**520**

*for floodwall segments, staging areas would be included in the 80 ft wide permanent ROW.

Table 3-2 lists the ROW width required per levee or floodwall segment. The width includes a 15 ft of vegetation free zone (VFZ) on each side of the levee/floodwall segment.

Table 3.2 Typical Widths of Permanent ROW for Levee and Floodwalls Segments

Levee and Floodwall Segments	Width of Permanent ROW (ft)*
Western High Ground Tie-in	160
West Slidell	300
South Slidell	160
Floodwall Segments	80
Access Roads	NA

***(Includes 15-ft VFZ on both sides)**

3.1 ACCESS ROUTES AND STAGING FOR MILE BRANCH

Site access to Mile Branch would be via public roads and public rights of way.

Staging areas are assumed to be dry. Any trees would be removed and hauled away to an approved facility. If necessary, crushed stone would be placed in the staging area prior to construction. After construction, the crushed stone would be removed and the disturbed areas would be fertilized and seeded.

For the culvert and bridge replacement work, all staging areas were assumed to be located within the individual structure construction areas. Staging areas are to be tree and vegetation free and covered with crushed stone.

3.1 ACCESS ROUTES AND STAGING FOR LEVEE CONSTRUCTION

There are locations where an existing road would be used for access. In other locations, a new road would be built.

New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for VFZ on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

LEVEE CONSTRUCTION EXCEPT REFUGE AREA

For staging areas for levee construction, crushed stone would be placed (assuming crushed stone for vehicle parking/staging and for path from road to area).

Any trees would be removed and hauled away to an approved facility. Contractor would use the area to process material prior to levee construction.

LEVEE CONSTRUCTION ON REFUGE AREA

For the construction of the levee on the refuge land (from Bayou Bonfouca to the railroad tracks), the ingress and egress would be at the Norfolk Southern railroad tracks on the east side of Bayou Bonfouca and existing roads on the west side. A one-way flow of traffic would be maintained. The USACE would need to obtain permission from the railroad owner (Norfolk Southern Railway Corp.) prior to construction. An access road would be constructed on the protected side of the ROW between the proposed crown of the levee and Bayou Bonfouca. The access road would be a temporary road. Once construction is complete, the area would be cleared of vegetation within the right of way and graded to drain away from the levee. Access during future inspections would be done by driving on the crown of the levee.

There would be one 2-acre staging area on the reach on the refuge land that would be considered a temporary easement. The staging area would be located off the refuge and would be used to process the material prior to building the levee. Staging areas would be required to be continuously accessible. Any trees would be removed and hauled away to an approved facility. The area would be restored to pre-construction elevation that existed prior to impacting the site due to construction activities.

3.2 ACCESS ROUTES AND STAGING AREAS FOR STRUCTURES

Existing public roads would be utilized for access to the maximum extent as possible. In locations where access cannot be achieved via existing roadways, a new road would be constructed. Construction of new roads would require permanent ROW.

New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for VFZ on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

For the floodwall segments, the temporary ROW (during construction) and the permanent ROW would be as shown in Table 3.3 below.

Table 3.3: ROW for Floodwall Segments

Floodwall Segments		Staging Area (Acres)	Permanent Access (Acres)
Western High Ground Tie-in for 2082			
N/A			
West Slidell			
Properties west of Doucette Road		0.4	0.4
North Side Bayou Paquet Drive		0.3	0.3

Bayou Paquet/Mayer Drive		1.6	1.6
South Slidell			
Front Street/Railroad		1.6	1.6
Mariners Cove Boulevard		0.6	0.6
Oak Harbor Country Club		0.2	0.2
Old Spanish Trail		0.3	0.3
Esprit du Lac Street		0.5	0.5
Substation Floodwall		2.2	2.2
Highway 190 Business		0.5	0.5
Utility Corridor		4.1	4.1
Hollywood Drive to Yaupon		4.2	4.2
Manzella Drive to Gause Boulevard		0.7	0.7
Total		**18**	**18**

For the floodgates and pump stations, the temporary ROW (staging area during construction) and the permanent ROW would be as shown in Table 3.4.

Table 3.4: ROW for Floodgates and Pump Stations

Floodgates and Pump Stations	Pump Station	Pumping Capacity (cfs)	Staging Area (Acres)	Permanent Area (Acres)
Western High Ground Tie-in for 2082				
Sluice gate near Shannon Drive	No		0.75	1.25
Sluice gate at Tammany Trace	No		0.75	1.25
West Slidell				
Sluice Gate # 7 (Near CC Road)	No		0.75	1.25
Sluice Gate # 6 (Bayou Paquet North Tributary)	Yes	300	0.75	1.25
Bayou Paquet Navigable Gate and Pump Station	Yes	500	0.75	1.25
Bayou Liberty Navigable Gate and Pump Station	Yes	1800	4	8
Bayou Bonfouca Navigation Gate and Pump Station	Yes	2000	4	8
Sluice Gate # 2 (Bayou Bonfouca Sluice Gate)	No		0.75	1.25
South Slidell				
W-14 Canal Navigable Gate and Pump Station	Yes	1000	0.75	1.25
Sluice Gate # 8 (Kings Point East) and Pump Station	Yes	200	0.75	1.25

Sluice Gate # 10 (Near East Terminus)	No		0.75	1.25
Reine Canal and Pump Station	Yes	200	0.75	1.25
French Branch at I-10 and Pump Station	Yes	450	0.75	1.25
Total for Floodgates and Pump Stations			**16.25**	**29.75**

3.3 ACCESS ROUTES AND STAGING AREAS FOR VEHICULAR, PEDESTRIAN AND RAILROAD GATES INITIAL CONSTRUCTION

For the vehicular, pedestrian and railroad gates, the temporary ROW (staging area during construction) and the permanent ROW would be as shown in Table 3.5:

Table 3.5: ROW for Vehicular, Pedestrian and Railroad Gates

Name	Staging Area (Acres)	Permanent ROW (Acres)
Western High Ground Tie-in for 2082		
Tammany Trace Pedestrian Gate	0.75	1.25
Tranquility Road Vehicular Gate	0.75	0
West Slidell		
Bayou Paquet Road Floodgate # 2	0.75	0
Mayer Drive Vehicular Gate	0.75	0
Railroad Floodgate	0.75	0
South Slidell		
Hwy 11 Vehicular Gate	0.75	0
Mariners Cove Floodwall and Vehicular Gate	0.75	0
Oak Harbor Vehicular Gate	0.75	0
Oak Harbor Country Club Vehicular Gate	0.75	0
Old Spanish Trail Floodgate (Hwy 433)	0.75	0
Hardin Road Substation Gate	0.75	0
Hwy 190-B Floodgate (East Floodwall)	0.75	0
South Holiday Drive Vehicular Gate	0.75	0
Jaguar Drive Vehicular Gate	0.75	0
Natchez Drive Vehicular Gate	0.75	0
Kisatchie Drive Vehicular Gate	0.75	0
Manzella Drive Vehicular Gate	0.75	0

3.4 STAGING AREAS AND ACCESS MATERIALS

LEVEE

For staging areas and access roads for levee construction, not including area for material processing during levee construction, a 7-inch depth of stone, and 115 lbs/cubic feet stone weight was assumed.

MILE BRANCH AND STRUCTURES

For the construction in Mile Branch and for the construction of structures, the staging areas and access roads, were assumed to have a 7-inch depth of crushed stone.

4 MILE BRANCH CHANNEL IMPROVEMENTS

The proposed work at Mile Branch would be located in a heavily populated area. There are properties in close proximity of the Mile Branch. There are no surveys available for this area.

Figure 4-1 provides the location of this work.

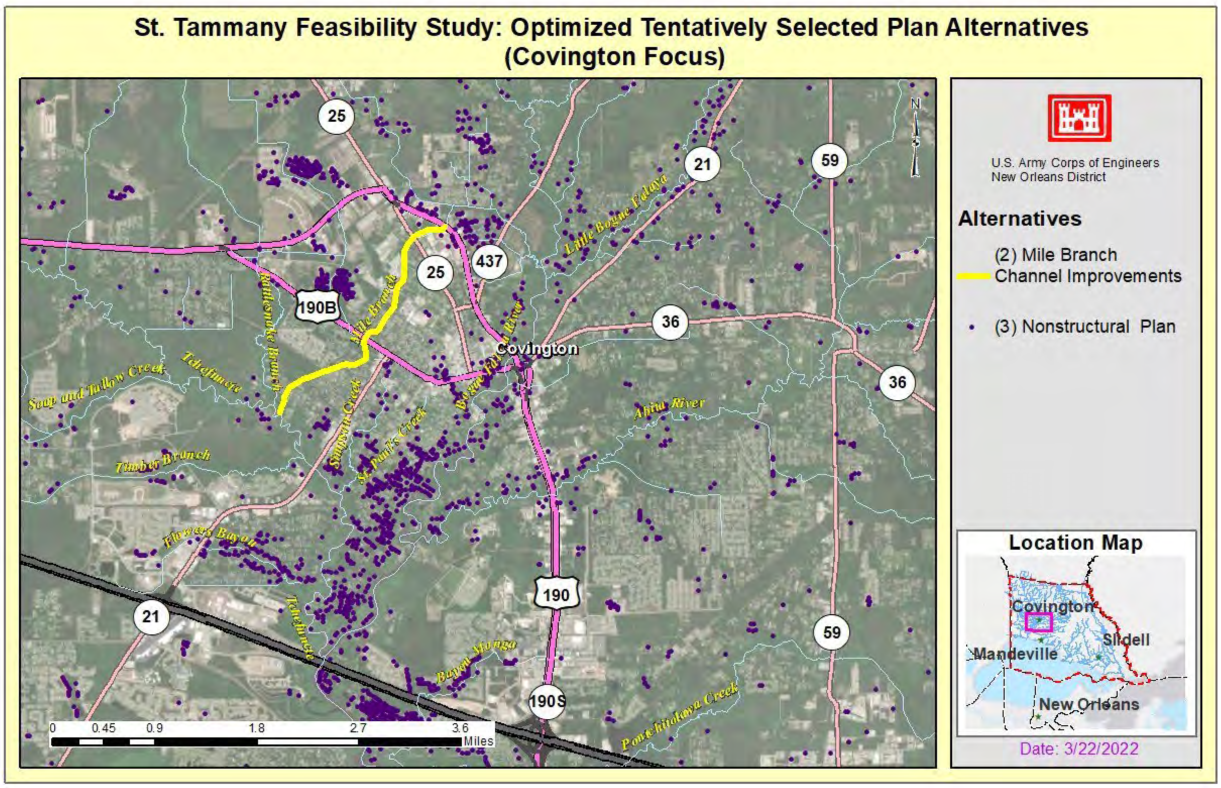

Figure 4-1. Optimized Tentatively Selected Plan Alternatives- Covington Focus

The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and ending at the intersection of Mile Branch and the Tchefuncte River. Refer to Figure 4-2.

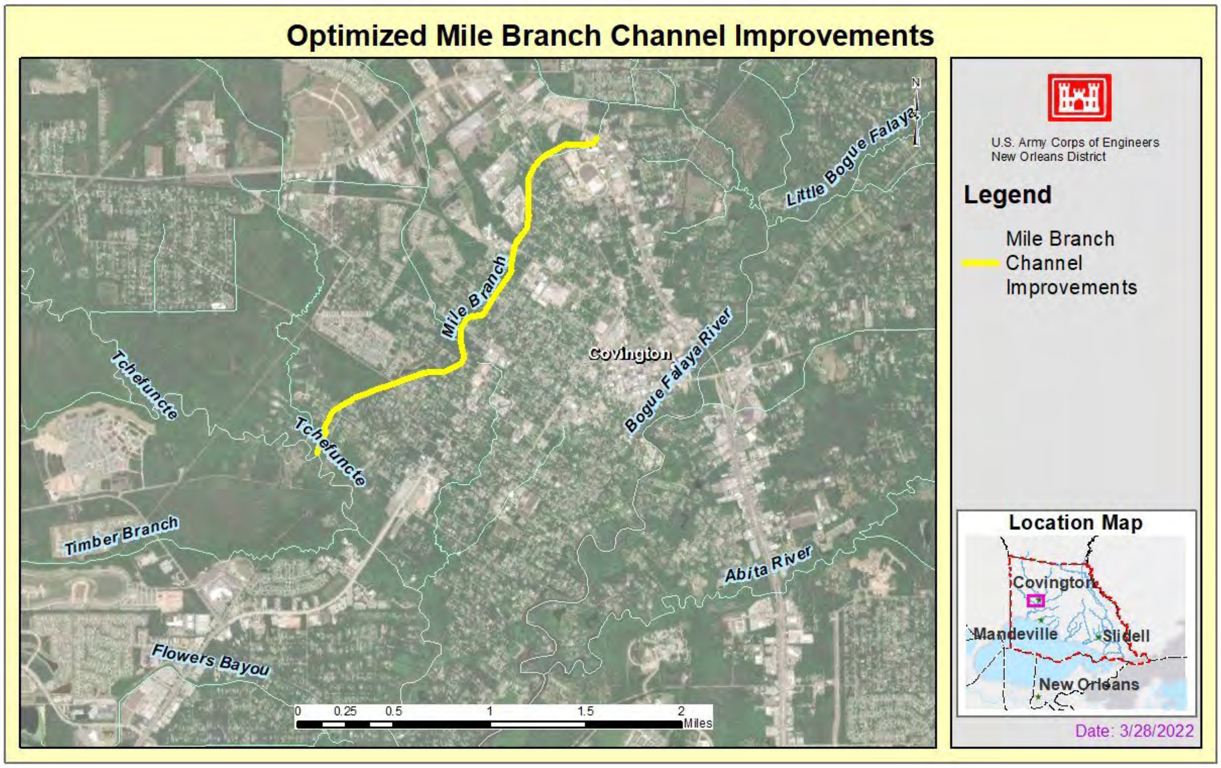

Figure 4-2. Optimized Mile Branch Channel Improvements

The preliminary design assumes an existing bank elevation of 1 ft, a 10-ft bottom width at elevation (-) 5 ft. The bank is at 1V:3H slope. The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel bottom would be lowered by 5 ft. Refer to Figure 4-3 for typical cross-section.

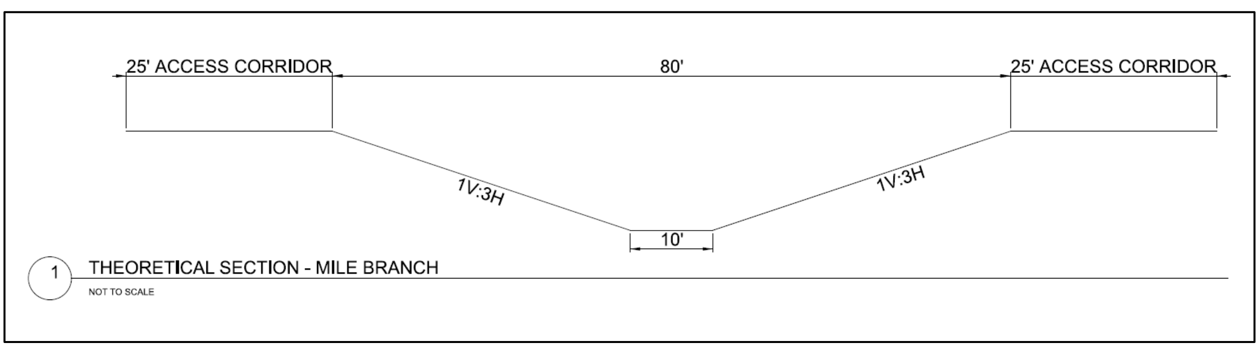

Figure 4-3. Mile Branch Improvements- Typical Cross-Section

Approximately 20 acres of channel would be cleared and grubbed prior to mechanical dredging. An assumed maximum of 130,000 cubic yards of material may be mechanically dredged from the channel. Material removed may include sediment, trees, debris, or other

obstructions within the waterway. For the channel improvements, approximately 34 acres of ROW would be needed for a temporary easement.

Riparian Zone bioengineering techniques and nature-based-solutions (NBS) would be considered as appropriate for Mile Branch FRM during PED in coordination with the NFS and resource agencies. A backwater area was included in the study phase.

4.1 STRUCTURAL IMPROVEMENTS

The Mile Branch channel improvements may include bridge replacements or new culverts (starting from north to south) at 29^{th}, 28^{th}, 25^{th}, 23^{rd}, 21^{st}, 19^{th}, and 18^{th} Avenues. No work is anticipated at the 15^{th} and 11th Avenue channel crossings as those bridges have been replaced prior to this study (and the new bridges were designed to safely pass higher flows on Mile Branch).

Assumptions for channel improvements included a 65 ft from the centerline of each side of the channel for ROW as a general guideline (total width of 130 ft); which includes space for equipment access. All work would be within the project footprint. Temporary work easement would be within ROW. The material to be disposed of would be trucked away from the site. Assumption is that all access would be through public lands.

Additional refinements would occur during PED. Future surveys would determine final channel section and bridge replacements or new culverts. Impacts to habitat and real estate would also be minimized. Opportunities to include natural features would be considered in future designs.

4.2 ACCESS ROUTES AND ROW CRITERIA FOR MILE BRANCH

Figure 4-4 provides the locations of the Mile Branch channel improvements including the structural improvements.

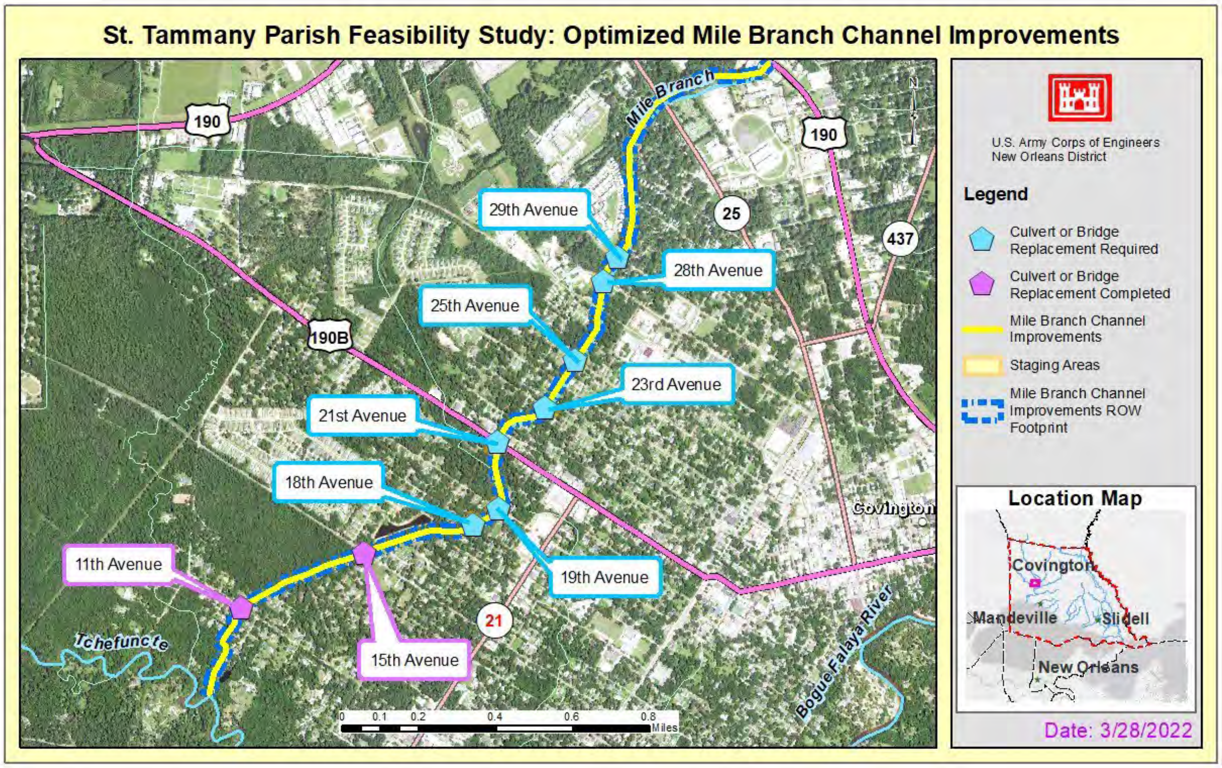

Figure 4.4. Optimized Mile Branch Improvements- Structural Improvements

Reference Table 3.1 for a listing of the staging areas and acres required for the structural improvements for Mile Branch. Table 4-1 below lists the staging area locations required for the bridge/culvert replacements and the necessary acres.

Table 4.1: Staging areas for the bridge/culvert replacements

Location	Temporary ROW Staging Area (Acres)
29th Avenue	0.37
28th Avenue	0.35
25th Avenue	0.20
23rd Avenue	0.21
21st Avenue	0.36
19th Avenue	0.36
18th Avenue	0.38
TOTAL	**2.23**

From:	Gunning, Kristin T MVN
To:	Soileau, Karen
Cc:	Stiles, Sandra E CIV USARMY CEMVN (USA); Gilmore, Tammy F CIV USARMY CEMVN (USA); Behrens, Elizabeth H CIV USARMY CEMVN (USA)
Subject:	St. Tammany DEIS BA
Date:	Monday, July 3, 2023 1:14:27 PM
Attachments:	STPS BA USFWS 20230622.pdf

Good afternoon,

Please see the attached Biological Assessment for the St. Tammany Parish, Louisiana Draft Environmental Impact Statement.

Best,

Kristin Gunning
Biologist, Environmental Studies Section
Regional Environmental Planning Division, South
USACE, New Orleans District

ST. TAMMANY PARISH, LOUISIANA FEASIBILITY STUDY REVISED DRAFT INTEGRATED FEASIBILITY REPORT WITH DRAFT ENVIRONMENTAL IMPACT STATEMENT

THREATENED AND ENDANGERED SPECIES BIOLOGICAL ASSESSMENT

June 22, 2023

The purpose of this Biological Assessment (BA) is to assess the effects of the proposed project and determine whether the project may affect any Federally threatened, endangered, proposed or candidate species. This BA is prepared in accordance with legal requirements set forth under Section 7 of the Endangered Species Act (16 U.S.C. 1536 (c)).

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Appendix D   Conservation Measures

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1 Description of the Action

1.1 Project Name

St. Tammany Parish, Louisiana Feasibility Study - Revised Draft Integrated Feasibility Report with Draft Environmental Impact Statement

1.2 Introduction

Section 7(a)(2) of the Endangered Species Act (ESA) of 1973, as amended, requires that "Each Federal agency shall in consultation with and with the assistance of the secretary, insure that any action authorized, funded or carried out by such agency…is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species…"

The U.S. Army Corp of Engineers (USACE), New Orleans District (MVN), has prepared this Biological Assessment (BA) to evaluate the potential impacts associated with the proposed flood risk reduction project, St. Tammany Parish, Louisiana Feasibility Study. This BA provides the information required pursuant to the ESA and implementing regulation (50 CFR 402.13), to comply with the ESA. Additional legal authorities include the National Environmental Policy Act (NEPA) of 1969, 42 U.S.C. section 4321, et seq.; the Fish and Wildlife Conservation Act of 1958 (PL 85-624; 16 U.S.C. 661 et seq.); the Marine Mammal Protection Act of 1972 (MMPA); and the Migratory Bird Treaty Act of 1918 (MBTA). A BA has been submitted to the U.S. Fish and Wildlife Service (USFWS) and the National Marine Fisheries Service (NMFS) by the USACE, MVN to initiate informal consultation regarding potential impacts to threatened and endangered species from construction related to St. Tammany Parish, Louisiana Feasibility Study. This BA addresses impacts from the proposed action to species within USFWS jurisdiction. A separate BA was submitted to the NMFS to address species and critical habitat within NMFS jurisdiction.

A search on the USFWS' Information for Planning and Consulting (IPaC) site, conducted on February 23, 2023, resulted in a list of ESA-listed species that should be considered when assessing the impacts of this project. That list includes the alligator snapping turtle, eastern black rail, West Indian manatee, red-cockaded woodpecker, gopher tortoise, ringed map turtle, Gulf sturgeon, Louisiana quillwort, monarch butterfly, and Gulf sturgeon Critical Habitat. Only impacts to the West Indian manatee, Louisiana quillwort, Gulf sturgeon, Gulf sturgeon critical habitat, Gopher tortoise, and red-cockaded woodpecker are discussed in this BA.

Email correspondence with USFWS determined that the black rail is known to occur in the Gulf Coast Chenier Plain of Louisiana (specifically Cameron and Vermilion Parishes); Since the proposed action would not impact this area, "no effect" determination can be made for this species. Additionally, a "no effect" determination can be made for the ringed map turtle as it's known range in Louisiana, the Pearl and Bogue Chitto Rivers, would not be impacted by the proposed project.

The monarch butterfly is listed in the ESA as a "candidate" species. Candidate species receive no protections under the ESA. Should a listing decision be made prior to completion of the proposed action, CEMVN will reinitiate consultation with the USFWS.

The alligator snapping turtle is listed in the ESA as "proposed threatened". Proposed species are not protected by the take prohibitions of Section 9 of the ESA until the rule to list is finalized. Under section 7(a)(4) of the ESA, Federal agencies must confer with the Service if their action will jeopardize the continued existence of a proposed species. Correspondence between the USFWS and USACE determined a conference is not necessary because of the scale of the project relative to the range of this species and the availability of suitable habitat (Appendix B). Measures to minimize impacts to the alligator snapping turtle provided by the USFWS is included in Section 1.5.3.

Marine Mammal Protection Act prohibits the take (i.e., harass, hunt, capture, or kill) of all marine mammals. The responsibilities for the protection, conservation, and management of marine mammals are shared by the U.S. Fish and Wildlife Service and NOAA Fisheries. Within the Action Area, the West Indian manatee is protected under the MMPA and ESA. Impacts to the manatee are discussed in this BA.

The Migratory Bird Treaty Act (MBTA) (16 U.S.C. 703, et seq.) is the primary legislation in the United States established to conserve migratory birds. The MBTA prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests, except when specifically authorized by the Department of the Interior. An IPaC search indicated there are 40 species of MTBA-listed birds within the Action Area. While the MBTA has no provision for allowing incidental take, USFWS recognizes that some birds may be taken during project construction/operation, even if all reasonable measures to avoid take are implemented.

1.3 Project Description

The proposed action consists of the construction of a levee and floodwall system along an alignment in South and West Slidell, Louisiana, channelization of a portion of the Mile Branch in Covington, Louisiana (Figure 1), and the creation of new habitat mitigation areas to offset losses within the project's construction footprint areas.

Channel improvements would occur on the lower 2.15 miles (11,341 ft channel) of Mile Branch in Covington, Louisiana. The proposed work would consist of approximately 20 acres of channel that would be cleared and grubbed prior to mechanical dredging.

The levee and floodwall system consists of construction of a total of approximately 18.4 miles (96,950 feet) of earthen levee and floodwall which includes approximately 15 miles (79,100 feet) of levees constructed in separate (non-continuous) segments, and

3.4 miles (17,850 feet) of separate (non-continuous) segments of a floodwall (Figure 3). Features included in the system design consist of eight pump stations, thirteen sluice gates/lift gates, sixteen vehicular floodgates, one pedestrian floodgate, one railroad gate, and eleven road ramps (Table 3). See Appendix A for details of the project features.

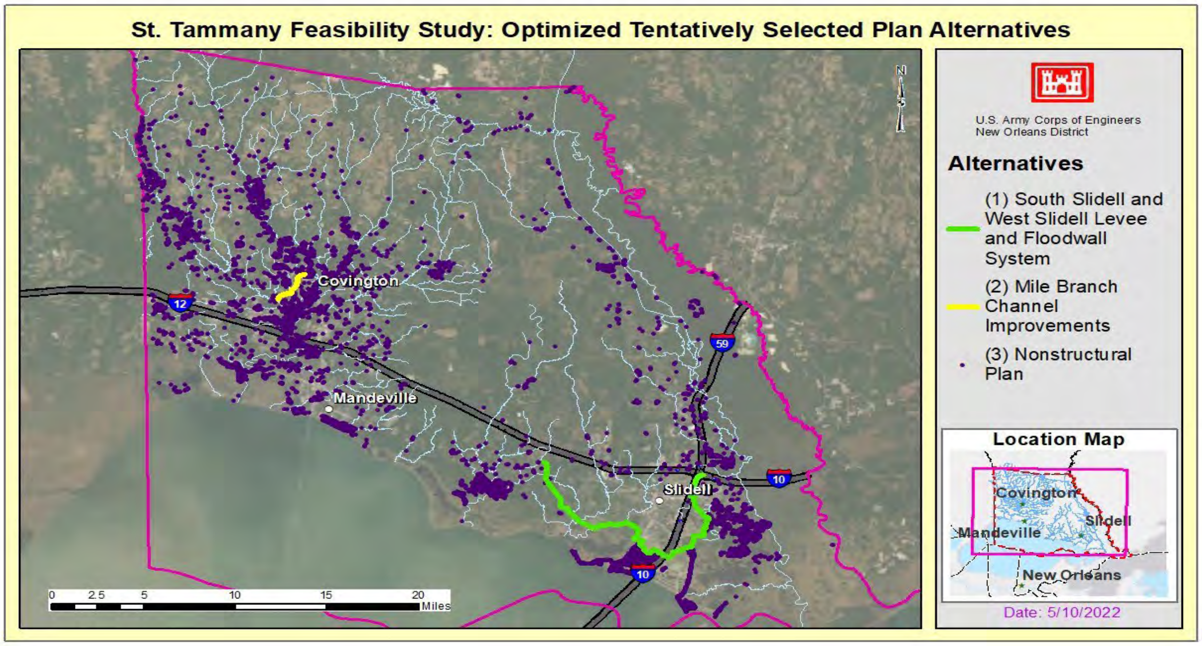

Figure 1. Proposed levee alignment and channel improvements in St. Tammany Parish, Louisiana.3.

1.3.1 Location

The channel improvement project is located in St. Tammany Parish, Louisiana within the City of Covington. The levee and floodwall system would be constructed in southeast St. Tammany Parish near Slidell, Louisiana. The M2 mitigation site is located along the northeast shore of Lake Pontchartrain near Big Branch Marsh National Wildlife Refuge.

1.3.2 Description of the Project Habitat

The Louisiana Department of Wildlife and Fisheries, Wildlife Diversity Program, identified 22 habitat types occurring within St. Tammany Parish. Of the 22 vegetative habitat types identified, 15 are classified as wetlands, of which all are in a state of decline. Habitat identified within the Action Area include fresh marsh, intermediate marsh, longleaf pine flatwood savannas, fresh floating/submerged vegetation, mixed hardwood-loblolly forest, longleaf pine flatwoods, upland longleaf pine forests, and open water (Table 1).

Table 1. Status of vegetative types in St. Tammany Parish (source: Louisiana Department of Wildlife and Fisheries, 1999 and St. Tammany New Directions 2025 web site).

Vegetative Type	Abundance/Status	Trend
Fresh Marsh	Rare	Stable/Very Slowly Declining
Intermediate Marsh	Common	Stable/Very Slowly Declining
Longleaf Pine Flatwood Savannah	Rare	Declining
Fresh Floating/Submersed Vegetation	Common	Stable
Mixed Hardwood-Loblolly Forest	Uncommon	Declining
Longleaf Pine Flatwoods	Critically Imperiled	Rapidly Declining
Upland Longleaf Pine Forest	Critically Imperiled	Rapidly Declining

Freshwater marsh is found surrounding bodies of open water and is located along the shoreline of Lake Pontchartrain and along the mouth of the Pearl River. It forms in accreting, sediment rich, high-energy environments typical for this region and is dominated by rush and reed plant species like cattails and arrowhead. These marshes can form detached mats of vegetation, known as flotant, which encourage colonization by other plant species. Fresh marshes provide nursery habitat for estuarine-dependent species important to recreational and commercial fisheries such as blue crab, white shrimp, Gulf menhaden, Atlantic croaker, red drum, southern flounder, bay anchovy, striped mullet, and others. Fresh marshes also provide habitat for largemouth bass, warmouth, black crappie, blue catfish, bowfin, and gar.

Intermediate marsh is a unique type of wetland marsh found in the Action Area whose vegetative community reflects the shifts in salinity associated with proximity to marine environments. This type of marsh is the middle part of the gradient found in vegetative communities shifting from fresh to saline waters, and the marsh species that are found in this type like saltmeadow grass are capable of withstanding spikes of salinity that are associated with tropical storm surge events. It is commonly a narrow band of vegetation when compared with other marsh types due to the large differences between freshwater and brackish salinities. Wildlife found within an intermediate marsh is less diverse than found in freshwater marshes, but more individuals may be present.

Pine savannas are scattered within the Action Area and are a managed habitat type within the Bayou Bonfouca NWR. They are found naturally on broad "flats" in an interdigitated mosaic with mesic to dry-mesic (non-wetland) longleaf pine flatwoods, savannas occupying the poorly drained and seasonally saturated/flooded depressional areas and low flats, while the non-wetland flatwoods occupy the better drained slight rises and low ridges. They are subject to a highly fluctuating water table, from surface saturation/shallow flooding in late fall/winter/early spring to growing-season droughtiness.

Uplands scattered throughout the parish are dry and generally consist of a mixed hardwoods and loblolly pine forest as well as dry-mesic pine flatwoods. Mixed hardwood-loblolly pine forests are distributed in a variety of ecological settings statewide on broad ridgetops and gentle side slopes in terrace uplands; on middle and lower slopes between uplands and stream bottoms; and at the heads of drainages along small, intermittent streams.

Open water habitats within Lake Pontchartrain are characterized by sandy bottoms and relatively shallow depths extending to 15 feet (NOAA Chart 11639). Desktop review of National Oceanic and Atmospheric Administration Bathymetric Data of Lake Pontchartrain (ESD-PHB-21, W00561) indicate water depth between approximately 3 ft to 11 ft in the vicinity of the M2 borrow site.

1.3.3 Project Proponent Information

Requesting Agency

Department of Defense (DOD)
Army Corp of Engineers (COE)
Kristin Gunning
7400 Leake Avenue
New Orleans, LA 70118
504-862-1514
Kristin.t.gunning@usace.army.mil

Lead Agency

Same as Requesting Agency

1.3.4 Project Purpose

St. Tammany Parish has experienced repeated, widespread flooding from rainfall and riverine bank overtopping, and storm surge, including historic impacts during Hurricane Katrina in August of 2005 and recently with the flood of August 2016. The purpose of the proposed project is to construct a flood risk reduction system to reduce the severity of flood damages and risk to public health and safety, caused by heavy rainfall, riverine flooding, tropical storms, and hurricanes.

1.3.5 Project Type and Deconstruction

Mile Branch Channel Improvements

Construction

This feature consists of channel improvements on the lower 2.15 miles (11,341 ft channel) of Mile Branch in Covington, Louisiana. The proposed work would consist of approximately 20 acres of channel that would be cleared and grubbed prior to mechanical dredging (Figure 2). Table 2 lists the Mile Branch attributes of the tentatively selected plan (TSP) for the 50-year period of analysis.

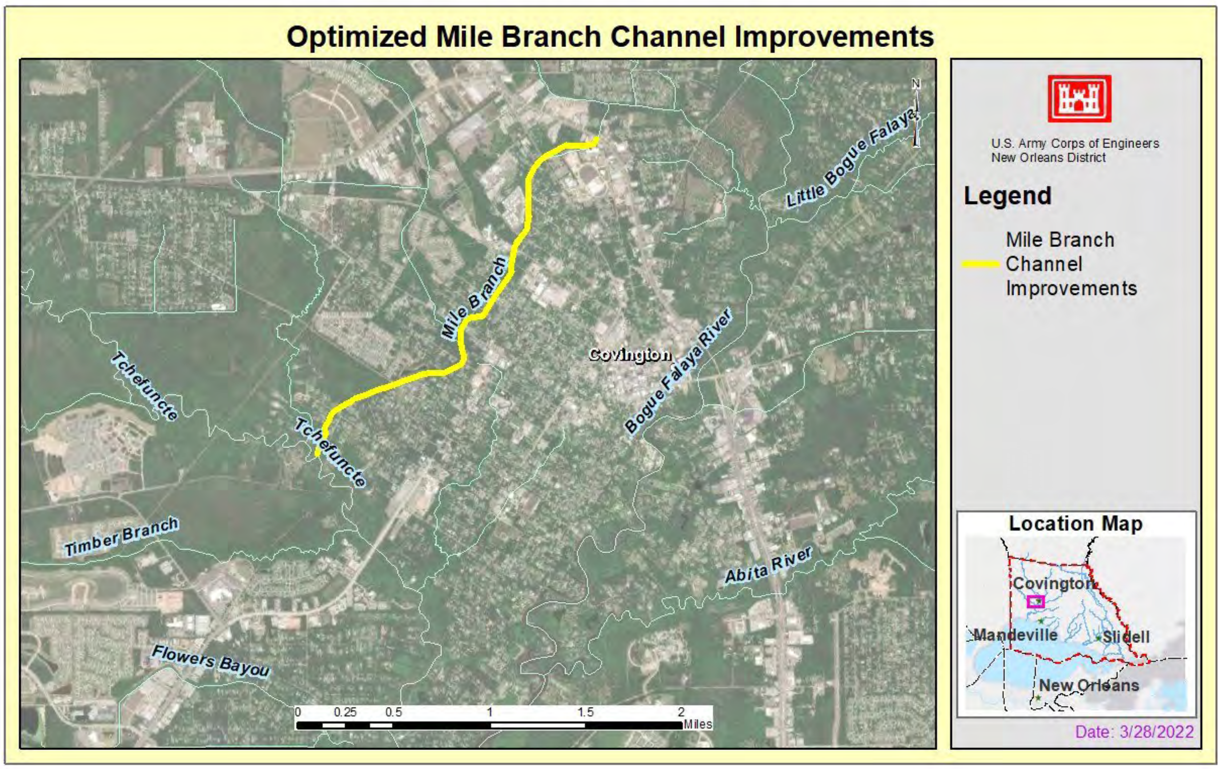

Figure 2. Mile Branch Channel Improvements

Table 2. Summary Table of TSP for Mile Branch

Attribute	Mile Branch Channel Improvements
Total Length of improvements	2.15 miles (11,341 feet)
Material to be Mechanically Dredged	130,000 cubic yards
Access Roads for both clearing and for bridge replacement	0 acres
Number of staging areas for clearing and grubbing and mechanical dredging and for culvert/bridge replacement	19 (7 for culvert/bridge replacements, 11 for clear and grubbing and mechanical dredging and one that becomes a backwater area)
Number of Bridge Replacements of Culverts	7
Temporary ROW	7.3 acres (2.2 acres for culvert/bridge replacements and 5.1 acres for clear and grubbing and mechanical dredging)
Permanent ROW	38.5 acres (34 acres for clear and grubbing and mechanical dredging and 4.5 acres for one staging area that becomes a backwater area)

The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and end at the intersection of Mile Branch and the Tchefuncte River. Assumptions for channel improvements included a 65-ft from the centerline of each side of the channel for right of way (ROW) as a general guideline (total width of 130 ft).

The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel would be widened as well as deepened. The channel bottom would be lowered by 5 ft. Work would be done by excavators or small skid steers and all work would be performed from the bank. The trees located close to the bank would be removed and the banks would be stabilized, seeded, and fertilized to have a grass cover. Material removed may include sediment, trees, debris, or other obstructions within the waterway. Removed material would be trucked off-site and disposed at a facility licensed to handle the material.

For the channel improvements, approximately 34 acres of permanent ROW would be needed. This area would include 25 ft on each side of the Mile Branch channel. Within the 34 acres, approximately 20 acres of channel would be cleared and grubbed prior to mechanical dredging. Up to 130,000 cubic yards of material may be mechanically dredged from the channel and would be removed by truck or sidecast along the bank. Sidecast material would temporarily increase water turbidity and decrease water quality, and naturally revegetate or move through the water channel to be deposited downstream. Removed material would be trucked off-site and disposed at a facility licensed to handle the material.

Mile Branch improvements may include bridge replacements or culverts. Approximately 2.2 acres would be required for staging along the various areas of the bridge/culvert replacements.

Riparian Zone bioengineering techniques and nature-based-solutions (NBS) would be considered as appropriate for Mile Branch FRM during PED in coordination with the NFS and resource agencies. A backwater area would be created off of mile branch that provides 3 acres of mud bottom as a project feature. Ideally, a free exchange of water between mile branch and the backwater area would be preferred, however, if access to Mile Branch must be provided along the full length of Mile Branch, then culverts would be required to allow inflow and outflow between the two areas. Culverts would be placed at an elevation that allows frequent water exchange between Mile Branch and the backwater area to avoid stagnation. The site would be excavated 3-5-ft below the average stage of Mile Branch to achieve both deep-water and shallow water habitat. A 40-ft buffer would be planted with bottomland hardwoods around the east, south, and west perimeter of the site. The 40-ft buffer should not be higher than the existing elevation to allow run-off from adjacent areas to flow into the backwater area. The deep-water area would be excavated at a 3:1 slope away from the buffer to achieve the required depth of the site. Finger islands would be created within the site and planted with BLH. Excavated material from within the site would be hauled off-site. The internal tree "fingers" would be at a lower elevation than the perimeter forested buffer. The fingers should be at the former natural ground elevation or a foot or two lower but would be sufficient to support BLH species. Deep water "channels" would extend through the southern end of the tract to encourage circulation throughout the site. Some shallow areas should be provided for marsh or swamp vegetation growth.

Staging and Access

Site access to Mile Branch would be via public roads and public rights of way.

Staging areas are assumed to be dry. Any trees would be removed and hauled away to an approved facility. If necessary, crushed stone would be placed in the staging area prior to construction. After construction, the crushed stone would be removed, and the disturbed areas would be fertilized and seeded.

For the culvert and bridge replacement work, all staging areas were assumed to be located within the individual structure construction areas. Staging areas are to be tree and vegetation free and covered with crushed stone.

South and West Slidell Levee and Floodwall Alignment

Construction

The levee and floodwall system would consist of a total of approximately 18.4 miles (96,950 feet) of earthen levee and floodwall which includes approximately 15 miles (79,100 feet) of levees constructed in separate (non-continuous) segments, and 3.4 miles (17,850 feet) of separate (non-continuous) segments of a floodwall (Figure 3). Construction of the levee alignment would impact approximately 520.7 acres of permanent ROW and it would require approximately 7,069,000 cubic yards of fill, including fill material required for future levee lifts (estimates include a 30 percent contingency). Table 3 provides a summary of the attributes of the South and West Slidell Levee and Floodwall System. Table 4 is a summary of the levee quantities required for the initial construction.

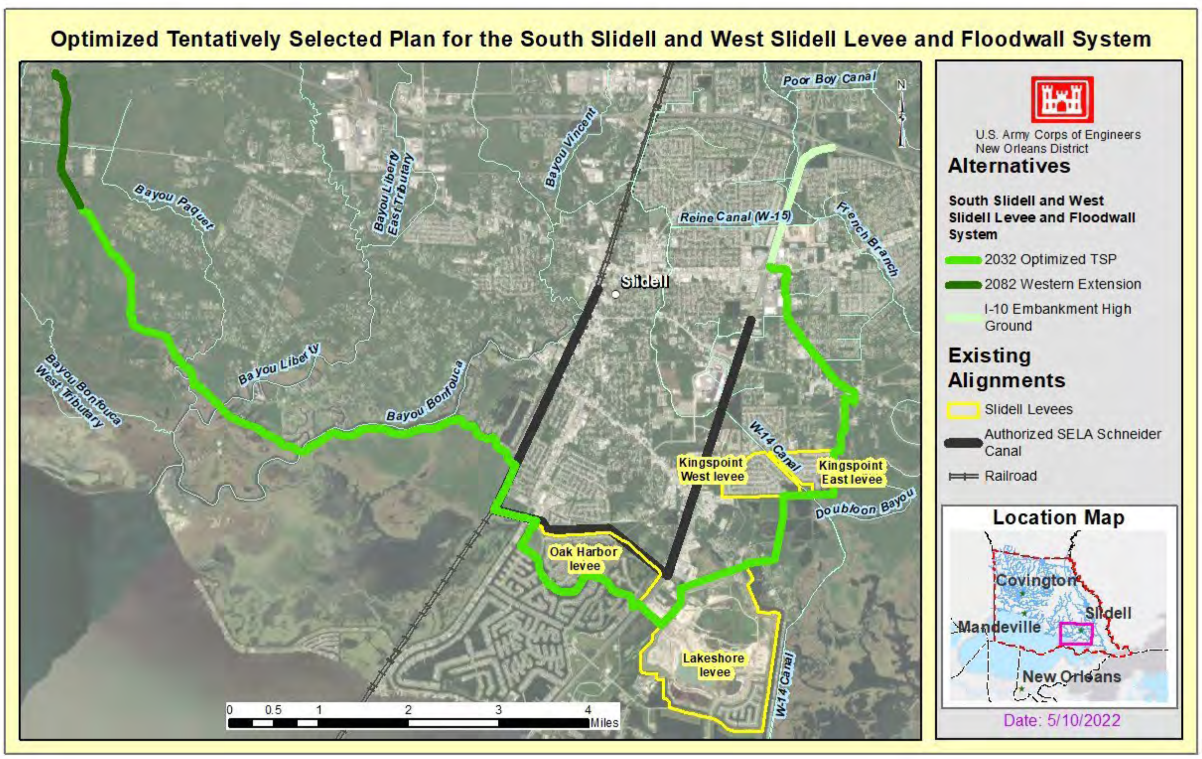

Figure 3. South and West Slidell Levee and Floodwall alignment in St. Tammany Parish, Louisiana

Table 3. Summary Table of South Slidell and West Slidell Levee and Floodwall System

Attribute	South Slidell and West Slidell Levee and Floodwall System
Total Length of alignment	18.4 miles (96,950 feet)
Length of Floodwall	3.4 miles (17,850 feet)
Length of earthen Levee	15 miles (79,100 feet)
Temporary Acres of Construction for Levee and Floodwall system	109 acres
Permanent Acres for Levee and Floodwall system	521 acres
Hydraulic Design Elevation Range (Dependent on location)	13.5 to 16 (year 2032) 17.5 to 20 (year 2082)
Pump Stations	8
Sluice Gates/Lift Gates	13
Number of Vehicular Floodgates	16
Number of Pedestrian Floodgates	1
Number of Railroad Gates	1
Number of Road Ramps	11
Fill (Borrow Material) Required	7,069,000 cubic yards

Table 4. Initial levee alignment ROW and fill quantities

Levee Alignment ROW and Levee Quantities Initial Construction (Year 2032)	
WEST SLIDELL	
Permanent ROW	240 acres
Fill Material (includes 30% contingency)	2,007,000 cubic yards
SOUTH SLIDELL	
Permanent ROW	120 acres
Fill Material (includes 30 %contingency)	825,000 cubic yards**
TOTAL	
Permanent ROW	360 acres
Fill Material (includes 30 % contingency)	2,832,000 cubic yards

**includes quantities for I-10 portion of the alignment.

Levee Lifts

Levee lifts would be required over the 50-yr period of analysis. The levee lift schedule would follow the hydraulic design elevation requirements and thus were divided into 3 geotechnical reaches: Oak Harbor South; I-10 Crossing; and Slidell East/Northeast as illustrated in Table 5. The fourth lift (final lift for the 50-year period of analysis), projected to occur in year 2076 would elevate the levee to a construction elevation of 19 ft.

Table 5. Future Levee Lifts

	Construction Lift (year)	**Construction Elevation (feet)**	**Permanent ROW (acres)**	**Fill Material (+30% contingency; cubic yards)**
WEST SLIDELL				
First lift	2033	16	N/A	771,000
Second lift	2038	17.5	N/A	901,000
Third lift	2051	19	N/A	685,000
Fourth lift	2076	19	30 *	709,000 *
SOUTH SLIDELL				
Oak Harbor South				
First Lift	2035	17	N/A	106,000
Second Lift	2048	18	N/A	120,000
Third Lift	2064	19	N/A	115,000
I-10 Crossing**				
Slidell East / Northeast				
First Lift	2034	19	N/A	271,000
Second Lift	2047	20.5	N/A	295,000
Third Lift	2064	21.5	N/A	264,000
Total For Future Lifts				
			30	4,237,000
Total for Life of the Project (initial construction + lifts)				
			390	**7,069,000**

***** Includes the levee quantities (192,000 cubic yards) for the Western High Ground Tie-in for Year 2082.
** I-10 Crossing features would be constructed to the 2082 elevation and therefore would not require additional lifts.

<u>Western Extension</u>

The Western High Ground Tie-in for Year 2082 is shown in dark green in Figure 3. Based on modeling, the western extension would not be necessary until the year 2076 when the risk reduction would be needed. It is anticipated that this levee segment would be constructed during the fourth levee lift of the West Slidell alignment.

The alignment would commence north of US Highway 190 in the neighborhood near the intersection of North Tranquility Road and Shannon Drive between two properties. The alignment would be a berm with hydraulic design elevation of 17.5 ft for year 2082. The alignment would switch to levee (hydraulic design elevation of 17.5 ft (Year 2082)) and would continue south on the edge of the properties and cross US Highway 190, the Tammany Trace Bike Trail and South Tranquility Road on the eastern side of Pineridge Road. The alignment would run south southeast an additional 890 feet past the intersection with South Tranquility Road and tie with the existing year 2032 alignment for West Slidell.

West Slidell Alignment

Construction

Levee construction would commence on the south side of US Highway 190 and South Tranquility Road, and on the eastern side of Pineridge Road. For the West Slidell portion of the alignment, the levee segments would have a hydraulic design elevation of 13.5 ft (Year 2032).

The alignment would run southward and on the west side of Tranquility Road (CC Road) and then it would turn in the southeast direction crossing Bayou Paquet Road and would stay on the east side of Bayou Paquet Channel to avoid impact to the Big Branch Marsh National Wildlife Refuge (NWR). It would cross Bayou Paquet and Bayou Liberty and would continue eastward on the northside of the Big Branch Marsh NWR. It would then cross Bayou Bonfouca and would continue on the south bank of the bayou (northern side of the refuge) until reaching the Norfolk Southern Railway Corp. railroad tracks west of US Highway 11 in the vicinity of Dellwood Pump Station in Slidell. The West Slidell Alignment is shown in Figure 4. A typical levee cross-section for West Slidell is shown in Figure 5.

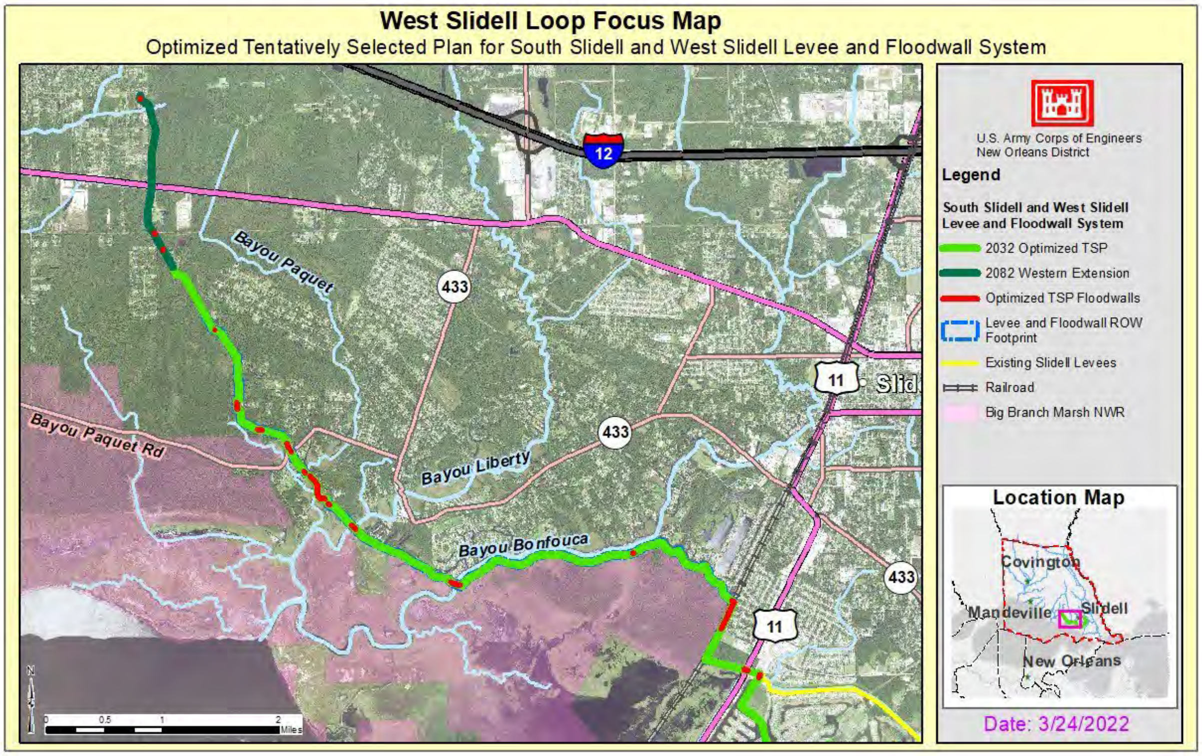

Figure 4. West Slidell and the South Slidell Levee and Floodwall System

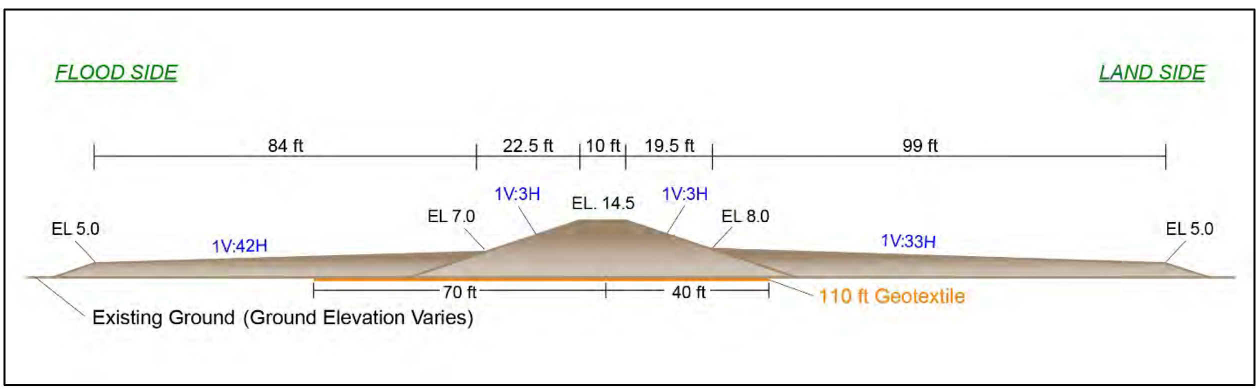

Figure 5. Typical Cross-Section with Berms for West Slidell

South Slidell Alignment

Construction

The levee and floodwall system alignment from West Slidell would continue to South Slidell. From the railroad gate connecting West Slidell with South Slidell, the alignment would transition to a floodwall running parallel along the east side of the railroad tracks. The floodwall by the railroad tracks would have a hydraulic design elevation of 16.5 ft for year 2082.

The alignment would transition to levee when it turns east toward Highway 11 where it would cross Highway 11 and would turn south in the vicinity of the existing Schneider Canal Pump Station and then turn east (on a portion of the existing Oak Harbor ring levee). It would then run on the south side of Oak Harbor Boulevard and would cross to the north side immediately past Mariners Cove Boulevard. The levee along the south side of the Oak Harbor would have a hydraulic design elevation of 14 ft for year 2032.

The alignment would run on a portion of the existing Oak Harbor ring levee. The alignment would turn north and then east in the vicinity of the I-10. The I-10 would be raised to ramp over the new levee section (hydraulic design elevation of 18.5 ft for year 2082).

The alignment would continue southeast and would tie to an existing portion of the Lakeshore Estates ring levee. It then would turn north and then east and cross Old Spanish Trail/Highway 433, continue north and tie into a portion of the existing King's Point west levee. The section of levee would have a hydraulic design elevation of 16 ft for year 2032.

The alignment would cross the W-14 Canal and would tie to a portion of the existing King's Point east levee and would turn north. The levee would have a hydraulic design elevation of 16 ft for year 2032. The levee would turn east and then north. Immediately south of Highway 190 Business it would turn from levee to floodwall to provide risk reduction to the existing Hardin Road power substation. The floodwall would have a hydraulic design elevation of 18.5 ft for year 2082.

The alignment would cross Highway 190 Business and continue northwest on the west side of the existing CLECO Corporate Holdings, LLC utility corridor. It would cross South Holiday Drive and continue north. Itwould then turn east on Manzella Drive and turn north in the middle of the block between Yaupon Drive and Malbrough Drive.

The alignment would cross Gause Boulevard as a ramp crossing and would turn west and tie to high ground (hydraulic design elevation of 18.5 ft for year 2082) in the vicinity of the I-10. There would be additional road ramps for businesses on the north side of Gause Boulevard, the I-10 Service Road and the I-10 on-ramp for the I-10 eastbound at Gause Boulevard. The West Slidell Alignment is shown in Figure 6. A typical levee cross-section for West Slidell is shown in Figure 7.

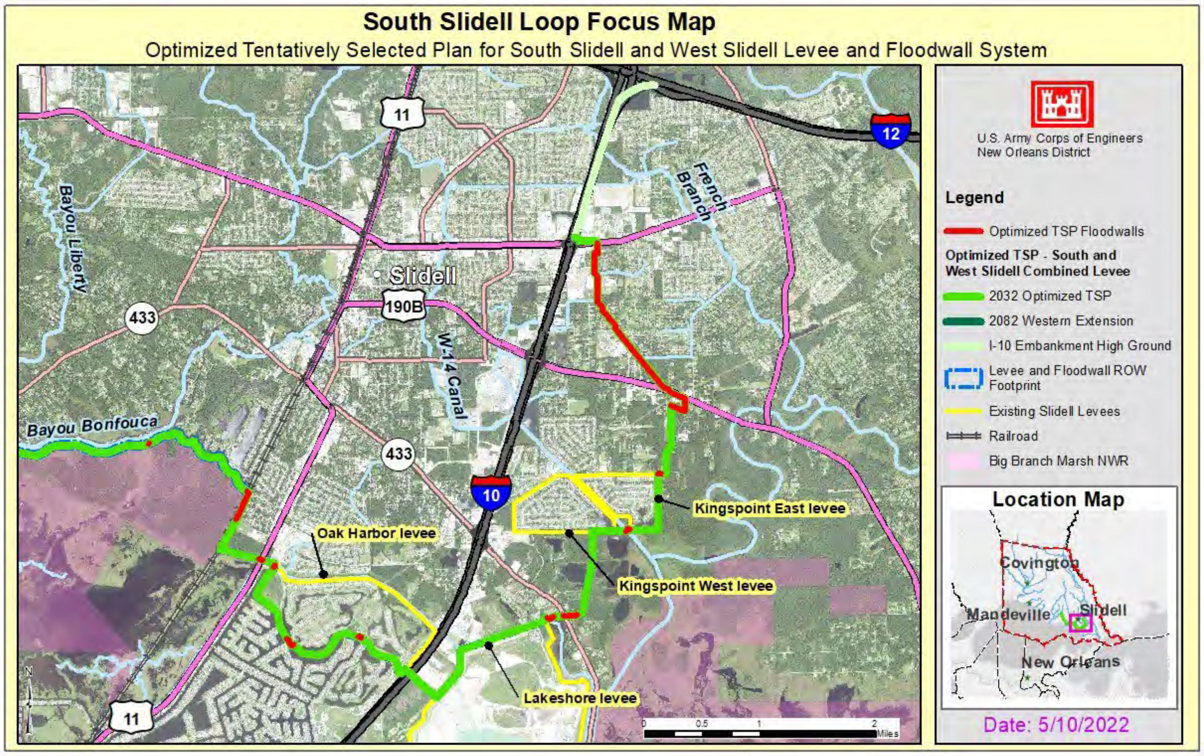

Figure 6. South Slidell Levee and Floodwall System

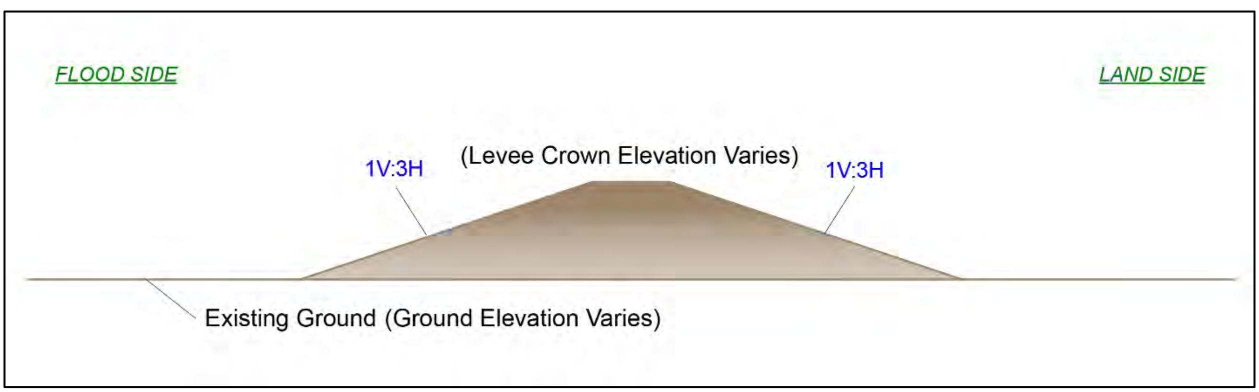

Figure 7. Typical Cross-section for South Slidell

Temporary Bypass Channel

Temporary bypass channels would be constructed at locations where a pump station or floodgate is proposed within the limits of a channel. The temporary bypass channels would route water around the structures in order for the construction to be done in dewatered conditions.

In order to maintain pre-construction flow conditions and minimize environmental impacts during construction, the temporary bypass channels would be similarly sized to the channels being impacted. After construction, the bypass channel is assumed to be included in the footprint of the structure site and the channel flow would be rerouted through the new structure feature. Navigation of common local vessels would be considered for the bypass channels, and design features of a navigable bypass channel would be developed during PED.

Temporary Retaining Structures (TRS)

Temporary Retaining Structures (cofferdams) are temporary features that facilitate the construction of major structures. Cofferdams allow water or other materials to be removed inside the TRS in order to work in an excavated and/or dewatered condition.

Cofferdams would be required during the construction of the pump stations and floodgates. Qualified designers employed or sub-contracted by the construction contractors would design the TRS for this project.

Pump Stations

The Optimized TSP would include a total of eight (8) pump stations. These pump stations are divided into large pumping capacity and small pumping capacity.

In West Slidell there would be two (2) pump stations with large pumping capacity and two (2) pump stations with small pumping capacity. In South Slidell there would be four (4) pump stations with small pumping capacity (Table 6). Large pump stations were assumed to have similar components and configuration as the USACE West Shore Lake Pontchartrain Reserve Relief Canal Pump Station. Small pump stations would have similar pumping capacities to the Prescott Road Pump Station for the Lake Pontchartrain Lakeshore study. These studies can be found at the following linkhttps://www.mvn.usace.army.mil/Missions/Environmental/NEPA-Compliance-Documents/Bipartisan-Budget-Act-2018-BBA-18/West-Shore-Lake-Pontchartrain/.

Table 6: Pump Stations

Pump Station Location	Pump Station Capacity
Western High Ground Tie-in for 2082	
N/A	
West Slidell	
Bayou Liberty	1,800 cfs
Bayou Bonfouca	2,000 cfs
Bayou Paquet North Tributary	300 cfs
Bayou Paquet	500 cfs
South Slidell	
W-14 Canal	1,000 cfs
Kings Point	200 cfs
Reine Canal	200 cfs
French Branch at the I-10	450 cfs

Access and Staging

Existing public roads would be utilized for access to the maximum extent possible. New roads would be constructed in locations where access cannot be achieved via existing roadways. Construction of new roads would require permanent ROW. New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for vegetation free zones (VFZ) on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

For construction of the levee on refuge land (from Bayou Bonfouca to the railroad tracks), the ingress and egress would be at the Norfolk Southern railroad tracks on the east side of Bayou Bonfouca and existing roads on the west side. A one-way flow of traffic would be maintained. The USACE would need to obtain permission from the railroad owner (Norfolk Southern Railway Corp.) prior to construction. A temporary access road would be constructed on the protected side of the ROW between the proposed crown of the levee and Bayou Bonfouca. Once construction is complete, the area would be cleared of vegetation within the right of way and graded to drain away from the levee. Access during future inspections would be done by driving on the crown of the levee.

There would be one temporary 2-acre staging area in the reach on refuge land but would be located off the refuge. This staging area would be used to process the material prior to building the levee. The area would be restored to pre-construction elevation that existed prior to impacting the site.

Table 7 provides a summary of the necessary staging areas and permanent ROW required for construction of the levee and floodwall segments for the 50-yr period of analysis. Staging areas would be required to be continuously accessible. The staging areas required during initial construction of the levee alignment would be the same staging areas required for construction of future levee lifts. Staging areas are assumed to be dry. Any trees would be removed and hauled away to an approved facility. If necessary, crushed stone would be placed in the staging area prior to construction. After construction, the crushed stone would be removed and the disturbed areas would be fertilized and seeded.

For the culvert and bridge replacement work, all staging areas were assumed to be located within the individual structure construction areas. Staging areas are to be tree and vegetation free and covered with crushed stone.

Table 7. Summary of Staging Areas and Permanent ROW

SUMMARY of STAGING AREAS AND PERMANENT ROW		
Levees	**Staging Areas (Acres)**	**Permanent ROW (Acres)**
Western High Ground Tie In	2	30
West Slidell	8	270
South Slidell (includes 23 acres for I-10)	29	120
Sub-Total for Levees	**39**	**420**
Floodwall Segments		
Western High Ground Tie In	NA	NA
West Slidell	0	3.7
South Slidell	0	22.7
Sub-Total for Floodwall Segments	**0 ***	**26.4**
Floodgates and Pump Stations		
Western High Ground Tie In	1.5	2.5
West Slidell	11	21
South Slidell	3.75	6.25
Sub-Total for Floodgates and Pump Stations	**16.25**	**29.75**
Vehicular, Pedestrian, and Railroad Gates		
Western High Ground Tie In	1.5	1.25
West Slidell	1.25	0

South Slidell	9	0
Sub-Total for Vehicular, Pedestrian, and Railroad Gates	**11.75**	**1.25**
Road Ramps		
Western High Ground Tie In	0.5	0
West Slidell	0	0
South Slidell	5	0
Sub-Total for Road Ramps	**5.5**	**0**
Access Roads - New		
Western High Ground Tie In	0.1	0.1
West Slidell	0.45	0.45
South Slidell	2.75	2.75
Access Roads - Existing		
Western High Ground Tie In	0	0
West Slidell	15.8	0
South Slidell	9.9	0
Sub-Total for Access Roads	**29**	**3.3**
Mile Branch Channel Improvements	7.3	38.5
Sub-Total for Mile Branch Channel Improvements	**7.3**	**38.5**
Total Acres for 50-year Period of Analysis	**109**	**520**

*for floodwall segments, staging areas would be included in the 80 ft wide permanent ROW.

Mitigation

The proposed project was designed to avoid and minimize impacts to significant resources to the extent practicable. However, unavoidable impacts to local habitats would occur and would be offset through compensatory mitigation.

Mitigation credits would be purchased from approved mitigation banks for impacts to Riparian and Pine Savanna habitats. Impacts to Big Branch Marsh National Wildlife Refuge would be mitigated by managing pine savanna habitat (PSR-01) within the refuge via controlled burns. An existing gravel logging road would be improved and provide access to the site (Figure 8).

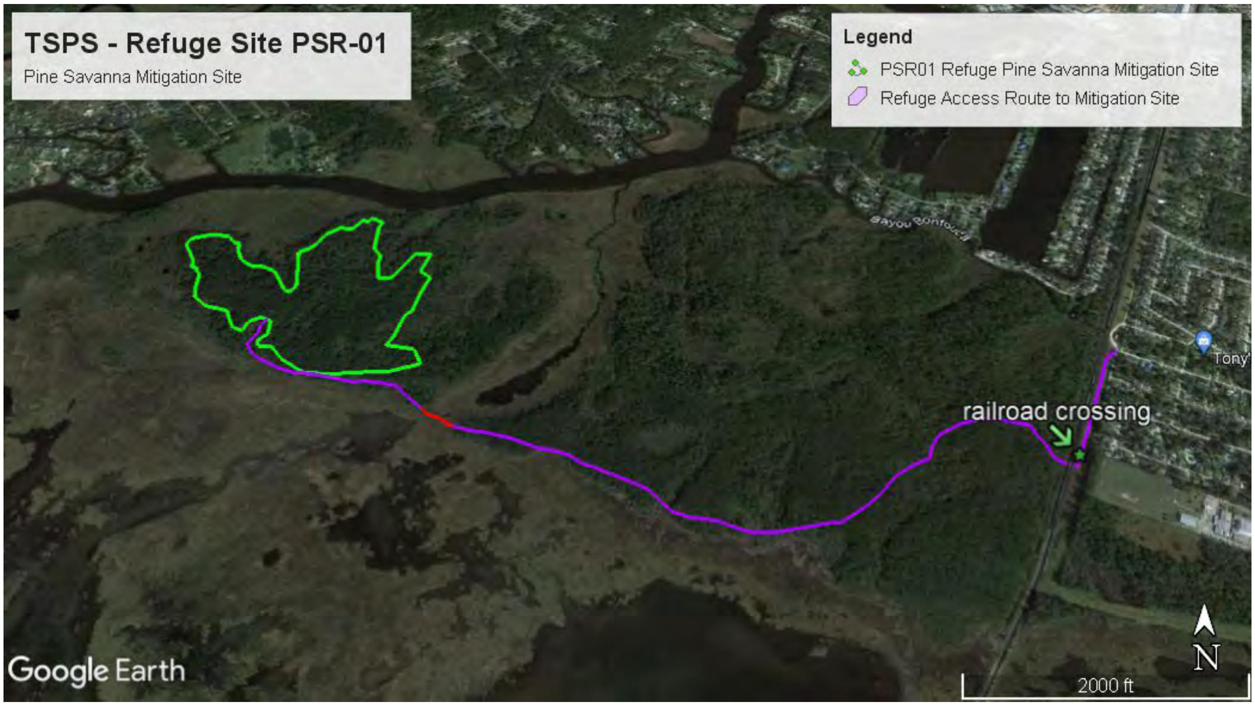

Figure 8. Pine Savanna Mitigation Site within Big Branch Marsh National Wildlife Refuge.

Proposed mitigation for marsh consists of 200 acres of marsh creation on the north shore of Lake Pontchartrain, east of the Causeway Bridge near Lacombe. The assumed existing elevation is -1.65' NAVD88. Initial target elevation for dredge fill would be to approximate elevation +2.5 NAVD88, to ultimately hit a target marsh elevation of +1.0 NAVD88. At this 35% design level, total perimeter retention would be required to retain dredge material and allow for vertical accretion. Approximately 14,718 linear ft of new retention dike would be required along the limit of the project footprint. The dike would be built with borrow from within the footprint. The dike would be built with a 5 ft crown width to elevation +4.8' NAVD88, to provide one ft of freeboard during pumping operation and allow for settlement. This dike would be degraded in year 1, upon settlement and dewatering of the created marsh platform. The degraded material can be disposed of in the original borrow canal if settlement allows or cast into the open water immediately outside of the project footprint. Spill boxes or weirs would be constructed at pre-determined locations within the retention dike to allow for effluent water release from within the marsh creation area. If deemed necessary by the construction contractor, low level interior weir or baffle dikes can be constructed to assist in vertical stacking of dredged material.

Marsh creation would require borrow of approximately 2,200,000 cubic yards of material. A borrow site of 134 acres would accommodate this requirement. The borrow plan is to obtain material from Lake Pontchartrain, requiring a buffer of 2,000 ft between the existing shoreline and the borrow area limit. Borrow would not be allowed greater than 10 ft below the existing lake bottom, except that a tolerance of 1-ft below this target elevation would be provided the contractor to account for inaccuracies in the dredging process. To assure adequate borrow, the fill quantity was doubled account for unsuitable materials, unknown utilities, unidentified anomalies, and/or unsighted cultural finds. An access corridor of approximately 7,340 linear feet would be allowed from the lake to the proposed marsh creation site. The access corridor can be used to establish a pipeline corridor, offload equipment as necessary, and transport personnel to and from the worksite. The contractor would be instructed to minimize usage and damage within the access corridor, by using existing waterways for daily transportation of supplies and personnel where possible.

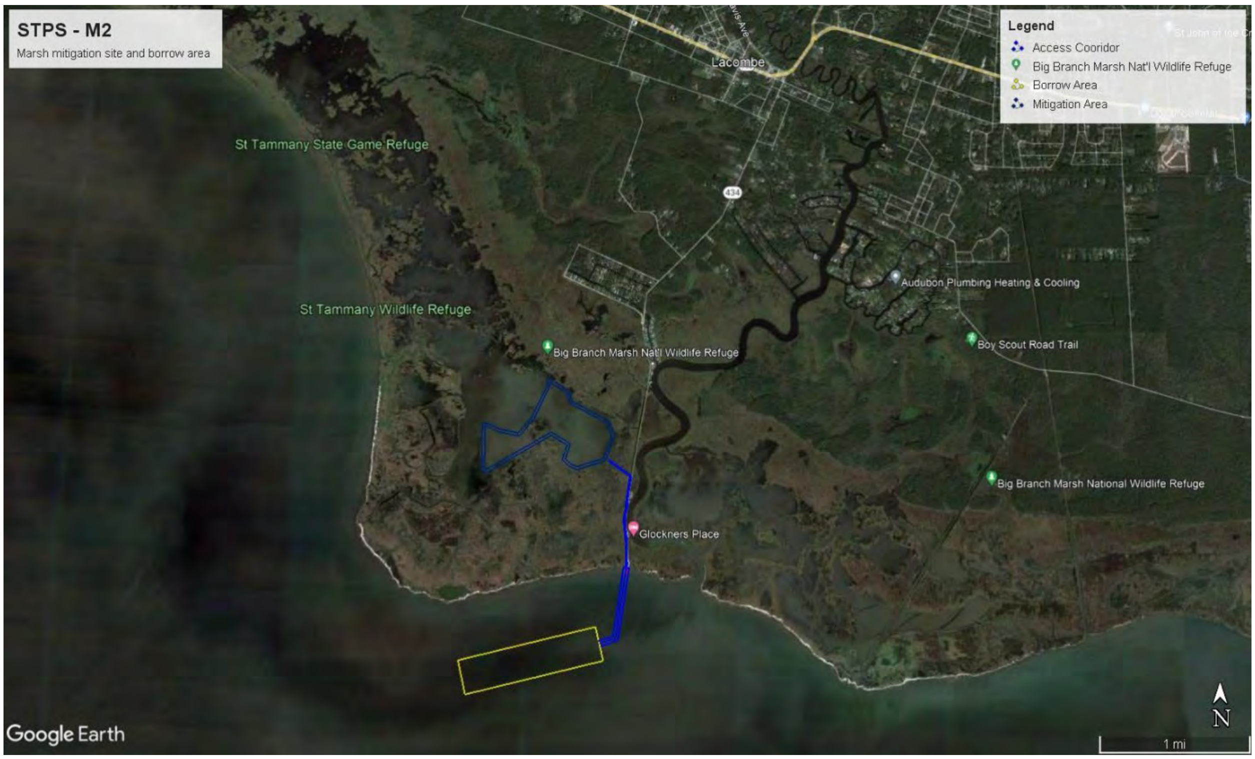

Figure 9. Marsh mitigation site and borrow area.

1.3.6 Anticipated Environmental Stressors

1.3.6.1 Animal Features

Existing terrestrial wildlife habitat and wildlife resources within the Project Area would be directly impacted by the removal of existing terrestrial habitat along the proposed 18.4-mile levee and floodwall system, as well as, lower 2.15 miles of Mile Branch. Though the existing terrestrial habitats would be removed, similar habitat is located adjacent to the project area that could be utilized by local wildlife during construction.

Disturbance from excavation and placement of material along the proposed levee and floodwall alignment, as well as, from within Lake Pontchartrain and Mile Branch could result in death of individuals if they are unable to flee the construction work area. This is especially relevant to sessile species. Mitigation measures, including habitat restoration activities, would be implemented to offset the intensity of these impacts during and after the construction activities are completed.

1.3.6.2 Aquatic Features

Construction of the levee and floodwall system includes the removal of approximately 157 acres of marsh, swamp, and BLH habitat. Indirect impacts to approximately 1,707 acres of marsh, swamp, and BLH habitats would result from the alteration of drainage and flow on the protected side of the levee, and anticipated erosion of marsh on the floodside of the levee.

Approximately 20 acres of Mile Branch Channel would be cleared and grubbed prior to mechanical dredging. Indirect impacts are estimated to be approximately 23 acres of BLH and swamp habitat and include the potential shifting of vegetative communities as the result of changes in hydrology.

A 200-acre marsh site would be created on the north shore of Lake Pontchartrain to offset some impacts from the proposed action. This would increase the available aquatic features within the project area by converting open water habitat to marsh. This new marsh would provide additional habitat to nearby species and increase the ecological value of the system as a whole.

Impacts to aquatic and fisheries resources associated with sedimentation poses a risk. Best Management Practices would be implemented to reduce this risk. The potential for sedimentation during construction could adversely affect food sources for aquatic species. However, this impact would be temporary.

Changes to overall available aquatic and fisheries habitat would be negligible in Lake Pontchartrain and Mile Branch as a result of the proposed action. The M2 marsh creation project would create 200 acres of aquatic and fish habitat on the north shore of Lake Pontchartrain, post-construction.

1.3.6.3 Environmental Quality Features

There would be temporary impacts to local water quality within the Lake Pontchartrain borrow pit during dredging. Changes to temperature, dissolved oxygen (DO), ultimate carbonaceous biochemical oxygen demand (CBODU), total nitrogen (TN), ammonia-nitrogen (NH3-N), nitrate-nitrite (NOX), organic nitrogen (Org-N), total phosphorus (TP), orthophosphate (PO4), organic phosphorus (Org-P), phytoplankton chlorophyll-a, and total suspended solids (TSS) could occur. However, these changes are expected to be negligible due to the small size of the borrow pit compared to the overall size of the Lake Pontchartrain basin and high flushing rate of the lake. Overall, there would be temporary short-term, adverse impacts to water quality both during and for a short time following construction.

Within Mile Branch, channelization and clearing of riparian corridors could increase runoff from nearby development which may increase input of CBODU, TN, NH-3N, NOX, Org-N, TP, PO4, Org-P, phytoplankton chlorophyll-a, and TSS. Additional nutrient input could increase growth of algae and macrophytes, which would in turn increase DO. In addition, reduced canopy cover exposes the channel to more direct sunlight which could alter temperature regimes. Increased water temperature and light may alter existing community structure. Implementation of BMPs could reduce long-term negative impacts from channel alterations.

Direct and indirect impacts to the air quality within the Project Area could occur as a result of construction activity (e.g., machinery/vehicle emissions, dust, etc.) However, impacts would be temporary, minor and limited to the construction period only.

1.3.6.4 Landform (topographic) Features

The current topographic features in the project area include the Mile Branch, Lake Pontchartrain and associated tributaries, natural ridges, Native American earthworks/mounds, existing levees, agricultural fields, and residential areas.

1.3.6.5 Soil and Sediment

On the lower 2.15 miles (11,341 ft) of Mile Branch, approximately 130,000 cubic yards of channel would be dredged and the material placed in the designated disposal areas. The levee and floodwall system would consist of a total of approximately 18.4 miles (96,950 feet) of earthen levee and floodwall which would impact approximately 520.7 acres of permanent ROW and would require approximately 7,069,000 cubic yards of fill. Fill would be obtained from CEMVN approved borrow sources. Creation of 200 acres of marsh to offset impacts from the levee and floodwall system construction would require borrow of approximately 2,200,000 cubic yards of material from a 134-acre borrow site within Lake Pontchartrain.

Indirect impacts to soils within the Project Area could be anticipated because of ongoing operations and associated maintenance through the life of the project. There is potential for increased sedimentation in Mile Branch and Lake Pontchartrain from dredging operations. Best Management Practices would be implemented to reduce temporary adverse impacts from sedimentation.

1.4 Action Area

Pursuant to 50 C.F.R. § 402.02, the term action area is defined as "all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action." Accordingly, the action area typically includes the affected jurisdictional waters and other areas affected by the authorized work or structures within a reasonable distance. The ESA regulations recognize that, in some circumstances, the action area may extend beyond the limits of the Corps' regulatory jurisdiction.

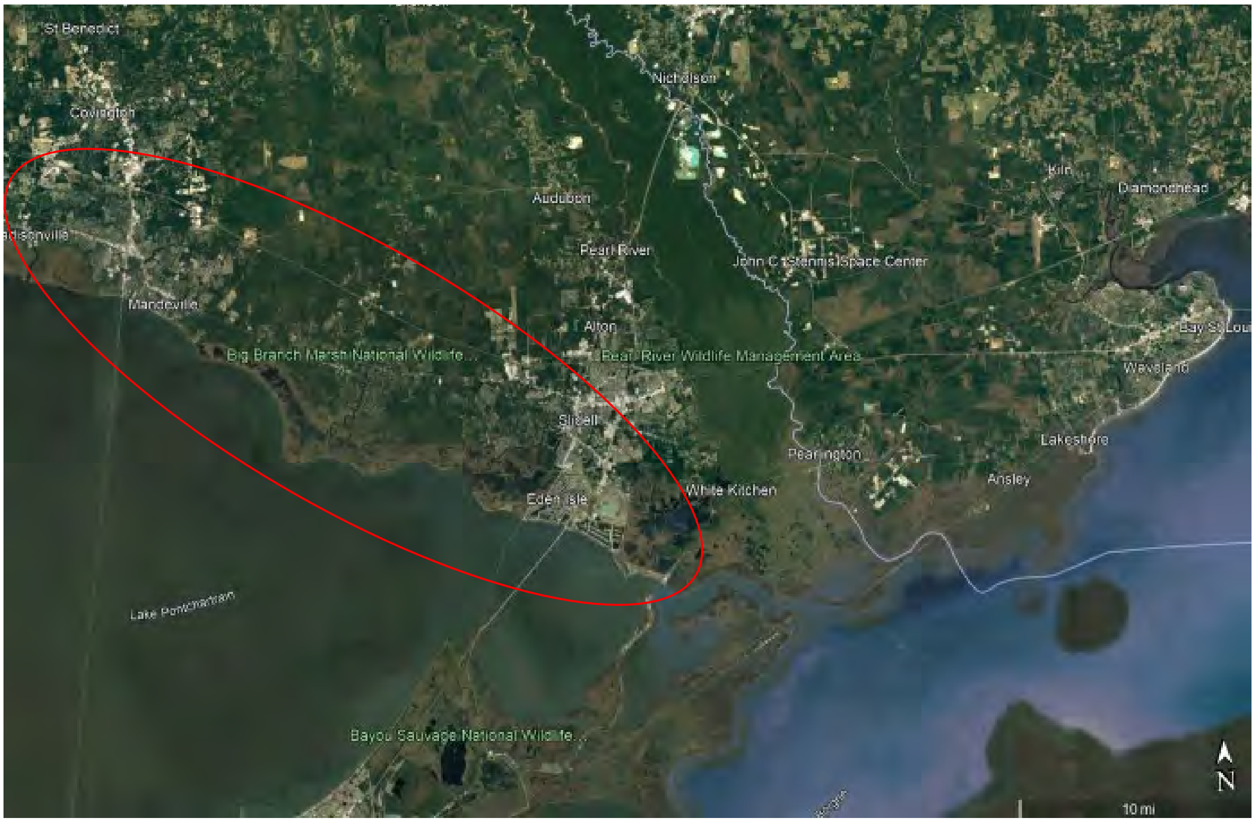

Figure 10. Approximate Action Area in St. Tammany Parish, Louisiana.

For the purposes of this consultation, CEMVN has defined the action area to include the following:

Mile Branch

This feature consists of channel improvements on the lower 2.15 miles (11,341 ft channel) of Mile Branch in Covington, Louisiana. The proposed work would consist of approximately 20 acres of channel that would be cleared and grubbed prior to mechanical dredging (Figure 2). The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and end at the intersection of Mile Branch and the Tchefuncte River.

Levee and Floodwall System

The levee and floodwall system would consist of construction of approximately 18.4 miles of earthen levee and floodwall in St. Tammany Parish, Louisiana. Construction of the levee alignment would impact approximately 520.7 acres of permanent ROW and it would require approximately 7,069,000 cubic yards of fill, including fill material required for future levee lifts. Figures 3, 4, and 6 provide illustrations of the proposed levee and floodwall alignment.

PSR-01 Mitigation Site

Impacts to Big Branch Marsh National Wildlife Refuge would be mitigated by managing approximately 70 acres of pine savanna habitat (PSR-01) within the refuge via controlled burns. Figure 8 provides an illustration of PSR-01.

M2 Mitigation Site

Proposed mitigation for marsh consists of 200 acres of marsh creation on the north shore of Lake Pontchartrain, east of the Causeway Bridge near Lacombe. Borrow would be obtained from a 134-acre site within Lake Pontchartrain. Figure 9 provides an illustration of the M2 mitigation site.

1.5 Conservation Measures

1.5.1. Gulf Sturgeon

To reduce impacts to Gulf sturgeon*, Protected Species Construction Conditions* and *Vessel Strike Avoidance Measures*, developed by NMFS, would be implemented for the proposed project. See Appendix D for detailed information on these measures.

1.5.2 West Indian Manatee

To minimize the potential for construction activities to cause adverse impacts to manatees, the standard manatee protection measures developed by the USFWS, Lafayette, Louisiana Field Office and located in Appendix D-3, would be implemented when activities are proposed that would impact habitat where manatees could occur.

1.5.3 Alligator Snapping Turtle

To minimize the potential for construction activities to cause adverse impacts to alligator snapping turtles, the USFWS recommends the conservation measures located in Appendix D-4

2 Species Affects Analysis

2.1 Gopher Tortoise (*Gopherus polyphemus*)

2.1.1 Status of the Species

2.1.1.1. Legal Status

The gopher tortoise is listed as threatened under the Endangered Species Act (Federal Register Vol. 87, No. 196, October 12, 2022).

2.1.1.2 Recovery Plans

The most recent recovery plan available for the gopher tortoise is dated December 1990 (Appendix C-1). A SSA dated August 2021 is also available (Appendix C-1).

2.1.1.3 Life History Information

The gopher tortoise occurs in the Southeastern Atlantic and Gulf Coastal Plains from southern South Carolina west through Georgia, the Florida panhandle, Alabama, and Mississippi to eastern Louisiana, and south through peninsular Florida (Auffenberg and Franz 1982). The gopher tortoise is the only tortoise that is native to the southeastern United States and is known to live up to 60 years in the wild.

Gopher tortoises prefer “open” longleaf pine-scrub oak communities that are thinned and burned every few years. Despite being an ectotherm that spends much of its time basking in the sun, the gopher tortoise builds elaborate underground burrows in dry, sandy soil where it nests, which can be used by other species. Habitat degradation (lack of thinning or burning on pine plantations), predation, and conversion to agriculture or urbanization have contributed to the decline of this species. That habitat decline has concentrated many remaining gopher tortoise populations along pipeline and power line rights-of-way (ROW) within their range. Tortoise burrows also can be found along road ROWs, and other marginal habitats, including fence rows, orchard edges, golf course roughs and edges, old fields, and pasturelands. Tortoises are often pushed into these areas due to adjacent habitat becoming unsuitable.

Gopher tortoises were found to mostly forage on foliage, seeds, and fruits of grasses and forbs, generally in an area of about 150 feet surrounding burrows (McRae et al. 1981). Although they feed primarily on broadleaf grasses, wiregrass (*Aristida stricta var. beyrichiana*), asters, legumes, and fruit, they are known to eat more than 300 species of plants (Garner and Landers 1981; Ashton and Ashton

2004; Richardson and Stiling 2019). The diet of adults resembles that of a generalist herbivore, with at least some preference for certain plants over others, and may also include insects and carrion (Macdonald and Mushinsky 1988; Birkhead et al. 2005; Richardson and Stiling 2019). Legumes are thought to be particularly important for re-conditioning females after egg laying, and it has been shown that clutch sizes and percent of gravid females were lowest in areas with low percent cover of legumes (White 2009).

Gopher tortoises mostly breed from May through October (Landers et al. 1980; McRae et al. 1981; Taylor 1982; Diemer 1992a; Ott-Eubanks et al. 2003). Female gopher tortoises usually lay eggs from mid-May through mid-July, and incubation lasts 80 - 110 days (Diemer 1986). Tortoises may nest in the soil at the entrance of a burrow (Butler and Hull 1996; Smith et al. 1997a), or in other open sandy areas, when available (Landers et al. 1980). Range wide, average clutch size varies from about four to eight eggs/clutch (Ashton et al. 2007).

2.1.1.4 Conservation Needs

The SSA dated August 2021 includes conservation measures for the gopher tortoise. Below are the conservation measures listed in the SSA. See Appendix C-1 for further details on each.

- Federal and State Protections and Conservation
- Florida Gopher Tortoise Management Plan and Permitting Guidelines
- Relocation, Translocation, Recipient Sites, and Headstarting
- Gopher Tortoise Conservation and Crediting Strategy
- Conservation Agreements
- Conservation Strategies, Best Management Practices, and Other Conservation Initiatives and Guidelines
- Conservation Lands

2.1.2 Environmental Baseline

2.1.2.1 Species Presence and Use

USFWS determined the eastern and western portions of the gopher tortoise's range meet the criteria of Distinct Population Segments (DPS) under the ESA.

The eastern DPS includes the states of Florida, Georgia, South Carolina, and most of Alabama. Although the eastern DPS is threatened by habitat loss and fragmentation due to urbanization, climate warming, sea-level rise and habitat management, many of these populations are in good condition. In addition, habitat restoration efforts, implementation of best management practices, and conservation measures to benefit the gopher tortoise have contributed to the eastern DPS no longer meeting the criteria for ESA listing.

In terms of the estimated range wide number of gopher tortoises, the majority of gopher tortoise individuals and populations are found in the eastern DPS. Only 8 percent of the estimated range wide population occur in the western DPS and include many small, isolated populations. Populations in the western DPS are characterized by life-history differences including smaller clutch size, lower hatch rate, and larger home range, likely related to the clay soil and poorer quality habitat in the western portion of the range. Populations in the western DPS also exhibit lower resiliency and are more vulnerable to catastrophic events. The western DPS continues to meet the definition of a threatened species under the ESA.

Gopher tortoises occur in 3 parishes in Louisiana: Washington, Tangipahoa, and St. Tammany. The action area is listed under the western DPS.

2.1.2.2 Species Conservation Needs Within the Action Area

The SSA dated August 2021 includes conservation measures for the gopher tortoise. Below are the state conservation measures that might be applicable to the action area. See Appendix C-1 for further details.

- The gopher tortoise population in Louisiana is listed as threatened under the Endangered Species Act. Also ranked as S1 (critically imperiled) in Louisiana. The gopher tortoise is protected by regulation and prohibits the take, possession, export/sale, and killing of gopher tortoises.
- Translocation describes the intentional capture and transfer of individuals (or groups of individuals) from one location to another. Translocation is commonly used as a conservation strategy to mitigate the loss of tortoises from land slated for development. These displaced tortoises are often translocated to reestablish extirpated populations or augment existing populations (Griffith et al. 1989).
- The Range wide Conservation Strategy for the Gopher Tortoise was developed in 2013 by the USFWS to guide conservation of the gopher tortoise. Specifically, this Strategy is designed for partners, including the states within gopher tortoise range, USFWS, and other public and private entities to collect and share information on gopher tortoise threats, outline highest priority conservation actions, and identify organizations best suited to undertake those conservation actions.

2.1.2.3 Habitat Condition (General)

Gopher tortoise habitat comprises well-drained sandy soils (burrowing, sheltering, and breeding), with an open canopy, sparsely vegetated midstory, and abundant herbaceous groundcover (feeding). Generally, upland habitat within the action area consists of densely forested areas and anthropogenic landscapes such as rights-of-way. Gopher tortoise surveys conducted by LA Department of Wildlife and Fisheries staff, along with USACE and USFWS personnel, determined that dense forested habitat within the action area was not suitable for gopher tortoises. Additionally, surveys of areas that were not heavily forested and appeared suitable for tortoises found no evidence of tortoises or their burrows.

2.1.2.4 Influences

Habitat loss and fragmentation, roads, climate conditions, disease human activities, predation, and non-native and invasive species all influence the persistence of the species.

Urbanization and major roads (Auffenberg and Franz 1982; Diemer 1986; Diemer 1987; Enge et al. 2006), incompatible and/or insufficient habitat management, and certain types of agriculture (Lohoefener and Lohmeier 1984; Auffenberg and Franz 1982; Hermann et al. 2002) can negatively impact gopher tortoises and gopher tortoise habitat. Invasive species can influence gopher tortoises either through direct impacts (e.g., predation; Mann 1995; Engeman et al. 2009; Engeman et al. 2011; Dziadzio et al. 2016b; Bartoszek et al. 2018) or alterations to habitat structure and/or function (Lippincott 1997; Bastios 2007).

Climate change has the potential to negatively impact habitat through the loss of habitat due to sea level rise (Hayhoe et al. 2018), limitations on number of suitable burn days due to changes in temperature (Kupfer et al. 2020), precipitation, increased flooding due to predicted increases in the severity of hurricanes (Castellon et al. 2018), and human migration from inundated coastal areas to inland areas, with subsequent impacts to gopher tortoises (Ruppert et al. 2008).

A number of diseases have been documented in gopher tortoises, including fungal keratitis (Myers et al. 2009); iridovirus; ranavirus (Johnson et al. 2008); herpesvirus; bacterial diseases related to Salmonella spp., Mycoplasma spp., Helicobacter sp. (Desiderio et al. 2021), and Dermatophilus; and numerous internal and external parasites (Ashton and Ashton 2008, pp. 39-41). Upper Respiratory Tract Disease (URTD) resulting from two Mycoplasma species (*M. agassizii and M. testudineum*) has received the most attention recently. URTD has been documented throughout much of the tortoise's range (Berish et al. 2010; McGuire et al. 2014a; Goessling et al. 2019), but the magnitude of threat URTD poses to gopher tortoise populations and tortoise demographics is uncertain (Karlin 2008).
Human harvest of gopher tortoises for consumption has historically influenced gopher tortoise populations, particularly in portions of the Florida panhandle. Tortoises were harvested in large numbers during the Great Depression, a practice

which continued for decades following the Depression (Tuma and Sanford 2014). Prior to the closure of tortoise harvest in the late 1980s, a community in Okaloosa County held an annual tortoise cookout (Enge et al. 2006). Low numbers of tortoises on sites with otherwise adequate habitat were speculated to reflect episodes of human predation in the 1980s and 1990s in Mississippi (Lohoefener and Lohmeier 1984; Mann 1995; Estes and Mann 1996). Though this practice is not as common as it was prior to the 1980's, localized harvest still occurs in some rural areas across the Southeast (Rostal et al. 2014) but is likely not a significant threat to current populations.

Rattlesnake roundups are locally organized events that offer prizes for the largest and most rattlesnakes caught. Historically, there were multiple roundups throughout the Southeast. With the recent conversion of two roundups to wildlife festivals (Claxton, GA in 2012; Whigham, GA in 2021), only one roundup remains in the Southeast, in Opp, Alabama.

The technique of blowing fumes of noxious liquids (otherwise known as “gassing”) down tortoise burrows was used primarily to collect snakes for these rattlesnake roundups (Means 2009). It is thought this practice of gassing burrows harms or harasses the resident tortoise, though research that quantifies negative direct impacts (i.e., mortality) is limited. For example, one study found that no tortoises died or showed ill-effects after being gassed in their burrows; however, this study did not examine potential long-term impacts or repeated gassing (Speake and Mount 1973). Tortoise burrows have also been excavated to retrieve snakes, sometimes in conjunction with burrow gassing (Means 2009), rendering the burrows unusable.

Gopher tortoise nest predation varies annually and across sites, ranging from approximately 45-90 percent in a given year (Landers et al. 1980; Wright 1982; Marshall 1987). Gopher tortoises are most susceptible to predation within their first year of life, though most predation appears to occur within 30 days of hatching (Pike and Seigel 2006; Smith et al. 2013). Overall annual hatchling survival has been estimated to be approximately 13% (Perez-Heydrich et al. 2012). In some instances, predation-related mortality may reach 100% within one-year post-hatching (Pike and Seigel 2006).

Raccoons are the most frequently reported predator of nests and juvenile gopher tortoises (Landers et al. 1980; Butler and Sowell 1996); other predators of nests and/or juvenile tortoises include gray fox (*Urocyon cinereoargenteus*), striped skunk (*Mephitis mephitis*), Virginia opossum, coyote (*Canis latrans*), nine-banded armadillo, several snake species (e.g. *Agkistrodon piscivorus, Drymarchon corais, Masticophis flagellum*), fire ants (*Conomyrma spp., Solenopsis invicta*)., and red-tailed hawks (*Buteo jamaicensis*) (Douglass and Winegarner 1977; Fitzpatrick and

Woolfenden 1978; Landers et al. 1980; Wilson 1991; Mann 1995; Butler and Sowell 1996; Wetterer and Moore 2005; Pike and Seigel 2006). Twenty-five species—12 mammals, 5 birds, 6 reptiles and 2 invertebrates—are known to be predators of eggs, emerging neonates, hatchlings, and older tortoises (Ashton and Ashton 2008). Adult gopher tortoises are less likely to experience predation except by canines (e.g., domestic dogs, coyotes, foxes) and humans (Causey and Cude 1978; Taylor 1982; Hawkins and Burke 1989; Mann 1995). Some predators are subsidized by human activities such as habitat fragmentation and edge effect (e.g., red imported fire ants) (Wetterer and Moore 2005), roads and infrastructure (e.g., red imported fire ants) (Stiles and Jones 1998), increased availability of food (e.g., raccoons), reduction or elimination of top carnivores (e.g., coyotes, red foxes) (Crooks and Soule 1999), ecological perturbations allowing range expansion (e.g., coyotes), and simply because some are domestic and associated with humans (e.g., cats and dogs).

2.1.2.5 Additional Baseline Information

On June 14, 2022, Louisiana Department of Wildlife and Fisheries staff, along with CEMVN and USFWS personnel, conducted gopher tortoise surveys within the project area. Half of the areas assessed appeared to be uninhabitable for gopher tortoises due to the dense forests completely covering these areas. In areas with suitable habitat, no evidence of gopher tortoises or their burrows were observed. Additional information regarding these surveys is located in Appendix E-1.

2.1.3 Effects of the Action

2.1.3.1 Indirect Interaction

Construction activities, such as clearing, fill placement, and heavy machinery use, could eliminate suitable gopher tortoise foraging habitat by physically removing or smothering herbaceous groundcover. Additionally, compaction of soil could limit the ability of tortoises to create burrows for sheltering and nesting.

2.1.3.2 Direct Interactions

In areas where tortoises may be present, noise and activity associated with construction would likely temporarily displace gopher tortoises from active construction zones to other nearby habitat. Displacement of tortoises is not likely to significantly impact the species where suitable habitat is available nearby.

Additionally, tortoises may be physically injured or killed if struck by equipment or materials during construction. This effect is discountable due to the ability of the species to move away from the project site if disturbed.

2.1.4 Cumulative Effects

For purposes of consultation under ESA Section 7, cumulative effects are those caused by future state, tribal, local, or private actions that are reasonably certain to occur in the Action Area. Future Federal actions that are unrelated to the proposed action are not considered, because they require separate consultation under Section 7 of the ESA. At this time the USACE is unaware of any future state, tribal, local, or private non-Federal unrelated to the proposed action that are reasonably certain to occur in the Action Area.

2.1.5 Discussion and Conclusion

The proposed project would not occur near or affect any known gopher tortoise burrows. In addition, field surveys conducted by the LDWF, CEMVN, and USFWS indicated that the majority of the project area does not contain suitable soils for gopher tortoise burrows. Therefore, CEMVN has determined that the proposed action will not likely adversely affect the gopher tortoise.

2.2 Gulf Sturgeon (*Acipenser oxyrinchus desotoi*)

2.2.1 Status of the Species

2.2.1.1. Legal Status

The Gulf Sturgeon is listed as Threatened under the Endangered Species Act (Federal Register Vol. 56, No. 189, September 30, 1991).

2.2.1.2 Recovery Plans

The most recent recovery plan available for the Gulf sturgeon is dated September 1995 (Appendix C-2).

2.2.1.3 Life History Information

The Gulf sturgeon is an anadromous fish (ascending rivers from the sea for breeding) that have historically inhabited coastal rivers from the Mississippi in Louisiana to the Tampa Bay in Florida. The Gulf sturgeon is one (1) of two (2) geographically dispersed subspecies of the Atlantic Sturgeon (*Acipenser oxyrhynchus*).

The Gulf sturgeon is characterized by a sub-cylindrical body that is imbedded with bony plates or "scutes". The snout of the fish is greatly extended and bladelike and includes four (4) fleshy barbells in front of the mouth. The upper lobe of the tail is longer than the lower lobe. Adult specimens generally range in size from 1.8 to 2.4 meters (m) or six (6) to eight (8) feet in length. They are typically light brown to dark brown in color but are known to vary in color from grayish brown to bluish black on their back and sides, grading to white on their belly.

Age at sexual maturity ranges from 8 to 12 years for females and 7 to 9 years for males (Huff 1975). The Gulf sturgeon is a long-lived species, with some individuals reaching at least 42 years in age (Huff 1975).

The feeding habits of the Gulf sturgeon vary, depending upon the fish's age (i.e., young-of-year, juvenile, sub-adult, adult) and is closely associated with migration and spawning habits. Throughout fall and winter, juveniles feed in the lower salinity areas in the river mouth and estuary while subadults and adults migrate and feed in the estuaries and nearshore Gulf of Mexico habitat (Foster 1993). Some Gulf sturgeon may also forage in the open Gulf of Mexico.

The Gulf sturgeon typically inhabits the coastal rivers of the Gulf of Mexico during the warmer months of the year and generally overwinters in estuaries and bay environments within the Gulf of Mexico. The adults move into the tributary rivers for spawning in the spring and return to the Gulf waters in the fall. Spawning occurs in the upper reaches of rivers, at least 100 km (62 miles) upstream of the river mouth in habitats consisting of one or more of the following: limestone bluffs and outcroppings, cobble, limestone bedrock covered with gravel and small cobble, gravel, and sand. These hard bottom substrates are required for egg adherence and shelter for developing larvae. Documented spawning depths range from 1.4 to 7.9 m (4.6 to 26 ft).

2.2.1.4 Conservation Needs

There are currently no conservation plans for the Gulf sturgeon. However, there is a Recovery Plan dated 1995 that includes an outline for recovery actions addressing threats to the Gulf sturgeon. Below are the main objectives. See Appendix C-2 for further details.

- Determine essential ecosystems, identify essential habitats, assess population status, and refine life history investigations in management unit rivers.
- Protect individuals, populations, and their habitats.
- Coordinate and facilitate exchange of information on Gulf sturgeon conservation and recovery activities.

2.2.2 Environmental Baseline

2.2.2.1 Species Presence and Use

The Gulf sturgeon is an anadromous fish that migrates from salt water into coastal rivers to spawn and spend the warm summer months. Subadults and adults typically spend the three to four coolest months of the year in estuaries or Gulf of Mexico waters foraging before migrating into the rivers. This migration typically occurs from mid-February through April. Most adults arrive in the rivers when temperatures reach 70 degrees Fahrenheit and spend 8 to 9 months each year in the rivers before returning to estuaries or the Gulf of Mexico by the beginning of October.

Prior to the listing of the species, Davis et al. (1970) reported the collection of Gulf sturgeon from Lake Pontchartrain during a Louisiana Department of Wildlife and Fisheries (LDWF) anadromous fish survey from 1966 to 1969. From 1988 to 1999, LDWF, through various means and studies, captured and recorded at least 60 Gulf sturgeon throughout Lake Pontchartrain, Lake Catherine, the Rigolets and Lake Borgne. A LDWF trammel net study conducted by Inland Fisheries Division in the spring of 2001 resulted in the capture of three young of the year juvenile sturgeon at the intersection of the East Pearl River and Little Lake. In 2002, LDWF Seafood Division reported the capture of a Gulf sturgeon in one of their gill nets while sampling in a cove west of Alligator Point, Lake Borgne. By-catch of Gulf sturgeon has been reported by several recreational and commercial fishermen within these waters. A total of 177 Gulf sturgeon, measuring up to 7.2 feet in length and weighing from 2 to 152 lbs, were captured in these lakes and in the Rigolets from October 1991 to September 1992 (Rogillio, 1993). Reynolds (1993) reported that sturgeon measuring up to 7.2 feet in length and weighing up to 258 lbs were incidentally caught by shrimp trawlers, netters, and recreational anglers from 1889 to 1993 in Lake Pontchartrain.

2.2.2.2 Species Conservation Needs within the Action Area

There are currently no conservation plans for the Gulf sturgeon. However, there is a Recovery Plan dated 1995 that includes an outline for recovery actions addressing threats to the Gulf sturgeon. Below are the objectives that might be applicable to the action area. See Appendix C-2 for further details.

- Survey, monitor, and model populations.
- Reduce or eliminate unauthorized take.
- Identify and eliminate known or potentially harmful chemical contaminants, and water quantity and water quality problems which could impede recovery of Gulf sturgeon.
- Restore, enhance, and provide access to essential habitats.

2.2.2.3 Habitat Condition (General)

The extent of potential habitat for the Gulf sturgeon, within the project area, is the approximately 134-acre M2 borrow site located within Lake Pontchartrain. Lake Pontchartrain contains suitable sturgeon habitat that is characterized by sandy bottoms and relatively shallow depths extending to 15 feet (NOAA Chart 11639). Desktop review of National Oceanic and Atmospheric Administration Bathymetric Data of Lake Pontchartrain (ESD-PHB-21, W00561) indicate water depth between approximately 3 ft to 11 ft in the vicinity of the M2 borrow site.

2.2.2.4 Influences

Over- fishing, associated with the commercial uses, resulted in a significant decline in Gulf sturgeon numbers throughout most of the 20th century. Incidental catch of Gulf sturgeon in other fisheries occurred at significant levels during the same time periods. Habitat losses associated with the construction of water control structures including dams and sills along the Gulf of Mexico drainage basins have contributed to a decline in populations throughout the historic range. Dam construction in several of the rivers has severely restricted the sturgeon’s access to historic migration routes and spawning areas. Water quality such as pollution, temperature, and dissolved oxygen levels are also a threat.

2.2.2.5 Additional Baseline Information

There is no additional baseline information.

2.2.3 Effects of the Action

2.2.3.1 Indirect Interactions

Indirect impacts to Gulf Sturgeon could occur due to turbidity from construction which would be minimized by utilizing dikes to contain the dredged material. In addition, any runoff from construction activities on land would be controlled through the use of best management practices and adherence to regulations governing stormwater runoff at construction sites and staging areas.

Hypoxic and anoxic conditions can occur in deep borrow pits that have a tendency to accumulate organic material. This accumulation would be reduced for the M2 borrow pit within Lake Pontchartrain by limiting the depth of the pit to 10 feet. Therefore, effects to Gulf sturgeon from hypoxic or anoxic conditions are discountable.

No permanent indirect impacts to gulf sturgeon are expected to occur from construction of the propose project.

2.2.3.2 Direct Interactions

Gulf sturgeon may be physically injured if struck by construction equipment, vessels, or materials during dredging. This effect is discountable due to the ability of the species to move away from the project site if disturbed. Gulf sturgeon are mobile and are able to avoid construction noise, moving equipment, and placement or removal of materials during construction. NMFS has previously determined in dredging Biological Opinions (e.g., (NMFS 2007)) that, while ocean-going hopper-type dredges may lethally entrain sturgeon, non-hopper type dredging methods, such as the cutterhead dredging method used in this project, are slower and extremely unlikely to adversely affect Gulf sturgeon.

The construction activities and related construction noise may prevent or deter Gulf sturgeon from entering the project area. However, the effect to sturgeon from temporary avoidance of the project area due to construction activities, including related noise, would likely be insignificant. The size of the area from which animals would avoid is relatively small in comparison to the available similar habitat nearby, which would be accessible to sturgeon during construction. Disturbances and loss of habitat access would be temporary and limited to days of in-water construction. After the project is completed, Gulf sturgeon would be able to return to the project area.

The effect to Gulf sturgeon from the potential loss of foraging habitat due to dredging is also expected to be insignificant. Gulf sturgeon are opportunistic feeders that forage over large areas and would be able to locate prey beyond the small dredging footprint (approximately 134 acres). Also, impacts to foraging resources from dredging are temporary since benthic invertebrate populations in dredged areas have been observed to recover in 3-24 months after dredging (Culter and Mahadevan 1982; Saloman et al. 1982; Wilber et al. 2007).

2.2.4 Cumulative Effects

For purposes of consultation under ESA Section 7, cumulative effects are those caused by future state, tribal, local, or private actions that are reasonably certain to occur in the Action Area. Future Federal actions that are unrelated to the proposed action are not considered, because they require separate consultation under Section 7 of the ESA. At this time the USACE is unaware of any future state, tribal, local, or private non-Federal unrelated to the proposed action that are reasonably certain to occur in the Action Area.

2.2.5 Discussion and Conclusion

To reduce impacts to Gulf sturgeon, a cutterhead dredge would be utilized to remove borrow material from the designated borrow area. This equipment is slower moving and has not been identified as equipment that would impact Gulf sturgeon. Additionally, protected species construction conditions developed by NMFS would be implemented for the proposed project (Appendix D-1 and D-2).

Based upon literature review, available survey data, the current status of the species, the environmental baseline for the action area, and the effects of the action, the USACE has determined that implementation of the proposed action is not likely to adversely affect the Gulf sturgeon.

2.3 Louisiana Quillwort (*Isoetes louisianensis*)

2.3.1 Status of the Species

2.3.1.1. Legal Status

The Louisiana quillwort is listed as Endangered under the Endangered Species Act (Federal Register Vol. 57, No. 209, October 28, 1992).

2.3.1.2 Recovery Plans

The most recent recovery plan available for the Louisiana quillwort is dated September 1996 (Appendix C-3).

2.3.1.3 Life History Information

Louisiana quillwort is a small, semi-aquatic, facultative evergreen plant with spirally arranged leaves (sporophylls) arising from a globose, two-lobed corm. The hollow leaves are transversely septate, and measure approximately 0.12 inches wide and up to 16 inches long.

Louisiana quillwort occurs in the East Gulf Coastal Plain physiographic province in Pleistocene Prairie Terraces and Pleistocene High Terraces in southeastern Louisiana an in Pleistocene High Terraces in southern Mississippi. This species grows on sand and gravel bars on the accreting sides of streams and moist overflow channels within riparian forest and bay head swamp communities. The Louisiana quillwort is believed to be dependent on a special hydrologic regime resulting from the presence of small springs scattered at the base of banks or bluffs.

2.3.1.4 Conservation Needs

There are currently no conservation plans for the Louisiana quillwort. However, there is a Recovery Plan dated September 1996 that includes an outline for recovery actions addressing threats to the Louisiana quillwort. Below are the main objectives. See Appendix C-3 for further details.

- Protect known populations by protecting their habitat
- Conduct life history research
- Monitor population trends and developing threats
- Search for additional populations in southeastern Louisiana, southern Mississippi, and south Alabama
- Preserve genetic stock
- Inform the public about the conservation needs of the species

2.3.2 Environmental Baseline

2.3.2.1 Species Presence and Use

Louisiana quillwort is currently known to occur in Washington and St. Tammany parishes in Louisiana and two counties in southern Mississippi. In Washington parish the species has been identified within the Bogue Chitto River watershed in upper Mill Creek and the lower portions of Thigpen and Clearwater Creeks. In St. Tammany parish, the species had been identified within the Tchefuncta River watershed and is known to occur in the following locations:

- The Bogue Falaya River drainage: (1) Over 1,500 plants are located along a 1.0 km (0.6 mile) section of a tributary to the Bogue Falaya. (2) Approximately 50 plants occur near the headwaters of a small drainage of LaTice Branch Creek.
- The Little Bogue Falaya River drainage: Over 350 plants are located at the Little Bogue Falaya River southeast of Barkers Corner.
- The Abita River drainage: (1) Approximately 400 plants occur along a 0.5 km (0.3 mile) section of Abita Creek, and 18 plants occur at a site on Coon Creek, a small tributary of Abita Creek. These two sites are considered a single population. (2) Two plants are located at Ten-Mile Creek.
- Bayou Chinchuba drainage: Bayou Chinchuba drains directly into Lake Pontchartrain. This population of over 350 plants is atypical because it occurs in a seasonally-flooded small depression in wet-loblolly pine flatwoods instead of near a streamside.

2.3.2.2 Species Conservation Needs within the Action Area

There are currently no conservation plans for the Louisiana Quillwort. However, there is a Recovery Plan dated September 1996 that includes an outline for recovery actions addressing threats to the Louisiana Quillwort. Below are the objectives that might be applicable to the action area. See Appendix C-3 for further details.

- Protect known populations by protecting their habitat
- Monitor population trends and developing threats
- Search for additional populations in southeastern Louisiana, southern Mississippi, and south Alabama

2.3.2.3 Habitat Condition (General)

Louisiana quillwort is apparently restricted to areas in or near shallow (0.75 to 2.5 feet with occasional deeper pools), blackwater streams in riparian woodland and bayhead forests of pine flatwoods and upland pine forests. Within the Action Area, Mile Branch is located within the known range of the Louisiana quillwort. However, the USFWS determined Mile Branch does not contain suitable habitat for the quillwort (Appendix B).

2.3.2.4 Influences

Major threats to this species include habitat loss through hydrologic modifications of stream habitat, and land use practices that significantly alter stream water quality and hydrology.

Habitat loss through land use practices that significantly transform riparian forest communities and alter stream quality and dynamics, poses the most serious threat to populations of Louisiana quillwort. This species is adapted to a dynamic stream environment and is negatively affected by adverse anthropogenic changes. Anthropogenic constraints change natural drainage patterns and stream dynamics, potentially damaging quillwort habitat and possibly inhibiting formation of new habitat. Dredging, ditching, channelization, road construction, and offroad vehicles (ORV) can alter natural processes and result in habitat loss.

Timber removal increases surface runoff and contributes to stream erosion and sediment siltation. Removal of canopy alters light and temperature regimes on the forest floor; soils become drier and weedy vegetation tends to invade. Logging adjacent to creeks creates debris and detritus which can obstruct water flow and change stream dynamics. While streamside management zones (SMZs) are theoretically protective buffers to the streams themselves, observations of logging practices in Mississippi show that logging sometimes occurs to the stream edge, that slash is frequently left in the drainage, and that quillwort habitat is crossed by skidders and trucks during timber harvest. These generally rough logging trails and roads are then used by hunters and others until saplings regenerate and block vehicular access.

Sand and gravel mining poses a significant threat, as evidenced by portions of Clearwater Creek in Washington Parish, Louisiana, that have been completely cleared, channelized, and re-routed. Degradation of water quality from siltation, prolific algal growth, and sediment pollution from overflow of adjacent gravel pits was observed at the creek site (McInnis 1991a). Mining operations in or adjacent to creeks and rivers can have a detrimental effect upon aquatic resources.

2.3.2.5 Additional Baseline Information

There is no additional baseline information.

2.3.3 Effects of the Action

2.3.3.1 Indirect Interactions

No indirect interactions are anticipated as existing data indicates the Louisiana quillwort do not utilize the project area.

2.3.3.2 Direct Interactions

No direct interactions are anticipated as existing data indicates the Louisiana quillwort do not utilize the project area.

2.3.4 Cumulative Effects

For purposes of consultation under ESA Section 7, cumulative effects are those caused by future state, tribal, local, or private actions that are reasonably certain to occur in the Action Area. Future Federal actions that are unrelated to the proposed action are not considered, because they require separate consultation under Section 7 of the ESA. At this time the USACE is unaware of any future state, tribal, local, or private non-Federal unrelated to the proposed action that are reasonably certain to occur in the Action Area.

2.3.5 Discussion and Conclusion

The Louisiana quillwort grows on sand and gravel bars on the accreting sides of streams and moist overflow channels within riparian forest and bay head swamp communities. Mile Branch does not contain suitable habitat for the Louisiana quillwort; therefore, it is unlikely that the proposed action will adversely affect the species.

Based upon literature review and available survey data, and the effects of the action, the CEMVN has determined that channelization at Mile Branch will have no effect on the Louisiana quillwort.

2.4 Red-Cockaded Woodpecker (*Picoides borealis*)

2.4.1 Status of the Species

2.4.1.1. Legal Status

The red-cockaded woodpecker (RCW) is listed as Endangered under the Endangered Species Act (Federal Register Vol. 35, No. 165, August 25, 1970).

2.4.1.2 Recovery Plans

The most recent recovery plan available for the RCW is dated January 2003 (Appendix C-4).

2.4.1.3 Life History Information

RCWs are black and white with a ladder back and large white cheek patches. These cheek patches distinguish RCWs from all other woodpeckers in their range. RCWs are black with black and white barring on their backs and wings. Their breasts and bellies are white to grayish white with distinctive black spots along the sides of the breast changing to bars on the flanks. Central tail feathers are black and outer tail feathers are white with black barring. Adults have black crowns, a narrow white line above the black eye, a heavy black stripe separating the white cheek from a white throat, and white to grayish or buffy nasal tufts. Bills are black, and legs are gray to black.

RCWs are endemic to open, mature and old growth pine ecosystems in the southeastern United States but were once common throughout the longleaf pine ecosystem, which covered at least 90 million acres before European settlement (Frost 2006). Historical population estimates are 1-1.6 million family groups (Conner et al. 2001a), the social unit of RCWs. The birds inhabited the open pine forests of the southeast from New Jersey, Maryland and Virginia to Florida, west to Texas and north to portions of Oklahoma, Missouri, Tennessee and Kentucky.

RCWs are a cooperatively breeding species, living in family groups that typically consist of a breeding pair with or without one or two male helpers. Females may become helpers but do so at a much lower rate than males. The ecological basis of cooperative breeding in this species is unusually high variation in habitat quality, due to the presence or absence of a critical resource. This critical resource is the cavities that RCWs excavate in live pines, a task that commonly takes several years to complete. RCWs exploit the ability of live pines to produce large amounts of resin, by causing the cavity tree to exude resin through wounds, known as resin wells, that the birds keep open. This resin creates an effective barrier against climbing snakes. Longleaf pine is a preferred tree species for cavity excavation because it produces more resin, and for a longer period of time, than other southern pines.

2.4.1.4 Conservation Needs

The Recovery Plan for the RCW, dated January 2003 includes primary actions needed to accomplish the ultimate (delisting) and interim (downlisting) recovery goals. Below are the main objectives. See Appendix C-4 for further details.

- Application of frequent fire to both clusters and foraging habitat
- Protection and development of large, mature pines throughout the landscape
- Protection of existing cavities and judicious provisioning of artificial cavities
- Provision of sufficient recruitment clusters in locations chosen to enhance the spatial arrangement of groups
- Restoration of sufficient habitat quality and quantity to support the large populations necessary for recovery

2.4.2 Environmental Baseline

2.4.2.1 Species Presence and Use

RCWs prefer open longleaf pine uplands throughout the southeast. RCWs roost and forage year-round and nest seasonally (i.e., April through July) in open, park-like stands of mature pine trees containing little hardwood component, a sparse midstory, and a well-developed herbaceous understory. RCWs can tolerate small numbers of overstory and midstory hardwoods at low densities found naturally in many southern pine forests, but they are not tolerant of dense midstories resulting from fire suppression or from overstocking of pine. Trees selected for cavity excavation are generally at least 60 years old, although the average stand age can be younger. The collection of one or more cavity trees plus a surrounding 200-foot wide buffer of continuous forest is known as a RCW cluster. RCW foraging habitat is located within one-half mile of the cluster and is comprised of pine and pine-hardwood stands (i.e., 50 percent or more of the dominant trees are pines) that are at least 30 years of age and have a moderately low average basal area (i.e., 40 – 80 square feet per acre is preferred. The proposed project would be located in a parish known to be inhabited by RCWs, however, it is anticipated that this species is more of a concern toward the northern border of the parish, where uplands are more common and there is less development.

2.4.2.2 Species Conservation Needs within the Action Area

The Recovery Plan for the RCW, dated January 2003 includes primary actions needed to accomplish the ultimate (delisting) and interim (downlisting) recovery goals. Below are the objectives that might be applicable to the action area.

- Protection and development of large, mature pines throughout the landscape

- Protection of existing cavities and judicious provisioning of artificial cavities

2.4.2.3 Habitat Condition (General)

RCWs require open pine woodlands and savannahs with large old pines for nesting and roosting habitat (clusters). RCWs also require abundant foraging habitat that consists of mature pines with an open canopy, low densities of small pines, little or no hardwood or pine midstory, few or no overstory hardwoods, and abundant native bunchgrass and forb groundcovers. Old growth pine savannas are scattered within the Action Area and are a managed habitat type within the Bayou Bonfouca NWR. Surveys conducted by the USFWS determined that suitable RCW nesting and foraging habitat exists within the Action Area.

2.4.2.4 Influences

Primary threats to species viability for red-cockaded woodpeckers all have the same basic cause: lack of suitable habitat. Red-cockaded woodpeckers require open mature pine woodlands and savannahs maintained by frequent fire, and there is very little of this habitat remaining (Lennartz et al. 1983, Frost 1993, Simberloff 1993, Ware et al. 1993). On public and private lands, both the quantity and quality of red-cockaded woodpecker habitat are impacted by past and current fire suppression and detrimental silvicultural practices (Ligon et al. 1986, 1991, Baker 1995, Cely and Ferral 1995, Masters et al. 1995, Conner et al. 2001). Serious threats stemming from this lack of suitable habitat include (1) insufficient numbers of cavities and continuing net loss of cavity trees (Costa and Escano 1989, James 1995, Hardesty et al. 1995); (2) habitat fragmentation and its effects on genetic variation, dispersal, and demography (Conner and Rudolph 1991b); (3) lack of foraging habitat of adequate quality (Walters et al. 2000, 2002a, James et al. 2001); and (4) fundamental risks of extinction inherent to critically small populations from random demographic, environmental, genetic, and catastrophic events (Shaffer 1981, 1987).

2.4.2.5 Additional Baseline Information

Surveys of the project area conducted by the USFWS identified four RCW clusters within one-half mile of the action area. A foraging habitat analysis determined that the proposed action does not significantly impact the amount of suitable habitat available to nearby RCW clusters (Appendix E-2).

2.4.3 Effects of the Action

2.4.3.1 Indirect Interactions

Clearing of forested areas to construct the approximately 18.40-mile levee and floodwall system could result in removal of suitable RCW nesting trees. In a survey of the project area conducted by USFWS, four RCW clusters were identified near the proposed alignment. A foraging habitat analysis determined the proposed project did not significantly impact the amount of suitable habitat available to these clusters (Appendix E-2). In addition, indirect impacts from construction activities would be controlled through the use of best management practices and adherence to regulations governing stormwater runoff at construction sites and staging areas. No permanent indirect impacts to RCWs are expected to occur from construction of the proposed project.

2.4.3.2 Direct Interactions

Noise and activity associated with construction would likely temporarily displace RCWs from active construction zones to other nearby habitat. Displacement of birds is not likely to significantly impact the species as there is a sufficient amount suitable habitat available adjacent to the project area.

Additionally, RCWs may be physically injured or killed if struck by equipment or materials during construction. This effect is discountable due to the ability of the species to move away from the project site if disturbed.

2.4.4 Cumulative Effects

For purposes of consultation under ESA Section 7, cumulative effects are those caused by future state, tribal, local, or private actions that are reasonably certain to occur in the Action Area. Future Federal actions that are unrelated to the proposed action are not considered, because they require separate consultation under Section 7 of the ESA. At this time the USACE is unaware of any future state, tribal, local, or private non-Federal unrelated to the proposed action that are reasonably certain to occur in the Action Area.

2.4.5 Discussion and Conclusion

Surveys of the project area conducted by the USFWS determined that the proposed action does not significantly impact the amount of suitable habitat available to nearby RCW clusters.

Based upon literature review, available survey data, the current status of the species, the environmental baseline for the action area, and the effects of the action, the USACE has determined that implementation of the proposed action is not likely to adversely affect RCWs.

2.5 West Indian Manatee (*Trichechus manatus*)

2.5.1 Status of the Species

2.5.1.1. Legal Status

The West Indian manatee is listed as threatened under the Endangered Species Act (Federal Register Vol. 32, No. 48, March 11, 1967).

2.5.1.2 Recovery Plans

The most recent recovery plan available for the West Indian manatee is dated October 2001 (Appendix C-5).

2.5.1.3 Life History Information

West Indian manatees are massive fusiform-shaped animals with skin that is uniformly dark grey, wrinkled, sparsely haired, and rubber-like. Manatees possess paddle-like forelimbs, no hind limbs, and a spatulate, horizontally flattened tail. Adults average about 3.0 m (9.8 ft) in length and 1,000 kg (2,200 lbs) in weight but may reach lengths of up to 4.6 m (15 ft) (Gunter 1941) and weigh as much as 1,620 kg (3,570 lbs) (Rathbun et al. 1990).

In general, the data show that manatees exhibit opportunistic, as well as predictable patterns in their distribution and movement. They are able to undertake extensive north-south migrations with seasonal distribution determined by water temperature. When ambient water temperatures drop below 20° C (68°F) in autumn and winter, manatees aggregate within the confines of natural and artificial warm-water refuges or move to the southern tip of Florida (Snow 1991). Most artificial refuges are created by warm-water outfalls from power plants or paper mills. As water temperatures rise manatees disperse from winter aggregation areas. While some remain near their winter refuges, others undertake extensive travels along the coast and far up rivers and canals.

Manatees are herbivores that feed opportunistically on a wide variety of submerged, floating, and emergent vegetation. Because of their broad distribution and migratory patterns, West Indian manatees utilize a wider diversity of food items and are possibly less specialized in their feeding strategies than manatees in tropical regions (Lefebvre et al. 2000). Shallow grass beds with ready access to deep channels are preferred feeding areas in coastal and riverine habitats. Manatees often use secluded canals, creeks, embayments, and lagoons, particularly near the mouths of coastal rivers and sloughs, for feeding, resting, cavorting, mating, and calving (Marine Mammal Commission 1986, 1988). In estuarine and brackish areas, natural and artificial fresh water sources are sought by manatees.

Female manatees appear to reach sexual maturity by about age five but have given birth as early as four (Marmontel 1995; Odell et al. 1995; O'Shea and Hartley 1995; Rathbun et al. 1995), and males may reach sexual maturity at 3 to 4 years of age (Hernandez et al. 1995). Breeding takes place when one or more males (ranging from 5 to 22) are attracted to an estrous female to form an ephemeral mating herd (Rathbun et al. 1995). Mating herds can last up to 4 weeks, with different males joining and leaving the herd daily (Hartman 1979; Bengtson 1981; Rathbun et al. 1995). Although breeding has been reported in all seasons, Hernandez et al. (1995) reported that histological studies of reproductive organs from carcasses of males found evidence of sperm production in 94% of adult males recovered from March through November. Only 20% of adult males recovered from December through February showed similar production. The length of the gestation period is uncertain but is thought to be between 11 and 14 months (Odell et al. 1995; Rathbun et al. 1995; Reid et al. 1995). The normal litter size is one, with twins reported rarely (Marmontel 1995; Odell et al. 1995; O'Shea and Hartley 1995; Rathbun et al. 1995). Manatees may live in excess of 50 years.

2.5.1.4 Conservation Needs

The Recovery Plan for the West Indian Manatee dated October 2001 includes actions needed to achieve species recovery. Below are the main objectives. See Appendix C-5 for further details.

- Minimize causes of manatee disturbance, harassment, injury and mortality
- Determine and monitor the status of the manatee population
- Protect, identify, evaluate, and monitor manatee habitats
- Facilitate manatee recovery through public awareness and education

2.5.2 Environmental Baseline

2.5.2.1 Species Presence and Use

The West Indian manatee is known to regularly occur in Lakes Pontchartrain and Maurepas and their associated coastal waters and streams. It also can be found less regularly in other Louisiana coastal areas, most likely while the average water temperature is warm. Based on data maintained by the Louisiana Department of Wildlife and Fisheries, Wildlife Diversity Program, over 80 percent of reported manatee sightings (1999-2011) in Louisiana have occurred from the months of June through December. Manatee occurrences in Louisiana appear to be increasing and they have been regularly reported in the Amite, Blind, Tchefuncte, and Tickfaw Rivers, and in canals within the adjacent coastal marshes of southeastern Louisiana. Manatees may also infrequently be observed in the Mississippi River and coastal areas of southwestern Louisiana. Cold weather and outbreaks of red tide may adversely affect these animals. However, human activity is the primary cause for declines in species number due to collisions with boats and barges, entrapment in flood control structures, poaching, habitat loss, and pollution.

2.5.2.2 Species Conservation Needs within the Action Area

The Recovery Plan for the West Indian Manatee dated October 2001 includes actions needed to achieve species recovery. Below are the objectives that might be applicable to the action area. See Appendix C-5 for further details.

- Minimize causes of manatee disturbance, harassment, injury and mortality
- Protect, identify, evaluate, and monitor manatee habitat
- Facilitate manatee recovery through public awareness and education

2.5.2.3 Habitat Condition (General)

The West Indian manatee lives in freshwater, brackish and marine habitats. The extent of potential habitat for the manatee, within the project area, is the approximately 134-acre M2 borrow site located within Lake Pontchartrain and adjacent tributaries. Habitat within Lake Pontchartrain is characterized by sandy bottoms and relatively shallow depths extending to 15 feet.

2.5.2.4 Influences

Human activity is the primary cause for declines in species number due to collisions with boats and barges, entrapment in flood control structures, poaching, habitat loss, and pollution. Collisions with watercraft account for an average of 24 percent (%) of known manatee deaths in Florida annually (1976-2000), with 30% in 1999 and 29% in 2000. Deaths attributed to water control structures and navigational locks represents 4% of known deaths. The future of the current system of warm-water refuges for manatees is uncertain as deregulation of the power industry in Florida occurs, and if minimum flows and levels are not established and maintained for the natural springs on which many manatees depend.

2.5.2.5 Additional Baseline Information

There is no additional baseline information.

2.5.3 Effects of the Action

2.5.3.1 Indirect Interaction

Indirect impacts could occur due to turbidity from construction degrading water quality. Turbidity would be minimized by utilizing dikes to contain the dredged material within the M2 marsh creation area. In addition, any runoff from construction activities on land would be controlled through the use of best management practices and adherence to regulations governing stormwater runoff at construction sites and staging areas. No permanent indirect impacts to manatees are expected to occur from construction of the proposed project.

2.5.3.2 Direct Interactions

Proposed construction at the M2 mitigation site would convert approximately 200 acres of shallow open water to brackish marsh. The average depth at this location is less than 2 feet and is not prime habitat for manatee foraging due to the limited amount of grass beds and access to deeper waters. The proposed borrow location would be approximately 134 acres within Lake Pontchartrain and would be more conducive to manatee moving through the area based on depth and access to deeper waters, but foraging potential is still low based on the limited amount of grass beds. During borrow excavation, increased turbidity would occur, but would be reduced by the movement of the tides. Based on the footprint and location of the borrow area in relation to the 403,000-acre lake, significant impacts to manatee would not be anticipated.

2.5.4 Cumulative Effects

For purposes of consultation under ESA Section 7, cumulative effects are those caused by future state, tribal, local, or private actions that are reasonably certain to occur in the Action Area. Future Federal actions that are unrelated to the proposed action are not considered, because they require separate consultation under Section 7 of the ESA. At this time the USACE is unaware of any future state, tribal, local, or private non-Federal unrelated to the proposed action that are reasonably certain to occur in the Action Area.

2.5.5 Discussion and Conclusion

To minimize the potential for construction activities to cause adverse impacts to manatees, *Standard Manatee Conditions for In-Water Activities*, developed by the USFWS, Lafayette, Louisiana Field Office, would be implemented when activities are proposed that would impact habitat where manatees could occur (Appendix D-3).

Based upon literature review, available survey data, the current status of the species, the environmental baseline for the action area, and the effects of the action, and implementation of minimization measures, the CEMVN has determined that implementation of the proposed action is not likely to adversely affect the West Indian Manatee.

3 Critical Habitat Effects Analysis

On March 19, 2003, the Service and the National Marine Fisheries Service (NMFS) published a final rule in the Federal Register (Volume 68, No. 53) designating critical habitat for the Gulf sturgeon in Louisiana, Mississippi, Alabama, and Florida.

Primary consideration must be given to the physical and biological features (PBFs) of the habitat under review that are essential to the conservation of the species and that may require special management considerations or protection.

The PBFs essential for the conservation of the Gulf sturgeon populations include those habitat components that support feeding, resting, and sheltering, reproduction, migration and physical features necessary for maintaining the natural processes that support these habitat components.

Based upon the identified PBFs for the Gulf sturgeon, the USFWS and NMFS identified a total of fourteen (14) Critical Habitat Units. Critical Habitat Unit 8 covers the proposed project area and includes Lake Pontchartrain, Lake St. Catherine, The Rigolets, Little Lake, Lake Borgne, and Mississippi Sound in Jefferson, Orleans, St. Tammany, and St. Bernard Parish, Louisiana, Hancock, Jackson, and Harrison Counties in Mississippi, and in Mobile County, Alabama. The borrow area for the M2 mitigation site, located within Lake Pontchartrain, is included in Critical Habitat Unit 1

Of the PBFs identified for Gulf sturgeon critical habitat, food, water quality, and sediment quality are found within the Action Area.

Adult and subadult Gulf sturgeon feed on amphipods, lancelets, polychaetes, gastropods, molluscs and/or crustaceans within estuarine and marine habitats. Dredging may remove substrates containing sturgeon prey items. However, overall impacts to sturgeon prey are expected to be insignificant since the estimated impact area is relatively small compared to the surrounding area available (approximately 134 acres). Effects to sturgeon prey are also expected to be temporary and short-term in nature, consisting of a temporary loss of benthic invertebrate populations in the dredged areas. Observed rates of benthic community recovery after dredging range from 3-24 months (Culter and Mahadevan 1982; Saloman et al. 1982; Wilber et al. 2007). The relatively species-poor benthic assemblages associated with low salinity estuarine sediments can recover in periods of time ranging from a few months to approximately one year, while the more diverse communities of high salinity estuarine sediments may require a year or longer.

Localized and temporary reductions in water quality through increased turbidity may result from dredging. Effects to water quality from localized and temporary increased turbidity are expected to be insignificant because the Action Area is also in a high wave/current area where construction-induced turbidity is not expected to remain and where turbidity curtains are not practical to use. Effects to temperature, salinity, pH, hardness, oxygen content, and other chemical characteristics of water quality are also not expected to result from dredging activities.

Effects to sediment quality from dredging would be insignificant. During prior consultations (BAs for SER-2010-4236 and SER-2014-14728, hereby incorporated by reference), surveys were conducted by USGS and NOAA that used remote imagery to determine bottom substrates within Lake Pontchartrain. The majority of Lake Pontchartrain bottoms were defined as having sandy composition and thus prime habitat for sturgeon.

The borrow site is approximately 2,000 ft from the shoreline and likely receives fine sediment from wave induced shoreline erosion. The sandier composition areas, which are located further into the lake center, would be avoided and thus minimizing impacts to sturgeon foraging. Given that prime habitat is available nearby, any Gulf Sturgeon that may be present would likely congregate in the ample nearby prime habitat, especially during construction. No permanent alteration of habitat composition is expected to occur within the action area.

Based upon the assessment completed, it was determined that the proposed action would not result in an adverse modification to Gulf sturgeon critical habitat.

4 Summary Discussion, Conclusion, and Effect Determinations

4.1 Effect Determination Summary

Species Common Name	Scientific Name	Listing Status	Present in the Action Area	Effect Determination
West Indian Manatee	(*Trichechus manatus)*	Threatened	Yes	NLAA
Red-Cockaded Woodpecker	(*Picoides borealis)*	Endangered	Yes	NLAA
Gopher Tortoise	(*Gopherus polyphemus)*	Threatened	No	NLAA
Gulf Sturgeon	(*Acipenser oxyrinchus desotoi*)	Threatened	Yes	NLAA
Louisiana Quillwort	(*Isoetes louisianensis*)	Endangered	No	NE
Gulf Sturgeon Critical Habitat		Final	Yes	NLAA

4.2 Summary Discussion

The proposed action consists of the construction of approximately 18.4 miles of earthen levee and floodwall in St. Tammany Parish, Louisiana, channelization of the lower 2.15 miles of Mile Branch in Covington, Louisiana, creation of an approximately 200 acres marsh site on the north shore of Lake Pontchartrain utilizing borrow from Lake Pontchartrain, and other mitigation measures to offset losses within the project's construction footprint areas.

A search on the USFWS' IPaC site indicated that the ESA-listed, eastern black rail, West Indian manatee, red-cockaded woodpecker, gopher tortoise, ringed map turtle, Gulf sturgeon, monarch butterfly, Louisiana quillwort, and Gulf sturgeon Critical Habitat could occur in the project area and should be considered when assessing the impacts of this project. Upon further conference with the USFWS on the project, the USFWS and CEMVN determined that the ringed map turtle and eastern black rail are unlikely to occur in the project area, therefore, only impacts to the West Indian manatee, Louisiana quillwort, Gulf sturgeon, Gulf sturgeon critical habitat, Gopher tortoise, and red-cockaded woodpecker were evaluated in this BA.

The monarch butterfly is listed in the ESA as a "candidate" species. Candidate species receive no protections under the ESA. Should a listing decision be made prior to completion of the proposed action, CEMVN will reinitiate consultation with the USFWS.

The alligator snapping turtle is listed in the ESA as “proposed threatened”. Proposed species are not protected by the take prohibitions of Section 9 of the ESA until the rule to list is finalized. However, under section 7(a)(4) of the ESA, Federal agencies must confer with the Service if their action will jeopardize the continued existence of a proposed species. Since the alligator snapping turtle may occur in the project area, the USFWS provided a list of minimization measures to reduce potential adverse effects to the species.

To reduce impacts to the West Indian manatee and the Gulf sturgeon, implementation of the proposed action would include Standard Manatee Conditions for In-Water Activities, Protected Species Construction Conditions, and Vessel Strike Avoidance Measures. In summary, the contractor will be responsible for instructing all personnel regarding the potential presence of protected species in the area and the need to avoid collisions with these animals. If protected species are sighted within 150 of the area, all operations of moving equipment must cease until the species has departed the area on its own volition. There also would be reporting requirements, restrictions on vessel operation, and restrictions on the use of siltation barriers.

4.3 Conclusion

Based on currently available historical and catch data; a review of current literature and studies; and with the employment of avoidance measures recommended through guidelines set up during coordination with USFWS and NMFS, the CEMVN believes that the actions, as proposed, may affect but are not likely to adversely affect the federally listed species of Gulf Sturgeon, West Indian manatee, Red-Cockaded woodpecker, gopher tortoise, and gulf sturgeon critical habitat, and will have no effect on the Louisiana quillwort,.

Based on the information provided in this document, the CEMVN requests concurrence with may affect, but are not likely to adversely affect determination for the gulf sturgeon, West Indian manatee, red-cockaded woodpecker, Louisiana Quillwort, gopher tortoise, and gulf sturgeon Critical Habitat.

The Record of Decision will not be signed until ESA coordination is complete.

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Appendix A Detailed Project Description

SUMMARY

PROJECT DESCRIPTION
for the
Optimized Tentatively Selected Plan
St Tammany Parish Louisiana Feasibility Study

1.0 INTRODUCTION

Subsequent to the release of the June 2021 Draft Integrated Feasibility Report and Draft Environmental Impact Statement (DIFR and DEIS), the Project Delivery Team (PDT) conducted additional engineering, economic, and environmental investigations on the individual features of the Optimized Tentatively Selected Plan (TSP) which is comprised of a structural plan and a non-structural plan. Information gathered by the PDT through these additional investigations, together with the consideration of comments received from the public, stakeholders, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service assisted the PDT in further refining the design of the Draft TSP. This document is a summary project description of the proposed Optimized TSP. Refer to Appendix F and H for the full description of the non-structural plan and Appendix D for full description of the structural plan.

1.1 SCOPE OF WORK

The Optimized TSP includes a non-structural plan and a structural plan. For planning purposes, the 50-yr period of analysis for the study was estimated to be from the year 2032 to 2082. Project authorization would occur in the year 2024 and kick-off planning, engineering, and design (PED). PED was originally estimated to be complete by the year 2027. Initial construction of the project would begin 2027 and conclude by the year 2032 (base year). These original assumptions will be revised once the construction schedule is prepared by the Cost team in MVN Engineering. Figure 1-1 illustrates the optimized TSP including a non-structural and a structural plan.

<u>Non-Structural Plan</u>:

Insert summary of the non-structural plan from Economics.

<u>Structural Plan</u>:

The structural plan consists of construction of a levee and floodwall system along an alignment in South and West Slidell and channelization of a portion of the Mile Branch in Covington.

1.2 **Mile Branch Channel Improvement:** This measure consists of channel improvements on the lower 2.15 miles (11,341 ft channel) of Mile Branch in Covington, Louisiana. The proposed work would consist of approximately 20 acres of channel that would be cleared and grubbed prior to mechanical dredging.

The mechanical dredging would consist of a maximum of 130,000 cubic yards of fill dredged from the channel. There are no surveys available for this area for this study, and no surveys will be conducted during the study phase. The existing elevations used for the hydraulic analysis and design of the Optimized TSP were obtained from the LIDAR raster dataset. Designs are based on existing information gathered from reports provided by the non-Federal sponsors as shown on Table 1.2 in the main report.

Design refinements would occur during PED based on field data collections. Based on data collected, the design would be refined to minimize impacts to aquatic and riparian habitat and real estate. Riparian Zone bioengineering techniques and nature-based-solutions (NBS) would be incorporated as appropriate during PED in coordination with the NFS and resource agencies. A backwater area has been incorporated in the design of Mile Branch.

Table 1.1 lists the Mile Branch attributes of the TSP for the 50-year period of analysis.

Table 1.1 Summary Table of TSP for Mile Branch

Attribute	**Mile Branch Channel Improvements**
Total Length of improvements	2.15 miles (11,341 feet)
Material to be Mechanically Dredged	130,000 cubic yards
Access Roads for both clearing and for bridge replacement?	0 acres
Number of staging areas for clearing and grubbing and mechanical dredging and for culvert/bridge replacement	19 (7 for culvert/bridge replacements, 11 for clear and grubbing and mechanical dredging and one that becomes a backwater area)
Number of Bridge Replacements of Culverts	7
Temporary ROW	7.3 acres (2.2 acres for culvert/bridge replacements and 5.1 acres for clear and grubbing and mechanical dredging)
Permanent ROW	38.5 acres (34 acres for clear and grubbing and mechanical dredging and 4.5 acres for one staging area that becomes a backwater area)

The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and end at the intersection of Mile Branch and the Tchefuncte River. Assumptions for channel improvements included a 65-ft from the centerline of each side of the channel for ROW as a general guideline (total width of 130 ft).

The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel would be widened as well as deepened. The channel bottom would be lowered by 5 ft. All work would be performed from the bank. The trees located close to the bank would be removed. The banks would be stabilized and seeded and fertilized to have a grass cover. Work would be done by excavators or small skid steers.

Material removed may include sediment, trees, debris, or other obstructions within the waterway. Removed material would be trucked off-site and disposed at a facility licensed to handle the material. Site access to Mile Branch would be via public roads and public rights of way.

For the channel improvements, approximately 34 acres of permanent ROW would be needed. This area would include 25 ft on each side of the Mile Branch channel. Within the 34 acres, approximately 21 acres of channel would be cleared and grubbed prior to mechanical dredging. An assumed maximum of 130,000 cubic yards of material may be mechanically dredged from the channel.

Mile Branch improvements may include bridge replacements or culverts. Approximately 2.2 acres would be required for staging along the various areas of the bridge/culvert replacements.

1.3 <u>South and West Slidell Levee and Floodwall Alignment:</u> The levee and floodwall system would consist of a total of approximately 18.4 miles (96,950 feet) of earthen levee and floodwall which includes approximately 15 miles (79,100 feet) of levees constructed in separate (non-continuous) segments, and 3.4 miles (17,850 feet) of separate (non-continuous) segments of a floodwall. Construction of the levee alignment would impact approximately 520.7 acres of permanent ROW and it would require approximately 7,069,000 cubic yards of fill, including fill material required for future levee lifts (estimates include a 30 percent contingency). Table 1.2 provides a summary of the attributes of the South and West Slidell Levee and Floodwall System. Table 1.3 is a summary of the levee quantities required for the initial construction.

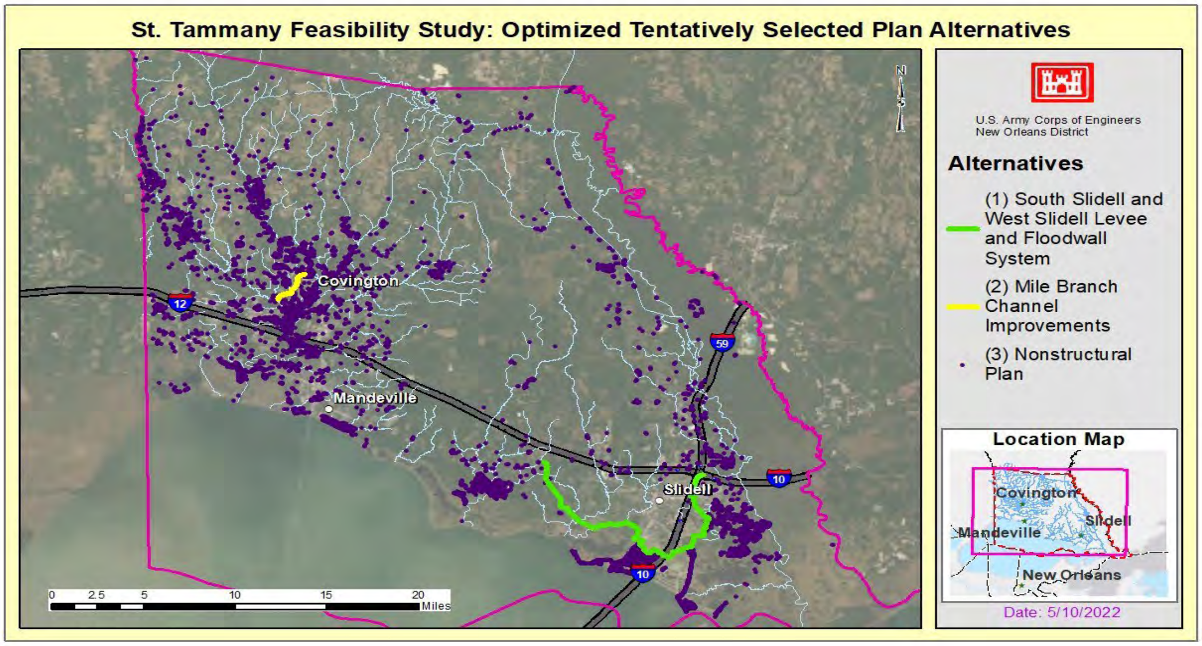

Figure 1-1. Optimized Tentatively Selected Plan

Table 1.2 Summary Table of South Slidell and West Slidell Levee and Floodwall System

Attribute	**South Slidell and West Slidell Levee and Floodwall System**
Total Length of alignment	18.4 miles (96,950 feet)
Length of Floodwall	3.4 miles (17,850 feet)
Length of earthen Levee	15 miles (79,100 feet)
Temporary Acres of Construction for Levee and Floodwall system	109 acres
Permanent Acres for Levee and Floodwall system	521 acres
Hydraulic Design Elevation Range (Dependent on location)	13.5 to 16 (year 2032) 17.5 to 20 (year 2082)
Pump Stations	8
Sluice Gates/Lift Gates	13
Number of Vehicular Floodgates	16
Number of Pedestrian Floodgates	1
Number of Railroad Gates	1
Number of Road Ramps	11
Fill (Borrow Material) Required	7,069,000 cubic yards

The existing elevations utilized were obtained from the LIDAR raster dataset. No survey data was obtained at this stage of the study; therefore, a 30% contingency was

used for the calculation of the borrow quantities for the South Slidell and West Slidell levee alignment.

Table 1.3 Summary Table: TSP Levee Quantities for Initial Construction

Levee Alignment ROW and Levee Quantities Initial Construction (Year 2032)	
WEST SLIDELL	
Permanent ROW	240 acres
Fill Material (includes 30% contingency)	2,007,000 cubic yards
SOUTH SLIDELL	
Permanent ROW	120 acres
Fill Material (includes 30 %contingency)	825,000 cubic yards**
TOTAL	
Permanent ROW	360 acres
Fill Material (includes 30 % contingency)	2,832,000 cubic yards

**includes quantities for I-10 portion of the alignment.

Levee lifts would be required over the 50-yr period of analysis. The levee lift schedule would follow the hydraulic design elevation requirements and thus were divided into 3 geotechnical reaches: Oak Harbor South; I-10 Crossing and Slidell East/Northeast as illustrated in Table 1-4. The fourth lift (final lift for the 50-year period of analysis), projected to occur in year 2076 would elevate the levee to a construction elevation of 19 ft. It is during the scheduled 4th lift that construction of the Western High Ground Tie-in would be necessary for year 2082. The fill quantities listed for the 4th lift, include quantities for the construction of the Western High Ground Tie-In.

Table 1.4. Future Levee Lifts

	Construction Lift (year)	**Construction Elevation (feet)**	**Permanent ROW (acres)**	**Fill Material (+30% contingency; cubic yards)**
WEST SLIDELL				
First lift	2033	16	N/A	771,000
Second lift	2038	17.5	N/A	901,000
Third lift	2051	19	N/A	685,000
Fourth lift	2076	19	30 *	709,000 *
SOUTH SLIDELL				
Oak Harbor South				
First Lift	2035	17	N/A	106,000
Second Lift	2048	18	N/A	120,000
Third Lift	2064	19	N/A	115,000
I-10 Crossing**				
Slidell East / Northeast				

First Lift	2034	19	N/A	271,000
Second Lift	2047	20.5	N/A	295,000
Third Lift	2064	21.5	N/A	264,000
Total For Future Lifts				
			30	4,237,000
Total for Life of the Project (initial construction + lifts)				
			390	**7,069,000**

***** Includes the levee quantities (192,000 cubic yards) for the Western High Ground Tie-in for Year 2082.

** I-10 Crossing features would be constructed to the 2082 elevation and therefore would not require additional lifts.

2 LEVEE AND FLOODWALL SYSTEM DESCRIPTION

The levee and floodwall system consists of a combination of portions of the West Slidell levee alignment and the South Slidell levee alignment. The two alignments would be connected by a new railroad gate across the existing Norfolk Southern Railway Corp. railroad tracks. The alignment is shown in lime green in Figure 1-2.

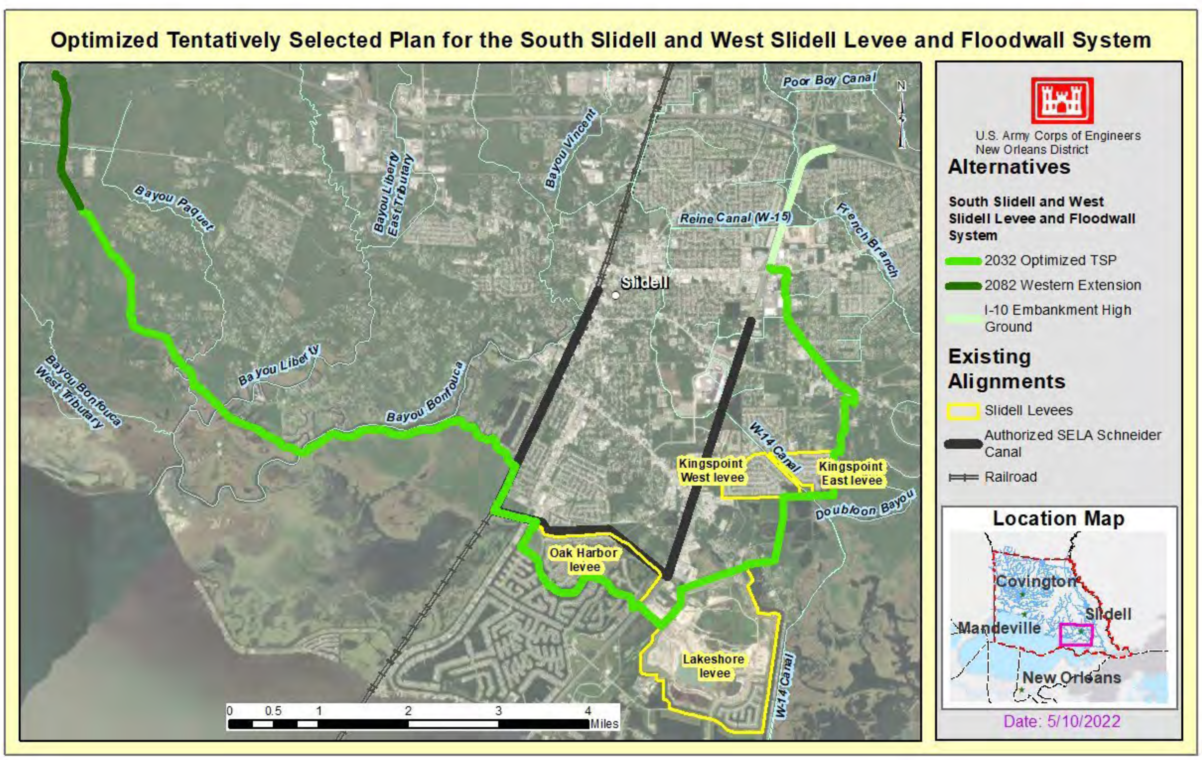

Figure 2-2. Optimized TSP for the West Slidell and the South Slidell Levee and Floodwall System

2.2 LEVEE AND FLOODWALL ALIGNMENT AND STRUCTURES

This section describes the alignment starting on the northwest end and continuing east. For floodwall segments refer to table 2.4, for pump stations refer to Table 2.9, for sluice, lift and sector gates refer to table 2.7, and for vehicular, pedestrian, and railroad floodgates refer to Table 2.8. All structural components would be constructed during initial construction.

2.2.1 WESTERN EXTENTION

Western Terminus: The intermediate scenario of relative sea level change between years 2032 and 2082 was used to develop the 2082 hydraulic design elevations. Based on that analysis, the levee was extended to the west to maintain a 1% risk reduction. The Western High Ground Tie-in for Year 2082 is shown in dark green in Figures 1-3 and 1-4. Based on modeling, the western extension would not be necessary until the year 2076 when the risk reduction would be needed. It is anticipated that this levee segment would be constructed during the fourth levee lift of the West Slidell alignment.

The alignment would commence north of US Highway 190 in the neighborhood near the intersection of North Tranquility Road and Shannon Drive between two properties. The alignment would be a berm with hydraulic design elevation of 17.5 ft for year 2082. The alignment would switch to levee (hydraulic design elevation of 17.5 ft (Year 2082)) and would continue south on the edge of the properties and cross US Highway 190, the Tammany Trace Bike Trail and South Tranquility Road on the eastern side of Pineridge Road. The alignment would run south southeast an additional 890 feet past the intersection with South Tranquility Road and tie with the existing year 2032 alignment for West Slidell.

2.2.2 WEST SLIDELL ALIGNMENT

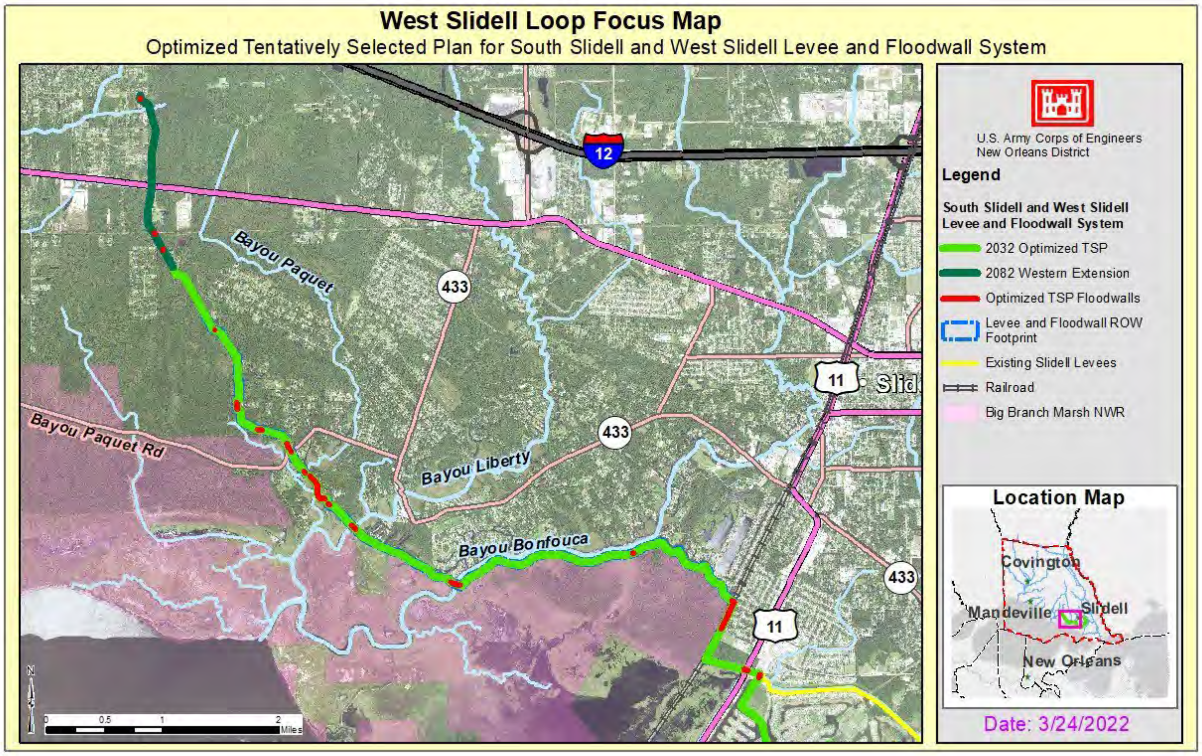

Figure 1-3. West Slidell Levee and Floodwall System- Optimized Tentatively Selected Plan Focus with Floodwall Segments

West Slidell Levee Segment: Levee construction would commence on the south side of US Highway 190 and South Tranquility Road, and on the eastern side of Pineridge Road. For the West Slidell portion of the alignment, the levee segments would have a hydraulic design elevation of 13.5 ft (Year 2032).

The alignment would run southward and would run on the west side of Tranquility Road (CC Road) and then it would turn in the southeast direction crossing Bayou Paquet Road and would stay on the east side of Bayou Paquet Channel to avoid impact to the Big Branch Marsh National Wildlife Refuge (NWR). The alignment would cross Bayou Paquet and Bayou Liberty and would continue eastward on the northside of the Big Branch Marsh NWR. The alignment would cross Bayou Bonfouca and would continue on the south bank of the bayou (northern side of the refuge) until reaching the Norfolk Southern Railway Corp. railroad tracks west of US Highway 11 in the vicinity of Dellwood Pump Station in Slidell.

2.2.3 SOUTH SLIDELL ALIGNMENT

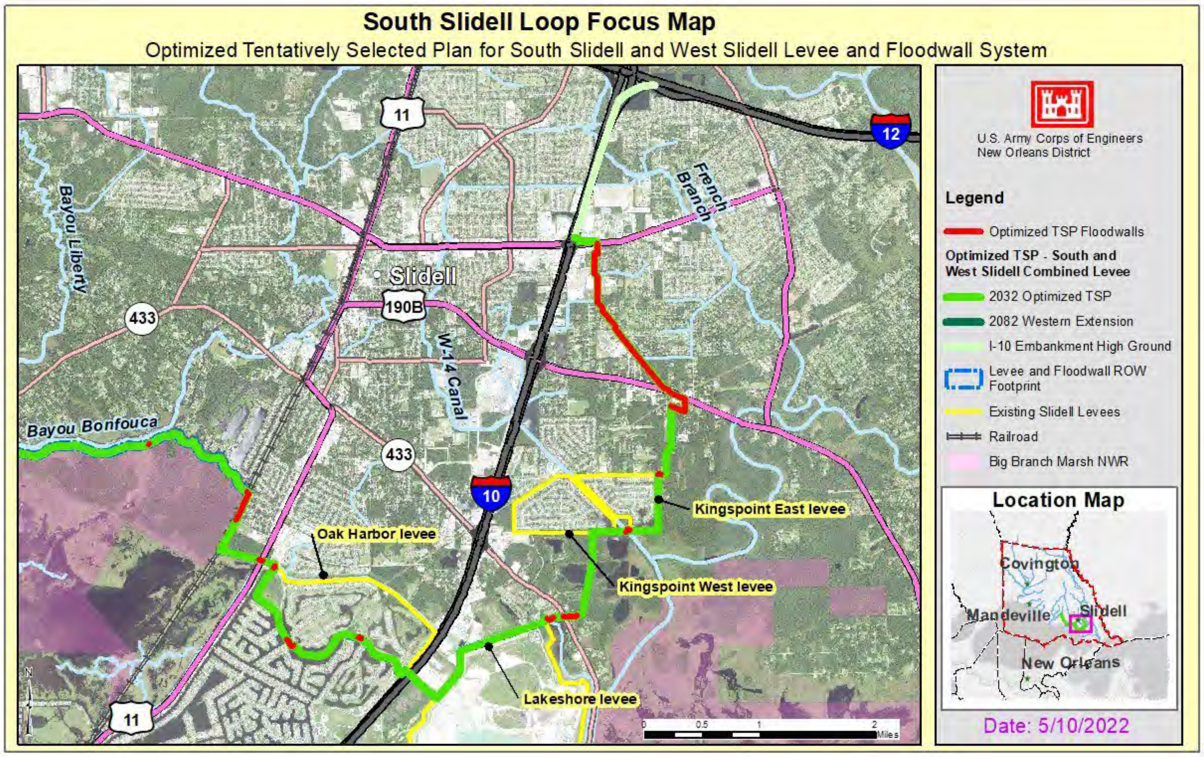

Figure 1-4. South Slidell Levee and Floodwall System- Optimized Tentatively Selected Plan Focus

South Slidell Levee Segment: The levee and floodwall system alignment from West Slidell would continue to South Slidell. From the railroad gate connecting West Slidell with South Slidell, the alignment would transition to a floodwall running parallel along the east side of the railroad tracks. The floodwall by the railroad tracks would have a hydraulic design elevation of 16.5 ft for year 2082.

The alignment would transition to levee when it turned east toward Highway 11. The alignment would cross Highway 11 and would turn south in the vicinity of the existing Schneider Canal Pump Station and then turn east (on a portion of the existing Oak Harbor ring levee). The alignment would run on the south side of Oak Harbor Boulevard and would cross to the north side immediately past Mariners Cove Boulevard. The levee along the south side of the Oak Harbor would have a hydraulic design elevation of 14 ft for year 2032.

The alignment would run on a portion of the existing Oak Harbor ring levee. The alignment would turn north and then east in the vicinity of the I-10. The I-10 would be raised to ramp over the new levee section (hydraulic design elevation of 18.5 ft for year 2082).

The alignment would continue southeast and would tie to an existing portion of the Lakeshore Estates ring levee. The alignment then would turn north and then east and cross Old Spanish Trail/Highway 433. The alignment would continue north and tie to a portion of the existing King's Point west levee. The section of levee would have a hydraulic design elevation of 16 ft for year 2032.

The alignment would cross the W-14 Canal and would tie to a portion of the existing King's Point east levee and would turn north. The levee would have a hydraulic design elevation of 16 ft for year 2032. The levee would turn east and then north. Immediately south of Highway 190 Business the alignment would turn from levee to floodwall to provide risk reduction to the existing Hardin Road power substation. The floodwall would have a hydraulic design elevation of 18.5 ft for year 2082.

The alignment would cross Highway 190 Business and continue northwest on the west side of the existing CLECO Corporate Holdings, LLC utility corridor. The alignment would cross South Holiday Drive and continue north. The alignment would turn east on Manzella Drive and turn north in the middle of the block between Yaupon Drive and Malbrough Drive.

The alignment would cross Gause Boulevard as a ramp crossing and would turn west and tie to high ground (hydraulic design elevation of 18.5 ft for year 2082) in the vicinity of the I-10. There would be additional road ramps for businesses on the north side of Gause Boulevard, the I-10 Service Road and the I-10 on-ramp for the I-10 eastbound at Gause Boulevard.

The existing highway embankment would serve as the means of risk reduction in order for the project to form a continuous system up to the elevation required in 2082. Refer to light green portion of the alignment in Figure 1-5.

CLECO Corporate Holdings, LLC has right-of-way use requirements pertaining to USACE work around their existing utility lines on the northeast corner of the floodwall alignment that would have to be met to provide clearance for construction activities (i.e., pile driving).

INTERSTATE 10 ELEVATION

The I-10 road surface would be raised to construction elevation 21.5 ft to ramp over the new levee section to stay above the hydraulic design elevation for year 2082, to ensure the entire pavement section remains above the hydraulic design elevation across the interstate. The hydraulic design elevation at this location for year 2082 is 18.5 ft. The pavement section was assumed to have a thickness of 2.5 ft.

The existing elevation of the I-10 at the proposed location is approximately 12.8 feet as per LIDAR raster dataset. This proposed location is the highest elevation of the I-10 in the vicinity of the proposed alignment. The I-10 elevation is lower (approximately 10 feet) on the adjacent areas.

The levee and the Interstate 10 would be lifted during initial construction in year 2032 to construction elevation of 21.5 ft to avoid future disruptions to the traffic on the interstate.

2.3 TYPICAL SECTION AND ELEVATIONS

2.3.1 WEST SLIDELL LEVEE DIMENSIONS AND QUANTITIES

The dimensions for the new West Slidell levee may be found in Table 2.1 and Figure 1-5.

Geotextile would be placed for West Slidell during initial construction under the levee. Geotextile would be placed 70 ft from the centerline of the levee on the floodside and 40 ft from the centerline of the levee on the land side for a total of 110 ft.

Table 2.1. West Slidell Levee

West Slidell Levee **Initial Construction**	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Floodside Berm Slope	1V:42H
Landside Berm Slope	1V:33H
Construction Elevation	14.5 ft
Geotextile	13,200 lbs/ft

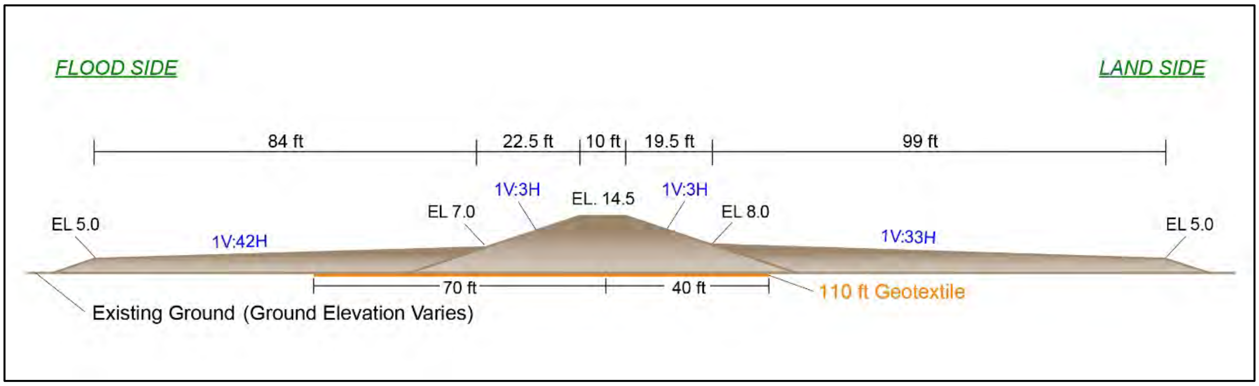

Figure 1-5. Typical Cross-Section with Berms for West Slidell

The hydraulic design elevations of the new West Slidell levee would be 13.5 feet (year 2032) and the 17.5 ft (year 2082). Right of way for the levee was assumed to be 300 ft wide.

2.3.2 SOUTH SLIDELL DIMENSIONS QUANTITIES

The dimensions for the new South Slidell levee may be found in Table 2.2 and Figure 1-6. The construction elevation for the first lift would vary depending on location. This portion of the alignment would not have berms or geotextile.

Table 2.2. South Slidell Levee

South Slidell Levee Initial Construction	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Construction Elevation	Varies

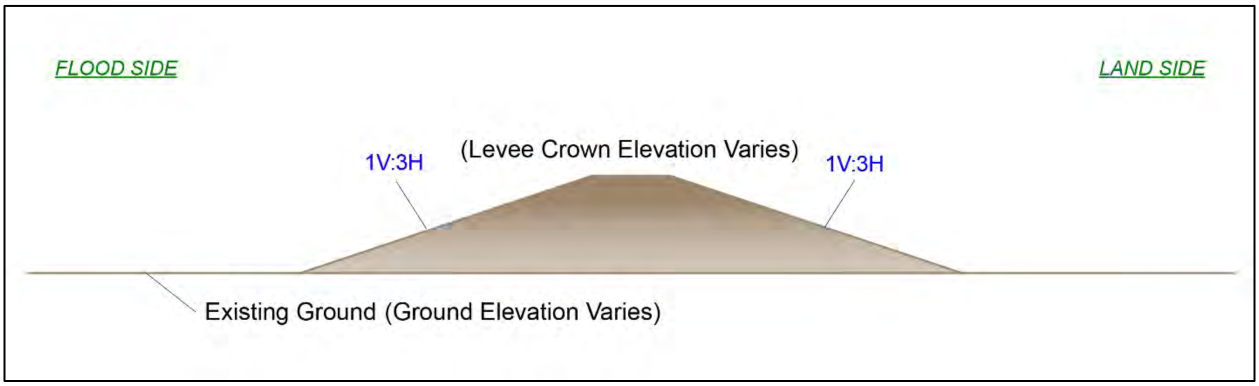

Figure 1-6. Typical Cross-section for South Slidell

The hydraulic design elevation of the new South Slidell levee would vary between 14 ft and 16 ft (year 2032) depending on the location.

2.4 FUTURE LEVEE LIFTS

To maintain the levee crown at or above the base year (2032) and future year (2082) design elevations while accounting for levee settlement and relative sea level rise, levees would be constructed in multiple lifts over the period of analysis. Both the design elevations and constructed "top of levee" elevations vary by location. Design elevations vary by levee location because of surge and wave differences due to storm path, wind speeds and direction, etc.

Levee portions of the Optimized TSP would require future lifts to bring the levees to hydraulic design elevations for year 2082.

For West Slidell, four future levee lifts are projected to be needed. The assumed cross-section for these lifts would have a 10 ft wide levee crown and side slopes of 1V:3H.

Existing berm sections from initial construction would be in place on both sides of the levee.

For the first lift (Year 2033) and the second lift (Year 2038), it was assumed that in addition to elevating the levee, the berm previously built during initial construction would settle 25 percent. Additional material would be placed on the berms during these two lifts.

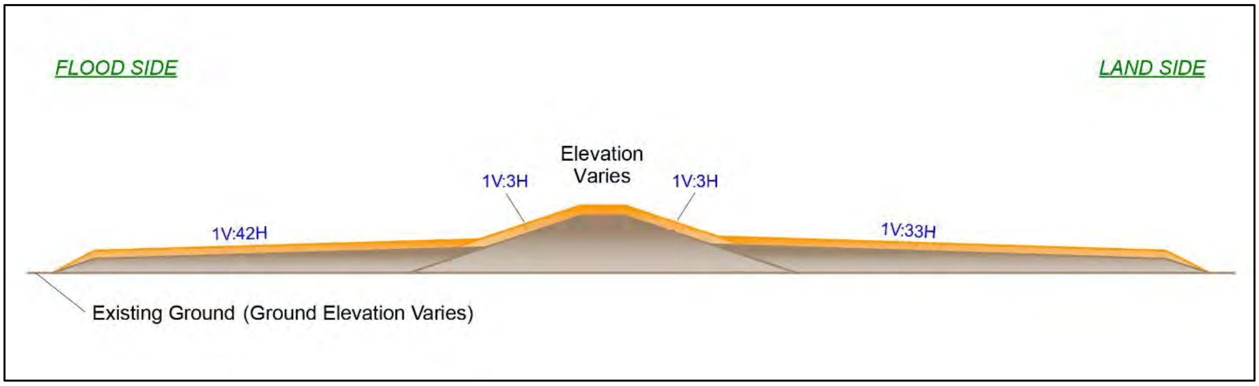

Figure 1-7. Typical Cross-section with berms for First and Second Lifts for West Slidell

For the third lift (Year 2051) and the fourth lift (Year 2076), it was assumed that no additional material would be placed on the berms.

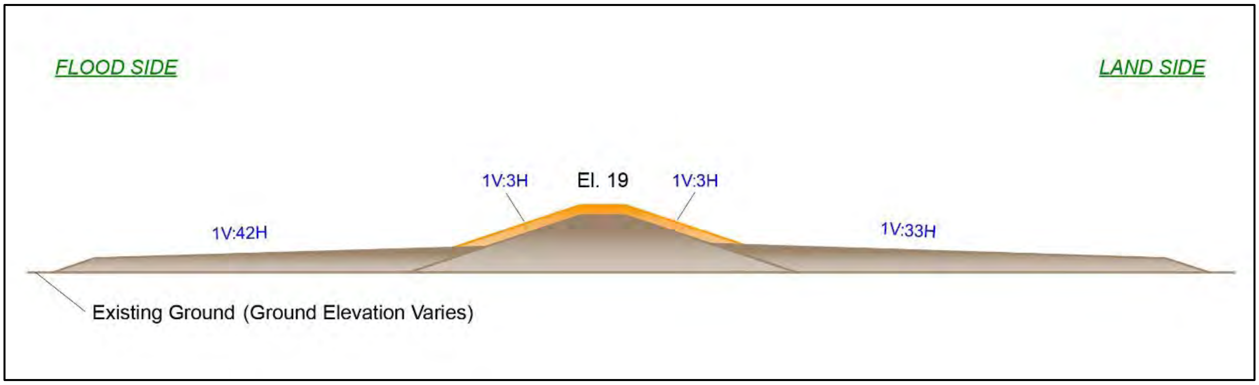

Figure 1-8. Typical Cross-section with berms for Third and Fourth Lifts for West Slidell

2.4.1 WESTERN HIGH GROUND TIE-IN LEVEE CONSTRUCTION

The construction of the Western High Ground Tie-In would be performed during the fourth lift for West Slidell which is projected for year 2076. The dimensions for the Western High Ground Tie-In may be found in Table 2.3 and Figure 1-9. This portion of the alignment would not have berms or geotextile.

Table 2.3. Western High Ground Tie-In *Levee*

Western High Ground Tie-In	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Construction Elevation	19 ft

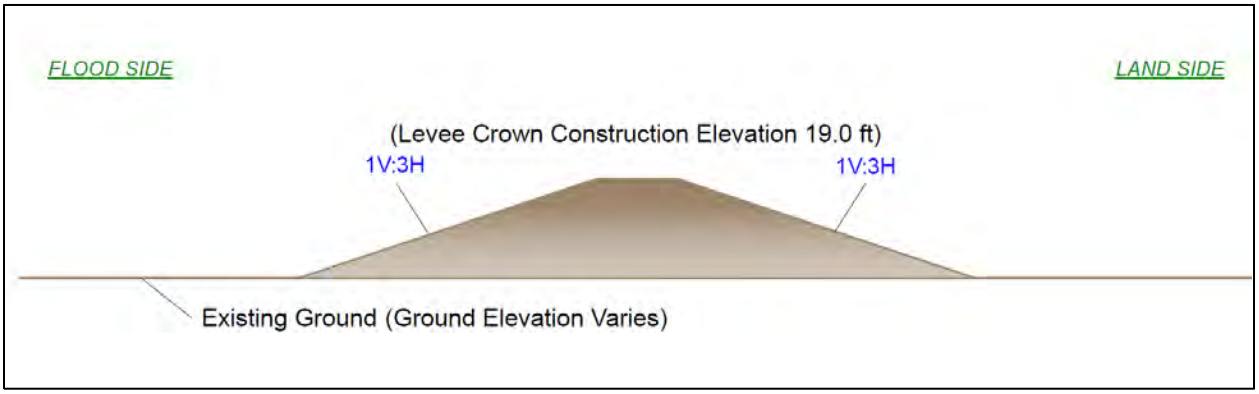

Figure 1-9. Typical Cross-section for the Western High Ground Tie-in for Year 2082

The lift schedules for West Slidell consisted of one geotechnical reach as shown in Figure 1-9. The hydraulic design elevation is 13.5 ft for year 2032 and 17.5 ft for year 2082 are shown in the design line in blue. The red lines represent the projected lifts.

2.4.2 SOUTH SLIDELL LEVEE TYPICAL CROSS SECTION FOR FUTURE LIFTS

The future lifts for South Slidell levee would have a 10 feet wide levee crown and side slopes of 1V:3H.

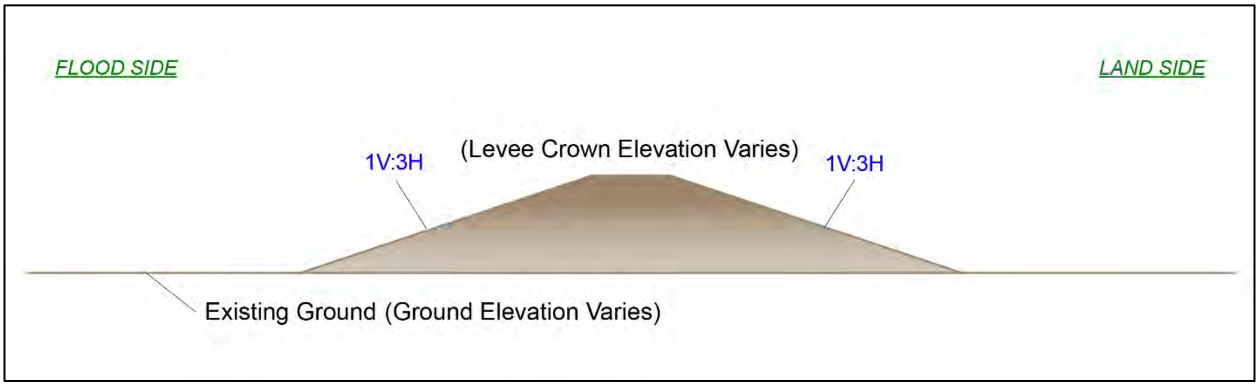

Figure 1-10. Typical Cross-section for South Slidell for Future Lifts

2.5 Typical Floodwall Section and Elevations

The T-wall sections would vary based on location. Table 2.4 lists the floodwall segment and the various dimensions for each floodwall segment.

Table 2.4. Floodwall Segment dimensions

Description of Floodwall Segment	Length of Floodwall Segment (ft)	Base of Slab BOS (ft)	Base of Wall BOW (ft)	Top of Wall TOW (ft)	Stem Height (ft)	Wall Thick (ft)	Slab Width (ft)	Number of piles per row
Western High Ground Tie-in for Year 2082								
N/A								
West Slidell								
Properties at the end of West Doucette	350	1.5	4.5	17.5	**13**	2	15	3
North Side Bayou Paquet Dr.	250	-1.5	1.5	16.5	**15**	2.5	20	4
Bayou Paquet/Mayer Dr.	1400	-1.5	1.5	16	**14.5**	2.5	20	4
South Slidell								
Front Street/ Railroad	1375	-0.5	2.5	16.5	**14**	2.5	20	4
Old Spanish Trail	300	-2.5	0.5	18.5	**18**	2.5	20	4
Esprit du Lac Street	450	1	4	18.5	**14.5**	2.5	20	4
Substation Floodwall	1950	4.5	7.5	18.5	**11**	2	15	3
Highway 190 Business	430	5	8	18.5	**10.5**	2	15	3
Utility Corridor	3530	5	8	18.5	**10.5**	2	15	3
Hollywood Dr. to Yaupon	3700	9	12	18.5	**6.5**	1.5	10	2
Manzella Dr. to Gause	650	10.5	13.5	18.5	5	1.5	10	2

2.6 CONCRETE AND PILE QUANTITIES FOR FLOODWALL SEGMENTS

The floodwall segments would require the following concrete quantities during initial construction as shown on Table 2.5.

Table 2.5: Concrete Quantities for Floodwall Segments

CONCRETE FLOODWALL SEGMENTS	
Total Concrete Quantities	36,200 cubic yards
Total Sheetpile Quantities	451,400 square feet
Total Length of Piles	887,000 linear feet

Total Slope Paving for floodwall/levees tie-ins	7,000 square feet

Table 2.6: Pile Quantities for Floodwall Segments

PILES FOR FLOODWALL SEGMENTS	
Type of pile	18-inch pipe
Configuration	1H:2V battered
Length of each pile	101 feet
Total Length of Piles	26,300 linear feet

2.7 FLOODGATES DESIGN INFORMATION

The Optimized TSP would include a total of 13 gates. Three (3) gates would be lift gates and one gate would be a sector gate. These gates would allow navigation of recreational vessels. There are nine (9) sluice gates which would be control structures (non-navigable).

During construction of the gated structures, temporary bypass channels would be constructed for recreational vessels in Bayous Paquet, Bonfouca, and Liberty.

Table 2.7: Floodgate Dimensions

Description of the Floodgate	Type of Gate	Width of Opening of the Gate (ft)	Ground/ Sill Elevation (ft)	Structural Height of Drainage Gate (ft)
Western High Ground Tie-in for Year 2082				
Sluice gate near Shannon Drive	Sluice	4	15.5	2.0
Tammany Trace Sluice Gate	Sluice	15	12	5.5
West Slidell				
Sluice Gate # 7 (Near CC Road)	Sluice	25	8.6	8.9
Sluice Gate # 6 (Bayou Paquet North Tributary)	Sluice	75	0.8	15.2
Bayou Paquet Gate Nav. Gate	Lift	90	-0.5	16.5
Bayou Liberty Nav. Gate	Lift	80	-6.8	22.8
Bayou Bonfouca Nav. Gate	Lift	110	-9	25.0
Sluice Gate # 2 (Bayou Bonfouca Sluice Gate)	Sluice	50	0.4	15.6
South Slidell				
W-14 Canal Nav. Gate	Sector	90	0.1	18.4
Sluice Gate # 8 (Kings Point East)	Sluice	90	4.4	14.1

Sluice Gate # 10 (Near Eastern Terminus)	Sluice	20	10.5	8.0
Reine Canal	Sluice	30	7.5	11.0
French Branch at I-10	Sluice	25	8.3	10.2

The floodgate locations and minimum sizes above are an estimate. A detailed interior drainage design would be provided during PED.

Limited information and estimates of channel depths and widths has been considered in estimates of the minimum gated opening dimensions. An increase in the size of the gated openings would likely benefit environmental conditions and would provide additional flood flow conveyance. Any channel constriction such as a gate has the potential to locally increase velocities, which could erode natural channels.

It is assumed that most of these floodgate locations would need to retain some flood conveyance capacity during construction. During PED, bypass channels would be considered as part of the design.

Temporary Bypass Channel

Temporary bypass channels would be constructed at locations where a pump station or floodgate is proposed within the limits of a channel. The temporary bypass channel would route water around the structure in order for the construction to be done in dewatered conditions.

In order to maintain pre-construction flow conditions and minimize environmental impacts during construction, the temporary bypass channels would be similarly sized to the channels being impacted. After construction, the bypass channel is assumed to be included in the footprint of the structure site and the channel flow would be rerouted through the new structure feature. Navigation of common local vessels would be considered for the bypass channels, and design features of a navigable bypass channel would be developed during PED.

Temporary Retaining Structures (TRS)

Temporary Retaining Structures (cofferdams) are temporary features that facilitate the construction of major structures. Cofferdams allow water or other materials to be removed inside the TRS in order to work in an excavated and/or dewatered condition.

Cofferdams would be required during the construction of the pump stations and floodgates. Qualified designers employed or sub-contracted by the construction contractors would design the TRS for this project.

2.8 TYPES OF FLOODGATES

2.8.1 FISH-FRIENDLY LIFT GATE

For Bayou Paquet, Bayou Bonfouca and Bayou Liberty, the proposed navigable gates would be designed to have a small amount of restriction and a gradual slope so that fish and larvae may traverse the structures. The navigable gates would consist of a lift gate which would be raised during open mode to let water and recreational vessels traverse. This design would include smaller sluice gates on both sides of the lift gate to simulate the natural opening of the bayous.

During PED, the PDT would consider additional fish-friendly studies and input provided by the NFS, USFWS and National Marine Fisheries Service criteria, including the rock arch and rock ramp designs.

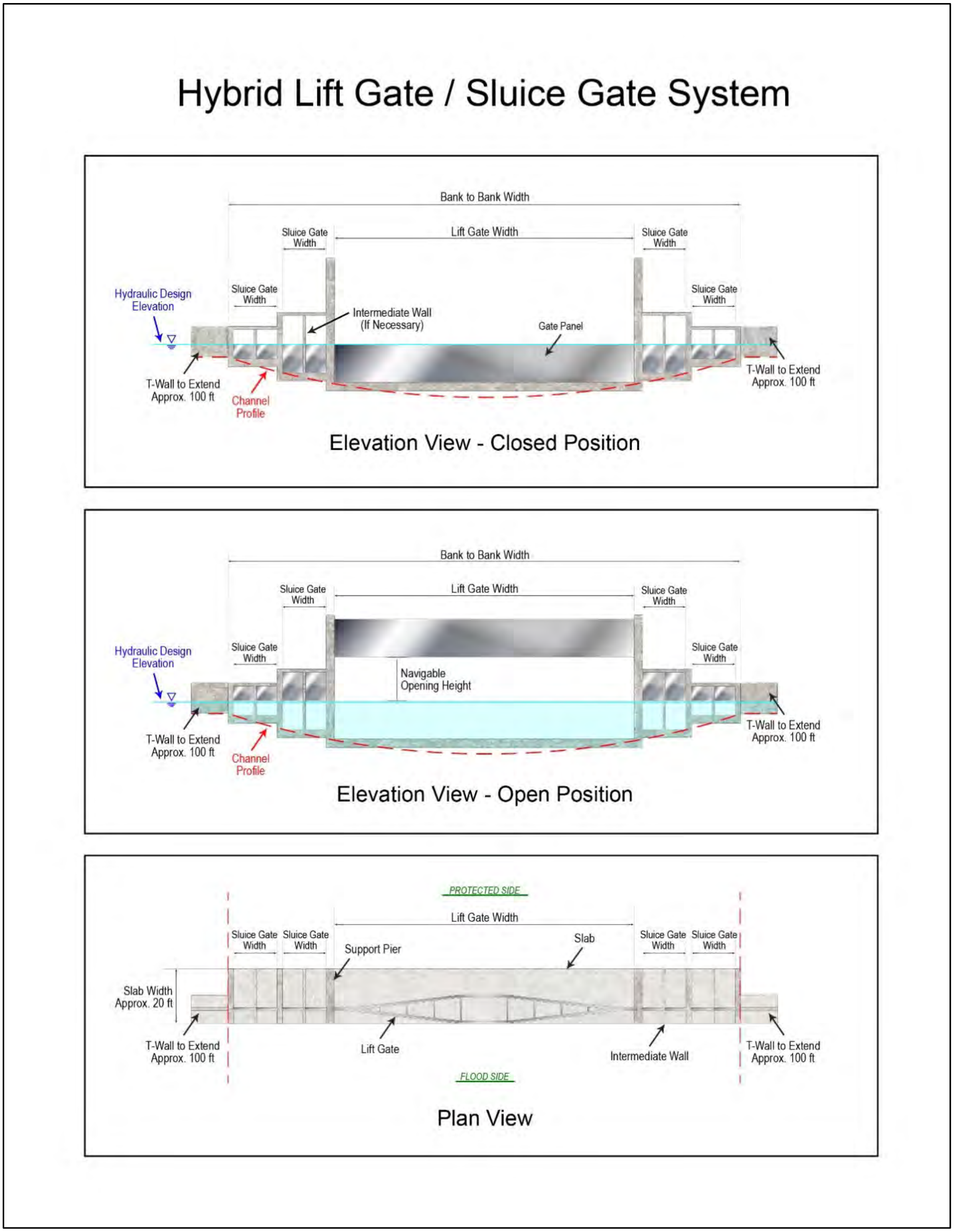

Figure 1.11. Typical Fish-Friendly Gate - Elevation and Plan Views

2.8.2 SLUICE GATE

A sluice gate is a structure that contains a movable gate or series of movable gates that, when lifted, allow material and water to flow under it. Generally, sluice gates are not navigable as they do not raise high enough, or they have fixed components that do not allow vessels to pass through."

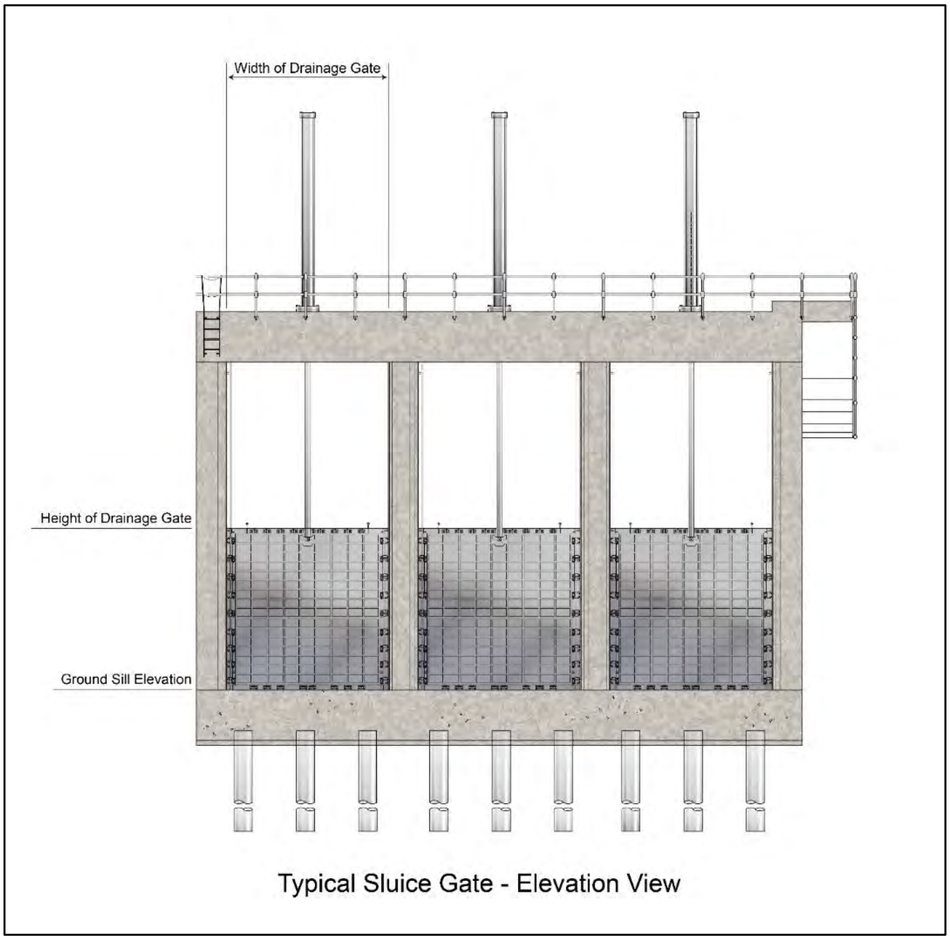

Figure 1-12. Sluice Gate - Elevation View

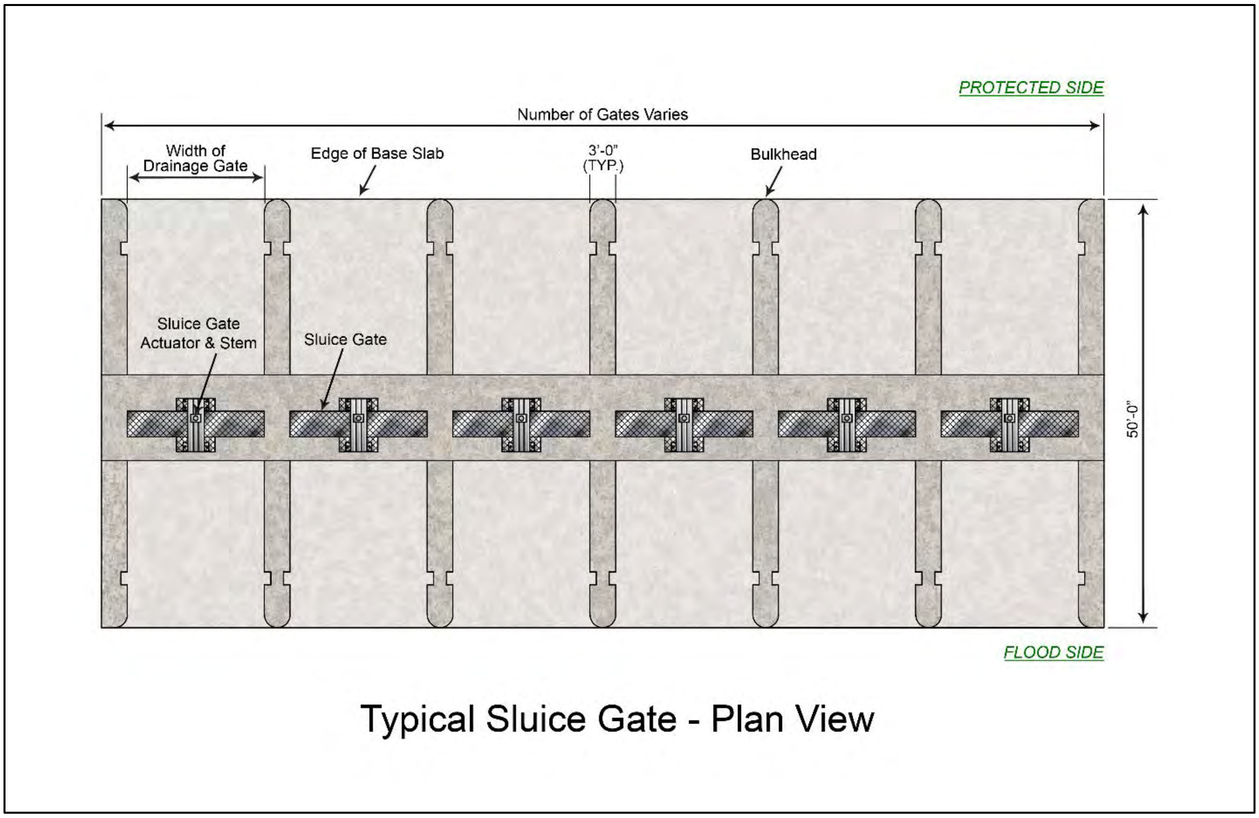

Figure 1-13. Sluice Gate - Plan View

2.8.3 SECTOR GATE

A sector gate is a pie-slice structure that allows navigation to get through when in the open position.

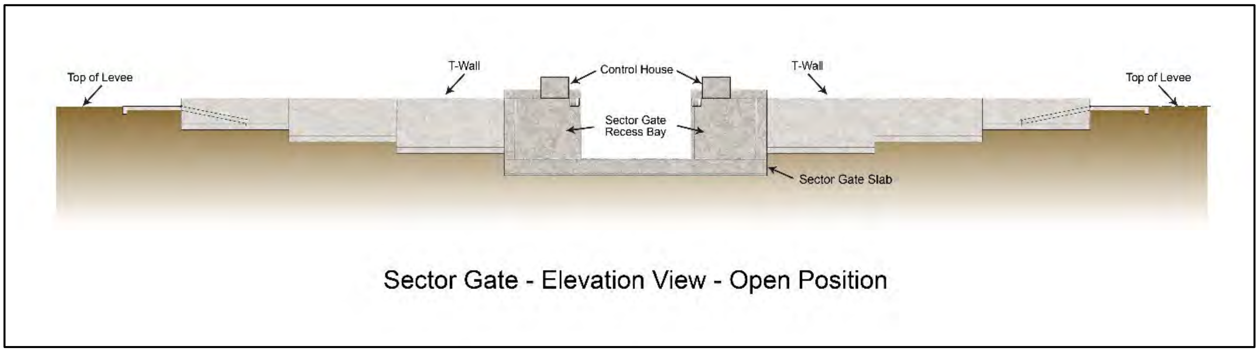

Figure 1-14. Sector Gate - Elevation View with Gates in Open Position

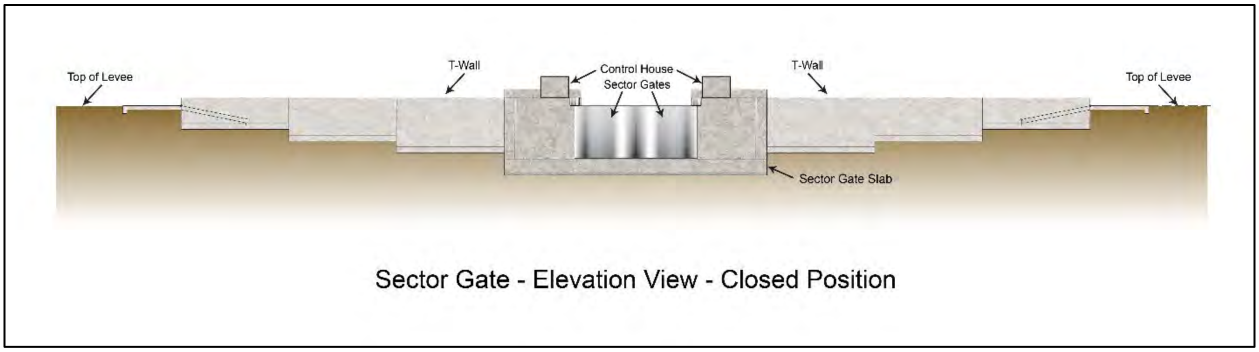

Figure 1-15. Sector Gate - Elevation View with Gates in Closed Position

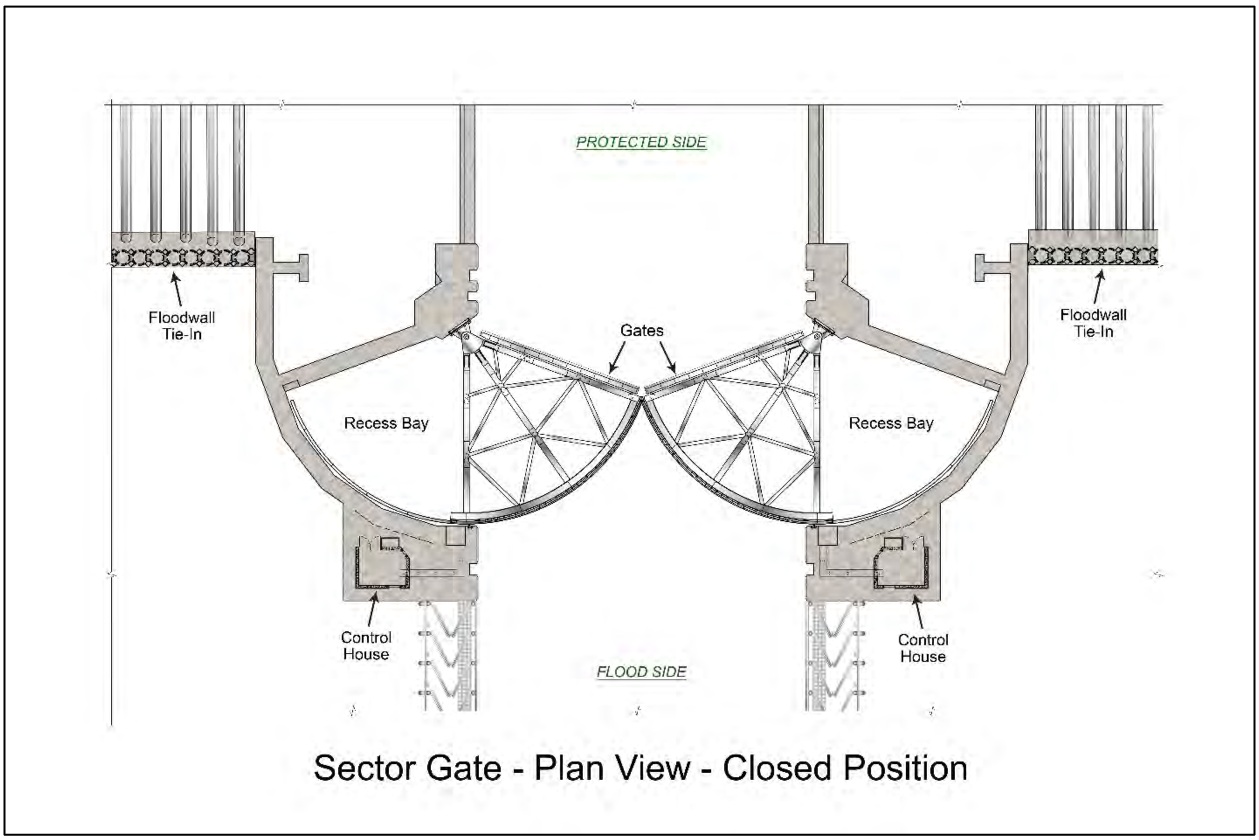

Figure 1-16. Sector Gate - Plan View

2.8.4 ROLLER GATE

A roller gate is a structure that uses rollers for the gate to open and close. The operating motion of the gate is typically parallel to the skin plate face of the gate.

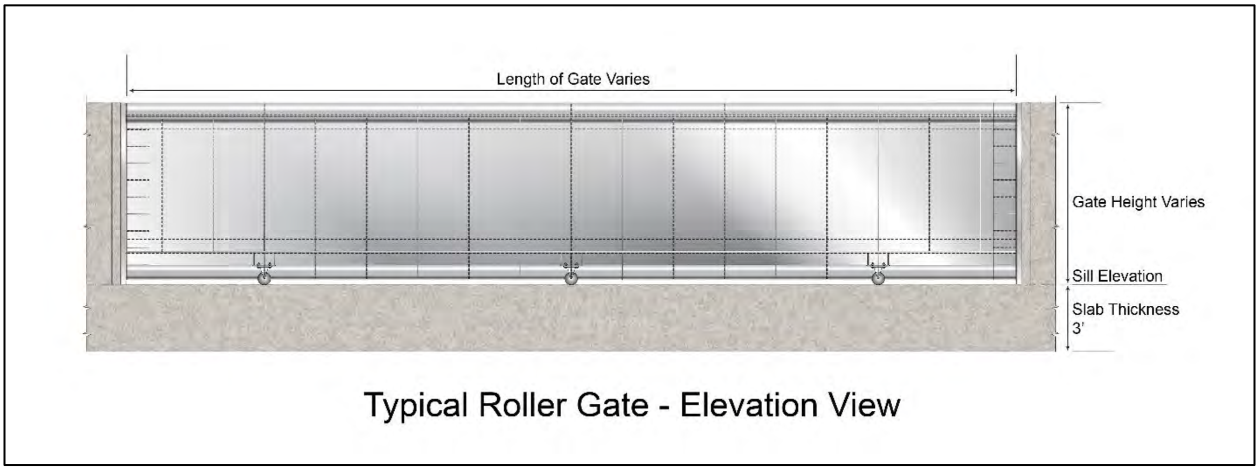

Figure 1-17. Roller Gate - Elevation View

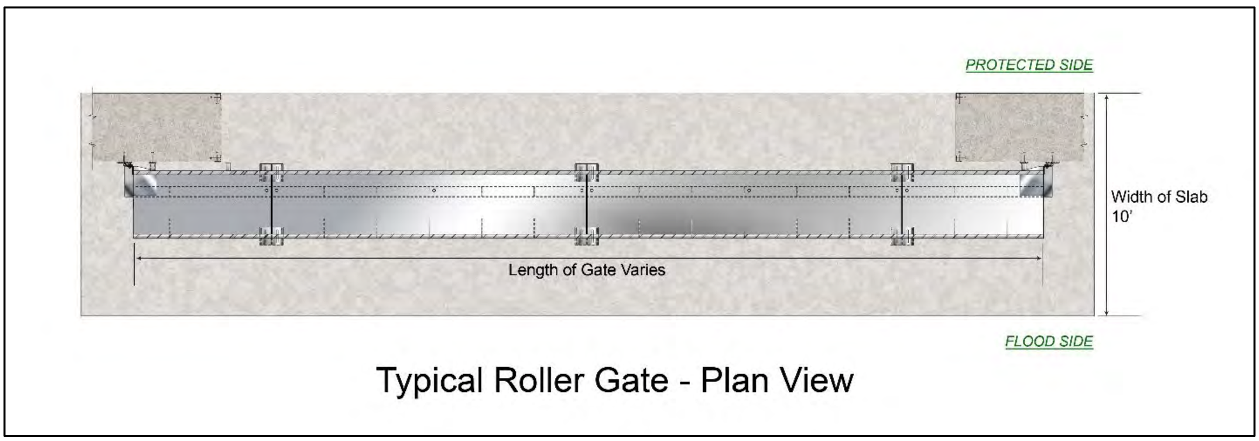

Figure 1-18. Roller Gate - Plan View

2.8.5 SWING GATE

A swing gate is a structure that uses a hinge system to open horizontally. The gate can be actuated through automated mechanical means such as hydraulic arm or manually.

It was assumed that a swing gate would be constructed where the alignment crosses the Southern Railway Corp. railroad tracks. (The analysis for this gate was based on Mississippi River Levee (MRL) Carrollton Railroad Gate.)

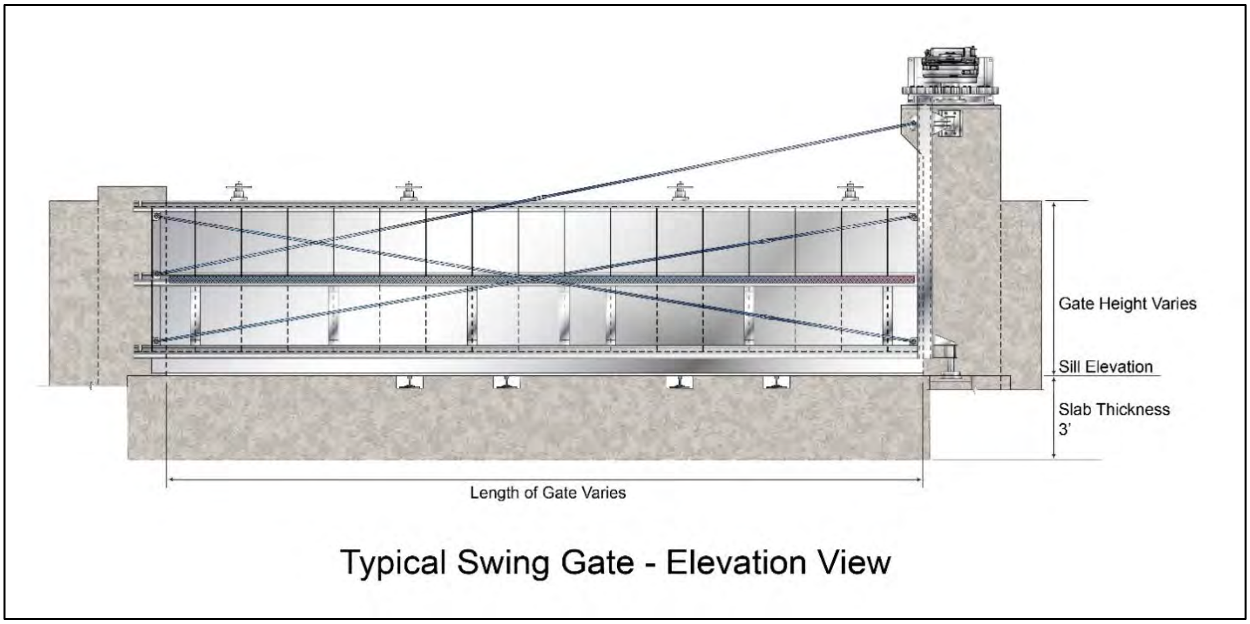

Figure 1-19. Swing Gate - Elevation View

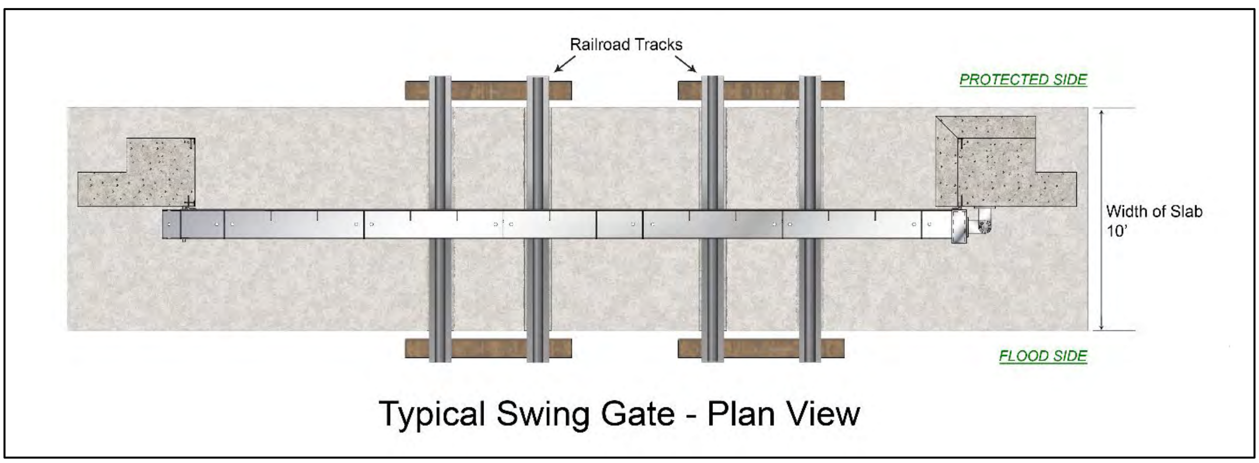

Figure 1-20. Typical Swing Gate - Plan View

2.9 VEHICULAR, PEDESTRIAN AND RAILROAD GATES DESIGN INFORMATION

Table 2.8 contains the design information for the vehicular, pedestrian and railroad gates for the Optimized TSP.

Table 2.8: Vehicular, Pedestrian and Railroad Gates

Name	Description	Type	Mode	Width	Ground/ Sill Elevation (ft)	Design Height (ft)	Height of Gate (ft)
Western High Ground Tie-in for 2082							
Tammany Trace Pedestrian Gate and Culvert	10-ft Pedestrian Gate at Tammany Trace with Lift Gate for Culvert on south side	Swing	Pedestrian	10	13	17.5	3.5
Tranquility Road Vehicular Gate	20-ft Vehicular Gate at Tranquility Road	Roller	Vehicle	20	12	17.5	4.5
West Slidell							
Bayou Paquet Road Floodgate # 2	60-ft Floodgate at Bayou Paquet Road	Roller	Vehicle	60	3	16	13
Mayer Drive Vehicular Gate	20-ft Vehicular Gate at Mayer Road	Roller	Vehicle	20	2.5	16	13.5
Railroad Floodgate	60-foot floodgate for Railroad	Swing	Railroad	60	0.5	16.5	16
South Slidell							
Hwy 11 Vehicular Gate	75-ft Roller Gate at Hwy 11 (Pontchartrain Drive)	Roller	Vehicle	75	4	16.5	12.5
Mariners Cove Floodwall and Vehicular Gate	500 Linear feet of floodwall for narrow section of Oak Harbor levee at Mariners Cove Blvd	Roller	Vehicle	50	10.5	16.5	6
Oak Harbor Vehicular Gate	Floodwall and 20-foot Vehicular Gate for Oak Harbor	Roller	Vehicle	20	11.5	16.5	5
Oak Harbor Country Club Vehicular Gate	Floodwall and 20-foot Vehicular Gate for access to Oak Harbor Country Club	Roller	Vehicle	20	11.5	16.5	
Old Spanish Trail Floodgate (Hwy 433)	30-foot roller gate at Hwy 433 east crossing (Old Spanish Trail)	Roller	Vehicle	30	3.5	18.5	15

Hardin Rd Substation Gate	20-foot roller gate for access from Hardin Road to power substation	Roller	Vehicle	20	8	18.5	10.5
Hwy 190-B Floodgate (East Floodwall)	50-foot roller gate at Hwy 190-B east crossing (Fremaux Road)	Roller	Vehicle	50	9	18.5	9.5
South Holiday Drive Vehicular Gate	20-foot roller gate at South Holiday Drive	Roller	Vehicle	20	14	18.5	4.5
Jaguar Drive Vehicular Gate	20-foot roller gate at Jaguar Avenue	Roller	Vehicle	20	12	18.5	6.5
Natchez Drive Vehicular Gate	20-foot roller gate at Natchez Avenue	Roller	Vehicle	20	12	18.5	6.5
Kisatchie Drive Vehicular Gate	20-foot roller gate at Kisatchie Avenue	Roller	Vehicle	20	14	18.5	4.5
Manzella Drive Vehicular Gate	20-foot roller gate at Manzella Drive (Added to extend floodwall to 18.5 ft ground elevation south of Hwy 190)	Roller	Vehicle	20	15	18.5	3.5

2.10 PUMP STATIONS DESIGN INFORMATION

The Optimized TSP would include a total of eight (8) pump stations. These pump stations are divided into large pumping capacity and small pumping capacity.

In West Slidell there would be two (2) pump stations with large pumping capacity and two (2) pump stations with small pumping capacity. In South Slidell there would be four (4) pump stations with small pumping capacity.

Table 2.9: Pump Stations

Pump Station Location	**Pump Station Capacity**
Western High Ground Tie-in for 2082	
N/A	
West Slidell	
Bayou Liberty	1,800 cfs

Bayou Bonfouca	2,000 cfs
Bayou Paquet North Tributary	300 cfs
Bayou Paquet	500 cfs
South Slidell	
W-14 Canal	1,000 cfs
Kings Point	200 cfs
Reine Canal	200 cfs
French Branch at the I-10	450 cfs

The Optimized TSP would include two (2) pump stations with large pumping capacity at Bayou Liberty (1,800 cfs) and Bayou Bonfouca (2,000 cfs). These pump stations were assumed to have similar components and configuration as the USACE West Shore Lake Pontchartrain Reserve Relief Canal Pump Station (WSLP Pump Station). The structural quantities from the Reserve Relief Canal Pump Station were scaled accordingly to reflect the size of the pump stations for this study.

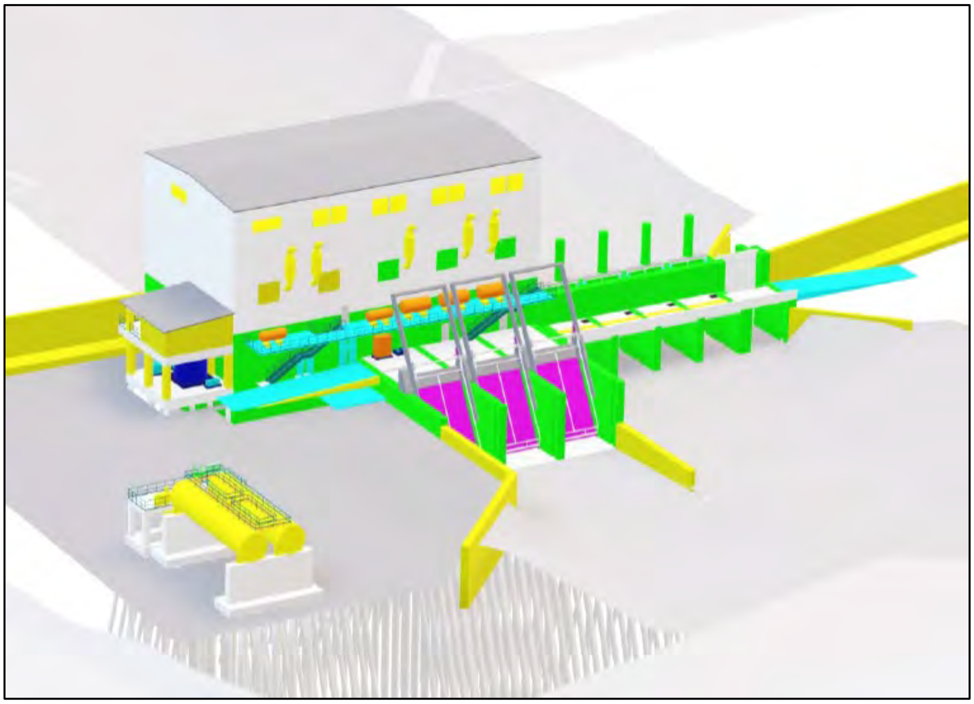

Figure 1-21. Typical Site Plan of a Pump Station with Large Pumping Capacity

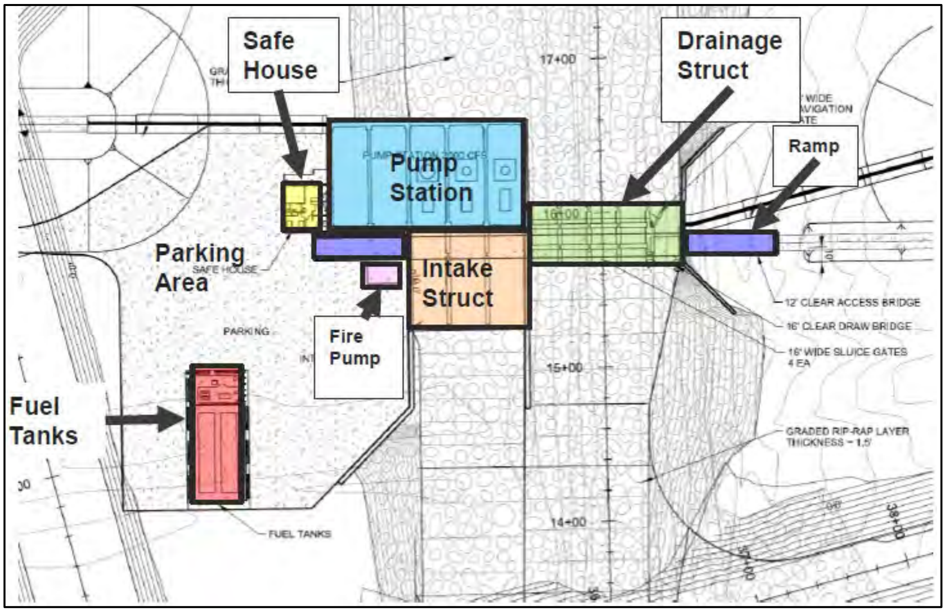

Figure 1-22. Typical Layout of a Pump Station with Large Pumping Capacity

The TSP would include six (6) pump stations with small pumping capacity at sluice gate #6 on the Bayou Paquet North Tributary (300 cfs), Bayou Paquet lift gate (500 cfs), W-14 Canal (1,000 cfs), sluice gate # 8 at Kings Point (200 cfs), Reine Canal (200 cfs) and at French Branch at the I-10 (450 cfs).

These pump stations would have similar pumping capacities to the Prescott Road Pump Station for the Lake Pontchartrain Lakeshore study. The structural quantities from the Prescott Road Pump Station were scaled accordingly to reflect the size of the pump stations for this study.

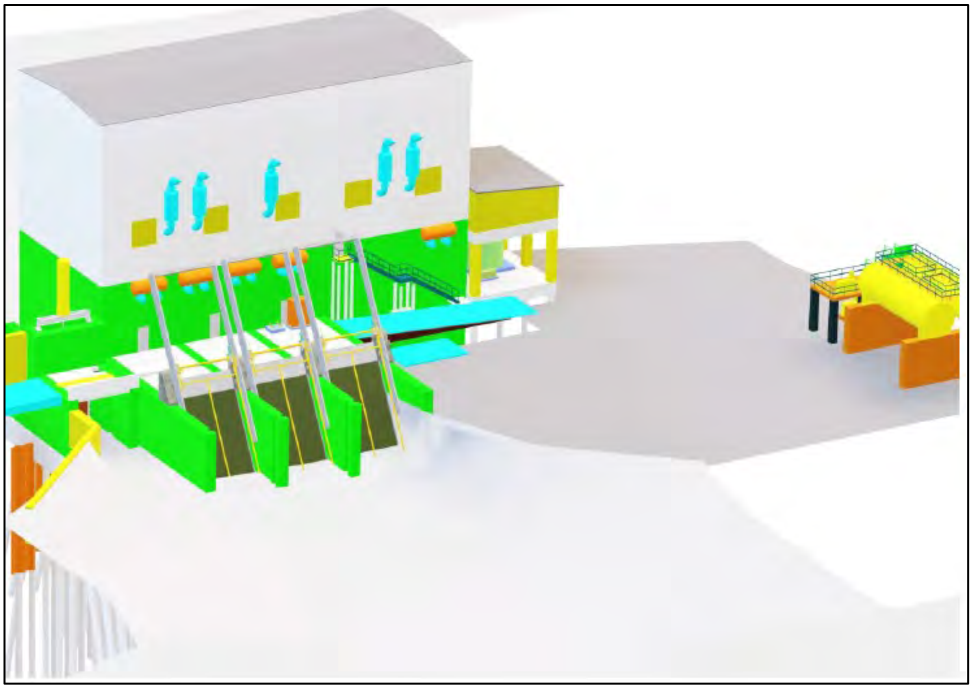

Figure 1-23. Typical Site Plan of a Pump Station with Small Pumping Capacity

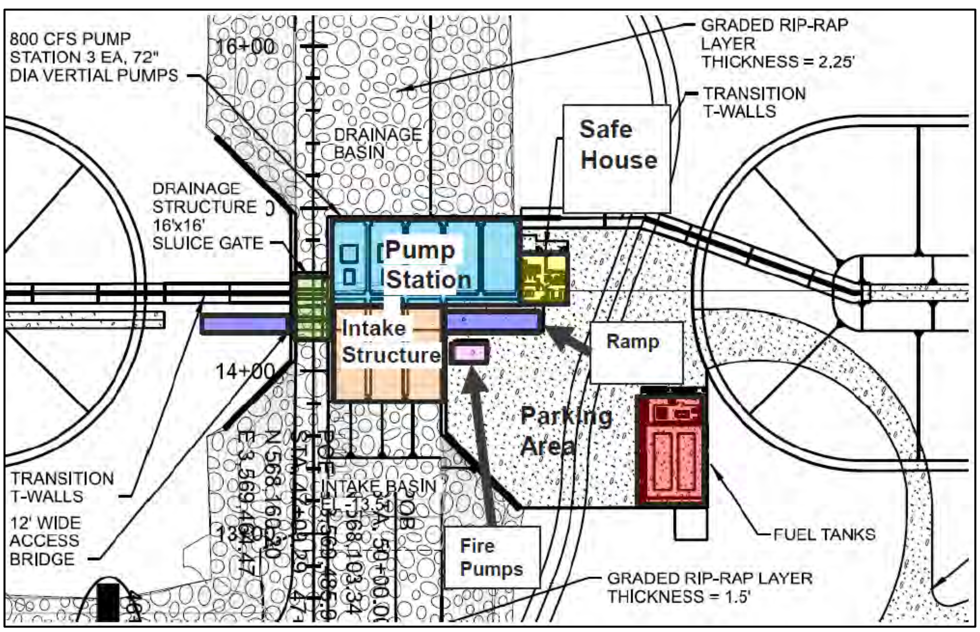

Figure 1-24. Typical Layout of a Pump Station with Small Pumping Capacity

Note: the schematics on this section were obtained from a presentation prepared by Stantec.

3 ACCESS ROUTES AND STAGING AREAS REQUIRED

Table 3.1 provides a summary of the necessary staging areas and permanent ROW required for construction of the levee and floodwall segments for the 50-yr period of analysis. The staging areas required during initial construction of the levee alignment would be the same staging areas required for construction of future levee lifts.

Table 3.1 Summary of Staging Areas and Permanent ROW

SUMMARY of STAGING AREAS AND PERMANENT ROW		
Levees	**Staging Areas (Acres)**	**Permanent ROW (Acres)**
Western High Ground Tie In	2	30
West Slidell	8	270
South Slidell (includes 23 acres for I-10)	29	120
Sub-Total for Levees	**39**	**420**
Floodwall Segments		
Western High Ground Tie In	NA	NA
West Slidell	0	3.7
South Slidell	0	22.7
Sub-Total for Floodwall Segments	**0 ***	**26.4**
Floodgates and Pump Stations		
Western High Ground Tie In	1.5	2.5
West Slidell	11	21
South Slidell	3.75	6.25
Sub-Total for Floodgates and Pump Stations	**16.25**	**29.75**
Vehicular, Pedestrian, and Railroad Gates		
Western High Ground Tie In	1.5	1.25
West Slidell	1.25	0
South Slidell	9	0
Sub-Total for Vehicular, Pedestrian, and Railroad Gates	**11.75**	**1.25**
Road Ramps		
Western High Ground Tie In	0.5	0
West Slidell	0	0
South Slidell	5	0
Sub-Total for Road Ramps	**5.5**	**0**
Access Roads - New		
Western High Ground Tie In	0.1	0.1
West Slidell	0.45	0.45
South Slidell	2.75	2.75
Access Roads - Existing		
Western High Ground Tie In	0	0
West Slidell	15.8	0
South Slidell	9.9	0
Sub-Total for Access Roads	**29**	**3.3**
Mile Branch Channel Improvements	7.3	38.5

Sub-Total for Mile Branch Channel Improvements	**7.3**	**38.5**
Total Acres for 50-year Period of Analysis	**109**	**520**

*for floodwall segments, staging areas would be included in the 80 ft wide permanent ROW.

Table 3-2 lists the ROW width required per levee or floodwall segment. The width includes a 15 ft of vegetation free zone (VFZ) on each side of the levee/floodwall segment.

Table 3.2 Typical Widths of Permanent ROW for Levee and Floodwalls Segments

Levee and Floodwall Segments	Width of Permanent ROW (ft)*
Western High Ground Tie-in	160
West Slidell	300
South Slidell	160
Floodwall Segments	80
Access Roads	NA

***(Includes 15-ft VFZ on both sides)**

3.1 ACCESS ROUTES AND STAGING FOR MILE BRANCH

Site access to Mile Branch would be via public roads and public rights of way.

Staging areas are assumed to be dry. Any trees would be removed and hauled away to an approved facility. If necessary, crushed stone would be placed in the staging area prior to construction. After construction, the crushed stone would be removed and the disturbed areas would be fertilized and seeded.

For the culvert and bridge replacement work, all staging areas were assumed to be located within the individual structure construction areas. Staging areas are to be tree and vegetation free and covered with crushed stone.

3.1 ACCESS ROUTES AND STAGING FOR LEVEE CONSTRUCTION

There are locations where an existing road would be used for access. In other locations, a new road would be built.

New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for VFZ on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

LEVEE CONSTRUCTION EXCEPT REFUGE AREA

For staging areas for levee construction, crushed stone would be placed (assuming crushed stone for vehicle parking/staging and for path from road to area).

Any trees would be removed and hauled away to an approved facility. Contractor would use the area to process material prior to levee construction.

LEVEE CONSTRUCTION ON REFUGE AREA

For the construction of the levee on the refuge land (from Bayou Bonfouca to the railroad tracks), the ingress and egress would be at the Norfolk Southern railroad tracks on the east side of Bayou Bonfouca and existing roads on the west side. A one-way flow of traffic would be maintained. The USACE would need to obtain permission from the railroad owner (Norfolk Southern Railway Corp.) prior to construction. An access road would be constructed on the protected side of the ROW between the proposed crown of the levee and Bayou Bonfouca. The access road would be a temporary road. Once construction is complete, the area would be cleared of vegetation within the right of way and graded to drain away from the levee. Access during future inspections would be done by driving on the crown of the levee.

There would be one 2-acre staging area on the reach on the refuge land that would be considered a temporary easement. The staging area would be located off the refuge and would be used to process the material prior to building the levee. Staging areas would be required to be continuously accessible. Any trees would be removed and hauled away to an approved facility. The area would be restored to pre-construction elevation that existed prior to impacting the site due to construction activities.

3.2 ACCESS ROUTES AND STAGING AREAS FOR STRUCTURES

Existing public roads would be utilized for access to the maximum extent as possible. In locations where access cannot be achieved via existing roadways, a new road would be constructed. Construction of new roads would require permanent ROW.

New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for VFZ on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

For the floodwall segments, the temporary ROW (during construction) and the permanent ROW would be as shown in Table 3.3 below.

Table 3.3: ROW for Floodwall Segments

Floodwall Segments		Staging Area (Acres)	Permanent Access (Acres)
Western High Ground Tie-in for 2082			
N/A			
West Slidell			
Properties west of Doucette Road		0.4	0.4
North Side Bayou Paquet Drive		0.3	0.3

Bayou Paquet/Mayer Drive		1.6	1.6
South Slidell			
Front Street/Railroad		1.6	1.6
Mariners Cove Boulevard		0.6	0.6
Oak Harbor Country Club		0.2	0.2
Old Spanish Trail		0.3	0.3
Esprit du Lac Street		0.5	0.5
Substation Floodwall		2.2	2.2
Highway 190 Business		0.5	0.5
Utility Corridor		4.1	4.1
Hollywood Drive to Yaupon		4.2	4.2
Manzella Drive to Gause Boulevard		0.7	0.7
Total		**18**	**18**

For the floodgates and pump stations, the temporary ROW (staging area during construction) and the permanent ROW would be as shown in Table 3.4.

Table 3.4: ROW for Floodgates and Pump Stations

Floodgates and Pump Stations	Pump Station	Pumping Capacity (cfs)	Staging Area (Acres)	Permanent Area (Acres)
Western High Ground Tie-in for 2082				
Sluice gate near Shannon Drive	No		0.75	1.25
Sluice gate at Tammany Trace	No		0.75	1.25
West Slidell				
Sluice Gate # 7 (Near CC Road)	No		0.75	1.25
Sluice Gate # 6 (Bayou Paquet North Tributary)	Yes	300	0.75	1.25
Bayou Paquet Navigable Gate and Pump Station	Yes	500	0.75	1.25
Bayou Liberty Navigable Gate and Pump Station	Yes	1800	4	8
Bayou Bonfouca Navigation Gate and Pump Station	Yes	2000	4	8
Sluice Gate # 2 (Bayou Bonfouca Sluice Gate)	No		0.75	1.25
South Slidell				
W-14 Canal Navigable Gate and Pump Station	Yes	1000	0.75	1.25
Sluice Gate # 8 (Kings Point East) and Pump Station	Yes	200	0.75	1.25

Sluice Gate # 10 (Near East Terminus)	No		0.75	1.25
Reine Canal and Pump Station	Yes	200	0.75	1.25
French Branch at I-10 and Pump Station	Yes	450	0.75	1.25
Total for Floodgates and Pump Stations			**16.25**	**29.75**

3.3 ACCESS ROUTES AND STAGING AREAS FOR VEHICULAR, PEDESTRIAN AND RAILROAD GATES INITIAL CONSTRUCTION

For the vehicular, pedestrian and railroad gates, the temporary ROW (staging area during construction) and the permanent ROW would be as shown in Table 3.5:

Table 3.5: ROW for Vehicular, Pedestrian and Railroad Gates

Name	Staging Area (Acres)	Permanent ROW (Acres)
Western High Ground Tie-in for 2082		
Tammany Trace Pedestrian Gate	0.75	1.25
Tranquility Road Vehicular Gate	0.75	0
West Slidell		
Bayou Paquet Road Floodgate # 2	0.75	0
Mayer Drive Vehicular Gate	0.75	0
Railroad Floodgate	0.75	0
South Slidell		
Hwy 11 Vehicular Gate	0.75	0
Mariners Cove Floodwall and Vehicular Gate	0.75	0
Oak Harbor Vehicular Gate	0.75	0
Oak Harbor Country Club Vehicular Gate	0.75	0
Old Spanish Trail Floodgate (Hwy 433)	0.75	0
Hardin Road Substation Gate	0.75	0
Hwy 190-B Floodgate (East Floodwall)	0.75	0
South Holiday Drive Vehicular Gate	0.75	0
Jaguar Drive Vehicular Gate	0.75	0
Natchez Drive Vehicular Gate	0.75	0
Kisatchie Drive Vehicular Gate	0.75	0
Manzella Drive Vehicular Gate	0.75	0

3.4 STAGING AREAS AND ACCESS MATERIALS

LEVEE

For staging areas and access roads for levee construction, not including area for material processing during levee construction, a 7-inch depth of stone, and 115 lbs/cubic feet stone weight was assumed.

MILE BRANCH AND STRUCTURES

For the construction in Mile Branch and for the construction of structures, the staging areas and access roads, were assumed to have a 7-inch depth of crushed stone.

4 MILE BRANCH CHANNEL IMPROVEMENTS

The proposed work at Mile Branch would be located in a heavily populated area. There are properties in close proximity of the Mile Branch. There are no surveys available for this area.

Figure 4-1 provides the location of this work.

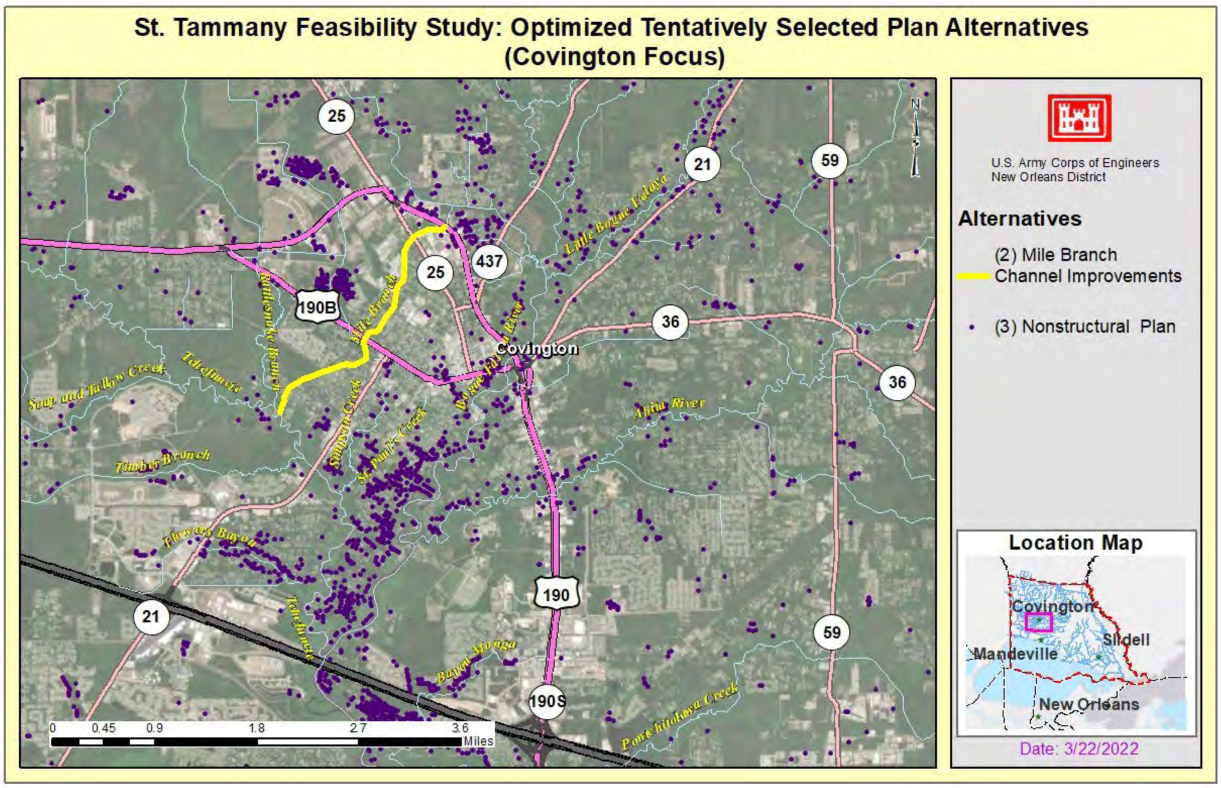

Figure 4-1. Optimized Tentatively Selected Plan Alternatives- Covington Focus

The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and ending at the intersection of Mile Branch and the Tchefuncte River. Refer to Figure 4-2.

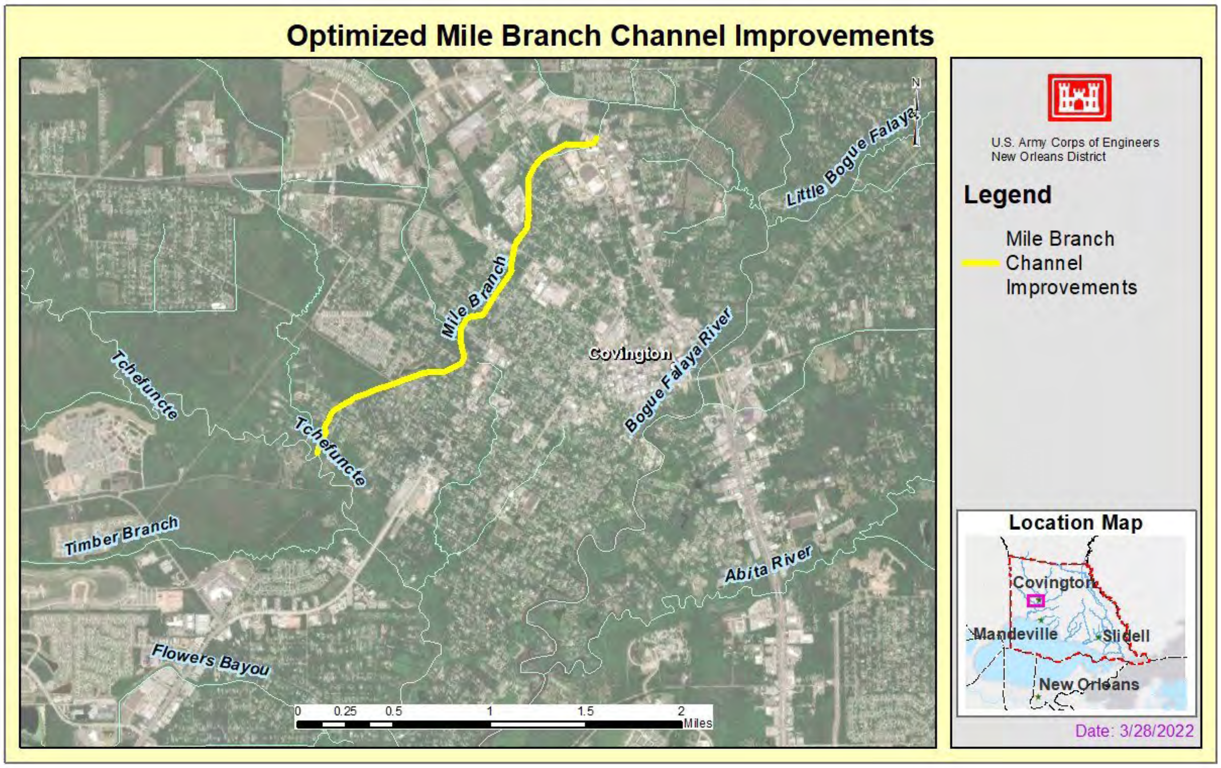

Figure 4-2. Optimized Mile Branch Channel Improvements

The preliminary design assumes an existing bank elevation of 1 ft, a 10-ft bottom width at elevation (-) 5 ft. The bank is at 1V:3H slope. The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel bottom would be lowered by 5 ft. Refer to Figure 4-3 for typical cross-section.

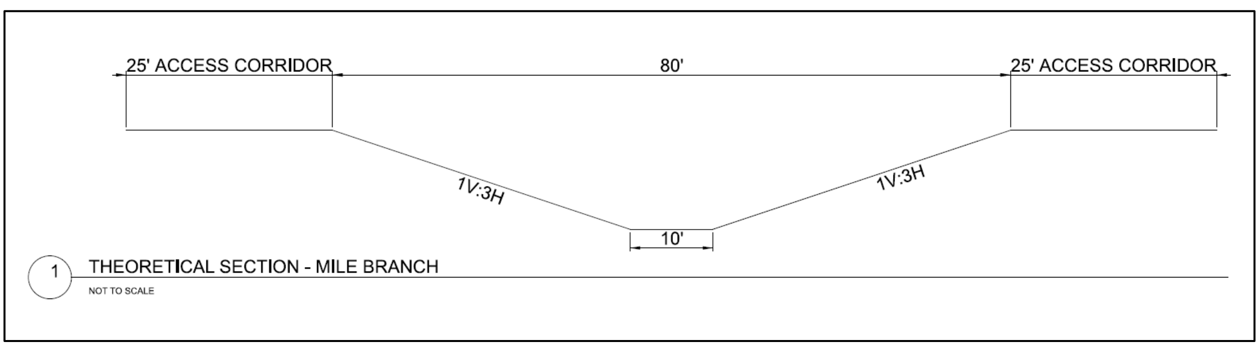

Figure 4-3. Mile Branch Improvements- Typical Cross-Section

Approximately 20 acres of channel would be cleared and grubbed prior to mechanical dredging. An assumed maximum of 130,000 cubic yards of material may be mechanically dredged from the channel. Material removed may include sediment, trees, debris, or other

obstructions within the waterway. For the channel improvements, approximately 34 acres of ROW would be needed for a temporary easement.

Riparian Zone bioengineering techniques and nature-based-solutions (NBS) would be considered as appropriate for Mile Branch FRM during PED in coordination with the NFS and resource agencies. A backwater area was included in the study phase.

4.1 STRUCTURAL IMPROVEMENTS

The Mile Branch channel improvements may include bridge replacements or new culverts (starting from north to south) at 29^{th}, 28^{th}, 25^{th}, 23^{rd}, 21^{st}, 19^{th}, and 18^{th} Avenues. No work is anticipated at the 15^{th} and 11th Avenue channel crossings as those bridges have been replaced prior to this study (and the new bridges were designed to safely pass higher flows on Mile Branch).

Assumptions for channel improvements included a 65 ft from the centerline of each side of the channel for ROW as a general guideline (total width of 130 ft); which includes space for equipment access. All work would be within the project footprint. Temporary work easement would be within ROW. The material to be disposed of would be trucked away from the site. Assumption is that all access would be through public lands.

Additional refinements would occur during PED. Future surveys would determine final channel section and bridge replacements or new culverts. Impacts to habitat and real estate would also be minimized. Opportunities to include natural features would be considered in future designs.

4.2 ACCESS ROUTES AND ROW CRITERIA FOR MILE BRANCH

Figure 4-4 provides the locations of the Mile Branch channel improvements including the structural improvements.

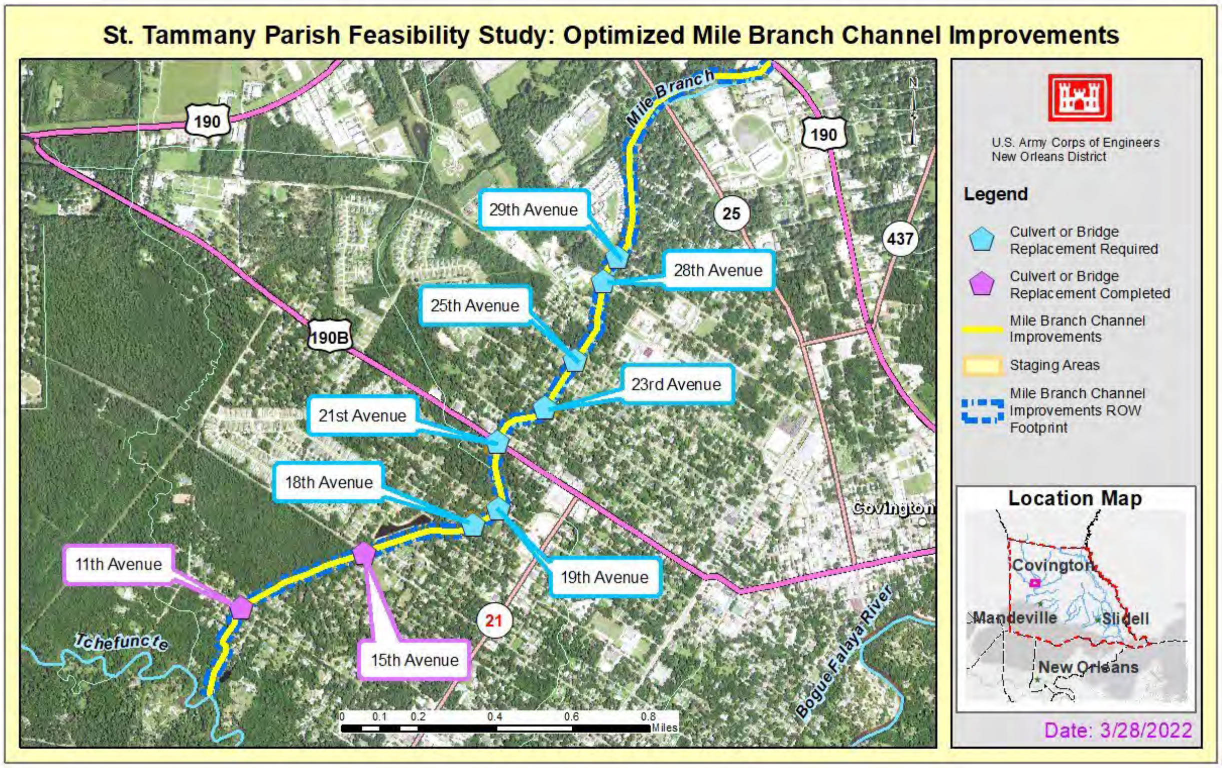

Figure 4.4. Optimized Mile Branch Improvements- Structural Improvements

Reference Table 3.1 for a listing of the staging areas and acres required for the structural improvements for Mile Branch. Table 4-1 below lists the staging area locations required for the bridge/culvert replacements and the necessary acres.

Table 4.1: Staging areas for the bridge/culvert replacements

Location	Temporary ROW Staging Area (Acres)
29th Avenue	0.37
28th Avenue	0.35
25th Avenue	0.20
23rd Avenue	0.21
21st Avenue	0.36
19th Avenue	0.36
18th Avenue	0.38
TOTAL	**2.23**

Appendix B IPaC report and USFWS email confirmation

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Louisiana Ecological Services Field Office
200 Dulles Drive
Lafayette, LA 70506
Phone: (337) 291-3100 Fax: (337) 291-3139

In Reply Refer To: February 23, 2023
Project Code: 2023-0030784
Project Name: St. Tammany Parish Study

Subject: List of threatened and endangered species that may occur in your proposed project location or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, and candidate species, as well as designated and proposed critical habitat that may occur within the boundary of your proposed project and may be affected by your proposed project. The Fish and Wildlife Service (Service) is providing this list under section 7 (c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.). Changes in this species list may occur due to new information from updated surveys, changes in species habitat, new listed species and other factors. Because of these possible changes, feel free to contact our office (337-291-3109) for more information or assistance regarding impacts to federally listed species. The Service recommends visiting the ECOS-IPaC site or the Louisiana Ecological Services Field Office website (https://www.fws.gov/southeast/lafayette) at regular intervals during project planning and implementation for updated species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the habitats upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 et seq.), Federal agencies are required to utilize their authorities to carry out programs for the conservation of Federal trust resources and to determine whether projects may affect Federally listed species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2) (c)).

Bald eagles have recovered and were removed from the List of Endangered and Threatened Species as of August 8, 2007. Although no longer listed, please be aware that bald eagles are protected under the Bald and Golden Eagle Protection Act (BGEPA) (16 U.S.C. 668 et seq.).

The Service developed the National Bald Eagle Management (NBEM) Guidelines to provide landowners, land managers, and others with information and recommendations to minimize potential project impacts to bald eagles, particularly where such impacts may constitute "disturbance", which is prohibited by the BGEPA. A copy of the NBEM Guidelines is available at: https://www.fws.gov/migratorybirds/pdf/management/nationalbaldeaglenanagementguidelines.pdf

Those guidelines recommend: (1) maintaining a specified distance between the activity and the nest (buffer area); (2) maintaining natural areas (preferably forested) between the activity and nest trees (landscape buffers); and (3) avoiding certain activities during the breeding season. Onsite personnel should be informed of the possible presence of nesting bald eagles within the project boundary, and should identify, avoid, and immediately report any such nests to this office. If a bald eagle nest occurs or is discovered within or adjacent to the proposed project area, then an evaluation must be performed to determine whether the project is likely to disturb nesting bald eagles. That evaluation may be conducted on-line at: https://www.fws.gov/southeast/our-services/eagle-technical-assistance/. Following completion of the evaluation, that website will provide a determination of whether additional consultation is necessary. The Division of Migratory Birds for the Southeast Region of the Service (phone: 404/679-7051, e-mail: SEmigratorybirds@fws.gov) has the lead role in conducting any necessary consultation.

Activities that involve State-designated scenic streams and/or wetlands are regulated by the Louisiana Department of Wildlife and Fisheries and the U.S. Army Corps of Engineers, respectively. We, therefore, recommend that you contact those agencies to determine their interest in proposed projects in these areas.

Activities that would be located within a National Wildlife Refuge are regulated by the refuge staff. We, therefore, recommend that you contact them to determine their interest in proposed projects in these areas.

Additional information on Federal trust species in Louisiana can be obtained from the Louisiana Ecological Services website at: https://www.fws.gov/southeast/lafayette

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries
- Marine Mammals

OFFICIAL SPECIES LIST

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

Louisiana Ecological Services Field Office
200 Dulles Drive
Lafayette, LA 70506
(337) 291-3100

PROJECT SUMMARY

Project Code: 2023-0030784
Project Name: St. Tammany Parish Study
Project Type: Levee / Dike - New Construction
Project Description: The proposed project consists of construction of a levee and floodwall system along an alignment in South and West Slidell, Louisiana and channelization of a portion of the Mile Branch in Covington, Louisiana. Project authorization would occur in the year 2024 and kick-off planning, engineering, and design (PED). PED was originally estimated to be complete by the year 2027. Initial construction of the project would begin 2027 and conclude by the year 2032 (base year).

Project Location:

The approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/@30.347470649999998,-90.05709851555773,14z

Counties: St. Tammany County, Louisiana

ENDANGERED SPECIES ACT SPECIES

There is a total of 9 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

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1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

MAMMALS

NAME	STATUS
West Indian Manatee *Trichechus manatus* There is **final** critical habitat for this species. Your location does not overlap the critical habitat. ***This species is also protected by the Marine Mammal Protection Act, and may have additional consultation requirements.*** Species profile: https://ecos.fws.gov/ecp/species/4469	Threatened

BIRDS

NAME	STATUS
Eastern Black Rail *Laterallus jamaicensis ssp. jamaicensis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/10477	Threatened
Red-cockaded Woodpecker *Picoides borealis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7614	Endangered

REPTILES

NAME	STATUS
Alligator Snapping Turtle *Macrochelys temminckii* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/4658	Proposed Threatened
Gopher Tortoise *Gopherus polyphemus* Population: Western DPS No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6994	Threatened
Ringed Map Turtle *Graptemys oculifera* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/2664	Threatened

FISHES

NAME	STATUS
Gulf Sturgeon *Acipenser oxyrinchus (=oxyrhynchus) desotoi* There is **final** critical habitat for this species. Your location overlaps the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/651	Threatened

INSECTS

NAME	STATUS
Monarch Butterfly *Danaus plexippus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9743	Candidate

FERNS AND ALLIES

NAME	STATUS
Louisiana Quillwort *Isoetes louisianensis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7756	Endangered

CRITICAL HABITATS

There is 1 critical habitat wholly or partially within your project area under this office's jurisdiction.

NAME	STATUS
Gulf Sturgeon *Acipenser oxyrinchus (=oxyrhynchus) desotoi* https://ecos.fws.gov/ecp/species/651#crithab	Final

USFWS NATIONAL WILDLIFE REFUGE LANDS AND FISH HATCHERIES

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

The following FWS National Wildlife Refuge Lands and Fish Hatcheries lie fully or partially within your project area:

FACILITY NAME	ACRES
BIG BRANCH MARSH NATIONAL WILDLIFE REFUGE https://www.fws.gov/refuges/profiles/index.cfm?id=43558	19,394.796

MARINE MAMMALS

Marine mammals are protected under the Marine Mammal Protection Act. Some are also protected under the Endangered Species Act[1] and the Convention on International Trade in Endangered Species of Wild Fauna and Flora[2].

The responsibilities for the protection, conservation, and management of marine mammals are shared by the U.S. Fish and Wildlife Service [responsible for otters, walruses, polar bears, manatees, and dugongs] and NOAA Fisheries[3] [responsible for seals, sea lions, whales, dolphins, and porpoises]. Marine mammals under the responsibility of NOAA Fisheries are **not** shown on this list; for additional information on those species please visit the Marine Mammals page of the NOAA Fisheries website.

The Marine Mammal Protection Act prohibits the take of marine mammals and further coordination may be necessary for project evaluation. Please contact the U.S. Fish and Wildlife Service Field Office shown.

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1. The Endangered Species Act (ESA) of 1973.
2. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a treaty to ensure that international trade in plants and animals does not threaten their survival in the wild.
3. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

NAME

West Indian Manatee *Trichechus manatus*

Species profile: https://ecos.fws.gov/ecp/species/4469

IPAC USER CONTACT INFORMATION

Agency: Army Corps of Engineers
Name: Kristin Gunning
Address: 7400 Leake Ave
City: New Orleans
State: LA
Zip: 70118
Email kristin.t.gunning@usace.army.mil
Phone: 5048621514

Gunning, Kristin T MVN

From: Soileau, Karen <karen_soileau@fws.gov>
Sent: Tuesday, April 25, 2023 12:25 PM
To: Gunning, Kristin T MVN
Subject: [Non-DoD Source] Re: [EXTERNAL] Biological Assessment for St. Tammany SEIS

Hey Kristen,

For the threatened and endangered listed species we should address:

- West Indian manatee
- Louisiana quillwort
- Gulf sturgeon
- gopher tortoise
- RCW

We do not have any reports of black rails within the proposed project area. This species is known to occur in the Gulf Coast Chenier Plain of Louisiana (specifically Cameron and Vermilion Parishes); therefore, a "no affect" determination can be made for this species.

The Louisiana quillwort grows on sand and gravel bars on the accreting sides of streams and moist overflow channels within riparian forest and bay head swamp communities. We do not have suitable habitat in Mile Branch; therefore, a survey is not needed.

Gulf sturgeon - the proposed project does not occur within Gulf sturgeon critical habitat; however, potential impacts to the species should be addressed.

AST - proposed species are not protected by the take prohibitions of section 9 of the ESA until the rule to list is finalized. Under section 7(a)(4) of the ESA, Federal agencies must confer with the Service if their action will jeopardize the continued existence of a proposed species. Because of the scale of the project relative to the range of this species and the availability of suitable habitat a conference is not necessary. I am going into the office tomorrow, I'll get with our AST biologist to ask about minimization features for this species.

Monarch - candidate species receive no statutory protection under the ESA. I'll check tomorrow to see if there are any minimization features that we recommend for this species.

Let me know if you have any additional questions and I'll be back in touch with you tomorrow.

Thanks,

Karen Soileau
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
200 Dulles Drive
Lafayette, La 70506
Office: 337/291-3132

From: Gunning, Kristin T MVN <Kristin.T.Gunning@usace.army.mil>
Sent: Tuesday, April 25, 2023 10:57 AM
To: Soileau, Karen <karen_soileau@fws.gov>
Subject: [EXTERNAL] Biological Assessment for St. Tammany SEIS

Hi Karen,

I'm finishing up the BA for this St. Tammany project and I was hoping you could provide some guidance on a few things before I submit. I've included the project description, a KMZ of the proposed alignment, and the official species list for your reference. Listed species in the project area include:

- West Indian Manatee – Threatened
- Eastern Black Rail – Threatened
- RCW – Endangered
- Alligator Snapping Turtle – Proposed Threatened
- Gopher Tortoise – Threatened
- Ringed Map Turtle – Threatened
- Gulf Sturgeon – Threatened
- Monarch Butterfly – Candidate
- Louisiana Quillwort – Endangered
- Gulf Sturgeon CH

Do I need to consult on proposed threatened of candidate species? If so, does the service have any recommendations/requirements to minimize and/or avoid impacts to ASTs or monarchs?

From the map on IPaC, it appears that the Louisiana quillwort occurs in the area where the Mile Branch channelization will be occurring. Based on the Recovery Plan for the quillwort, this action has the potential to adversely affect the species. Do you know if any surveys for the presence of the quillwort have been done in the area and are there any recommendations/requirements that need to be implemented to reduce impacts on the species?

Thanks,

Kristin Gunning
Biologist, Environmental Studies Section
Regional Environmental Planning Division, South
USACE, New Orleans District

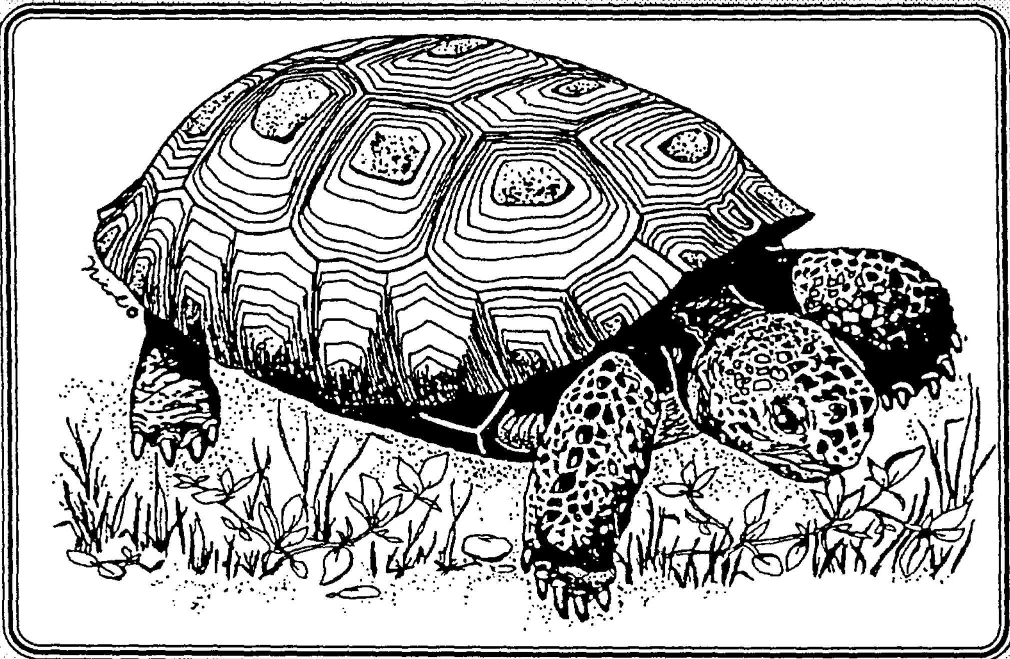
Appendix C Species Recovery Plans and Status Assessment Reports

Appendix C-1: Gopher Tortoise Recovery Plan and Species Status Assessment Report

Gopher Tortoise

(*Gopherus polyphemus*)

Recovery Plan



U.S. FISH AND WILDLIFE SERVICE
Southeast Region, Atlanta, Georgia

GOPHER TORTOISE

Gopherus polyphemus

RECOVERY PLAN

Prepared by
Wendell A. Neal
U.S. Fish and Wildlife Service

for

Southeast Region
U.S. Fish and Wildlife Service
Atlanta, Georgia

Approved: ______________________
Regional Director, U.S. Fish and Wildlife Service

Date: December 26, 1990

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the listed species. Plans are prepared by the U.S. Fish and Wildlife Service, sometimes with the assistance of recovery teams, contractors, State agencies, and others. Objectives will only be attained and funds expended contingent upon appropriations, priorities, and other budgetary constraints. Recovery plans do not necessarily represent the views nor the official positions or approvals of any individuals or agencies, other than the U.S. Fish and Wildlife Service, involved in the plan formulation. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species' status, and the completion of recovery tasks.

Literature Citations should read as follows:

U.S. Fish and Wildlife Service. 1990. Gopher Tortoise Recovery Plan. U.S. Fish and Wildlife Service, Jackson, Mississippi. 28 pp.

ADDITIONAL COPIES MAY BE PURCHASED FROM:

Fish and Wildlife Reference Service:
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814

301/492-6403 or
1/800/582-3421

The fee for the plan varies depending on the number of pages.

ACKNOWLEDGEMENTS

Ed Wester of Auburn University circulated this plan among knowledgeable persons on the Gopher Tortoise Council for review. Robert H. Mount, Professor Emeritus, Auburn University; Joan Diemer of the Florida Game and Fresh Water Fish Commission and Ren Lohoefener of the U.S. Fish and Wildlife Service are gratefully acknowledged for making significant contributions to the development of this plan.

The U.S. Fish and Wildlife Service thanks Ellen Nicol, an artist, writer, and reptile breeder from Anthony, Florida, for the cover sketch.

EXECUTIVE SUMMARY

<u>Current Status:</u> The western population of the gopher tortoise is listed as threatened. This population lies west of the Tombigbee and Mobile Rivers in Alabama, across south Mississippi and including extreme southeastern Louisiana. Threats include habitat alterations and illegal taking.

<u>Habitat Requirements and Limiting Factors:</u> The species is found on droughty, deep sand ridges which originally supported longleaf pine and patches of scrub oak. The most significant threats to the species are adverse habitat alteration, taking, and development of occupied habitats.

<u>Recovery Objective:</u> The two objectives of this plan consist of an immediate objective which is prevention of the listed population from becoming endangered and a long-term objective which is delisting.

<u>Recovery Criteria:</u> The necessary criteria for the above objectives are:

(1) Successful prevention of endangered status would be considered by evidence of an average of 5 gopher tortoise burrows per hectare (ha) on deep sandy soils (1.52 meters(+)) for a period of 30 years on the DeSoto National Forest. This would equate to an estimated population of 22,400 gopher tortoises on 7,343 ha of suitable habitat.

(2) For delisting, evidence is required of an average of 3 gopher tortoise burrows per ha on deep sandy soils (1.52 meters(+)) on private lands. This would equate to an estimated population of 34,000 gopher tortoises on 18,594 ha on privately-owned lands.

<u>Actions Needed:</u>

(1) Survey, monitor and assess status of populations as baseline for recovery actions.
(2) Protect and manage habitat on Federal lands.
(3) Encourage management of populations on private lands.
(4) Develop law enforcement strategy to curb illegal taking.
(5) Conduct population viability studies.
(6) Conduct telemetry studies to determine extent of reproductive isolation as a threat.
(7) Conduct genetic studies.
(8) Relocate threatened isolated individuals/colonies to protected and managed lands.

Total Estimated Costs of Recovery: Implementation of the recovery tasks for which cost estimates have been made total $433,000.00.

Date of Recovery: Unable to determine at this time due to the unknown response of the gopher tortoise population to improved management activities.

TABLE OF CONTENTS

I. INTRODUCTION

A. Background

The gopher tortoise (Gopherus polyphemus) is the only tortoise indigenous to the southeastern United States. It is found in varying numbers in xeric sandy habitats from South Carolina through Florida and west to extreme southeastern Louisiana. Within xeric sandy habitats, the range of G. polyphemus nearly coincides with the original range of the longleaf pine (Pinus palustris).

On July 18, 1984, Drs. Ren Lohoefener and Lynn Lohmeier petitioned the U.S. Fish and Wildlife Service to list the population of G. polyphemus west of the Tombigbee and Mobile Rivers under provisions of the Endangered Species Act. The petition and accompanying report (Lohoefener and Lohmeier 1984) presented substantial information on numbers and distribution of the western population. The Fish and Wildlife Service reviewed the petitioned action and on July 7, 1987, listed the western population as threatened under the Endangered Species Act (52 FR 25376-25380).

The basic biology of the tortoise has been reasonably well documented, although many specific details remain unknown. Many biological parameters for this species vary considerably, including: age (or size) at sexual maturity, clutch size, growth rates, phenological characteristics, burrow depths, specific food habits, and others (Diemer 1986). Biological information on G. polyphemus mostly originates from Georgia and Florida. This plan draws primarily from the research in Georgia by Landers and Buckner (1981) since their study sites are more similar to the western population (by latitude) than to populations in Florida. This recovery plan is aimed specifically at the western population, but of necessity relies greatly upon data sources and expertise developed elsewhere.

B. Description and Taxonomy

Gopherus polyphemus (Testudines, Testudinidae), described in 1802 by F.M. Daudin, is the only Gopherus in the southeastern United States. The gopher tortoise has a large shell, 15-37 centimeters (cm) (5.9-14.6 inches) long. It is a dark-brown to grayish-black terrestrial turtle with elephantine hind feet, shovel-like forefeet, and a gular projection beneath the head on the yellowish, hingeless plastron or undershell (Ernst and Barbour 1972). Gopher tortoise hatchlings are yellowish-orange, have a soft shell, and are 4-5 cm (1.5-2.0 inches) long at hatching.

Gopherus polyphemus is sexually dimorphic. In most cases, the sex of adults can be determined by shell dimensions. The male has a greater degree of plastral (lower shell) concavity, and a longer gular projection. However, the sex of tortoises around the size of maturity can be almost impossible to assess.

C. Life History and Ecology

Distribution

Historically, the western population was found in the longleaf pine hills of northern Mobile, Washington, and southeastern Choctaw Counties in Alabama; in the southeastern upland areas of the pinehills province in Mississippi (a 14-county area); and in the upland pine ridges in St. Tammany, Washington, and Tangipahoa Parishes, Louisiana (Lohoefener and Lohmeier 1984) (Figure 1). The amount of gopher tortoise habitat, as defined by Lohoefener and Lohmeier (1984), for the listed population by State is as follows: southwestern Alabama - 40,770 hectares (ha) or 100,741 acres (A); Louisiana - 4,815 ha or 11,898 A; and Mississippi - 102,084 ha or 252,246 A. The entire western population is found within the original range of the longleaf pine.

Habitat

Gopher tortoises occupy a wide range of upland habitat types; however, general physical and biotic features provided by Landers (1980) with slight modifications, characterize most suitable habitat. These are:

1. the presence of well-drained, sandy soils, which allow easy burrowing (because of lower ambient temperatures, the western population may require a meter or more of sandy soil depths);

2. an abundance of herbaceous ground cover; and

3. a generally open canopy and sparse shrub cover, which allow sunlight to reach the forest floor.

Juvenile habitat is generally considered to be similar to that of adults.

The traditional habitats of the western population of gopher tortoises are natural xeric communities, mostly of the longleaf-pine-scrub oak type, located on sand ridges. The original ecology of these xeric, fire-dependent communities has been significantly altered. Gopher tortoises may also be found in ruderal habitats such as fence rows, pastures, and field edges and power lines.

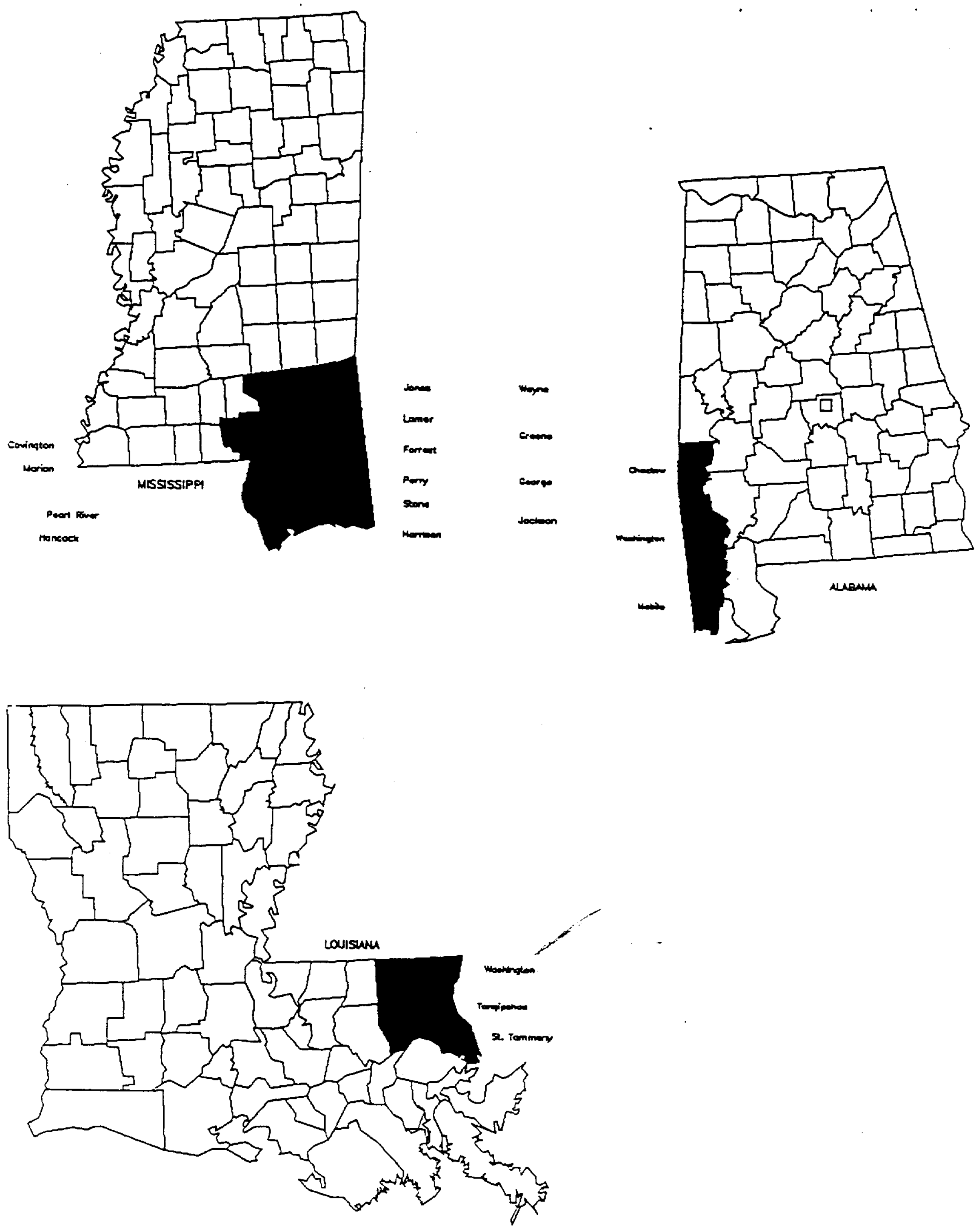


Figure 1. Range of Western Population of the Gopher Tortoise.

Soil conditions are responsible for the xerophytic nature of gopher tortoise habitats. Auffenberg and Iverson (1979) report a positive correlation between the amount of herbaceous ground cover and tortoise density, with grasses, grass-like plants and legumes being the most important food plants (Garner and Landers 1981). The amount and kind of low growing (within reach of a gopher tortoise) herbaceous plants may be a function of many variables, including timber age, density and species composition, burning history, nature and timing of past soil disturbance, and inherent soil fertility.

A relatively open canopy is necessary not only for herbaceous food plants but also for egg incubation. The female gopher tortoise selects a bare spot for nest excavation, normally in the mound of excavated sand at the burrow entrance. Landers and Buckner (1981) noted that when overstory overshadowed the burrow entrance, nests were selected in openings such as firelanes or roadsides.

The burrow is the focal point of many above ground activities and a major portion of the gopher tortoise's life is spent in the burrow. Most burrows have a single entrance, and adult burrows average about 4.5 meters (m) (15 feet) in length with a depth of 1.8 m (6 feet) (Hansen 1963). Small juveniles use similarly small burrows, often as shallow as a few inches. Single tortoises often excavate more than one burrow. Lohoefener and Lohmeier (1984) reported a correction factor of 0.625 in Mississippi for converting burrows counted to burrows occupied. The burrow provides protection from fire, predators, and climatic extremes, and habitat for a host of unique species. Jackson and Milstrey (1989) reported more than 60 vertebrate and 302 invertebrates species using gopher tortoise burrows. Some of the more commonly known burrow associates include the eastern diamondback rattlesnake (*Crotalus adamanteus*), the gopher frog (*Rana areolata*), and the eastern indigo snake (*Drymarchon corais couperi*).

Longevity and Reproduction

Longevity is estimated at 40-60 years (Landers 1980) and may extend to 80-100 years (Landers *et al*. 1982). Growth annuli on scutes become worn at 20-40 years, making age determination imprecise. Age at sexual maturity in the Georgia study (Landers *et al*. 1982) ranged from 19-21 years for females. These animals had a plastral length of 25-26.5 cm (9.8-10.4 inches). Males normally reach reproductive maturity at a smaller size and younger age than females. Growth rates vary with environmental and genetic factors among gopher tortoise populations.

Breeding periods may begin as early as February and extend into September, depending on location. The period of maximum reproductive activity reported by Landers et al. (1980) is May 18 through June 27. Iverson (1980) reported the nesting peak in Florida also to be May and June. Clutch sizes in Mississippi average 4.8 eggs (Lohoefener and Lohmeier 1984); however, this report was based on a rather small sample (N=14). Landers et al. (1980) reported a range in clutch size of 4-12 eggs with a mean and SD of 7.0 ± 1.7. He also found that clutch size increased with the size of the female. The lower value reported by Lohoefener and Lohmeier (1984) may have been due to limited sampling, the result of human depredation (leaving primarily smaller nesting females), or a combination of both. The nest is usually 15-25 cm (6-10 inches) beneath the surface (Landers et al. 1980). Incubation periods range from 80-90 days in northern Florida (Iverson 1980) to 110 days in South Carolina, the northern limit of the gopher tortoise's range (Wright 1982). Most gopher tortoise eggs never hatch because of predation.

Food

The gopher tortoise is the primary grazer in its xeric habitats (Landers 1980) and aids in seed dispersal for native grasses (Auffenberg 1966). Observations and studies of food habits come mainly from Georgia and Florida where wiregrass (Aristida stricta) is often considered an important food plant and is a common member of the longleaf-scrub oak community. However, in western parts of the coastal plain, bluestem grasses (Andropogon) are often the most common herbaceous species in mature longleaf pine forests (Wahlenberg 1946). Lohoefener and Lohmeier (1981) observed tortoises in Mississippi eating crabgrass (Digitaria sanguinalis) and panic grasses (Panicum). Garner and Landers (1981) found that broad-leaved grasses were staple foods while wiregrass was used mainly in early spring and summer. Their study also showed that wild legumes (Fabaceae), which are high in protein, were used extensively by juveniles. Garner and Landers (1981) also found that fleshy fruits were readily consumed, including blackberry (Rubus cunefolius), sloeplum (Prunus umbellata), blueberry (Vaccinium), maypop (Passiflora lutea), and hawthorne (Crataegus). Regardless of the specific plants available for forage, the conclusion reached by Garner and Landers (1981) that "grasses, grass-like plants and legumes are the most important food plants and evidently determine carrying capacity" is likely a statement equally applicable to the western population.

Activity/Movement

McRae et al. (1981) found activity to be very restricted during winter months. In fact, from late November through February, feeding activity was observed only five times. On unusually warm winter days when maximum temperature exceeded 26° Celsius (C) or 79° Fahrenheit (F), tortoises were occasionally observed at the burrow entrance (McRae et al. 1981). No crepuscular or nocturnal activity is reported. As temperatures rose during the spring (March and April), outside burrow activity was most often observed in the Georgia study during the warmest part of the day, 1600-1800h (hours). During July and August, McRae et al. (1981) found a bimodal movement pattern, the feeding forays peaking at mid-morning (1000-1200h) and mid-afternoon (1600-1800h), with much reduced activity during the hottest part of the day, 1300-1500h. They concluded that "activity throughout the year was correlated with ambient temperature; movement from the burrow was rare at coolest temperatures (<22° C or 72° F), was greatest at 28 to 31° C (82 to 88° F), and was curtailed at >32° C (90° F)."

Adult Movements

McRae et al. (1981) studied movement related to feeding separately from movements related to other behavior and determined 95 percent of all feeding activity took place within 30 m (33 yards) of the burrow being used. Auffenberg and Iverson (1979) reported increasing foraging radii from the burrow in areas with reduced ground cover. This suggests that food availability can increase or decrease foraging distances. McRae et al. (1981) trailed 13 adults and determined their movements to be in a nearly circular or elliptical pattern around the burrow. Depletion of preferred foods near burrows by late summer is thought to contribute to larger movements later in the year. In the Georgia study, the home ranges of males were much larger than females; males had a home range of 0.06-1.44 ha (0.14-3.56 A) with a mean of 0.47 ha (1.16 A), while females had a home range of 0.04-0.14 ha (0.10-0.35 A) with a mean of 0.08 ha (0.20 A) (McRae et al. 1981). The sexual differences are attributed to breeding forays by the males. Landers and Speake (1980) found the average colony typically used an area less than 4 ha (9.88 A).

Behavior

Gopher tortoises have a well-developed social structure, courtship, and territorial combat (Auffenberg 1966, Douglass 1976, McRae et al. 1981). Males bob their heads to attract females during the breeding season. The speed and amplitude of the head bobbing increases as the male draws closer to a reproductively active female, and the first contact between individuals consists of males biting females on the forelimbs and around the gular area, perhaps seeking olfactory cues (Auffenberg 1966). When males confront each other, there is usually some manifestation of dominance or submissive behavior. According to McRae et al. (1981), there is a dominance hierarchy in males based on size. In dense populations, smaller males are found around the colony's periphery rather than in the middle, close to the breeding females, as is the case with larger males.

D. Threats and Causes for Decline

Habitat Alteration

An understanding of the reasons behind the threatened status of G. polyphemus is perhaps the most essential step in developing this recovery plan. The gopher tortoise, historically and currently, is a component of xeric plant communities originally identified mostly by the occurrence of longleaf pine. The changes altering the original longleaf pine communities also changed the ecosystem of the gopher tortoise. This species was an animal of these forests, and to the extent maintenance of the listed population is possible, that goal is inextricably tied to forestland conditions.

Before the arrival of European colonists in the New World, the longleaf pine was the principal tree species on southeastern coastal plain upland soils. Croker (1987) cites 60 million acres in the original stands which he concludes are now reduced to about 4 million acres. After the red and white pine forests of New England and the Great Lake States were cut, lumbermen turned to the virgin longleaf stands, the mining of which peaked in 1909 (Croker 1987). Power skidders and railroad logging supported these final assaults.

Second growth longleaf pine stands came from the ruins of timber mining operations, but these second forests constituted a small fraction of the area of virgin stands. Because of planting difficulties with the longleaf pine, these droughty sites were often planted in slash (P. elliottii) and loblolly (P. taeda) pines. This practice, along with excessive burning intervals and intensive site preparation methods, continues on soils which originally supported longleaf pine.

Artificial planting of longleaf is now successful and many foresters are rediscovering the valuable traits of longleaf pine, including the fact that it can be successfully regenerated naturally through a shelterwood system of cutting combined with burning just in advance of an adequate seed fall. The U.S. Forest Service recently has adopted a practice of regenerating only longleaf pines on longleaf sites in the DeSoto National Forest. However, the agency's preferred method is by planting. Most private landowners continue to regenerate longleaf pine sites to off-site species.

The original longleaf pine community burned and reseeded naturally. It contained trees of many ages and a diverse ground cover with much edge, which would be of particular importance to the gopher tortoise. Landers and Speake (1980) found better gopher tortoise densities in longleaf pine - scrub oak stands that were thinned and burned every 2-4 years. Slash pine plantations, with a similar system of thinning and burning, had sparser population densities. While it is apparent that gopher tortoises can be maintained under a modified (heavily thinned, frequently burned) plantation system of management, Landers and Buckner (1981) showed that gopher tortoise densities are significantly greater (32 percent) in more naturally managed stands of longleaf.

The natural longleaf pine community and its associated biological diversity represent optimal forest habitat for the gopher tortoise. This community occurred in pure stands, constantly trending toward small even-aged groups of a few hundred square feet (Chapman 1909). Larger even-aged patches and strips were found following blowdowns from severe weather. These were often interspersed with patches or single survivors, creating open glades and a patchiness which favored the gopher tortoise. Management practices which alter this system include: clearcuts of large blocks (including the crowded planting of off-site species), diversity-diminishing soil churning activities that often accompany even-aged timber management, and prolonged burning intervals. Timber practices that most nearly mirror the natural system, such as a shelterwood regeneration system with frequent burning and natural regeneration, improve the soil and herbaceous cover condition to optimally support the gopher tortoise.

Longleaf pine trees, as well as fire-dependent annuals and perennials, originally existed in a summer burning cycle which has long since been interrupted. The change in fire frequency and timing may be the single most important factor influencing other alterations which have changed the original xeric communities. For example, it has been a common practice to remove most of the longleaf pines from these dry ridges and then to exclude fire (or at least fail to burn). This allows eventual occupancy by poor site oaks (Quercus laevis, Q. incana, Q. marilandica, and Q. margaretta) and woody shrubs such as yaupon (Ilex vomitoria) and gallberry (I. glabra). When the leaf litter from oaks becomes a thick mat, it retards fires that would otherwise be carried by longleaf pine needles and the common grass associates under the open longleaf pine canopy. Fire exclusion allows the oaks to mature and shade out herbaceous ground cover needed by gopher tortoises. This situation is not uncommon throughout the range of the gopher tortoise. Landers and Speake (1980) provided substantial evidence that these altered sites originally were good gopher tortoise habitat but now support the fewest gopher tortoises.

Hedrick and Zimmermann (1988) monitored gopher tortoise densities in various forest types and classes for a two-year period on the Conecuh National Forest in Alabama. Their unpublished data indicate gopher tortoise densities through three stand conditions (seedling/sapling stands, pole stands, and sawtimber stands). Gopher density was greatest (1 active burrow/1.51 ha or 3.73 A) in the seedling/sapling stands, greatly reduced (200 percent) in pole stands (1 active burrow/3.10 ha or 7.66 A) and followed by a large recovery (177 percent) in sawtimber (1 active burrow/1.75 ha or 4.32 A).

The current threats to the western population of the gopher tortoise in terms of habitat loss or degradation consist of certain forest management practices, conversion of dry sites to agriculture, road placement and other developments on these higher ridges, and urbanization (Lohoefener and Lohmeier 1984).

Predation

The gopher tortoise was a significant food source during the Great Depression, as reflected in the name "Hoover Chicken" (Hutt 1967). Gopher pulling removes an average of 20 percent of the larger tortoises, according to Taylor (1982). The taking of gopher tortoises by pulling (use of a long flexible rod with a hook) remains a cultural ethos in rural areas where the western population is found. The gopher tortoise's low reproductive rate, high mortality of eggs and young, slow growth to sexual maturity, and long life indicate a K-selected strategy adapting to xeric communities (Landers 1980). Annual population growth may only be 3-5 percent (Landers et al. 1980); accordingly, human predation on mature adults may produce long term adverse effects which are difficult to overcome. Because many gopher tortoises exist in degraded or declining habitats and populations are often fragmented, the adverse effects of even limited taking may be exacerbated. Lohoefener and Lohmeier (1984) report a significant number of Mississippi gopher tortoises being taken for pets.

Gopher tortoise predators, other than human beings, are many. The most important egg and hatchling predator appears to be the raccoon (Procyon lotor) (Landers and Speake 1980); however, a variety of mammals are reported predators of G. polyphemus, including gray foxes (Urocyon cinereoargenteus), striped skunks (Mephitis mephitis), opossums (Didelphis virginiana), armadillos (Dasypus novemcinctus) (Landers et al. 1980), and dogs (Canis domesticus) (Causey and Cude 1978). Imported fire ants (Solenopsis saevissima and/or S. victa) are reported as hatchling predators (Landers et al. 1980, Lohoefener and Lohmeier 1984). Snakes and raptors have also been reported as preying on G. polyphemus. Reported clutch and hatchling losses often approach 90 percent (Landers et al. 1980).

Other Mortality

Road mortality is reported by Landers and Buckner (1981) and Lohoefener and Lohmeier (1984) as a significant mortality factor. Lohoefener and Lohmeier (1984) believe nests and juveniles are often destroyed by intensive site preparation (heavy equipment). Tanner and Terry (1981) report a major reduction in burrow density in Florida which was believed attributable to roller chopping or web plowing. Diemer and Moler (1982) demonstrated that tortoises are able to dig out following chopping treatment on deep sandy soils, but concluded that additional data were needed regarding tortoise response to various site preparation techniques in different soil types.

Lohoefener and Lohmeier (1981) believed that a serious problem for the Mississippi gopher tortoise was isolation of sexually mature animals because of habitat fragmentation aggravated by forest management practices. Only 14 percent of the tortoises encountered in density survey transects by Lohoefener and Lohmeier (1981) in Mississippi were considered so situated that interactions with other sizeable (sexually mature) tortoises might occur. As further support for this hypothesis, the discontinuous nature and small size of Mississippi sand ridges, which are often separated by streams or wet boggy areas, may serve as impediments to courtship travels of adult males (Lohoefener and Lohmeier 1984).

Population Viability

Local populations of the western gopher tortoise can in theory become extirpated through chance events and these extirpations (and thus more rangewide extirpations) are inversely related to population size. Shaffer (1981) cites four sources of uncertainty to which a population may be subject: (1) demographic stochasticity, which arises from chance events in the survival and reproductive success of a finite number of individuals; (2) environmental stochasticity due to temporal variation of habitat parameters and the populations of competitors, predators, parasites, and diseases; (3) natural catastrophes, such as floods, fires, and droughts, which may occur at random intervals through time; and (4) genetic stochasticity resulting from changes in genetic frequencies due to founder effect, random fixation, or inbreeding. Based on the concern expressed by Lohoefener and Lohmeier (1984) regarding reproductive isolation, genetic drift and inbreeding may already be occurring.

Recovery, therefore, must consider population viability in establishing both the objectives and the procedures for meeting those objectives.

II: RECOVERY

A. Biological Perspective

The listed population of G. polyphemus could be considered relatively abundant. Lohoefener and Lohmeier (1984) estimated 10,923 tortoises of >23 cm (9.1 inches) carapace length (CL) in 102,084 ha (252,246 A) of Mississippi habitat; and 12,900 tortoises >23cm (9.1 inches) CL were estimated to occur in 40,370 ha (99,753 A) of Alabama habitat west of the Tombigbee and Mobile Rivers. However, the species is nearing extinction in an estimated 4,815 ha (11,898 A) of Louisiana habitat. About 80 percent (121,000 ha) of the available habitat occurs on corporately-owned lands.

Despite the relatively large number of extant individuals estimated, the long-term prospects for survival of the western population are dimming. In view of past, current, and predicted forest management practices, continued illegal taking, development on dry uplands, and private ownership of much of the gopher tortoise's habitat, this species is truly threatened in the western portion of its range. According to Donner and Hines (1987), timberland ownership in south Mississippi is mostly private (85 percent belonging to individuals, the forest industry and corporations, 11 percent belonging to the Federal government, with the remainder in State or county ownership).

Section 7 of the Endangered Species Act requires Federal agencies to insure that their actions do not jeopardize the continued existence of listed species. Beyond the jeopardy prohibition, Section 7 requires Federal agencies to use their authorities to further the purpose of the Act. The essential purpose of the Act is conservation of listed species. Section 7 is limited in scope to Federal actions. Thus, the role of Section 7 in recovery of this species will be limited because the majority of habitat is in non-Federal ownership. However, any advice given by Federal foresters or soil scientists to manage forests on state, local, and private lands is also subject to Section 7. Outside of Section 7, the Act may serve in protection, and therefore, possibly contribute to recovery, through exposure of certain activities under Section 9 (prohibition of take).

Through consultations with Federal landowners, it is expected that forest management practices will be designed to contribute significantly to recovery on these lands. However, because Federal ownership is comparatively small, rangewide recovery for this population requires significant success on privately-owned lands as well. Examples of such activities can be found in Mount et al. (1988).

Unfortunately, among private timberland owners, there are perceived problems with longleaf pine, its growth, value, and availability of seed stock. Individual small landowners often high grade their longleaf stands with little forethought to long-term timber production; they then exclude fire, thus creating a situation where the longleaf pine sites convert to scrub oak stands. If these landowners decide to regenerate, they will most often, on the advice of foresters, choose the off-site slash or loblolly. Such advice from Federal foresters or foresters supported by Federal monies should be subject to Section 7 consultation. The corporate or industrial landowner usually farms these sandy sites by clearcutting, replanting to off-site species, and starting over with the same practices at a 25-35 year rotation, devoting little attention between planting and harvest. These management policies, along with intensive site preparation, thick planting rates, and fire exclusion continue to threaten the existence of the western population.

B. Recovery Objectives

The immediate recovery objective is to prevent the western population from becoming an endangered species. To achieve this, the species' overall status must be stabilized or enhanced. Lohoefener et al. (in review) considers three to seven burrows per hectare as representing a recovered population density for a land unit the size of DeSoto National Forest. The upland forested habitat expected to support this density is likely underlain by Lakeland, Troup, or one of the more rarely encountered deep, sandy soils in excess of 1.52 meters (5 feet). On the Desoto National Forest, these soils are estimated to comprise 7,343 ha (18,144 A) (Arnold 1989). The best hope for recovery of the gopher tortoise is on these 7,343 ha of deep sands that represent original sandhill communities [and potentially provide the best chance for a large block of contiguous habitat being made available to gopher tortoises]. A range of three to seven burrows per ha = 22,029-51,401 x 0.61 (correction factor of tortoises per burrow) = 13,437-31,354 gopher tortoises. If a mid-range density of five gopher tortoise burrows per ha (approximately equating to a total of 22,400 gopher tortoises]) is accomplished on the Desoto National Forest, and maintained for a period of 30 years, the immediate goal of preventing the listed population from becoming endangered would be reached. Although little is known about the rates of gopher tortoise recruitment and present age-class distribution, this recovery objective assumes that once the stated density is maintained for 30 years that the recruitment rate is adequate for short-term stability.

A long-term objective, that of recovery to the point of no longer requiring protection of the Act, requires significant successes on the privately-owned lands having these deep sand ridges. Within the range of the western population, on private land, there are approximately 18,594 ha (45,945 A) of what originally constituted sandhill communities. Attaining the lower range of the recovery density for deep sands based on Lohoefener et al. (in review) would mean three burrows per ha (18,594 x 3 x 0.61) = (approximately 34,000 gopher tortoises on privately owned forested deep sands. To measure these goals, some form of survey is necessary and must be comparable to the original statistically derived estimate (Lohoefener and Lohmeier 1984).

C. Narrative Outline

1. Survey, monitor, and assess the status of populations. The original survey work by Lohoefener and Lohmeier (1984) needs to be updated to monitor status. There remains controversy about the abundance of the gopher tortoise. A survey will clarify the tortoise's status; moreover, it will provide an essential baseline for measuring the effectiveness of recovery activities. Surveys should also attempt to determine recruitment rates and age-class distribution, if possible.

1.1 Survey gopher tortoise populations on Federal and other public lands not previously surveyed. Baseline surveys will be necessary to track the effectiveness of habitat management.

1.1.1 Conduct status surveys on Camp Shelby. This requirement is incorporated into Section 7 compliance.

1.1.2 Conduct status surveys on DeSoto National Forest. This requirement is incorporated into Section 7 compliance.

1.1.3 Conduct surveys on State-owned Parklands, Wildlife Management Areas and 16th Section School lands. Colonies on public lands offer possibilities for conservation unavailable on private lands.

1.2 <u>Conduct rangewide surveys at 5-year intervals on public and private land.</u> This is necessary to determine the effectiveness of recovery activities. Surveys must be comparable by technique to existing data (Lohoefener and Lohmeier 1984), repeatable, and carried out during the same month because tortoise movements and burrow use may vary monthly.

1.2.1 <u>Assess the status of individual populations and of the species rangewide.</u> The goal of the recovery plan is to eliminate factors detrimental to the survival and recovery of the gopher tortoise. As data are acquired, the status of populations throughout the range will be reviewed and assessed as appropriate.

2. <u>Implement protection and management of habitat on Federal lands.</u> The principal threats on Federal lands, specifically the DeSoto National Forest, have been: (1) adverse timber management practices on the high, dry ridges where gopher tortoises occur, and (2) the military use of about 136,000 acres. These threats are being addressed through Section 7 consultation involving both Camp Shelby's land-altering activities and a habitat management plan by the Forest Service. The review of these actions will be an ongoing activity.

2.1 <u>Protect and manage all existing gopher tortoise colonies.</u> The colony sites on Camp Shelby will be protected either by staking burrows with steel posts or by fencing the colony site. For management purposes, a gopher colony is defined as three or more active adult burrows ($\geq$9 inches in width) within 300 feet of each other, or any combination of active adult and active hatchling/sub-adult burrows within 100 yards of each other; the colony site is defined as the active burrows making up a colony plus a 200-foot buffer around them.

Timber stands on Federal lands, where a colony is located, will be managed primarily for the gopher tortoise. Such management considerations will address: canopy closure in the stand, mid-story management, regeneration and site-preparation, planting rates, thinnings, burning and/or chemical treatment of hardwoods for colony site reclamation, and scheduling of harvest to avoid disturbance during nesting periods.

2.2 Manage habitat for present and future expansion. In order to reverse declines in gopher tortoise populations, it will be necessary to manage for optimum habitat conditions on some part of Federal ownerships. The Camp Shelby Section 7 consultation has resulted in the establishment of a 2,200-acre gopher refuge where military use is restricted and forest management is aimed at achieving and maintaining optimal habitat conditions.

2.3 Assess adequacy of established and proposed management plans. This is a continuous task accomplished largely through Section 7 of the Endangered Species Act. All Federal agencies must review their established and proposed programs, and for those that may affect the species, initiate consultation with the Fish and Wildlife Service. The Service will then review the action and prepare a biological opinion which addresses the likelihood of jeopardy to the continued existence of the species if the action is carried out. If jeopardy is likely, alternatives to remove jeopardy are presented in the opinion. All management programs for the species represent a "may affect" situation requiring consultation.

3. Encourage protection and management on private lands. Private lands contain the vast majority of forest possibly containing gopher tortoises. Accordingly, maintenance of the population is not possible without some significant successes on privately-owned timberlands. Promotion of protection and management of habitat on private lands is difficult because of the few legal responsibilities and the perceived economic interests of landowners. Therefore, special efforts are needed on private lands.

3.1 Provide information on management and legal requirements to private landowners and managers.

3.1.1 Develop informational articles and management guidelines oriented to private lands. Informational articles and management guidelines oriented to private lands should be developed. These articles and guidelines should include information and visual aids which identify the habitat of the species, and give detailed options by which the species' welfare can be maintained or enhanced without altering the total land management objectives of the owner or manager. These educational efforts could also emphasize the compatibility of gopher tortoise management with deer and quail management. Legal responsibilities of private landowners, through Sections 7 and 9 of the Endangered Species Act, should also be explained.

3.1.2 Distribute information to private landowners and managers through professional and industrial associations. The information developed in 3.1.1 should be distributed through a variety of professional and industrial associations and agencies, such as the State and private forestry branch of the U.S. Forest Service, county agricultural extension agents, and State forestry and wildlife associations.

3.2 Develop a cooperative agreement between the Fish and Wildlife Service and private landowners and implement where feasible. This agreement should specify management actions needed to protect the species and should identify the party responsible (landowner or Federal agency) for implementing the various actions. The agreement should set forth the total commitments of the two parties including land base, funds, equipment, manpower, and time period, and provide a means and a time frame for terminating the agreement.

3.3 Protect gopher tortoise habitat through easements, acquisitions, and donations. Lands containing gopher tortoises should receive special consideration when these lands would consolidate Federal ownership or control or would contribute to overall resource management objectives of the agencies. Private landowners should be encouraged to avail themselves of these options.

3.4 Recognize or reward protection and management efforts. Management efforts on private lands should be recognized and rewarded in view of the limited legal responsibilities involved. News media should be contacted and encouraged to provide favorable publicity to deserving landowners. News articles should be prepared for the news media where desirable or requested.

4. <u>Develop law enforcement strategy to curb illegal taking of gopher tortoises.</u> Gopher tortoise depredation by humans remains a practice in the rural areas where the listed population occurs. Habitat protection may be for naught if "taking" pressures continue to impact populations. Law enforcement must be a cooperative effort among the Fish and Wildlife Service, U.S. Forest Service, and the States. This effort may or may not involve the use of publicity.

5. <u>Conduct research on population viability.</u> This is needed to determine what densities and distributions are necessary to achieve minimum viable populations necessary for recovery goals. These factors are still unknown; yet they may eventually control the results of any scheduled recovery activity. Three areas, critical to understanding population viability, requiring baseline data, are (1) recruitment rates, (2) present age-class distribution, and (3) what constitutes contiguous habitat for the species.

6. <u>Conduct telemetry studies.</u> This is needed to determine whether or not seemingly isolated tortoises (particularly males) are in fact interacting with other tortoises. Data from telemetry studies will also yield information on what constitutes contiguous habitat for gopher tortoises.

7. <u>Conduct genetic studies.</u> This is needed to answer questions on the effects of augmentation and relocation efforts.

8. <u>Relocate reproductively isolated individuals to existing protected and managed colonies.</u> Animals that are determined to be in this category add nothing to maintenance or recovery. If introduced into an existing small colony which is protected and managed, they may contribute to the recovery goal. Such relocation should be done in accordance with the procedures outlined in Mount <u>et al.</u> (1988).

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PART III

IMPLEMENTATION SCHEDULE

Priorities in column one of the following implementation schedule are assigned as follows:

1. Priority 1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2. Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

3. Priority 3 - All other actions necessary to meet the recovery objective.

Key to Acronyms Used in This Implementation Schedule

MDWFP = Mississippi Department of Wildlife, Fisheries and Parks
USFS = U.S. Forest Service
LDWF = Louisiana Department of Wildlife and Fisheries
ALDNR = Alabama Department of Natural Resources

IMPLEMENTATION SCHEDULE

PRIOR-ITY #	TASK #	TASK DESCRIPTION	TASK DURATION	RESPONSIBLE PARTY: USFWS Region	RESPONSIBLE PARTY: USFWS Program	RESPONSIBLE PARTY: Other	COST ESTIMATES ($K) FY 1991	COST ESTIMATES ($K) FY 1992	COST ESTIMATES ($K) FY 1993	COMMENTS/NOTES *
1	2	Protection and management of publicly-owned habitat	continuous	4	FWE	MDWFP/ USFS	25			*Other agencies' responsibilities will be a cooperative nature, possibly on projects funded
2	1.1.1	Camp Shelby survey	<1 year	4	FWE	MDWFP/ USFS	3			under a Service contract. In some cases contracts may be let to
2	1.1.2	DeSoto National Forest survey	<1 year	4	FWE	MDWFP/ USFS	25			private individuals. The Army National Guard and USFS are
2	1.1.3	State/School lands survey	< year	4	FWE	MDWFP/ USFS	20			obligated to certain actions through Section 7 of the Act.
2	1.2	Population survey/ entire population	2 years	4	FWE	MDWFP/ USFS	35			Repeat every 5 years.
2	1.2.1	Assess rangewide status	2 years	4	FWE	MDWFP/ USFS	5			Repeat every 5 years.
3	3	Protection and management of private lands	Continuous	4	FWE	MDWFP/ USFS	10			
3	3.2	Cooperative agreements	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.
3	3.3	Easements/donations	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.

IMPLEMENTATION SCHEDULE

PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION	RESPONSIBLE PARTY: USFWS Region	RESPONSIBLE PARTY: USFWS Program	RESPONSIBLE PARTY: Other	COST ESTIMATES ($K): FY 1991	COST ESTIMATES ($K): FY 1992	COST ESTIMATES ($K): FY 1993	COMMENTS/NOTES *
3	3.4	Rewards	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.
2	4	Law enforcement strategy	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Continuous
3	5	Research population viability	3 years	4	FWE	MDWFP/ USFS	20	20	20	
3	6	Research genetics	1 year	4	FWE	University	20			
3	7	Telemetry studies	3 years	4	FWE	MDWFP/ USFS	15	15		
3	8	Relocate reproductively isolated tortoises	Continuous	4	FWE	MDWFP/ USFS LDWF ALDNR	15	10		
3	3	Protection and management of private lands	Continuous	4	FWE	MDWFP/ USFS	10			
3	3.2	Cooperative agreements	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.
3	3.3	Easements/donations	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.

IV: APPENDIX

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Species Status Assessment Report
for the
Gopher Tortoise
(*Gopherus polyphemus*)

Version 0.4

Adult gopher tortoise. Image credit: Jeffrey M. Goessling, Ph.D.

August 2021

U.S. Fish and Wildlife Service
Southeast Region
Atlanta, GA

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Additionally, valuable input into the analysis and reviews of a draft of this document were provided by Conor McGowan. We appreciate their input and comments, which resulted in a more robust status assessment and final report.

Suggested reference:

U.S. Fish and Wildlife Service. 2021. Species status assessment report for the Gopher Tortoise (*Gopherus polyphemus*), Version 0.4. August 2021, Atlanta, GA.

VERSION UPDATES

The changes from Version 0.1 (May 2021 – Internal Review) included minor grammatical and formatting changes.

The changes from Version 0.2 (June 2021 – Expert Review) included minor grammatical and formatting changes, addition of citations, incorporation of recipient sites, re-run of the future conditions modeling, and addition of pertinent information throughout the document.

The changes from Version 0.3 (Peer and Partner Review) included minor grammatical and formatting changes, addition of citations, minor map and table revisions, and addition of pertinent information throughout the document.

EXECUTIVE SUMMARY

The Species Status Assessment (SSA) reports the results of the comprehensive status review for the gopher tortoise (*Gopherus polyphemus*). For the purpose of this assessment, we define viability as the ability of the gopher tortoise to sustain resilient populations in the wild over time. Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (USFWS 2016, entire; Wolf et al. 2015, entire). This SSA provides a thorough assessment of biology and natural history and assesses demographic risks, stressors, and limiting factors in the context of determining the viability for the species.

The gopher tortoise is a burrowing reptile species generally associated with southern pine tree species occurring in the Southeastern Atlantic and Gulf Coastal Plains, from Southeastern South Carolina to extreme Southeastern Louisiana. Typical gopher tortoise habitat consists of an open canopy with diverse herbaceous vegetation on well-drained xeric soil with widely spaced trees and shrubs. These systems depend on frequent disturbance, primarily from fire, for the perpetuation and maintenance of species composition and structure within the natural community.

For the gopher tortoise to maintain viability, its populations or some portion thereof must be resilient. The best available information regarding the gopher tortoise and gopher tortoise habitat indicates that habitat loss, degradation, and fragmentation (due to land use changes), climate change, and habitat management are the most significant factors influencing gopher tortoise viability. Other factors influencing viability include road mortality, disease, human harvesting and rattlesnake roundups, predation, invasive flora and fauna, and other conservation measures, including relocation, translocation, and headstarting programs.

For this assessment, we defined populations for the species as contiguous areas surrounding known gopher tortoise burrows with habitat conducive to survival, movement, and inter-breeding

among individuals within the area. Using spatial survey data from across the range of the gopher tortoise, we delineated populations at two spatial scales: local populations and landscape populations, as defined below.

- **Local population**: geographic aggregations of individuals that interact significantly with one another in social contexts that make reproduction significantly greater between individuals within the aggregation than with individuals outside of the aggregation. Operationally delineated by identifying aggregations of individuals or burrows where individuals were clustered together within a 1,968 feet (600 m) buffer to the exclusion of other adjacent individuals or burrows. We delineated 656 local gopher tortoise populations with available spatial data.
- **Landscape population**: a series of local populations that are connected by some form of movement; individuals within a landscape population are significantly more likely to interact with other individuals within the landscape population than individuals outside of the landscape population. Operationally delineated by identifying local populations connected by habitat within 8,202 feet (2.5 km) buffer around each local population. We delineated 253 landscape populations with available spatial data.

We lack consistent and reliable estimates of density, sex ratios, recruitment, dispersal, habitat, and management effort for all populations, thus we qualitatively assessed resiliency by evaluating the estimated abundance of adult gopher tortoises as a metric for categorical levels of resiliency: high (greater than or equal to 250), moderate (51-249), and low (less than 50). Currently, there are an estimated 149,152 gopher tortoises from 656 spatially delineated local populations across the range of the species, with local abundance categories as follow: 360 low, 169 moderate, and 127 high.

To assess representation for gopher tortoise, we delineated five analysis units based on the results of a recent genetics study (Galliard et al. 2017, entire), physiographic regions, and the input of species experts. We evaluated current representation by examining the number of populations and their associated resiliency within the five population analysis units across the species' range. We report redundancy for gopher tortoise as the total number and resiliency of populations and their distribution within and among representative units. Although representation and redundancy have likely decreased significantly relative to the historical distribution of the species, there are still many resilient populations distributed across the range of the species, contributing to future adaptive capacity (representation), and buffering against the potential of future catastrophic events. Because the species is widely distributed across its range, it is highly unlikely any single event would put the species as a whole at risk, although the western most portions of the range are likely more vulnerable to such catastrophes given that most of the populations present in this unit are of low resiliency.

To assess viability for the gopher tortoise, we developed an analytical framework that integrates projections from multiple models of future anthropogenic and climatic change to project future trajectories/trends of gopher tortoise populations and identify stressors with the greatest influence on future population persistence. The modeling framework estimates the change in population growth and persistence probability of populations while accounting for geographic variation in life history, by linking intrinsic factors (demographic vital rates) to four extrinsic anthropogenic factors that are hypothesized to threaten gopher tortoise population persistence (climate warming, sea-level rise, urbanization, and shifts in habitat management).

Six scenarios of future climate warming, sea-level rise, urbanization, and habitat management were used to simulate population growth and extinction risk for gopher tortoises for 80 years into the future. Specifically, we created three scenarios with different levels of stressors (low stressors, medium stressor, and high stressors) that experienced habitat management consistent with contemporary target management goals. We then used the medium stressor values and built three additional models that varied in habitat management treatments, ranging from 'more management' conditions to worsening ('less management') and much worse ('much less management') conditions (Table ES-1).

Table ES-1.

Scenarios	Climate warming (deg C)	Sea-level rise (m)	Urbanization	Management
Low stressors	1.0	0.54 m	P = 0.95	Status quo
Medium stressors	1.5	1.83 m	P = 0.50	Status quo
High stressors	2.0	3.16 m	P = 0.20	Status quo
More management	1.5	1.83 m	P = 0.50	More
Less management	1.5	1.83 m	P = 0.50	Less
Much less management	1.5	1.83 m	P = 0.50	Much less

To assess future redundancy, resiliency, and representation of the gopher tortoise, we used population projections to estimate changes in gopher tortoise populations in the future under each of the six scenarios. We assessed the **resiliency** of future populations to changing environments by estimating persistence probability, categorized as 'extremely likely to persist', 'very likely to persist', 'more likely than not to persist', and 'unlikely to persist', and simulating the number of populations predicted to persist at the end of the projection. We assessed **redundancy** by measuring predicted changes in the total number of individuals, local populations, and landscape populations in the future. We summarized population trends by estimating population growth rate as increasing (greater than 1.00), stable (equals 1.00), or decreasing (less than 1.00). We evaluated how **representation** is predicted to change in the future by examining how population growth of total population size, number of populations, and number of landscape populations will vary by the five population genetic groups of tortoises across the species' range. For each scenario, we summarized the results among all populations across the species' range, but also by genetic units.

Overall projections suggest that extinction risk for the gopher tortoise is relatively low in the future. Of the individuals, local populations, and landscape populations modeled (a small subset of populations likely to occur across the landscape), mean projections among scenarios for 80 years in the future suggested the presence of 47,202–50,846 individuals (females) among 188–198 local populations within 106–114 landscape populations. The persistence of relatively large numbers of individuals and populations suggests resiliency of the species in the face of global change, and redundancy to buffer from future catastrophic events. The spatial distribution of populations predicted to persist in the future are distributed evenly among genetic analysis units, which suggests the persistence of genetic representation in the future as well.

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LIST OF ACRONYMS

Act	Endangered Species Act
AFB	Air Force Base
AFF	American Forest Foundation
ALRI	America's Longleaf Restoration Initiative
ASL	Above Sea Level
BMP	Best Management Practices
CCA	Candidate Conservation Agreement
CCAA	Candidate Conservation Agreement with Assurances
CFR	Code of Federal Regulations
DNA	Deoxyribonucleic Acid
DoD	Department of Defense
Forest Service	United States Forest Service
FNAI	Florida Natural Areas Inventory
FWC	Florida Fish and Wildlife Conservation Commission
FR	Federal Register
FY	Fiscal year
GDNR	Georgia Department of Natural Resources
GTC	Gopher Tortoise Council
INRMP	Integrated Natural Resources Management Plan
LIT	Local Implementation Team
LTDS	Line Transect Distance Sampling
MOA	Memorandum of Understanding
MVP	Minimum Viable Population
NCASI	National Council for Air and Stream Improvement
NF	National Forest
NOAA	U.S. National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWR	National Wildlife Refuge
RCP	Representative Concentration Pathway
Service	United States Fish and Wildlife Service
SFI	Sustainable Forestry Initiative
SLEUTH	Slope, Land use, Exclusion, Urban, Transportation, and Hill-shade model
SLR	Sea Level Rise
SSA	Species Status Assessment
SERPPAS	Southeast Regional Partnership for Planning and Sustainability
URTD	Upper Respiratory Tract Disease
U.S.	United States
U.S.C.	United States Code
USDA	United States Department of Agriculture
WLFW	Working Lands for Wildlife
WMA	Wildlife Management Area

CHAPTER 1 – INTRODUCTION

The gopher tortoise (*Gopherus polyphemus*) is a burrowing reptile species generally associated with southern pine tree species including longleaf pine (*Pinus palustris*), loblolly pine (*P. taeda*), slash pine (*P. elliottii*). Natural community associations include xeric oak (*Quercus* spp.) uplands including sandhills and scrub, longleaf pine savannas (i.e., Red Hills region), xeric hammocks, pine flatwoods, dry prairie, coastal grasslands and dunes, mixed hardwood-pine communities, and a variety of disturbed (ruderal) plant communities, occurring in the Southeastern Coastal Plain from Southeastern South Carolina to extreme Southeastern Louisiana (Auffenberg and Franz 1982, entire; Kushlan and Mazzottii 1984, entire; Diemer 1986, p. 125; Diemer 1987, p. 72; Breininger et al. 1994, entire). Typical gopher tortoise habitat consists of an open canopy with diverse herbaceous vegetation on well-drained xeric soil with widely spaced trees and shrubs. These systems depend on frequent disturbance, primarily from fire, for the perpetuation and maintenance of species composition and structure within the natural community.

Historically, lightning induced fires and later anthropogenic use of fire burned the landscape. Currently most natural fires are actively suppressed (via firefighting efforts), resulting in many areas that are overgrown and ultimately degraded (Wear and Greis 2002, 9. 135). Although current gopher tortoise management includes use of prescribed fire, many areas remain fire suppressed.

On July 7, 1987, the gopher tortoise was listed as a threatened species in the western portion of its range, from the Tombigbee and Mobile Rivers in Alabama west to southeastern Louisiana on the lower Gulf Coastal Plain under the Endangered Species Act of 1973, as amended (Act; 16 U.S.C. 1531-1543) (52 FR 25376-25380). A Recovery Plan was subsequently completed in 1990 (Service 1990, entire). On January 18, 2006, the U.S. Fish and Wildlife Service (Service), was petitioned to list the gopher tortoise in the eastern portion of its range as threatened under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543). On September 9, 2009, the Service published a 90-day finding (74 FR 46401) that the petition presented substantial scientific and commercial information indicating that listing may be warranted and that the Service would initiate a status review. As part of the 12-month finding published on July 27, 2011, the Service determined that the species warranted listing under the Act as threatened but listing was precluded in the eastern portion due to higher priority actions (76 FR 45130).

The Species Status Assessment (SSA) compiles the best available information and data regarding the species' biology and factors that influence the species' viability. The gopher tortoise SSA is a summary of the information assembled and reviewed by the Service and incorporates the best scientific and commercial data available. This SSA documents the results of the comprehensive status review for the entire range of the gopher tortoise and serves as the scientific document that informs future agency decisions for this species.

The SSA framework (Service 2016, entire) is intended to be an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain the species' long-term viability. The intent is for the SSA to be easily updated as new information becomes available and to support all functions of the Endangered Species Program. As such, the SSA report is a living document that may be used to inform Endangered Species Act decision making, such as listing, recovery, Section 7, Section 10, and reclassification decisions (the latter four decision types are only relevant should the species warrant listing under the Act). Therefore, we have developed this SSA to summarize the most relevant information regarding life history, biology, and factors influencing viability for the gopher tortoise. Additionally, we describe the current condition and forecast the possible response of the species to various factors and environmental conditions into the future to formulate a risk profile for the gopher tortoise.

This SSA is intended to provide the biological support for the decision on whether to propose to list or reclassify the species as threatened or endangered and, if so, to determine whether it is prudent to designate critical habitat in certain areas. Importantly, the SSA is not a decisional document by the Service; rather, it provides a review of available information strictly related to the biological status of the gopher tortoise. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the *Federal Register*, with appropriate opportunities for public input.

The objective of this SSA is to thoroughly describe the viability of the gopher tortoise based on the best scientific and commercial information available. Through this description, we determined what the species needs to support viable populations, its current condition in terms of those needs, and its forecasted future condition under plausible future scenarios. In conducting this analysis, we took into consideration likely changes in the environment – past, current, and future – to help understand what factors drive the species' viability at multiple spatial and temporal scales.

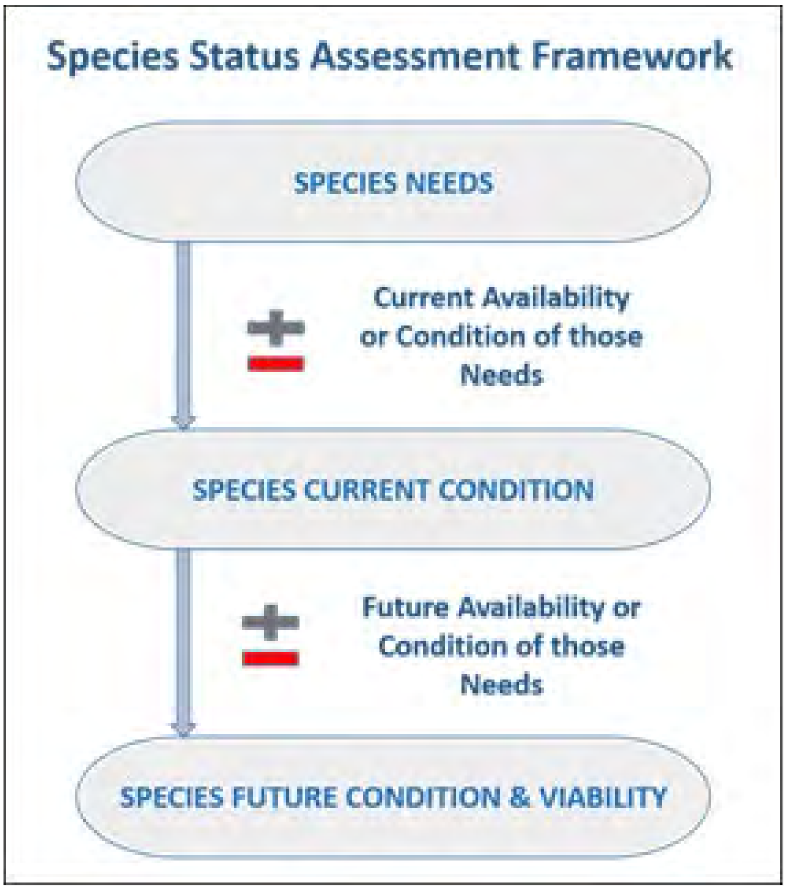

Figure 1. 1-SSA Framework

For the purpose of this assessment, we define 'viability' as the ability of a species to sustain populations in the wild over time. Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time (Service 2016, p. 9). Using the SSA framework (Figure 1.1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of the 3Rs: resiliency, redundancy, and representation (Wolf et al. 2015, entire; Service 2016, entire).

Resiliency is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature and rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates, such as survival and fecundity) (Redford et al. 2011, p. 40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

We can best gauge resiliency by evaluating population-level characteristics such as: demography (abundance and the components of population growth rate—survival, reproduction, and migration), genetic health (effective population size and heterozygosity), connectivity (gene flow and population rescue), and habitat quantity, quality, configuration, and heterogeneity. Also, for species prone to spatial synchrony (regionally correlated fluctuations among populations), distance between populations and degree of spatial heterogeneity (diversity of cover types or microclimates) are also important considerations.

Redundancy is the ability of a species to withstand catastrophes by possessing numerous populations distributed in space. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangel and Tier 1993, p. 1083). We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level. Redundancy is assessed by characterizing the number of resilient populations across a species' range. The more resilient populations a species has, distributed over a larger area, the better the chances that the species can withstand catastrophic events.

Representation is the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments—referred to as adaptive capacity—is essential for viability, as species need to continually adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by either [1] moving to new, suitable environments or [2] by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Beever et al. 2016, p. 132; Nicotra et al. 2015, p. 1270). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000, p. 290-291; Sgro et al. 2011, p. 327).

We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the range and environmental or ecological variation across the range), and smaller-scale variation (which might include measures of inter-population genetic diversity). In assessing the dispersal ability, it is important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess [1] natural levels and patterns of gene flow, [2] degree of ecological diversity occupied, and [3] effective population size. In our SSAs, we assess all three facets to the best of our ability based on available data.

To evaluate the current and future viability of the gopher tortoise, we assessed a range of conditions to characterize the species' 3Rs. This SSA provides a thorough account of known biology and natural history and assesses the risk of threats and limiting factors affecting the future viability of the species.

This SSA includes: (1) a description of gopher tortoise resource needs at both individual and population levels; (2) a characterization of the historical and current distribution of populations across the species' range; (3) an assessment of the factors that contributed to the current and future status of the species and the degree to which various factors influenced viability; and (4) a synopsis of the factors characterized.

CHAPTER 2 – SPECIES BIOLOGY AND INDIVIDUAL NEEDS

In this chapter, we provide biological information about the gopher tortoise, including its taxonomic history, morphological description, historical and current distribution and range, and known life history. We then outline the resource needs of individuals.

2.1 Taxonomy

The gopher tortoise is one of six living North American tortoise species and the only one indigenous to the Southeastern United States (Ernst and Lovich 2009, p. 581; Edwards et al. 2016, p. 131); the other congeneric species are found in western North America. First described by F.M. Daudin in 1802, *G. polyphemus* is classified as belonging to Class Reptilia, Order Testudines, and Family Testudinidae. Two of the most recent changes affecting the genus *Gopherus* are the reclassification of the desert tortoise (*G. agassizii*) into two species (Murphy et al. 2011, entire) – Agassiz's desert tortoise (*G. agassizii*) and Morafka's desert tortoise (*G. morafkai*) – and the subsequent reclassification of *G. morafkai* into two species as well (*G. morafkai* and *G. evgoodei*) (Edwards et al. 2016, entire). Recent morphological and genetic studies have reinforced the traditional assignment of all species into genus *Gopherus* (Crumly 1994, pp. 12-16). Allozyme differentiation has indicated that *G. polyphemus* is most closely related to *G. flavomarginatus* and is thus placed in a clade (genetically related group) distinct from the clade containing *G. berlandieri* and *G. agassizii* (Morafka et al. 1994, p. 1669).

The taxonomic status of the gopher tortoise throughout its range is considered valid (Integrated Taxonomic Information System 2021, p. 1). There is no taxonomic distinction between the gopher tortoise in the western and eastern portions of its range or at any level of geographic subdivision. We are aware of no efforts to reclassify the species.

2.2 Species Description

The gopher tortoise (Figure 2.1) typically has a domed, brown to grayish-black carapace approximately 10-15 inches (in; 25-38 centimeters; cm) in length and weighing approximately 9-13 pounds (lbs; 4.08-5.9 kilograms; kg) (Ernst et al. 1994, p, 466; Bramble and Hutchison 2014, p. 4). The plastron is yellowish and hingeless (Ernst et al. 1994, p. 466). A fossorial species (a species adapted to digging and living primarily underground), its hind feet are often described as elephantine or stumpy (round and pad-like), and the forelimbs are shovel-like, with claws used for digging (Ernst et al. 1994, p. 469). In comparison to females, males are smaller; usually have a larger gland under the chin, a longer gular projection, and more deeply concave plastron (Ernst et al. 1994, p. 466). Hatchlings are about 2 inches (51.4 cm) in length, with a softer, yellow-orange shell (Iverson 1980, p. 357; Butler et al. 1995, p. 174). Hatchling gopher tortoises are classified as those less than 2.4 inches (60 millimeters) in straight-line carapace length (CL), juveniles as those greater than 2.4 inches to 5.1 inches (60 millimeters to 130 millimeters) in CL, subadults as those greater than 5.1 inches to 8.6 inches (130 mm - 219 mm) in CL, and adults as those tortoises 8.7 inches (220 mm) in CL or greater (Landers et al. 1982, entire).

Figure 2. 1-Examples of typical size and coloration of gopher tortoise adult (Left), subadults (Center), and hatchlings (Right). Image credit: Michelina Dziadzio

2.3 Range and Distribution

The gopher tortoise occurs in the Southeastern Atlantic and Gulf Coastal Plains from southern South Carolina west through Georgia, the Florida panhandle, Alabama, and Mississippi to eastern Louisiana, and south through peninsular Florida (Figure 2.2; Auffenberg and Franz 1982, p. 95). The range of the gopher tortoise generally aligns with the historic range of the longleaf pine ecosystem (Auffenberg and Franz 1982, pp. 99-120). The eastern portion of the gopher tortoise's range includes Alabama (east of the Tombigbee and Mobile Rivers), Florida, Georgia, and southern South Carolina. The western range, west of the Tombigbee River in Alabama, Mississippi, and Louisiana, is currently listed as threatened under the Act (Figure 2.2). The core of the current distribution of the gopher tortoise occurs in the eastern portion of the range and includes peninsular Florida and southern Georgia. The gopher tortoise is more widespread and abundant in the core of its distribution, where these areas have been referred to as the "central" portion of the tortoise's geographic extent previously in the literature (Tuberville et al. 2009, p. 12) and more recently as east Georgia, west Georgia and peninsular Florida genetic units (Gaillard et al. 2017, pp. 500-502). It is estimated that approximately 86 percent of the forest area in the south is in private ownership and approximately 80 percent of the gopher tortoise range occurs in private ownership, with the remainder owned or managed by local, state, federal, or private conservation entities (Wear and Greis 2013, p. 103; NRCS 2018, p. 2).

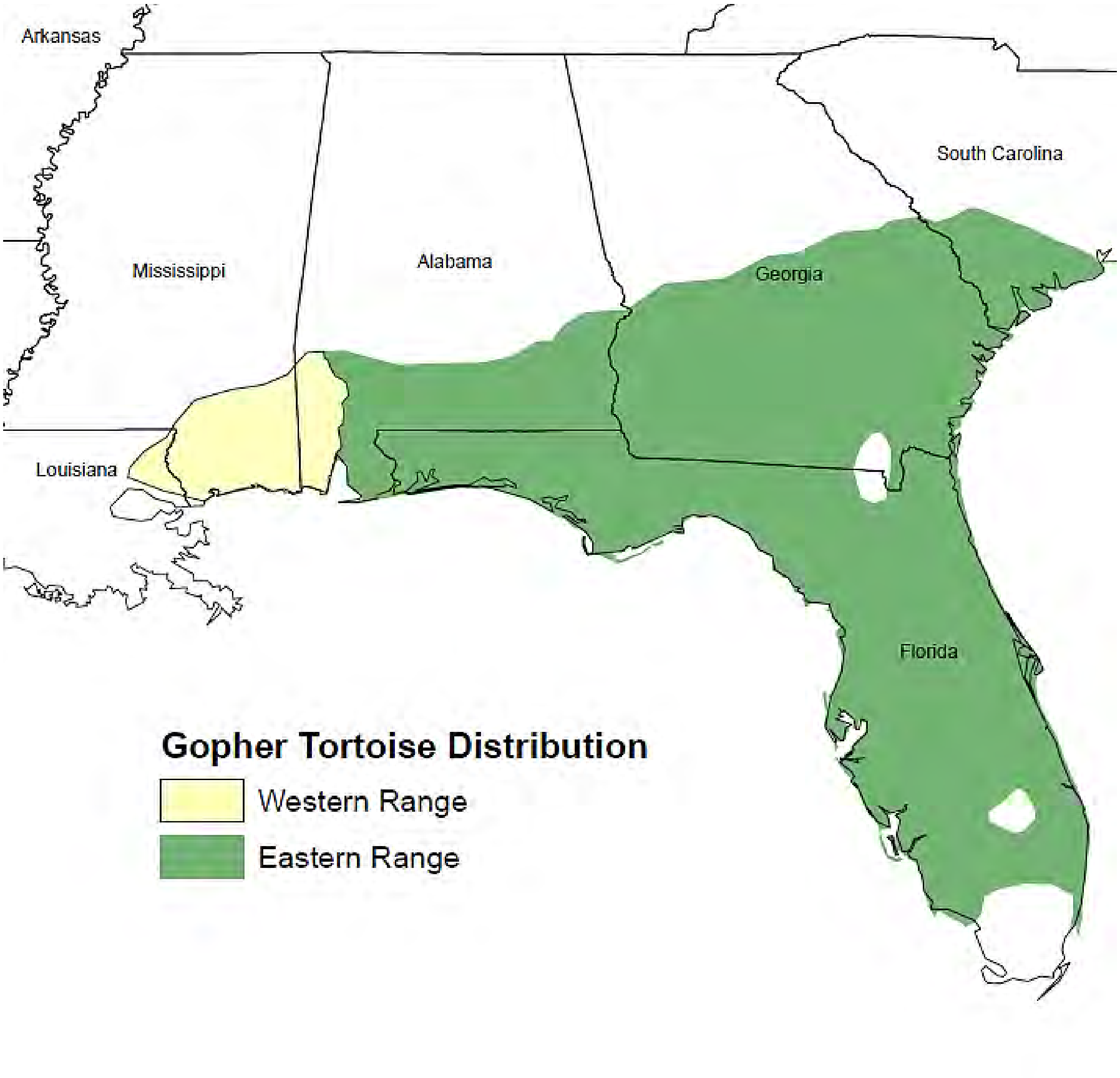

Figure 2. 2-Distribution of the gopher tortoise across the Southeastern United States.

2.4 Life History

Some of the challenges for the conservation of this species lie in its life history traits; specifically, the late age of reproductive maturity (estimated to be between 12 – 20 years), low reproductive output (estimated to be between 4 – 8 eggs/clutch), and long lifespan (generally estimated at 50–80 years) (Service 2013, p. 21). Below is a synthesis of the current state of knowledge of gopher tortoise life history.

Activity

Tortoises spend most of their time within burrows and emerge during the day to bask, feed, and reproduce (Service 2013, p. 21). Tortoises are active above ground when daytime temperatures range from 75 - 87 °Fahrenheit (F) (23.9 - 30.6 °Celsius; C) (McRae et al. 1981, pp. 167-168). Daily active periods are typically unimodal in spring and fall, with bimodal periods (early to mid-morning, middle to late afternoon) during the hotter temperatures of summer. Daily activity above ground becomes significantly reduced by the end of the growing season during October as temperatures begin to cool (McRae et al. 1981, p. 167-168). Gopher tortoises throughout most of the range shelter within their burrows during the dormant season, become torpid, do not eat, and rarely emerge, except on warm days to bask in sunlight at the burrow entrance (Service 2008, p. 10). Gopher tortoises become active again in April or when air temperatures are above 73.4 °F (23 ℃) (Douglass and Layne 1978, p. 364; Butler et al. 1995, pp. 175-177). One exception is in southern Florida, where the gopher tortoise is active every month of the year, though winter activity is restricted to warm (> 69.8 °F [21℃]) days (Douglass and Layne 1978, pp. 361-364; Moore et al. 2009, pp. 390-391; Castellon et al. 2018, pp. 9-10).

In a study that examined gopher tortoise populations on fire maintained longleaf pine stands, females may use an average of 5 burrows per year, while males occupy an average of 10 burrows per year (Ott-Eubanks et al. 2003, p. 318). In lower quality habitat, tortoises may use many more burrows and incur more significant energy expenditures, ultimately leading to low population densities and increased clumping of individuals into small enclaves (Ott-Eubanks et al. 2003, pp. 319-320). Males tend to use more burrows and move more frequently among their different burrows than females as they seek breeding opportunities (McRae et al. 1981, p. 174; Diemer 1992a, p. 285; 1992b, p. 162; Smith 1995, p. 12; Ott-Eubanks et al. 2003, p. 318).

Tortoises select and prefer burrow sites in open canopy areas where sunlight reaches the ground (Boglioli et al. 2000, pp. 703-704; Rostal and Jones 2002, pp. 484-485; McIntyre et al. 2019, p. 287). Such sites reflect areas where herbaceous forage plants are more abundant and for females, sunlight and soil temperatures for egg incubation are more suitable. Also, males select sites and burrows that increase their proximity to females and breeding opportunities (Boglioli et al. 2000, pp. 703-704; Ott-Eubanks et al. 2003, pp. 318-319). The repeated use and travel to the same burrows by individual tortoises on relatively pristine sites in some studies suggests that tortoises know the geography of their home range, burrows, and the location of neighboring tortoises (Ott-Eubanks et al. 2003, p. 318). In habitat of exceptionally poor quality, small groups of gopher tortoises will restrict movements to a few burrows and socialize only with a few neighboring individuals (Guyer et al. 2012, pp. 131–132). Burrow site selection within populations in coastal or other geographically isolated areas may be influenced by environmental conditions, such as storms and drought (Kushlan and Mazzotti 1984, p. 237; Waddle et al. 2006, pp. 282 – 283, Blonder et al. 2021, pp. 9–11)

Diet and Foraging

Gopher tortoises were found to mostly forage on foliage, seeds, and fruits of grasses and forbs, generally in an area of about 150 feet (45.7 meters; m) surrounding burrows (McRae et al. 1981, p. 169). Although they feed primarily on broadleaf grasses, wiregrass (*Aristida stricta var. beyrichiana*), asters, legumes, and fruit, they are known to eat more than 300 species of plants (Garner and Landers 1981, pp. 123–130; Ashton and Ashton 2004, pp. 33-35; Richardson and Stiling 2019, pp. 387-388). The diet of adults resembles that of a generalist herbivore, with at least some preference for certain plants over others, and may also include insects and carrion (Macdonald and Mushinsky 1988, pp. 349-351; Birkhead et al. 2005, p. 155; Richardson and Stiling 2019, pp. 387–388). Legumes are thought to be particularly important for re-conditioning females after egg laying, and it has been shown that clutch sizes and percent of gravid females were lowest in areas with low percent cover of legumes (White 2009, p. 12). In a study on patterns of gastrolith ingestion by adult female gopher tortoises, over 85% of gravid tortoises contained shell and stone gastroliths while only 5% of non-gravid female tortoises had shells and stones in the gut, suggesting opportunistic intake of calcium-rich gastroliths may provide important nutritional supplements for reproductive female gopher tortoises (Moore and Dornburg 2014, p. 57). Juvenile gopher tortoises tend to forage on fewer plant species, eat fewer grasses, and select more forbs, including legumes, than adults (Garner and Landers 1981, p. 131; Mushinsky et al. 2003, p. 352).

Reproduction and Growth

Gopher tortoises mostly breed from May through October (Landers et al. 1980, p. 355; McRae et al. 1981, pp. 172-173; Taylor 1982, entire; Diemer 1992a, pp. 282-283; Ott-Eubanks et al. 2003, p. 317). However, gopher tortoise populations in south Florida show courtship behavior year-round and have an extended reproductive season, producing young over a much longer period than other populations further north (Moore et al. 2009, p. 391). Females ovulate during the spring, but likely store sperm so that active breeding during ovulation may not always be required for fertilization (Ott et al. 2000, p. 308). Males travel to female burrows and copulation occurs above ground, often at the burrow entrance, more frequently during July to September, a period of peak sex and adrenal steroid hormones (Ott et al. 2000, p. 299; Ott-Eubanks et al. 2003, p. 318).

Females may mate with several males during a single mating season and males may search for prolonged periods for receptive females (Boglioli et al. 2003, p. 849; Johnson et al. 2009, p. 217). The multiple paternities of about 30 percent of the clutches in a Florida gopher tortoise population was confirmed to indicate males fertilizing multiple clutches and females with multiple mates. Paternity analysis of the above study also suggested that larger males may have a reproductive advantage over smaller males in mating with females (Colson-Moon 2003, pp. 38-40). Mean body mass of males mounting females did not differ from the mean mass of all other males from a study of 20 females that received 286 visits from males in a large population in southwestern Georgia (Boglioli et al. 2003, pp. 848-849). Local gopher tortoise populations have been described as colonies, with aggregations of burrows in which dominant males competitively and behaviorally exclude other males at female burrows to maintain a loose female harem as a mating system (Douglass 1986, pp. 175-176). However, recent literature has failed to support the conclusion that the term colony is appropriate for gopher tortoises or that the breeding system is consistent with defense of a harem. Instead, the activities are most consistent with scramble competition (Boglioli et al. 2003, p. 849; Johnson et al. 2009, p. 217). Tuberville et al. (2011, p. 181) compared successful mating (in terms of number of known offspring sired) of relocated males to resident males and found that size was unlikely to be the only or primary cue used by females in choosing males. Johnson et al. (2009, p. 217) found that males appear to chase other males during mating season, but females never do. In addition, aggregations of burrows in some areas and study sites may be an artifact of fragmentation and the concentration of burrows in the available remaining habitat (Mushinsky and McCoy 1994, pp. 44-45; Boglioli et al. 2003, p. 849). Outside influences such as geographic or environmental factors often play a role in shaping differences of behavior in local breeding populations.

Rangewide, average clutch size varies from about four to eight eggs/clutch (Ashton et al. 2007, p. 357). Clutch size generally is positively correlated with adult female size (Diemer and Moore 1994, p. 132; Smith 1995, pp. 22-23; Rostal and Jones 2002, p. 482). Female gopher tortoises with lower body condition scores and lower plasma phosphorus levels were less likely to have eggs (White 2009, pp. 84-97). Average clutch size in the western range, from 4.8 - 5.6 eggs/clutch, is comparably low (Seigel and Hurley 1993, p.6; Seigel and Smith 1996, pp. 10-11; Tuma 1996, pp. 22-23; Epperson and Heise 2003, pp. 318-321). Studies have examined the percentage of females gravid per year (Diemer and Moore 1994, pp. 133-134; Smith et al. 1997a, p. 598), however, it was unknown whether non-gravid females either did not ovulate or deposited their clutch before researchers caught them.

Female gopher tortoises usually lay eggs from mid-May through mid-July, and incubation lasts 80 - 110 days (Diemer 1986, p. 127). Tortoises may nest in the soil at the entrance of a burrow (Figure 2.3; Butler and Hull 1996, p. 16; Smith et al. 1997a, p. 599), or in other open sandy areas, when available (Landers et al. 1980, p. 357).. In an analysis of 19 gopher tortoise populations from across the geographic range, larger clutches were produced in areas that were more southern, warmer, had greater site productivity, and were less seasonal (Ashton et al. 2007, p. 359). In Mississippi, nests are up to 16 cm (6.3 in) in depth and located about 46 cm (18.1 in) from the opening of the burrow (Epperson and Heise 2003, p. 318). Incubation at temperatures from 27°C to 32°C (80.6°F to 89.6°F) is required for successful development and hatching (DeMuth 2001, pp. 1611-1613; Rostal and Jones 2002, p. 482). Sex determination is temperature dependent for gopher tortoises, with lower temperatures producing more males and higher temperatures producing more females. The pivotal temperature for a 1:1 sex ratio has been observed to be 29.3°C (84.7°F) (DeMuth 2001, pp. 1612-1613).

Figure 2. 3-Gopher tortoise burrow showing sandy apron and mouth/entrance (left) and gopher tortoise eggs in a nest excavated in a burrow apron (right). Image credit: Michelina Dziadzio.

Nest depredation by vertebrates can be a substantial threat to some gopher tortoise populations (See Chapter 3 below). A study in southern Georgia, found approximately 90 percent of nests were destroyed by predators (Landers et al. 1980, p. 355, 358), while in a controlled study in southwest Georgia, a nest predation rate of 65 percent was observed (Smith et al. 2013, p. 4). In a smaller study from southern Alabama, about 46 percent of nests (n = 11) were destroyed by raccoons (*Procyon lotor),* Virginia opossums *(Didelphis virginiana),* and nine-banded armadillos (*Dasypus novemcinctus)* (Marshall 1987, pp. 29-32). Egg hatching success at experimentally protected nests has ranged from 28-97 percent in Florida and Georgia (92 percent, Arata 1958, pp. 276-279; 86 percent, Landers et al. 1980, p. 359; 28 percent, Linley 1986, p. 23; 67 to 97 percent, Smith 1995, p. 25; 80.6 percent, Butler and Hull 1996, p. 16). In Mississippi, mean hatching success from protected nests in the field has ranged from 28.8-56 percent (Epperson and Heise 2003, p. 319; Noel et al. 2012, pp. 328-329).

Hatchlings excavate themselves from the nest and typically emerge from the middle of August through September (Epperson and Heise 2003, p. 319). Hatchlings and yearlings (zero to one year old) may temporarily shelter in adult burrows, bury under sand or leaf litter, or excavate a small burrow nearby (Douglass 1978, pp. 413-415; Wilson 1991, pp. 377-378; Butler et al. 1995, pp. 175-179; Pike 2006, pp. 70-73).

Gopher tortoise growth is most rapid during the juvenile stage, becoming slower at the onset of adulthood and reproductive maturity, followed by little or no adult growth, particularly later in maturity (Mushinsky et al. 1994, p. 122). Generally, tortoises become adults between 9 to 20 years of age, although reproductive maturity is determined by size rather than age. Growth rates and sizes at sexual maturity can vary among populations and habitat quality (Landers et al. 1982, pp. 104-105; Mushinsky et al. 1994, pp. 123-125).

Home range and Movement

Hatchling and yearling gopher tortoises initially move up to about 50 feet (15 m) from their nest to establish their first burrow, from which they will subsequently excavate and use about five burrows in a home range as small as about 0.5 acres (0.2 hectares; ha), to as large as 11.8 acres (4.8 ha) (Wilson 1991, p. 39; Butler et al. 1995, pp. 177-178; Epperson and Heise 2003, pp. 320-321; Pike 2006, pp. 70-72). On average, yearling gopher tortoises move relatively short distances to establish new burrows, although they are known to have traveled up to 1,485 ft (450 m) to new burrows (Butler et al. 1995, p. 178; Epperson and Heise 2003, pp. 320). Hatchlings and yearlings may also take shelter beneath litter and woody debris (Diemer 1992b, p. 163, pp. 178-179). Yearling and juvenile gopher tortoises typically forage within about 23 feet (7 m) of their burrow (McRae et al. 1981, pp. 175-176; Butler et al. 1995, pp. 178-179; Epperson and Heise 2003, pp. 320-321).

The burrows of a gopher tortoise represent the general boundaries of a home range, which is the area used for feeding, breeding, and sheltering (McRae et al. 1981, p. 176). The home range area tends to vary with habitat quality, becoming larger in areas of poor quality (Auffenberg and Iverson 1979, pp. 559-561; Castellon et al. 2012, p. 159; Guyer et al. 2012, p. 130). Males typically have larger home ranges than females (McRae et al. 1981, p. 175; Guyer et al. 2012, p. 130; Castellon et al. 2018, pp. 11–12). Mean home ranges of individual tortoises in Mississippi, Alabama, Florida, and Georgia have varied from 0.15–39.8 acres (0.06–16.1 ha) for males and 0.1–20.8 acres (0.04 – 8.4 ha) for females (McRae et al. 1981, pp. 175–176; Diemer 1992b, pp. 160-161; Tuma 1996, pp. 28-43; Ott-Eubanks et al. 2003, pp. 315–316; Guyer et al. 2012, pp. 128-129; Castellon et al. 2018, p. 17). In comparison to females, male gopher tortoises use more burrows, and during breeding season, move among burrows more frequently over longer distances (McRae et al. 1981, p. 174; Auffenberg and Iverson 1979, pp. 548–549; Diemer 1992b pp. 160-162; Smith 1995, p. 108; Tuma 1996, pp. 28-43; Ott-Eubanks et al. 2003, pp. 115-117; Guyer et al. 2012, pp. 128-129; Castellon et al. 2018, p. 17).

Home ranges are larger in the western portion of the range than those typically observed for tortoises in Alabama, Georgia, and Florida, most likely due to habitat quality differences (Lohoefener and Lohmeier 1984, p. 1-25; Epperson and Heise 2003, p. 315; Richter et al. 2011, p. 408). Gopher tortoise movements increase as herbaceous biomass and habitat quality decrease (Auffenberg and Iverson 1979, p. 558; Auffenberg and Franz 1982, p. 121. Castellon et al. 2018, p. 18). It is common for peripheral populations to differ from populations found in a species' core range where the habitat quality tends to be higher (Prieto-Ramirez et al. 2020, pp. 2–3), which may influence tortoise average home range size and movements but also highlights the species' plasticity.

As distances increase between gopher tortoise burrows, isolation among gopher tortoises also increases due to the decreasing rate of visitation and breeding by males to females (Boglioli et al. 2003, p. 848; Guyer et al. 2012, p. 131). Using extensive data from individual gopher tortoise inter-burrow movements and home range size, most breeding population segments have been found to consist of burrows no greater than about 549 feet (167 m) apart, (Ott-Eubanks et al. 2003, p. 320). Other studies and data show that gopher tortoises rarely move long distances from their burrows when mating (Guyer and Johnson 2002, pp. 6-8; Guyer et al. 2012, p. 131), though males will move longer distances from their burrows, up to 1,640 feet (500 meters), to a female burrow for mating opportunities. Gopher tortoises have been observed to move distances of over 4,921 feet (1,500 m) throughout multiple years (McRae et al. 1981, p.172; Diemer 1992b, p. 163; Castellon et al 2018, p. 20), however movements of this distance are not considered to be normal movements within a home range.

2.5 Genetics

Genetic flow in gopher tortoise populations is known to be influenced by distance, geographic features, and human influence by transporting tortoises across the range. There have been several phylogeographic studies of the gopher tortoise including mitochondrial DNA (Osentoski and

Lamb 1995 entire; Clostio 2012, entire) and microsatellites (Schwartz and Karl 2005, entire; Ennen et al. 2012, pp. 112 - 122; Clostio et al. 2012, entire; Gaillard et al. 2017, entire). Several studies showed genetic assemblages across the geographic range (Osentoski and Lamb 1995, p. 713; Ennen et al. 2012, pp.113-120; Clostio et al. 2012, pp. 617-620; Gaillard et al., 2017, pp. 501-503) but these studies were not entirely congruent in their delineations of western and eastern genetic assemblages. Recent microsatellite analysis suggests there are five main genetic groups, delineated by the Tombigbee and Mobile rivers, Apalachicola and Chattahoochee rivers, and the transitional areas between several physiographic province sections of the Coastal Plains (i.e., Eastern Gulf, Sea Island, and Floridian), and the authors suggest use of these groups as management units for conservation planning (Gaillard et al. 2017, pp. 505 - 507). In addition to the five genetic groups suggested by Gaillard et al. (2017), two additional genetic groups were loosely delineated by the Pascagoula and Chickasawhay rivers, and four genetic groups within the Florida region that seemed to reflect the influence of the local physiography (e.g., Atlantic Coast Ridge) (Gaillard et al. 2017, pp. 497-509).

A phylogenetic break (difference in genetics) had been reported between the western and eastern portions of the tortoise's range based on a 712 base pair portion of a mitochondrial gene (Ennen et al. 2012, pp. 113-116). However, the phylogenetic break did not entirely correspond to a particular geographic barrier because shared haplotypes from the eastern and western portions of the tortoise's range were found in the panhandle of Florida and in Georgia populations (Ennen et al. 2012, pp. 113-116). Research using another mitochondrial gene similarly found no shared haplotypes across the Mobile and Tombigbee Rivers (Clostio et al. 2012, pp. 619-620) but a recent study that genotyped 933 tortoises across the species' range recognizes five groups (or regions) delineated by the Tombigbee-Mobile Rivers, Apalachicola-Chattahoochee Rivers, and the transitional areas between several physiographic province sections of the Coastal Plains (i.e., Eastern Gulf, Sea Island, and Floridian) (Gaillard et al. 2017, entire). In addition, the periphery of the range is identified as having lower genetic diversity relative to the core and genetic admixture at sampling sites along the boundaries of the genetically defined groups (Gaillard et al. 2017, p. 509).

There are several smaller scale genetic analyses that have been conducted to better understand local and regional genetic variation in gopher tortoises. In the Florida panhandle, mitochondrial DNA analysis found minimal genetic diversity among six populations and suggested that gene flow occurred among these populations (Sinclair-Winters et al. 2011, pp. 153–155), which would be contrary to the findings of Clostio et al. (2012, pp. 617-618) and consistent with Ennen et al. (2012, p. 113). Subsequent analysis compared the above-referenced Florida panhandle genetics with those collected by Schwartz and Karl (2005, entire) and found a genetic break between peninsular Florida and the Florida panhandle, as did Osentoski and Lamb (1995, pp. 713-714), but these data indicated genetic exchange across the panhandle of Florida from Wakulla County to Escambia County, with no significant break at the Apalachicola River as suggested by Clostio et al. (2012, p. 618). Microsatellite DNA markers and mitochondrial DNA were used to determine whether gopher tortoise populations on Camp Shelby, Mississippi, were spatially structured, if spatial structure was affected by military activity and habitat quality, and whether there was a correlation between geographic distance and genetic relatedness (Richter et al. 2011, entire). Results indicated that there was genetic structure within these populations, and that genetic diversity and gene flow were affected by habitat quality and land use. Genetic distance did not seem to correlate with geographic distance (Richter et al. 2011, p. 412).

Analyses of mitochondrial DNA and nuclear DNA microsatellite markers showed that four gopher tortoise populations in Mississippi have lower genetic diversity than some populations in the eastern portion of the tortoise's range (Ennen et al. 2010, p. 34). This lower genetic variation and heterozygocity suggests either a prior population bottleneck, a historical persistence of the western populations with naturally low genetic diversity, or the fact that western sites are located on the periphery of the range (Ennen et al. 2010, p. 35; Ennen et al. 2011, p. 210; Gaillard et al. 2017, p. 509).

The last decade of genetic research has shown that genetic diversity exists among individuals in a population, among populations and across the range (Ennen et al. 2010, entire; Clostio et al. 2012, entire; Gaillard et al. 2017, entire). The most recent rangewide genetic analysis also confirmed that the periphery of the range has lower levels of genetic diversity relative to the core but also showed genetic admixture between units (Gaillard et al. 2017, p. 507). Evidence of tortoises with ancestry from different genetic sites is most likely due to the decades of tortoises being moved by humans (Gaillard et al. 2017, pp. 504-505). Gene flow is asymmetric from the Central genetic sites (Alabama) to the peripheral sites and gene flow is higher from the Central genetic sites (Alabama) to the Western site (western range). The Florida and the Western Georgia genetic sites has had low genetic flow in the Florida panhandle area (Gaillard et al 2017, pp. 504-509).

2.6 Population Dynamics

As long-lived animals, gopher tortoises naturally experience delayed sexual maturity, low reproductive rates, high mortality at young ages and small size-classes, and relatively low adult mortality. The growth and dynamics of populations are stochastically affected by natural variation due to demographic rates, the environment, catastrophes, and genetic drift (Shaffer 1981, pp. 131-132). Factors affecting population growth, decline, and dynamics include the number or proportion of annually breeding and egg-laying females (breeding population size), clutch size, nest depredation rates, egg hatching success, mortality (hatchling/yearling, juvenile-subadult, adult), the age or size at first reproduction, age- or stage-class population structure, maximum age of reproduction, and immigration/emigration rates.

These factors and data have been evaluated in several investigations of population viability to estimate the probabilities of gopher tortoise population extinction over time and the important factors affecting persistence (Cox et al. 1987, pp. 24-34; Cox 1989, p. 10; Lohoefener and Lohmeier 1984, entire; Miller 2001, entire; Epperson and Heise 2001, pp. 37-39; Wester 2004, pp. 16-20; McDearman 2006, entire; Tuberville et al. 2009, entire). These gopher tortoise population models and simulations varied with regard to specific objectives, model structure, transparency, simulation time, and actual demographic parameters. Nevertheless, the various projections of population growth, decline, and persistence time in different scenarios are plausible.

Using demographic data from various tortoise populations in Florida, it has been shown that more than 90 percent of simulated populations with 50 annually breeding individuals can persist up to 200 years under favorable habitat and management conditions, and a threshold of 130-150 tortoises were needed for persistence under moderate conditions (Cox et al. 1987, pp. 27-29). Favorable conditions reflected relatively high adult survival and fecundity in areas maintained by prescribed fire and protected from human encroachment and development. Populations of this size and demographic characteristics were considered the smallest potentially viable by their definition of persistence for at least 200 years. However, in another viability analysis using a different model with slightly different demographic parameters, it was reported that larger populations of about 200 gopher tortoises were required to achieve a 0.9 or greater probability of persisting for 200 years (Cox et al. 1994, p. 29).

Populations as small as 50 tortoises, exhibited positive growth rates and persistence, as modeled with VORTEX (Lacy and Pollak 2014, entire) by Miller (2001, p. 13) using demographic data from Florida. The potential effect of upper respiratory tract disease (URTD) was evaluated by increasing annual mortality as compared to a baseline model. URTD reduced the stochastic population growth rate, particularly in the panhandle population models, to such an extent that populations declined to eventual extirpation (Miller et al. 2001, pp. 26-27). An assumption was also made that a severe localized outbreak of URTD would only occur every 50 years (Miller et al. 2001, p. 28). Because this parameter was based on little quantifiable information, precise conclusions for how URTD impacts populations could not be made. However, this analysis highlights a need to better understand the extent with which URTD impacts gopher tortoise populations, and its frequency of occurrence.

The potential additive effects of fire ant (*Conomyrma* spp., *Solenopsis invicta*) predation on hatchling mortality was simulated, based on field and experimental data for clutch size, hatching success, and predation in the western range from study sites at Camp Shelby and DeSoto National Forest, Mississippi (Epperson and Heise 2001, entire). Without fire ants, the annual multiplicative population growth rate (lambda) was 1.018, with stable, slightly growing populations. With fire ants, lambda was 0.977, with a declining population trend and eventual extirpation. In subsequent VORTEX modelling, it was found that if the mortality from fire ant depredation is additive to other mortality sources, then all populations with an initial size from 10 to 200 gopher tortoises were extirpated within 200 years, with a mean time to extirpation from 32.2 to 80.9 years (McDearman 2006, pp. 6–7).

Population dynamics of turtles, as long-lived animals, have commonly been considered sensitive to demographic changes in adult survival and, in some cases, juvenile survival (Gibbons 1987, entire; Congdon et al. 1993, entire; Heppell 1998, entire). Likewise, models and simulations of gopher tortoise populations are most sensitive to adult, hatchling, and juvenile survival rates (Miller 2001, entire; Epperson and Heise 2001, entire; Wester 2005, entire). For example, the small but positive population growth rates modeled for a stable base population became negative when mortality of the 3–4 + year age class increased from 3.0 to 5.0 percent, or the yearling (0–1 year age class) mortality increased from 95 to 97 percent (Miller 2001, p. 10; McDearman 2006, p. 7). Hatchling survivorship has been shown to be the most critical life history stage driving viability of gopher tortoises due to the very small likelihood that hatchlings survive to their second year (Tuberville et al. 2009, p. 33). A 5 percent decrease (from 96 percent in the baseline model to 91 percent) in hatchling mortality was sufficient to shift the population growth rate from slowly declining (–1.5 percent) to slowly increasing (+1.1 percent) and to eliminate the probability of extinction within the 200 years (Tuberville et al. 2009, p. 33).

Changes in other vital parameters also affect population growth, although generally not to the proportionate extent of mortality (McDearman 2006, p. 7). The finite rate of increase changed from 1.002 to 1.006 when the minimum age of first reproduction was reduced from 20 to 17 years, and independently, average clutch size was increased from 4.79 to 5.60 (Table 2, McDearman 2006, p. 20). An increase in juvenile (0–1 year) mortality from 94.89 percent to 96.89 percent effectively reduced successful reproduction for each female by 40 percent and eliminated population growth, leading to long-term decline and/or extirpation (Miller 2001, entire).

Highly accurate measurements and assessments of sensitive demographic parameters affecting population growth and viability likely will be difficult to attain with confidence, particularly in small populations. Studies from large populations or cross-sectional studies from several populations may be required, if environmental heterogeneity can be controlled. With uncertainty in measuring key demographic and environmental factors, the goals and objectives for establishing viable populations and habitat should include larger populations than those identified as minimally viable.

The effects of geographic location and habitat quality on population growth rates for tortoises have been investigated (Tuberville et al. 2009, pp. 17-22). All model scenarios resulted in population declines of 1–3 percent per year and varied as a function of both location and habitat quality. Populations in the southern portion of the range were the most stable, whereas populations at the edge of the range were the least stable, particularly when found in marginal habitat (Tuberville et al. 2009, p 17). This highlights the importance of habitat management in stabilizing population growth for the species. While gopher tortoise populations may not persist if habitat quality remains poor for long periods of time, populations of at least 100 gopher tortoises were found to be reasonably resilient to variations in habitat quality and geographic location, but only populations of at least 250 tortoises were found to be able to persist for 200 years (Tuberville 2009 et al., p. 19).

A Gopher Tortoise Council (GTC) workshop defined minimum viable population (MVP) in terms of acceptable benchmarks for the purpose of conservation and recovery efforts and did not determine absolute minimum thresholds (GTC 2013, entire). Viability, as used under the MVP definition, is more of a "rule of thumb" for conservation planning purposes, and thus does not exactly align with the definition of viability used in this SSA (see Chapter 1, pages 7-8). A viable tortoise population, according to GTC MVP guidelines, was defined as consisting of at least 250 adult tortoises, at a density of at least 0.4 tortoises per ha, with an even sex ratio and evidence of all age classes present, on a property with at least 100 ha of high quality, well-managed tortoise habitat (GTC 2013, pp. 2-3). A primary support population was defined as consisting of 50-250 adult tortoises and these are considered as candidates of reaching viability through habitat restoration, natural recruitment increases, or population augmentation. A secondary support population was defined as <50 tortoises that have more constraints to reaching viability, but are important for education, community interest, and augmentation, and can persist long-term with rigorous habitat management and/or connectivity with other populations (GTC 2014, p. 4). It should be noted that support populations may persist for a long period of time under high-quality habitat conditions (Folt et al. 2021, p. 13), but are likely more vulnerable to stochastic events than populations that meets the minimum viable population MVP threshold (Miller et al. 2001, p. 28; GTC 2014, p. 4). In fact, a recent study from Conecuh NF demonstrated that some small populations remain stable or growing over a thirty-year period (Folt et al. 2021, entire).

2.7 Resource Needs and Habitat

Gopher tortoise habitat requirements include sufficient areas of open pine or other uplands where adequate sunlight reaches the forest floor to stimulate the growth and development of the herbaceous plant stratum for forage, with sufficient warmth for basking and the incubation of eggs (Landers 1980, p. 8; Lohoefener and Lohmeier 1981, entire; Auffenberg and Franz 1982, pp. 99, 104-107, 111, 120; Jones and Dorr 2004, p. 461; McDearman 2006, p. 2; McIntyre et al. 2019, p. 287). Low food availability negatively affects tortoise population densities and can be caused by plant growth suppression due to accumulated leaves, litter, low light associated with canopy closure (Landers and Speake 1980, p. 522), due, in turn to lack of regular disturbance such as prescribed fire. Longleaf pine and other open pine systems, sandhills, scrub (e.g., oak-palmetto, coastal, rosemary), xeric hammock, and ruderal (disturbed; e.g., roadsides, rights-of-way, grove/forest edges, fencerows, and clearings) plant communities most often provide the conditions necessary to support gopher tortoises (Auffenberg and Franz 1982, p. 99).

In the western fringe of the range, soils are loamy and contain more clay (Lohoefener and Lohmeier 1981, p. 240; Auffenberg and Franz 1982, pp. 114-115, Mann 1995, pp. 10–11). Higher clay content in soils may contribute to lower abundance and density of tortoises such as in Mississippi versus the eastern portion of the range (Estes and Mann 1996, p. 24; Jones and Dorr 2004, p. 461). Xeric (dry) conditions are less common west of the Florida panhandle (Craul et al. 2005, pp. 11-13). Ground cover in the Coastal Plains can be separated into two general regions, with the division in the central part of southern Alabama and northwest Florida. To the west, bluestem (*Andropogon* spp.) and panicum (*Panicum* spp.) grasses predominate (Mann 1995, p. 11); to the east, wiregrass (*Aristida stricta*) is most common (Boyer 1990, p. 3). However, gopher tortoises do not necessarily respond to specific plants but rather the physical characteristics of habitat (Diemer 1986, p. 126). Historically, gopher tortoises occurred in open longleaf pine forests, savannas, and xeric grasslands that covered the coastal plain in the Southeastern United States, and while some areas of habitat might have had wetter soils at times and been somewhat cooler, these areas were generally xeric, open, and diverse (Ashton and Ashton 2008, p. 73).

In addition to meeting foraging needs, gopher tortoises require a sparse canopy and litter-free ground for nesting (Landers and Speake 1980, p. 522). In Florida, the number of active burrows per gopher tortoise was found to be lower where canopy cover was high (McCoy and Mushinsky 1988, p. 35). Females require almost full sunlight for nesting (Landers and Buckner 1981, p. 5) because eggs are often laid in the burrow apron or other warm, sunny areas for appropriate incubation (Landers and Speake 1980, p. 522).

At one site in southwest Georgia, most gopher tortoises were found in areas with 30 percent or less canopy cover (Boglioli et al. 2000, p. 703). However, more extensive examination of the same site revealed that canopy cover alone may not always be indicative of gopher tortoise habitat (McIntyre et al. 2019, p. 288 – 289). Ecotones created by clearing were also favored by gopher tortoises in north Florida (Diemer 1992b, p. 162). When canopies become too dense, usually due to fire suppression, gopher tortoises tend to move into ruderal habitats such as roadsides with more herbaceous ground cover, lower tree cover, and significant sun exposure (Garner and Landers 1981, p. 122; McCoy et al. 1993, p. 38; Baskaran et al. 2006, p. 346). In Georgia, open-canopy pine areas were more likely to have burrows, support higher burrow densities, and have more burrows used by large, adult gopher tortoises than closed-canopy forests (Hermann et al. 2002, p. 294). Historically, open-canopied southern pine forests were maintained by frequent, lightning generated fires. Subsequently, in addition to prescribed fire, grazing, mowing, roller chopping, timber harvesting, and selective herbicide application may be used in the restoration, enhancement, and maintenance of some gopher tortoise habitat (Cox et al. 2004, p. 10; Ashton and Ashton 2008, p. 78; GDNR 2014, unpaginated; Rautsaw et al. 2018, p. 141).

Burrows

The burrows of a gopher tortoise (Figure 2.4) are the center of normal feeding, breeding, and sheltering activity. As mentioned above, gopher tortoises excavate and use more than one burrow for shelter beneath the ground surface. Burrows, which may extend for more than 30 feet, provide shelter from canid predators, fire, winter cold and summer heat (Hansen 1963, p. 359; Landers 1980, p. 6; Wright 1982, p. 50; Diemer 1986, p. 127; Boglioli 2000, p. 699). Digging burrows benefits the surrounding habitat by returning leached nutrients to the surface (Auffenberg and Weaver 1969, p. 191; Landers 1980, p. 2), and increasing the heterogeneity (diversity) of the habitat in the vicinity of the burrow (Kaczor and Hartnett 1990, p. 107). Burrows can also serve to shelter seeds from fires (Kaczor and Harnett 1990, p. 108). Many organisms adapted to hot summers and cool winters use gopher tortoise burrows for refuge (Landers and Speake 1980, p. 515). An estimated 60 vertebrates and 302 invertebrates share tortoise burrows (Jackson and Milstrey 1989, p. 87). Gopher tortoise burrows not only provide other species shelter from extreme environmental conditions and predation but may also be used as feeding or reproduction sites, and as permanent microhabitats for one or all life stages (Jackson and Milstrey 1989, p. 86).

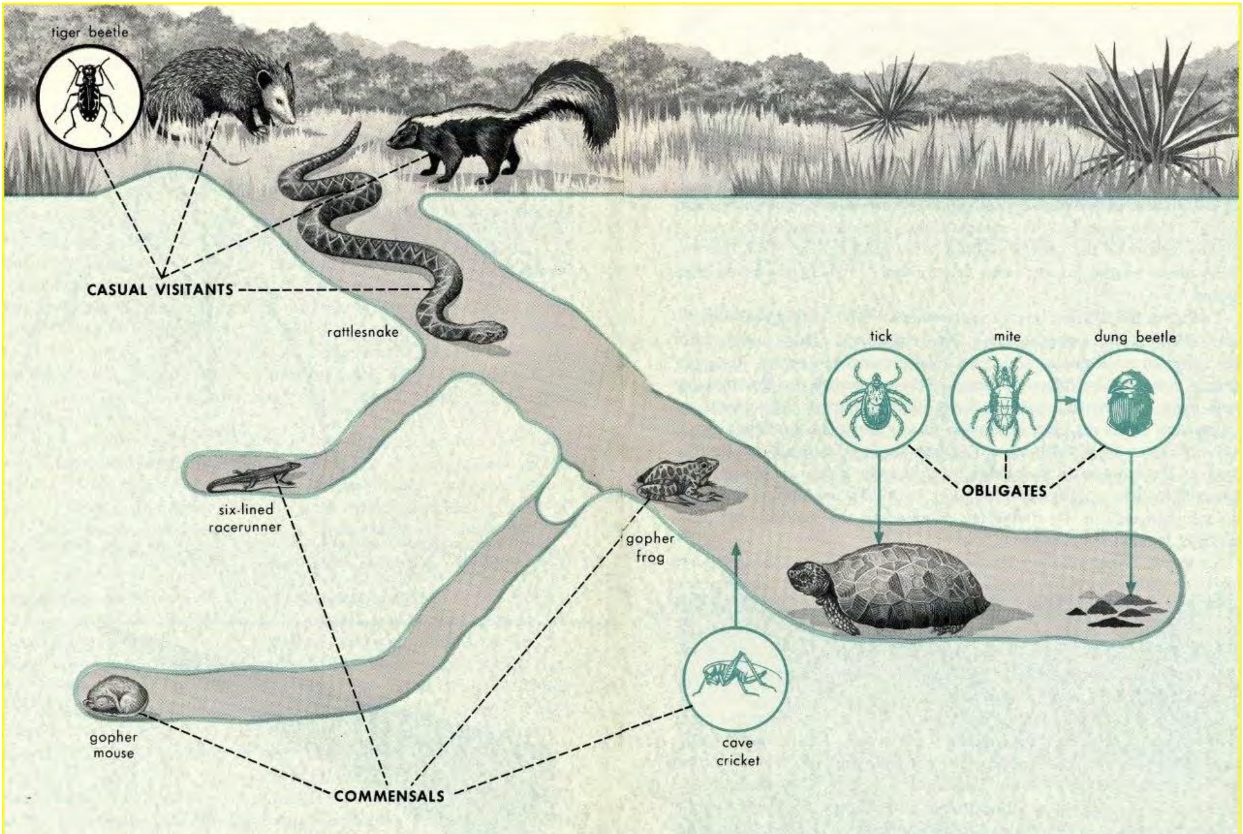

Figure 2. 4-Diagram of a gopher tortoise burrow showing a gopher tortoise near the end chamber, commensal species using side chambers, and casual visitants near the burrow opening. Image source: Dr. Walter Auffenberg, Florida Museum of Natural History (Auffenberg 1969).

In poor quality habitat where shrubs and hardwoods have encroached, gopher tortoises tend to excavate and use fewer burrows, likely due to limited availability of sites that are sufficiently open. The term “active burrow” is applied to burrows exhibiting indications they are likely inhabited by a gopher tortoise. Characteristics of active burrows (Figure 2.5) include fresh soil excavated from the interior of the burrow, deposited on the apron at the burrow entrance; tortoise feces on the apron or near the burrow entrance; and presence of eggshells and tracks (Auffenberg and Franz 1982, p. 76; Estes and Mann 1996, p. 11). Inactive burrows, which do not display conditions of recent use and occupancy by a gopher tortoise, are considered to be used as part of the annual home range of one or more gopher tortoises but are not currently occupied by a gopher tortoise. Indicators of inactive burrows include suitable size and shape of the burrow entrance; a recognizable apron of bare soil with or without encroachment of grasses or shrubs; and small amounts of leaf litter in the entrance that have not been moved by a gopher tortoise (Auffenberg and Franz 1982, p. 76; Estes and Mann 1996, p. 11). Abandoned burrows are unlikely to be used by a gopher tortoise and, normally, exhibit indications of erosion, a loss of shape and structure, and no apron. Occupancy of gopher tortoise burrows cannot be confirmed based on these characteristics.

Figure 2. 5-Images showing active gopher tortoise burrows, one in an open-canopy pine area (left) and the other showing gopher tortoise tracks (right) in a recently planted pine stand. Image credit: Angela Larsen-Gray.

Sand texture is most important in the formation of the burrow apron, which impedes rain from entering the burrow (Landers 1980, p. 6). Sand depth is also important because soil layers underlying it, such as clay, can impede digging and influence burrow depth (Baskaran et al. 2006, p. 347). Burrows in clay-type soils are more susceptible to regular winter flooding (Means 1982, p, 524). Additionally, burrows are shorter in clay soils, and clay soils may adversely affect nest success because these soils reduce exchange of oxygen and carbon dioxide (Wright 1982, p. 21; Ultsch and Anderson 1986, p. 790; Smith et al. 1997a, p. 599). Larger diameter burrow openings tend to result in longer burrows (Hansen 1963, p. 355). Burrows are usually distributed on higher ridge tops and their depths are sometimes limited by the water table (Baskaran et al. 2006, p. 346).

Tortoises select and prefer burrow sites in open canopy areas where sunlight reaches the ground (Boglioli et al. 2000, p. 703; Rostal and Jones 2002, p. 485). Such sites reflect areas where herbaceous plants for food are more abundant on the forest floor and, for females, sunlight and soil temperatures for egg incubation are more suitable. Also, males select sites and burrows that increase their proximity to females and breeding opportunities (Ott-Eubanks et al. 2003, p. 318; Boglioli et al. 2003, p. 849). The repeated use and travel to the same burrows by individual tortoises in stable habitat reveal that tortoises know the geography of their home range, burrows, and the location of neighboring tortoises (Ott-Eubanks et al. 2003, p. 318).

CHAPTER 3 – FACTORS INFLUENCING VIABILITY

Gopher tortoise life history, habitat needs, potential influencing factors (negative and positive) that are likely to affect the viability (Figure 3.1) of the species currently and into the future are identified and discussed in this chapter. Specific information and metrics associated with the current condition of gopher tortoise populations and habitat are discussed in Chapter 4.

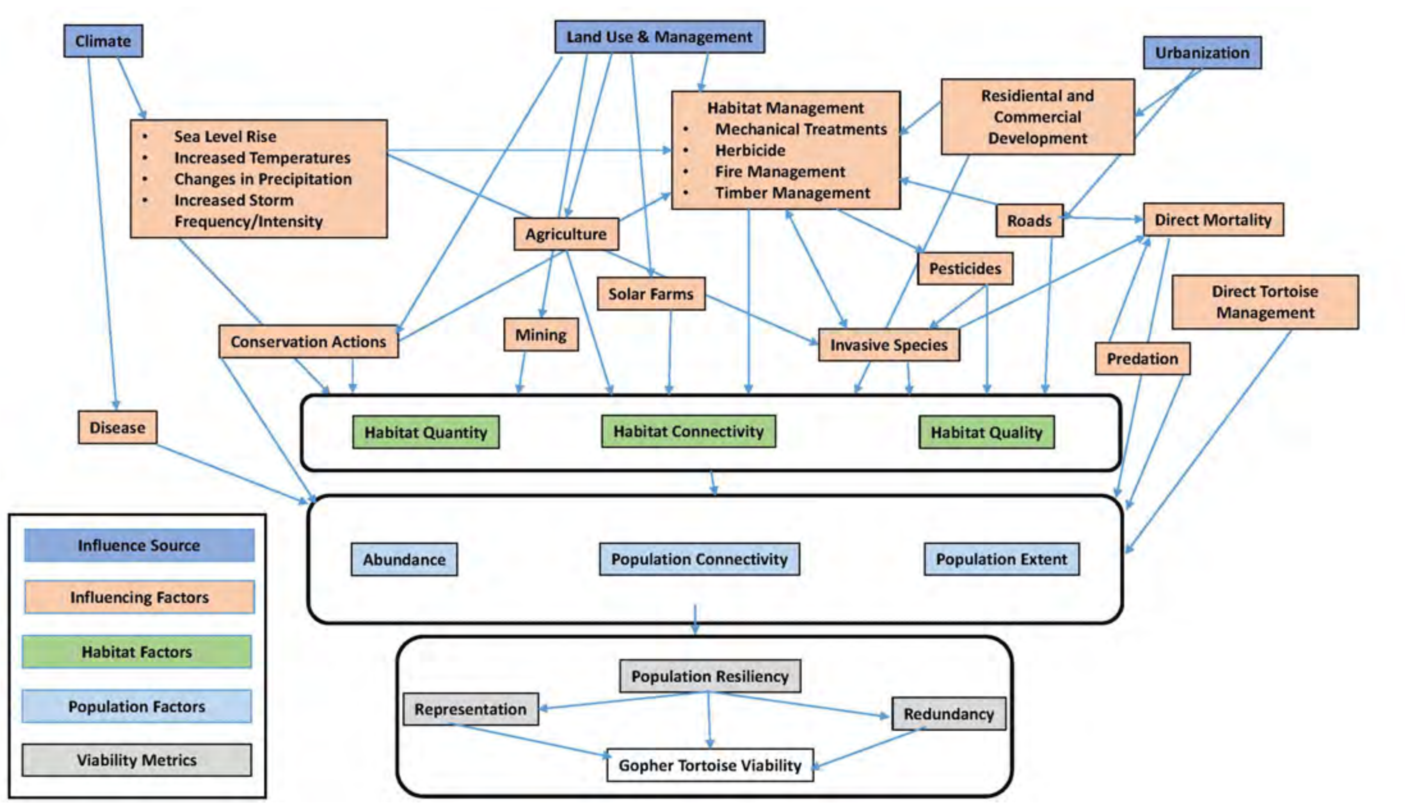

Figure 3. 1-Factors influencing the viability of the gopher tortoise.

3.1. Habitat Loss and Fragmentation

Gopher tortoise habitat comprises well-drained sandy soils (burrowing, sheltering, and breeding), with an open canopy, sparsely vegetated midstory, and abundant herbaceous groundcover (feeding). Gopher tortoise habitat occurs in a variety of upland natural communities such as sandhill, scrub, pine flatwoods (mesic and scrubby), xeric hammock, coastal habitats, and anthropogenic landscapes such as rights-of-way, pasturelands and planted pine stands. At a landscape scale, large swaths of interconnected, high quality habitat patches are likely to support viable populations, and ultimately lead to high resiliency of the species. Historically, open canopy conditions were maintained by frequent fires. Currently, habitat management is accomplished using prescribed fire, mechanical treatments (including timber harvesting), and herbicides. Habitat management activities may be implemented singularly or in combination (e.g., roller chopping followed by prescribed fire).

Urbanization and major roads (development; Auffenberg and Franz 1982, p. 112; Diemer 1986, p. 128; Diemer 1987, p. 74-75; Enge et al. 2006, p. 4), incompatible and/or insufficient habitat management, and certain types of agriculture (Lohoefener and Lohmeier 1984, pp. 2–6; Auffenberg and Franz 1982, p. 105; Hermann et al. 2002, pp. 294-295) can negatively impact gopher tortoises and gopher tortoise habitat. Invasive species can influence gopher tortoises either through direct impacts (e.g., predation; Mann 1995, p. 24;Engeman et al. 2009, p. 84; Engeman et al. 2011, p. 607; Dziadzio et al. 2016b, p. 531; Bartoszek et al. 2018, pp. 353-354) or alterations to habitat structure and/or function (Lippincott 1997, pp. 48-65; Bastios 2007, p. 24).

Climate change has the potential to negatively impact habitat through the loss of habitat due to sea level rise (Hayhoe et al. 2018, entire), limitations on number of suitable burn days due to changes in temperature (Kupfer et al. 2020, entire), precipitation, increased flooding due to predicted increases in the severity of hurricanes (Castellon et al. 2018, pp. 11-14), and human migration from inundated coastal areas, to inland areas, with subsequent impacts to gopher tortoises (Ruppert et al. 2008, p. 127).

Conservation of habitat through land acquisition and conservation actions on public and private lands and the retention of private forest lands, reduces the severity of some of these threats by providing protection of habitat across the landscape, maintaining connectivity between habitat patches, and increasing the opportunity for beneficial habitat management actions.

3.1.1. Historical Loss of Longleaf Pine and Longleaf Restoration

While gopher tortoises do occur and persist in open canopy stands of several southern pine species, gopher tortoises were historically associated with longleaf pine systems. Longleaf pine ecosystems are fire-dependent and once dominated the Coastal Plain of the Atlantic and Gulf coast regions, from Virginia to Texas (Ware et al. 1993, p. 447). Longleaf pine forests once covered an estimated 92 million acres (37 million ha) (Frost 1993, p. 20). By the 20th century, longleaf pine communities declined to less than 3 million acres due to forest clearing and conversion for agriculture, conversion from longleaf to other pine species, and development (Landers et al. 1995, p. 39). As a result of fire suppression and exclusion in many areas, currently, only an approximate 3 percent of remaining longleaf acres is in relatively natural condition (Simberloff 1993, p. 3; Frost 1993, p. 17; Jensen et al. 2008, p. 16).

America's Longleaf Restoration Initiative (ALRI) is a collaborative effort involving multiple public and private partners actively supporting efforts to restore and conserve longleaf pine ecosystems with a goal to increase longleaf coverage on the landscape to 8.0 million acres (3.2 million ha) (ALRI 2021, unpaginated). These efforts are focused within "significant landscapes" where Local Implementation Teams (LITs) are leading conservation efforts by coordinating partners, developing priorities, and fundraising to implement on-the-ground conservation (Figure 3.2). Several LITs are working within the range of the gopher tortoise to help restore longleaf pine on habitat utilized by gopher tortoises.

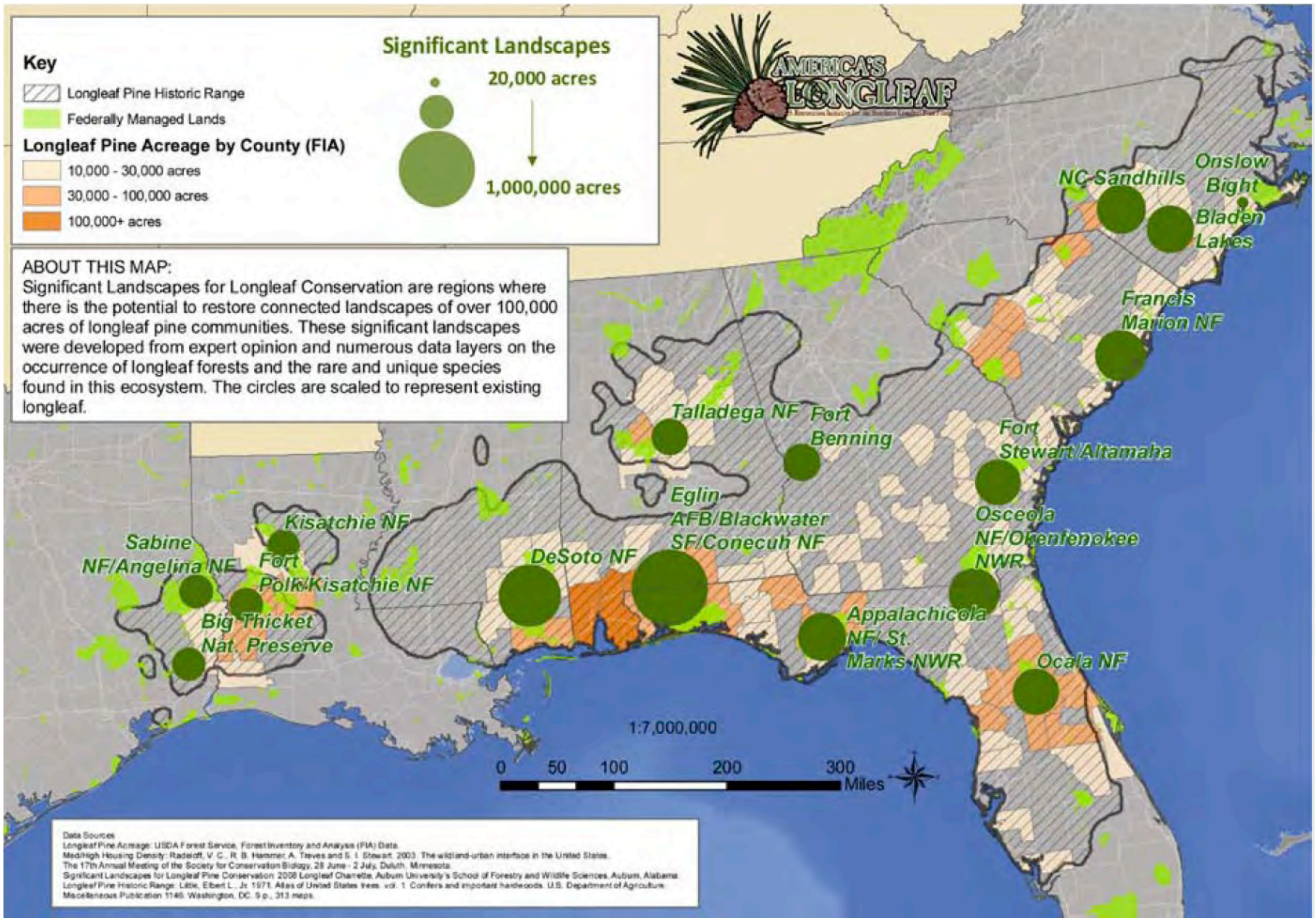

Figure 3. 2-Locations and relative size of existing longleaf acreages of Significant landscapes for Longleaf Conservation. Source: The Conservation Fund.

3.1.2 Fragmentation and Urbanization

The maintenance of habitat connectivity is important for gopher tortoise viability.

Human development of the landscape fragments and replaces natural areas with artificial structures, impervious surfaces, and manicured lawns and gardens containing non-native plant species (Sutherland 2009, p. 35), threatening wildlife communities, including gopher tortoise populations, that rely on a mosaic of interconnected uplands. In addition to the direct loss of habitat, development and urbanization may also threaten gopher tortoise populations on conservation lands by disrupting habitat connectivity across the landscape (decreasing immigration and emigration between local populations) and through the disruption of habitat management activities on conservation lands, particularly through the constraining of prescribed fire activities. In Florida, urban growth and development is identified as one of the primary threats to gopher tortoises (Auffenberg and Franz 1982, p. 112; Diemer 1986, p. 128; Diemer 1987, p. 74-75; Enge et al. 2006, p. 4). Georgia is also anticipated to see dramatic human population increases (Georgia Census 2021, unpaginated), leading to subsequent development and potential loss of gopher tortoise habitat.

Gopher tortoises can occur in residential areas despite the fact that these areas are typically of lower habitat quality. Urbanization impacts many wildlife species from direct loss of habitat, fragmentation of habitat, increased road mortality, increased human persecution, and by the increase in domestic predators, such as cats and/or dogs. Current research is lacking to quantify urbanized landscape impacts on survival, recruitment, health, and long-term persistence. However, urban tortoises may help bridge connectivity between natural habitats, though level of connectivity would vary significantly by how these areas are designed (e.g., presence of fencing, road density, habitat quality).

In addition to habitat loss, a direct impact from development could include mortality of gopher tortoises from entombment in their burrows (for more information regarding entombment, see Section 3.8). In the western portion of the range where the species is federally listed, individual gopher tortoises are translocated from development sites to avoid mortality for land development activities during consultation with the Service under sections 7 and 10 of the Act. Prior to 2007, gopher tortoise relocation was not mandated in Florida, but developers were required to mitigate for the loss of tortoises and habitat associated with the development site through an Incidental Take Permit. This mitigation was provided in the form of a monetary contribution or donation of protected habitat (i.e., conservation easement), with the goal of offsetting the effects of development projects on gopher tortoise populations in Florida. Although FWC no longer issues ITPs, they are perpetual, with many still active. Presently, Incidental Take permittees have the option to relocate gopher tortoises on-site or amend their permit to relocate tortoises to an approved recipient site for no additional mitigation. Since 2007 (76 FR 45130), in Florida, the state wildlife agency requires developers to relocate tortoises out of harm’s way (FWC 2007, p. 10). Other states (Georgia, Alabama and South Carolina) have some measure of legal protection for gopher tortoises, though gopher tortoise burrows are not protected uniformly across the range. When notified, these states work with developers when they identify tortoises on development sites. Conservation activities that assist in mitigating these direct impacts are discussed in detail in Section 3.9.3 (Relocation, Translocation, Recipient Sites, and Headstarting).

A primary driver of urbanization and subsequent habitat fragmentation impacting gopher tortoises is human population growth. Since 2010, with the exception of Mississippi, which shows a 6 percent decrease in human population, all other states within the limits of the historical range of the gopher tortoise have experienced growth in human populations with increases as of 2020 ranging from 3% in Louisiana to 15% in Florida (Table 3.1). Census projections over the next decade indicate similar percent increases from 2019 population numbers (Table 3.1). Additionally, census information available for Florida indicates an estimated 27% increase by 2045 from 2019 estimates (FEDR 2018, unpaginated).

State	2010	2020 (% change from 2010)	2030 Projections (projected % change from 2020)
Alabama	4,780,125	5,024,279 (increase 5%)	5,124,380 (increase 2%)
Florida	18,801,332	21,538,187 (increase 15%)	24,426,178 (increase13.4%)
Georgia	9,688,729	10,711,908 (increase 11%)	11,709,700 (increase 9%)
Louisiana	4,533,487	4,657,757 (increase 3%)	4,813,420 (increase 3%)
Mississippi	2,968,130	2,961,279 (decrease 6%)	3,092,410 (increase 4%)
South Carolina	4,625,366	5,118,425 (increase 11%)	5,488,460 (increase 7%)

Table 3. 1-Human population estimates and future projections (including percentage increases and decreases) for six states within historical range of the gopher tortoise (Blanchard 2007, p. 7; Culver College of Business 2021, unpaginated; FEDR 2018, unpaginated; Georgia Census

2021, unpaginated; Population Projections 2021, unpaginated; SCBCB 2009, p. 2; U.S. Census Bureau 2021, unpaginated).

3.1.3. Solar Farms

As interest in renewable energy increases, the development of solar farms across the landscape is also increasing (Figure 3.3). By 2019, Florida ranked fifth in the nation in total solar power generating capacity and utility (EIA 2018, unpaginated). In South Carolina, the state's net solar power production increased 70% between 2018 and 2019, with two dozen new solar farms becoming operational (EIA 2018, unpaginated). In Georgia, solar energy accounted for 2% of the in-state electricity in 2019 with half of the six largest facilities (capacities greater than 100 megawatts) coming on-line in 2019 (EIA 2018, unpaginated). While total solar generation is small in Alabama, it accounts for 4% of renewable energy in the state with the strongest solar resources located Southeast along the Gulf Coast (EIA 2018, unpaginated). Though the state's first facility came on-line in 2017, in Mississippi, utility-scale solar energy production is small, accounting for 0.5% of the state's total generation (EIA 2018, unpaginated). Solar power generated about one-tenth of Louisiana's renewable generation in 2020. Louisiana's utility-scale (facilities 1 megawatt or larger) solar generation was 40 times greater in 2020 than in 2019 (EIA 2018, unpaginated). A number of solar sites are known to have impacted gopher tortoise habitat. Some solar utility developers and companies recognize the potential impact that this type of development may have on rare species and their habitat and have begun working with conservation organizations to avoid and minimize impacts via strategic siting assessments (NASA Develop 2018, unpaginated). A primary concern regarding large-scale deployment of solar energy is the potentially significant land use requirements (Ong et al. 2013, p. iv), habitat fragmentation and possible exclusion of wildlife including gopher tortoises as a result of fencing, and the need to relocate tortoises from solar farm sites prior to construction. As solar farm development increases, particularly on rural lands, concerns over the protection of sensitive species such as the gopher tortoise are heightened (SELC 2017, p. 3).

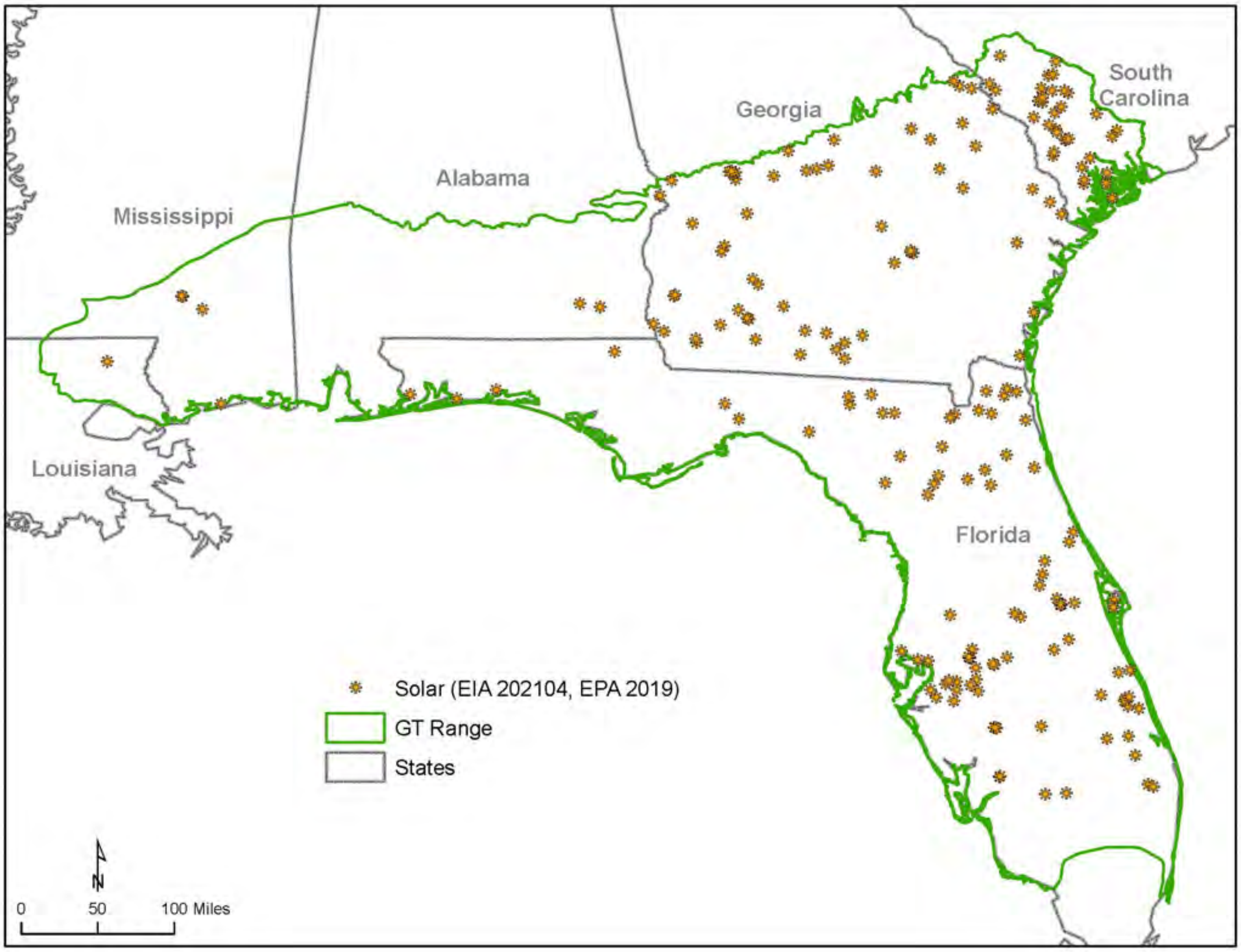

Figure 3. 3-Location of solar power plants within the range of the gopher tortoise.

3.1.4. Agricultural Lands

Over 80 percent of potential tortoise habitat is in private ownership, and much of this falls under agricultural uses. Surveys have shown that sites on suitable soils that had agriculture as the primary land use, were about 6 times less likely to have burrows and contained 20 times fewer gopher tortoise burrows than open pine sites (Hermann et al. 2002, pp. 294-295). Annually tilled agricultural fields are not inhabited by tortoises (Auffenberg and Franz 1982, p. 105). However, after several years of crop abandonment, succession of former agricultural fields into areas that are dominated by perennial herbaceous species may begin to attract gopher tortoises (Auffenberg and Franz 1982, p. 105). It may take many years for the preferred herbaceous species to be established on these fields, but if fire (or other vegetation management) is excluded from the site, the canopy will ultimately close and any gopher tortoises that may have re-colonized will evacuate the site (Auffenberg and Franz 1982, pp. 107-108). While the area of cropland in the South is forecasted to decline as much as 17 million acres (6.9 million hectares) by 2060 (from a base of 84 million acres (34 million hectares) in 1997) (Wear and Greis 2013, p. 45), it is unknown the extent to which abandoned agricultural fields will be restored to a level of suitability necessary to support viable gopher tortoise populations. However, restoration of abandoned agricultural fields into potential gopher tortoise habitat can be accomplished, provided soils are appropriate for gopher tortoises, as seen in the successes of the Conservation Reserve Program converting thousands of acres of agricultural land to forests.

3.2. Road Effects and Mortality

Roads create habitat fragmentation, isolate habitat, pose a barrier to movement, and increase direct mortality for many species of reptiles, including gopher tortoises (Andrews and Gibbons 2005, p. 772; Hughson and Darby 2013, pp. 227-228). Roads that bisect habitat pose hazards to gopher tortoises throughout the range (Figure 3.4), forcing individual gopher tortoises into unsuitable areas and onto highways (Diemer 1987, p. 75; Mushinsky et al. 2006, p. 38). Roads occurring within or adjacent to tortoise habitat are of particular concern because tortoises are attracted to road shoulders where open canopy, grassy areas are maintained (Steen and Gibbs 2004, entire; Steen at al. 2006, p. 271). In a recent study to determine if gopher tortoises use roadsides as movement pathways between larger habitat patches or as residential habitat, gopher tortoises appear to use roadsides independently of larger habitat patches, treating them as areas for residency as opposed to travel corridors among other habitat patches (Rautsaw et al. 2018, p. 141). Gopher tortoises residing along roadsides may be more susceptible to predation. Predators such as raccoons frequently use ecological edges and may occur in high densities in fragmented, suburban landscapes (Hoffman and Gottschang 1977, p. 633; Wilcove 1985, pp. 1213-1214).

While road mortality occurs in gopher tortoise populations, the extent to which it affects populations, or the species, is not well documented. Risk of road mortality on tortoises is likely related to the type of road and its traffic pattern (e.g., an unpaved rural road compared to a major highway), but this relationship has not been quantified. Increases in observed road mortality (episodic or consistent) may be a by-product of new construction, road expansion, or relocation of tortoises; however, there is no information directly linking road mortality to population declines and the magnitude of this influencing factor is uncertain. Information collected through FWC's citizen science application indicates that between 2014 and 2018, 470 tortoises were reported as sick, injured or dead, of which, 41% were tortoises injured or dead on roads (10th Annual GT CCA Report 2019, p. 95) (Figure 3.5).

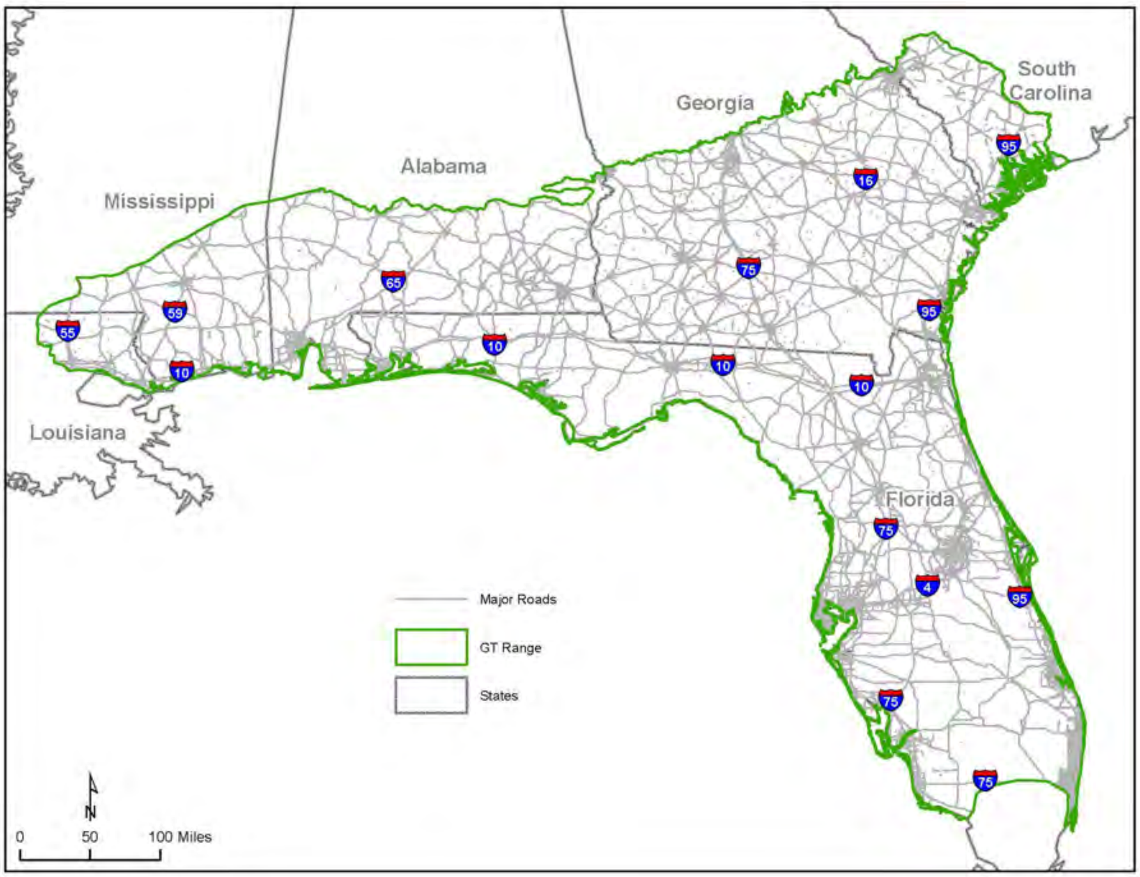

Figure 3. 4-Interstates and major freeways and highways occurring across the range of the gopher tortoise in Florida, Georgia, Louisiana, Mississippi, Alabama, and South Carolina.

Figure 3. 5-Images showing gopher tortoise burrow on road right-of-way (left) and road killed gopher tortoise (right). Image credit: Randy Browning (left) and Jeffrey M. Goessling, Ph.D. (right).

As development and subsequent habitat loss and fragmentation occurs, it is expected that gopher tortoises will continue to disperse to find better quality habitat, putting individual gopher tortoises at risk of road mortality. This threat is likely to increase as road densities and traffic volumes increase and habitat patches become more isolated and more difficult to manage (Enge et al. 2006, p. 10). Highway mortality of gopher tortoises will be highest where there are improved roads adjacent to gopher tortoise populations. Gopher tortoises in the vicinity of urban areas will be particularly vulnerable (Mushinsky et al. 2006, p. 362), especially in areas with heavy traffic patterns and/or high-speed limits. This threat is ongoing and will continue to occur in the future in peninsular Florida and urban centers in coastal portions of Georgia, Alabama and Mississippi where human populations are likely to increase as seen in urban modeling projections using SLEUTH (Terando et al. 2014, entire). Quantification of the effects of road mortality on gopher tortoise populations is difficult because there is no current rangewide monitoring effort for gopher tortoise road mortality.

The installation of wildlife barrier fences along roadways has the potential to minimize gopher tortoise road mortality. In Alabama, two road projects cumulatively resulted in the installation of approximately 16 kilometers (10 miles) of gopher tortoise fencing. The Mississippi Department of Transportation also used fencing to mitigate gopher tortoise road mortality and installed approximately 24 kilometers (15 miles) of fencing, which decreased road mortality in gopher tortoises from between 1 and 2 annually to none. The projects reduced or eliminated road mortality and contributed to sustainability of local gopher tortoise populations. However, they are small in scale and do not substantively reduce the threat of gopher tortoise road mortality throughout its range and they do not eliminate the habitat fragmentation caused by the roads. Additionally, while barrier fencing along roads may reduce road mortality, fencing may also further limit the movement of gopher tortoises.

3.3. Climate Conditions

In the Southeastern United States, the impacts of climate change are already occurring in the form of sea level rise and extreme rain events (Carter et al., 2018, p. 749). Changes in temperatures may result in more frequent drought, more extreme heat (resulting in increases in air and water temperatures), increased heavy precipitation events (e.g., flooding), more intense storms (e.g., frequency of major hurricanes increases), and rising sea level and accompanying storm surge (IPCC, 2014, entire). Higher temperatures and an increase in the duration and frequency of droughts will also increase the occurrence of wildfires and reduce the effectiveness of prescribed fires (Carter et al. 2018, pp. 773-774). Changes in climate may alter the abiotic conditions experienced by species assemblages, resulting in effects on community composition and individual species interactions (DeWan et al. 2010, p. 7; Carter et al. 2018, pp. 768-787).

Despite the recognition of climate effects on ecosystem processes, there is uncertainty about the exact climate future for the Southeastern United States and how the ecosystems and species in this region will respond. The Southeast is part of the transition zone between tropical and temperate climates where salt marshes, pine-dominated forests and hardwood forests meet mangrove forests, pine savannas and tropical freshwater wetlands in the Everglades. It should be recognized that the greatest threat to many species from climate change may come from synergistic effects. That is, factors associated with a changing climate may act as risk multipliers by increasing the risk and severity of more imminent threats. The effects of changing climate conditions are likely to influence gopher tortoises and gopher tortoise habitat.

Gopher tortoises exhibit temperature dependent sex determination, with pivotal temperature for a 1:1 sex ratio being observed at 29.3°C (84.7°F) (DeMuth 2001, pp. 1612-1613). Incubation temperature has also been shown to affect post-hatchling growth in gopher tortoises; eggs incubated at higher temperatures produced hatchlings that grew more than those incubated at lower temperatures, though growth rate was not determined to be significantly different until nearly 9-months post-hatching (Demuth 2001, p. 1614). Mean clutch sizes are also larger in warmer more productive environments (Ashton et al. 2007, pp. 355-362). Because of predicted increases in temperature across the Southeastern U.S. due to climate change, there are potential changes with skewed sex ratios, clutch sizes, hatchling success, and possibly hatchling condition. While temperatures are anticipated to increase in the future due to climate change, the extent to which this may influence gopher tortoise demography is uncertain as the gopher tortoise may modify nest site selection in at least two ways to buffer against potential impacts related to temperature dependent sex determination: selection of cooler nest sites (Czaja et al. 2020, entire), and altering timing of nesting to earlier in the season, and there is evidence that gopher tortoises may already exhibit both of these behaviors (Ashton and Ashton 2008, entire; Moore et al. 2009, entire; Craft 2021, pp. 42-45).

Frequency of severe hurricanes is predicted to increase in the future (IPCC 2014, entire; Carter et al. 2018, entire), and there is some potential for negative direct impacts to gopher tortoises. Gopher tortoise burrows may be impacted by flooding after a hurricane, causing abandonment, though the burrow may become useable again. Gopher tortoise movement was shown to significantly increase in areas that had a higher water table and frequent burrow flooding, though there does not appear to be large-scale shifts in movement to drier habitats for nesting during peak rains (Castellon et al. 2018, pp. 11-14). A study in Cape Sable, Florida, found a 76% decline in active burrows at the site during an 11-year period between 1990 and 2001, attributed largely to mortality as a result of declines in habitat quality and the effects of tropical storms (Waddle et al. 2006, pp. 281-283). Subsequently, in surveys done post hurricane Irma in 2018, evidence of activity in burrows was found but no tortoises were observed (Falk 2018, entire). In addition, over wash of coastal dunes may result in “salt burn” and loss of coastal vegetation, temporarily reducing forage availability in coastal natural communities used by gopher tortoises.

While other habitat management techniques may mitigate the reduced ability to implement prescribed fire, challenges associated with managing gopher tortoise habitat with prescribed fire are a substantial risk factor associated with climate change for this species. Predicted changes in temperature and precipitation due to climate change will limit the number of days with suitable conditions for prescribed burns (Kupfer et al. 2020, entire). This reduction in prescribed fire, combined with the effects of urbanization, will further restrict the ability to manage habitat with prescribed fire. As the ability to implement prescribed fire is increasingly constrained, the ability to reduce woody vegetation and maintain an open under- and mid-story will be limited, and gopher tortoise habitat will likely degrade. In addition to the constrained ability to implement prescribed fire in the future, modelling for the Southeastern United States suggests increased wildfire risk and a longer fire season, with at least a 30% increase from 2011 in lightning-ignited wildfire by 2060 (Vose et al. 2018, p. 239).

There is risk to coastal populations of gopher tortoises due to sea level rise and subsequent inundation and loss of habitat in coastal areas. Global mean sea level has risen 7-8 inches (16-21 cm) since 1900, with about half of that rise occurring since 1993 (Hayhoe et al. 2018, p. 85). In areas of the Southeast, tide gauge analysis reveals as much as 1 to 3 feet (0.30 to 0.91 m) of local relative SLR in the past 100 years (Carter et al. 2018, p. 757). The future estimated amount that sea level will rise depends on the response of the climate system to warming, and on the future scenarios of human-caused emissions (Hayhoe et al. 2018, p. 85). Additionally, the amount of gopher tortoise habitat predicted to be lost within a given population due to SLR varies considerably depending on the location of the population. Loss of habitat within a population will result in a decreased probability of population persistence.

Indirect impacts to gopher tortoises and their habitat may occur due to the relocation of people from flood-prone coastal areas to inland areas (Ruppert et al. 2008, p. 127), including the relocation of millions of people to currently undeveloped interior natural areas (Stanton and Ackerman 2007, p. 15). Alabama, Florida, Louisiana, and Mississippi's interior natural ecological communities will likely be impacted with the increasing need of urban infrastructure to support retreating coastal inhabitants. Increases in gopher tortoise habitat loss related to climate change would be in addition to the 20 percent loss projected to occur by 2060 due solely to people immigrating into Florida (FWC 2008, p. 2). Increasing threats of habitat loss due to coastal retreat is likely to also affect tortoise habitat inland from the Georgia, Alabama, and Mississippi coastal counties. The timing of these impacts will be dependent on the rate at which the sea level rises, and a gradual coastal retreat and concurrent impacts to gopher tortoises are likely during this time.

3.4. Disease

A number of diseases have been documented in gopher tortoises, including fungal keratitis (Myers et al. 2009, p. 582); iridovirus; ranavirus (Johnson et al. 2008, entire); herpesvirus; bacterial diseases related to *Salmonella* spp., *Mycoplasma* spp., *Helicobacter* sp. (Desiderio et al. 2021, entire), and *Dermatophilus*; and numerous internal and external parasites (Ashton and Ashton 2008, pp. 39-41). Upper Respiratory Tract Disease (URTD) resulting from two *Mycoplasma* species (*M. agassizii* and *M. testudineum*) has received the most attention recently (Figure 3.6). URTD has been documented throughout much of the tortoise's range (Berish et al. 2010, p. 696; McGuire et al. 2014a, pp. 737-739; Goessling et al. 2019, pp. 5-6), but the magnitude of threat URTD poses to gopher tortoise populations and tortoise demographics is uncertain (Karlin 2008, p. 1).

URTD has been linked to several large die-offs, the first of which occurred in 1989 on Sanibel Island, Lee County, Florida, and resulted in the estimated loss of 25-50 percent of the adult population (McLaughlin 1997, p. 6). Other large-scale mortality events implicating URTD as a causal factor have also occurred in Florida (Gates et al. 2002, entire; Rabatsky and Blihovde 2002, entire; Dziadzio et al. 2018, entire). Multiple dead individuals have also been found on sites where seroprevalence of *M. agassizii* was documented among living tortoises (Berish et al.

2000, p. 10). Other sites in the candidate range have documented instances of high seroprevalence of URTD (McGuire et al. 2014a, p. 738; Goessling et al. 2019, p. 5), but population-level effects of this disease were unknown. Additionally, there have been few symptomatic tortoises and no recorded deaths determined to be from URTD in the western range.

Figure 3. 6-Image of an adult gopher tortoise with nasal discharge associated with active Upper Respiratory Tract Disease (URTD). Image credit: Jessica McGuire.

Current hypotheses suggest that differences in virulence of various strains of Mycoplasma (Sandmeier et al. 2009, p. 1261) and increased susceptibility to infection due to environmental stressors (e.g., poor habitat quality) may increase risk of URTD outbreaks and associated mortality. However, tortoises have natural antibodies to *Mycoplasma* spp. (Hunter et al. 2008, p. 464) and these natural immune mechanisms may explain why die-offs are not more prevalent throughout the gopher tortoise's range (Gonynor and Yabsley 2009, pp. 1-2; Sandmeier et al. 2009, pp. 1261-1262). In contrast, research suggests that susceptible tortoises in high-seroprevalence (number of individuals exposed to disease) populations have decreased apparent survival and may experience a low level of increased mortality in the initial stages of disease

(Ozgul et al. 2009, p. 796). *Mycoplasma* spp. are spread through horizontal transmission via direct contact during courtship and mating activities (Jacobson et al. 2014, p. 260); thus, juvenile tortoises are less likely to be exposed to these pathogens. These juveniles may provide a pool of tortoises to aid in recruitment after a disease event (Wendland et al. 2010, p. 1257 and 1261); however, these size classes usually represent a small proportion of the overall population. Studies have documented low density populations with high proportions of immature tortoises (up to 71%) recovering from episodes of low apparent adult survival (Goessling et al. 2021, p. 140; Folt et al. 2021, p. 11).

URTD may also result in altered movement and behavior among gopher tortoises. Tortoises expressing severe clinical signs of URTD appear to alter their thermoregulatory behavior, basking outside the burrow more often at lower temperatures than asymptomatic tortoises (McGuire et al. 2014b, pp. 750-754). Tortoises have also been found to elevate their body temperatures behaviorally in response to acute infection (Goessling et al. 2017, p. 488). In addition, tortoises with severe clinical sign moved long distances over relatively short periods of time, potentially increasing dispersal rate of pathogens (McGuire et al. 2014b, pp. 750-754). Tortoises dispersing long distances increase their likelihood of encountering a road (i.e., a barrier), potentially limiting spread of disease but increasing risk of road mortality. However, other studies have found higher apparent survival of seropositive gopher tortoises than for seronegative individuals and suggested 1) this was due to seropositive tortoises representing those that survived the initial infection, and 2) that seropositive tortoises were less likely to emigrate from the site than seronegative individuals (Ozgul et al. 2009, p. 794).

The degree to which exposure to the pathogen correlates to clinical signs of URTD or die-offs is unclear, as is the degree of transfer between animals, and the potential for decreased resistance to the disease based on stresses from habitat modification or relocation. Nasal scarring has been found to be the only positive link between clinical sign and URTD diagnostic tests for *M. agassizii*, and there appears to be no connection between active clinical sign and antibody presence of *Mycoplasma* spp. (Goessling et al. 2019, p. 5). While large-scale die-offs due to URTD appear to be rare, correlations between exposure to *Mycoplasma* spp. and population declines are variable among geographic locations (McCoy et al. 2007, p. 173). Identifying effects of this disease on tortoise populations will require continuous long-term monitoring (Berish et al. 2010, p. 704).

3.5. Human Harvesting and Other Activities

3.5.1. Human Harvest

Human harvest of gopher tortoises for consumption has historically influenced gopher tortoise populations, particularly in portions of the Florida panhandle. Tortoises were harvested in large numbers during the Great Depression, a practice which continued for decades following the Depression (Tuma and Sanford 2014, pp. 145-146). Prior to the closure of tortoise harvest in the late 1980s, a community in Okaloosa County held an annual tortoise cookout (Enge et al. 2006, p. 5). Low numbers of tortoises on sites with otherwise adequate habitat were speculated to reflect episodes of human predation in the 1980s and 1990s in Mississippi (Lohoefener and Lohmeier 1984, p. 1-30; Mann 1995, p. 18; Estes and Mann 1996, p. 21). Though this practice is not as common as it was prior to the 1980's, localized harvest still occurs in some rural areas across the Southeast (Rostal et al. 2014, p. 146) but is likely not a significant threat to current populations.

3.5.2. Rattlesnake Roundups

Rattlesnake roundups are locally organized events that offer prizes for the largest and most rattlesnakes caught. Historically, there were multiple roundups throughout the Southeast. With the recent conversion of two roundups to wildlife festivals (Claxton, GA in 2012; Whigham, GA in 2021), only one roundup remains in the Southeast, in Opp, Alabama.

The technique of blowing fumes of noxious liquids (otherwise known as “gassing”) down tortoise burrows was used primarily to collect snakes for these rattlesnake roundups (Means 2009, p. 139). It is thought this practice of gassing burrows harms or harasses the resident tortoise, though research that quantifies negative direct impacts (i.e., mortality) is limited. For example, one study found that no tortoises died or showed ill-effects after being gassed in their burrows; however, this study did not examine potential long-term impacts or repeated gassing (Speake and Mount 1973, p. 273). Tortoise burrows have also been excavated to retrieve snakes, sometimes in conjunction with burrow gassing (Means 2009, p. 139), rendering the burrows unusable.

Use of gasoline or other chemical or gaseous substances to drive wildlife from burrows, dens, or retreats is now prohibited across Southeastern states (for example, see Alabama Regulation 220–2–.11, Georgia codes § 27–1–130 and 27–3–130, Florida Administrative Code 68A-4.001(2), and Mississippi Code R 5-2.2 B). Effective enforcement of existing regulations would likely be enhanced with development of a regulated harvest or a prohibition on rattlesnake harvest. The conversion of the one remaining roundup to a wildlife festival would reduce incidental mortality of tortoises during rattlesnake collection. While gopher tortoise mortality due to rattlesnake collection has not been quantified, this threat is primarily historical and is not likely a significant influence on populations as only one roundup in the Southeast remains.

3.6. Predation

Gopher tortoise nest predation (Figure 3.7) varies annually and across sites, ranging from ~45-90 percent in a given year (Landers et al. 1980, p. 358; Wright 1982, p. 59; Marshall 1987, pp. 29-32; see section 2.4 Life History above). Gopher tortoises are most susceptible to predation within their first year of life, though most predation appears to occur within 30 days of hatching (Pike and Seigel 2006, p. 128; Smith et al. 2013, pp. 4-5). For example, a 65 percent predation rate has been documented within 30 days of hatching at Camp Shelby, Mississippi; no tortoises within this sample survived to adulthood (Epperson and Heise 2003, p. 310 and 322). Overall annual hatchling survival has been estimated to be approximately 13% (Perez-Heydrich et al. 2012, p. 342). In some instances, predation-related mortality may reach 100% within one-year post-hatching (Pike and Seigel 2006, p. 128).

Raccoons are the most frequently reported predator of nests and juvenile gopher tortoises (Landers et al. 1980, p. 358; Butler and Sowell 1996, p. 456); other predators of nests and/or juvenile tortoises include gray fox (*Urocyon cinereoargenteus*), striped skunk (*Mephitis mephitis*), Virginia opossum, coyote (*Canis latrans*), nine-banded armadillo, several snake species (e.g. *Agkistrodon piscivorus, Drymarchon corais, Masticophis flagellum*), fire ants (*Conomyrma* spp., *Solenopsis invicta*)., and red-tailed hawks (*Buteo jamaicensis*) (Douglass and Winegarner 1977, p. 237; Fitzpatrick and Woolfenden 1978, p. 49; Landers et al. 1980, p. 358; Wilson 1991, p. 378; Mann 1995, pp. 24–25; Butler and Sowell 1996, pp. 456-457; Wetterer and Moore 2005, p. 353; Pike and Seigel 2006, p. 128). Twenty-five species—12 mammals, 5 birds, 6 reptiles and 2 invertebrates—are known to be predators of eggs, emerging neonates, hatchlings, and older tortoises (Ashton and Ashton 2008, p. 27). Adult gopher tortoises are less likely to experience predation except by canines (e.g., domestic dogs, coyotes, foxes) and humans (Causey and Cude 1978, pp. 94-95; Taylor 1982, p. 79; Hawkins and Burke 1989, p. 99, Mann 1995, p. 24). Some predators are subsidized by human activities such as habitat fragmentation and edge effect (e.g., red imported fire ants) (Wetterer and Moore 2005, pp. 352-353), roads and infrastructure (e.g., red imported fire ants) (Stiles and Jones 1998, p. 343), increased availability of food (e.g., raccoons), reduction or elimination of top carnivores (e.g., coyotes, red foxes) (Crooks and Soule 1999, entire), ecological perturbations allowing range expansion (e.g., coyotes), and simply because some are domestic and associated with humans (e.g., cats and dogs).

The gopher tortoise is a long-lived species, which naturally experiences high levels of mortality in early life stages. However, it is unknown what predation rate populations can sustain without impacting population resiliency. Studies on the long-term survival of juveniles across multiple populations are needed to determine the survival rates needed within this life stage to sustain viable populations.

Figure 3. 7-Image of predated gopher tortoise nest (left) and hatchling gopher tortoise predated by raccoon (right). Image credit: Michelina Dziadzio.

3.7. Non-native and Invasive Species

3.7.1. Invasive Flora

The spread of exotic plants species has the potential to alter and degrade gopher tortoise habitat and ultimately influence gopher tortoise viability on a site. Some species postulated to impact tortoise habitat include kudzu (*Pueraria montana*), Chinese privet (*Ligustrum sinense*), Callery pear (*Pyrus calleryana*), natal grass (*Melinis repens*), and Japanese climbing fern (*Lygodium japonicum*), though quantified impacts of these species on tortoises are unknown. One species known to impact gopher tortoise use of habitat is cogongrass (*Imperata cylindrica*), a prolific invasive which occurs throughout much of the gopher tortoise's range. Unlike other invasive plant species in upland communities, cogongrass can rapidly spread following disturbances including prescribed fire (Yager et al. 2010, entire; Holzmueller and Jose 2011, p. 436-437). It can quickly form a tall, dense ground cover with a dense rhizome layer and can outcompete native vegetation (Dozier et al. 1998, pp. 737-740; Mushinsky et al. 2006, p. 360; Minogue et al. 2018, p.1-4). Widespread areas of dense cogongrass (Figure 3.8) could result in habitat loss as gopher tortoises do not use these areas, nor do they consume cogongrass (Basiotis 2007, p. 21). Cogongrass can also decrease gopher tortoise habitat quality by reducing forage quality and quantity, and the availability of burrowing and nesting locations (Lippincott 1997, pp. 48-65; Basiotis 2007, p. 24). Additional research is needed to quantify the impacts of invasive vegetation spread on gopher tortoises and the quality of their habitat.

Figure 3. 8-Image of a heavy infestation of cogongrass (*Imperata cylindrica*). Image credit: Mississippi Forestry Commission

3.7.2. Invasive Fauna

The red imported fire ant was first introduced to the Southeastern U.S. in the early 1900s and now occurs throughout the gopher tortoise's range (United States Department of Agriculture, 2017, unpaginated). Fire ants frequent disturbed sites, particularly areas with disturbed soil, and are common in upland areas used by gopher tortoises (Shearin 2011, p. 22, 30). Gopher tortoises often nest in the soft disturbed soil of their burrow aprons. In one study, red imported fire ants were present at most gopher tortoise burrows, though present more often in disturbed areas (Wetterer and Moore 2005, p. 352) including recently burned sites, indicating risk of fire ant-related mortality of tortoise may be high. Fire ants are not able to breach hard smooth-shelled intact eggs (Diffie et al. 2010, p.295), such as gopher tortoise eggs, but will attack tortoises in the nest prior to emergence (Butler and Hull 1996, p. 17; Dziadzio et al. 2016b, p. 531); fire ants will also depredate hatchlings after they have left the nest (Mann 1995, p. 24)(27 percent post-hatchling mortality by fire ants; Epperson and Heise 2003, p. 320). Fire ants are aggressive, and their stings can result in direct mortality and reduced survival by limiting growth, altering behavior, and changing foraging patterns (Wilcox and Giuliano 2014, pp. 3-4; Dziadzio et al. 2016b, pp. 532-533). There is concern that fire ants could be contributing to the decline of the gopher tortoise if predation on hatchlings by fire ants is an additive source of mortality (Mann 1995, p. 24; Dziadzio et al. 2016b, p. 536). In the western range, gopher tortoise conservation banks and other related sites must include fire ant monitoring and control as part of their management plan to reduce the effects of predation on tortoise eggs and hatchlings (74 FR 46401).

The nine-banded armadillo arrived in the Southeast through a combination of natural range expansion in the mid-19th century and accidental releases of individuals (Taulman and Robbins 1996, pp. 644-645). They use a wide range of natural community types including pine forests, areas frequently occupied by gopher tortoises. They dig their own burrows, but also use the burrows of other species such as the gopher tortoise (Mengak 2004, p. 2) and are known predators of tortoise eggs (Douglass and Winegarner 1977, p. 237; Degroote et al. 2013, pp. 77-79). The relative importance of armadillos as a nest predator appears to vary by site. One study (Dziadzio et al. 2016a, p. 1318) compared predation of natural and artificial tortoise nests at burrows to nests at other open sites and found that 69 percent of natural and artificial nests were depredated by armadillos. Armadillos have the potential to negatively impact gopher tortoise populations if they are an additive source of nest predation, but additional information is needed to evaluate the potential impact of this species on gopher tortoise populations across their range.

Other invasive species that may negatively impact tortoises include the Argentine black and white tegu (*Salvator merianae*), Burmese python (*Python bivittatus*), and black spiny-tailed iguana (*Ctenosaura similis*). Breeding populations of these species are currently restricted to parts of southern and peninsular Florida (Engeman et al. 2011, p. 602, 605, 607), though tegus have recently established a new population in Southeastern Georgia (Haro et al. 2020, entire). Tegus and Burmese pythons have been occasionally found farther north, including recent sightings of numerous tegus in South Carolina (Andrew Grosse, South Carolina DNR, personal communication); Burmese pythons have been found as north as South Georgia (EDDMapS.com) though this individual was likely an escaped or released pet and not part of a breeding population. All three species have been observed using tortoise burrows (Engeman et al. 2009, p. 84; Engeman et al. 2011, p. 607; Bartoszek et al. 2018, pp. 353-354); Burmese pythons have also been observed in breeding aggregations and laying eggs within burrows (Bartoszek et al. 2018, pp. 353-354), though pythons were not documented depredating gopher tortoises in this study. Tegus and spiny-tailed iguanas are documented predators of tortoise eggs and/or juvenile tortoises (Avery et al. 2009, p. 435; Johnson and McGarrity 2017, p. 1; Offner 2017, pp. 56-57). Because of the limited current range of these species and inconsistent results predicting the potential for range expansion (Engeman et al. 2011, p. 602; Goetz et al. 2021, entire), it is unknown the extent of impact these species may have on gopher tortoise populations. New regulations in Florida (F.A.C. 68-5), Alabama (Regulation 220-2-.26), and South Carolina (Regulation123-152(A)) are being implemented to limit possession of black and white tegus to prevent the establishment of tegus in the wild. Therefore, the current threat of these species on gopher tortoise appears low in comparison to other threats.

There are additional non-native faunal species that may depredate tortoises, damage burrows, and/or degrade tortoise habitat, such as the wild pig (*Sus scrofa*), domestic dog (*Canis lupus familiaris*), and possibly domestic cat (*Felis catus*). Frequent damage to burrows could result in increased stress and eventual burrow abandonment by the tortoise. All three of these non-natives are found across the Southeast, but limited data are available to quantify their impacts on tortoise populations. Additional research is needed to determine if these non-native fauna are negatively impacting tortoise populations, and if so, to quantify the extent of this impact.

3.8. Habitat Management

During a workshop on gopher tortoise conservation at the Joseph W. Jones Ecological Research Center in Georgia in 2003, 30 invitees from 6 states ranked habitat destruction and lack of habitat management (e.g., no prescribed fire program) as the top two major threats to the gopher tortoise (Smith et al. 2006, pp. 326-327). Gopher tortoise habitat is maintained via periodic fire. High quality gopher tortoise habitat will only require prescribed fire at regular intervals for natural community maintenance. Areas of degraded gopher tortoise habitat (e.g., areas with little or no fire) require active habitat management, frequently requiring multiple habitat management tools (mechanical and chemical treatments) in conjunction with the reintroduction of prescribed fire to restore natural conditions. However, not all habitat management activities are uniformly beneficial to the species. In general, management actions that minimize soil disturbance, protect burrows, and maintain a diversity of groundcover plants by ensuring that sufficient sunlight reaches the ground are beneficial. Conversely, actions that cause significant soil disturbances or result in the loss of diverse groundcover are detrimental. Additionally, the lack of habitat management or infrequent management is also detrimental. Prescribed fire, selective use of herbicide, mechanical vegetation management (e.g., roller chopping and mowing), and timber harvesting are valuable management techniques in the restoration, management, and maintenance of gopher tortoise habitat and are frequently used in combination.

Heavy equipment is routinely used to manage gopher tortoise habitat occurring on public and private lands throughout the species range. Heavy equipment is utilized in activities such as site preparation, reforestation, restoration, prescribed fire, herbicide applications, and harvest operations (timber, pine straw, etc.). In addition to direct impacts to adult and juvenile tortoises and eggs as a result of crushing, heavy equipment can occlude burrows or cause burrow collapse. Several occasions of direct mortality from heavy equipment have been reported (Landers and Buckner 1981, pp. 1-7). Entombment from burrow collapse or occlusion was historically perceived as a threat, however numerous studies have documented survival and self-excavation by tortoises in collapsed burrows (Landers and Buckner 1981, pp. 1-7; Diemer and Moler 1982, pp. 634-637; Diemer 1992b, p. 163; Mendonca et al. 2007, pp. 3-4; Wester and Kolb 2008, pp. 505-507). No significant differences in home range sizes, number of burrows used, or movement patterns between pre and post burrow collapse were found in one study (Mendonca et al. 2007, pp. 19–21). However, they did suggest potential negative effects of burrow collapse depending upon time of collapse which may include decrease in mating opportunities and potential for gravid females to be unable to deposit eggs in suitable locations. While more information is needed, heavy machinery likely presents risks to gopher tortoise eggs and juveniles, as they are more difficult to detect and therefore more difficult to avoid (Greene et al. 2020, p. 54). A study to experimentally address the distance at which heavy equipment might collapse burrows found that on average, machinery could be operated within approximately 3 m without causing damage. This is important because forest management, including application of prescribed fire, requires operation of a variety of vehicles and heavy equipment. Increasingly, land managers are incorporating best practices into their management plans, including a buffer distance around burrows to minimize disturbance and hazards (Smith et al. 2015, pp. 459-460).

The habitat management methods discussed below are implemented to varying degrees across a variety of different land ownership and use types (e.g., conservation land, commercial forestry, family-owned lands, etc.).

3.8.1. Prescribed Fire

Historically, upland areas commonly associated with gopher tortoises were maintained by frequent, lightning-generated fires, with peak lightning ignition occurring during the growing season, spring to early summer (Knapp et al. 2009, p. 3). Additionally, Native Americans and later, early colonial settlers often burned areas in the winter, fall or late summer for specific purposes or desired effects (Fowler and Konopik 2007, pp. 165-166). While there is uncertainty regarding natural burn regimes among various cover types and along environmental gradients, fire return frequencies throughout the gopher tortoise range are estimated to range between two and six years (Guyette et al. 2012, p. 330). Anthropogenic use of fire has likely been occurring for at least 10,000 years in the Southeastern United States through the early 1900s, when the practice of fire suppression became prevalent on the landscape. Fire suppression resulted in fire being mostly absent on public lands until the 1980s, however some private working lands (farming, grazing, logging) remained managed with fire (Fowler and Konopik 2007, p. 171).

Loss and alteration of gopher tortoise habitat from fire exclusion or fire suppression has a significant effect on survival of gopher tortoises (Boglioli et al. 2000, p. 704). Although burning has generally been accepted as a primary management tool, increased urbanization limits its use in many locations (Ashton and Ashton 2008, p. 78) due to concerns for safety, particularly as it relates to smoke management. Urban sprawl can fragment habitat that supports tortoise populations, and in many areas, complicates the logistics of performing adequate and seasonally appropriate burns, further straining staff and budget resources. Human health and safety issues increasingly complicate fire management as human population grows in an area, resulting in narrow windows of opportunity to implement prescribed fire due to the required parameters (for example: weather, site specifics) for a safe burn. Because of this, many areas of habitat remain unburned each year and without other habitat management, further succeed into unsuitable conditions, hindering the viability of gopher tortoise populations (Kupfer at al. 2020, p. 765).

Many Southeastern pine forests have dense canopies, a high prevalence of mid-canopy shrubs, and suppressed or absent herbaceous ground cover due to fire exclusion (Yager et al. 2007, p. 428). Several studies have reported the direct effect to gopher tortoise populations from fire suppression. Gopher tortoise population life expectancy declined in fire-suppressed savanna communities (Auffenberg and Iverson 1979, p. 562). Gopher tortoise population reduction has been observed to be directly correlated with the degree and rate of successional habitat modification (Auffenberg and Iverson 1979, p. 562). Fire exclusion was observed to reduce a gopher tortoise population by 100 percent in 16 years (Auffenberg and Franz 1982, p. 108). In south-central Florida, sandhill and scrubby flatwoods were abandoned by gopher tortoises after about 20 years of fire exclusion (Ashton et al. 2008, p. 528). However, other types of management actions (e.g., mechanical and chemical treatments) may offset, or slow habitat degradation caused by fire suppression.

The regular application of prescribed fire is critical for the maintenance of habitat conditions required by the gopher tortoise. When applied at appropriate intervals, prescribed fire reduces shrub and hardwood encroachment, and stimulates growth of forage plants such as grasses, forbs, and legumes (Thaxton and Platt 2006, p. 1336). The physical result of fire to tree and shrub species in most cases, reduces canopy cover and creates more light gaps allowing greater sunlight penetration to the ground (Iglay et al. 2014, pp. 39–40). This promotes establishment and maintenance of understory herbaceous forage and is also important for basking and proper gopher tortoise egg incubation. Prescribed fire during the growing season often produces a more beneficial response in the herbaceous layer than dormant season fire (Fill et al. 2017, pp. 156–157). Growing season fire stimulates flowering in many grasses, increases species diversity among understory plants, and result in higher understory biomass production (FWC 2007, p. 32). Although the growing season was historically the primary season for natural lightning-strike fires, variability in fire season, intensity, and frequency may be important to maintaining herbaceous species diversity (FNAI 2010, p. 43).

Periodic burning or shrub removal can increase gopher tortoise carrying capacity (Stewart et al. 1993, p. 79). Mixed stands of longleaf pine, turkey oak, and other scrub oaks that were burned every 2 to 4 years have been found to produce high densities of gopher tortoises (Landers 1980, p. 7). In south-central Florida, tortoises moved into areas that were frequently burned and abandoned areas that were unburned or burned less frequently (Ashton et al. 2008, p. 527). Burned areas have been found to have more herbaceous ground cover and gopher tortoises than in unburned oak-palmetto (Breininger et al. 1994, p. 63). Burned pine stands and longleaf pine scrub oak ridges had nest densities four times higher than in unburned pine stands and ridges in one study (Landers and Buckner 1981, p. 5). Herbaceous ground cover was found to be 2.3 times higher and gopher tortoise density was 3.1 times higher in a frequently burned slash pine plantation compared to an adjacent unburned natural sandhill area (Landers and Speake 1980, p. 518).

On sites with advanced hardwood encroachment, prescribed fire alone may be insufficient in reducing the coverage of undesirable vegetation. Mechanical or chemical treatments are frequently utilized to reduce hardwood competition to levels where prescribed fire can be effective (Greene et al. 2020, p. 50). In addition to use in augmenting a prescribed fire program, these management techniques are increasingly important for areas where prescribed fire use is not a viable option, such as habitat in urbanized areas (Ashton and Ashton 2008, p. 78).

3.8.2. Herbicide Applications

The application of herbicide is a vegetation management tool utilized by some land managers to control unwanted/undesired vegetation, often in combination with mechanical or prescribed fire or when prescribed fire cannot be used. Herbicide may also be required in conjunction with fire, to effectively eradicate infestations of highly invasive species such as cogongrass (Sellers et al. 2018, p. 3) or mid-story overgrowth of drought resistant woody vegetation.

In gopher tortoise habitat, the type of herbicide and rate and method of application should be selected to target shrub and hardwood species with minimal impacts to nontarget plant species, especially herbaceous groundcover vegetation utilized by gopher tortoises. In managed forests, herbicide is used to suppress shrub and hardwood mid-story growth to reduce competition to planted trees or stimulate desired growth of planted trees at critical periods. Fire is often used in conjunction with herbicide treatment on private working forest lands (Miller and Chamberlain 2008, pp. 776-777; Jones et al. 2009, p. 1168, Iglay et al. 2013, p. 40; Platt et al. 2015, p. 913), especially for site preparation purposes. According to a survey of 30 private landowners, herbicide is the most common management tool in the Southeast on production timber forests (Lang et al. 2016, p. 21). Herbicide is also consistently used in public land management and to maintain utility rights-of-way, often in combination with mowing or brush-hogging, which can provide suitable conditions or dispersal corridors for gopher tortoises.

Targeted herbicide application likely has less of a direct impact to gopher tortoises than broadcast spraying, where overspray is a risk. However, no information is available on the direct adverse effects to gopher tortoises, and herbicides used for gopher tortoise habitat management are generally not toxic to wildlife when applied in accordance with label specifications. The main threat from broadcast spraying is over-application using a broad-spectrum chemical, which can kill a significant amount of gopher tortoise forage where populations occur. Cut-and-squirt methods or direct injection into unwanted shrubs or trees is also an effective and less invasive, though more labor-intensive method, of herbicide application. When used carefully, herbicide is another tool for use in the management of gopher tortoise habitat.

Rates and concentrations of herbicide application vary considerably throughout the range of the gopher tortoise and outcomes are often dependent on environmental factors. The primary purpose of herbicide application varies as well, as it is used in many industries such as production forests, agriculture, restoration, and property maintenance. Research has shown that herbaceous groundcover can be maintained and enhanced through targeted and selective herbicide treatment, especially when used in conjunction with prescribed fire (Miller and Chamberlain 2008, pp. 776-777; Jones et al. 2009, p. 1168, Iglay et al. 2013, p. 40; Platt et al. 2015, p. 913). Herbicide can reduce mid-story vegetation growth resulting in more sunlight reaching the ground. In addition, a more open canopy and mid-story allows for proper incubation of eggs and thermal regulation (basking) of tortoises. More research is needed concerning herbicides’ direct and indirect effects (short and long term) on gopher tortoise populations.

3.8.3. Mechanical Vegetation Management

Habitat management using mechanical means can be effective in reducing shrub and tree density to promote conditions favorable to herbaceous vegetation. Mechanical treatments are used in habitat restoration, site preparation to promote pine seedling survival and growth, maintenance, and in other agricultural and forestry endeavors. Mechanical vegetation management examples include mulching/chipping, subsoiling, shearing, stumping, root raking into piles or windrows, roller chopping, discing, and bedding. Depending on management objectives and treatment type, mechanical site preparation may result in substantial soil disturbance, affecting soil structure and chemistry and may increase invasive species on a site (Hobbs and Huenneke 1992, pp. 324–325, Jack and McIntyre 2017, p. 189). Careful and systematic cleaning of all mechanical equipment before and after use at every site can reduce the likelihood of spreading seeds of invasive plant species and are often incorporated into best management practices employed by managers (Miller et al. 2010, pp. 10–11). Some of the more intensive mechanical soil-disturbing practices utilized on some silvicultural sites include discing and bedding. While these activities do occur in gopher tortoise habitat, they tend to occur more so on wetter sites that are less suitable for gopher tortoises. Shearing and roller chopping are more common mechanical treatments used in restoration and for site preparation in areas likely to be used by gopher tortoises (Jack and McIntyre 2017, p. 200).

Because sandy and sandy-loam soils are much more erodible and mechanical site prep costs are increasing, herbicides are increasingly replacing mechanical site preparation on working forest lands in some areas. Mechanical vegetation management may be short-term option to maintain habitat in areas where fire use is restricted. Although mechanical vegetation management is effective in reducing the vertical structure and overgrowth in the mid and overstories, it is not an exact surrogate to fire in that mechanical treatments alone do not replicate the stimulation of plant growth, flowering and seed release, and soil nutrient cycling (Dean et al. 2015, pp. 55-56) provided by fire. In addition, mechanical treatments that are not followed up with herbicide applications and/or prescribed fire often result in more dense regrowth of hardwood or shrub species originally targeted for control. While empirical data on effects of mechanical vegetation management practices on gopher tortoise populations is largely lacking, best conservation practices (FDACS 2012, entire; FWC 2013, entire; USFWS 2013, entire; GDNR 2014, entire; FDACS 20115, entire) are available and are increasingly utilized by landowners and managers when using mechanical treatments (Jack and McIntyre 2017, p. 200).

Care should be taken in certain cover types where the gopher tortoise is known to occur. For example, in scrub, mechanical vegetation management is the only way to reset late successional conditions without burning under extreme wildfire conditions. However, scrub habitat is sensitive to soil disturbance and excessive soil disturbance may permanently alter it. Low ground pressure mulching equipment can be used to reduce above ground vegetation; however, care needs to be taken to leave the vegetation in a state where it can be consumed during prescribed burning. If vegetative material is mulched too fine or too much time elapses between mulching and burning, the material may not burn and may alter the soil and enhance conditions for invasive plant species (Hobbs and Huenneke 1992, pp. 324–325, Jack and McIntyre 2017, p. 189). While soil disturbance in scrub may permanently alter conditions, in the case of fire suppressed scrub, strategically creating sandy openings through mechanical soil disturbance may be necessary to create a matrix of open areas when coppicing fire adapted plants create a dense low overstory (S. Howarter, Service Biologist, comment submitted during review, 2021).

3.8.4. Timber Management

Not all forested lands provide appropriate conditions for gopher tortoises. However, on land with suitable soils and depending on forest management objectives, forests may provide the open canopy and the dense herbaceous groundcover conditions needed for gopher tortoise viability. . Several management goals are shared between timber and gopher tortoise habitat management. For example, reduction of hardwood competition is advantageous for the management of pine production and gopher tortoises because it favors pine survival and growth while allowing increased opportunity for sunlight to reach the ground, promoting herbaceous forage proliferation and suitable conditions for gopher tortoise basking and egg incubation (NRCS 2020, entire). Several management practices associated with working forests such as planting densities, age of stand, time until first and subsequent thinning(s), have a direct influence on whether these lands provide and maintain habitat for the species.

In slash pine plantations in Alabama, tortoise burrows were found in areas with the most open canopy. Burrow abandonment averaged 22 percent annually and abandoned burrows were associated with canopy closure, higher hardwood midstory, higher tree density and higher basal area (Aresco and Guyer 1999b, p. 32). Gopher tortoises more frequently abandoned burrows and emigrated from poor habitat conditions associated with closed canopy pines plantations (Diemer 1992a, p. 288; Aresco and Guyer 1999b, p. 32). Gopher tortoises often persist in pine plantations (slash and loblolly) at lower densities than reported in other cover types, and densities may be below the threshold necessary to sustain a viable population (Wigley et al. 2012, p. 42). Closed canopy conditions do not sustain gopher tortoises. A wide range of silvicultural practices influence canopy. Even-aged regeneration harvests often used in pine management provide abundant sunlight to stimulate groundcover vegetation establishment and growth. However, benefits are ephemeral as reforested areas grow and develop closed canopy conditions that shade groundcover (Greene et al. 2019, p. 203).

Most modern production forests incorporate management strategies to maintain open canopy conditions for the majority of a commercial stand's life. Reforestation at lower seedling densities can extend the interval to canopy closure. Pre-commercial and commercial thinning operations reduce canopy coverage and favors conditions that can support increased groundcover development. Recognizing that stand growth and development include periods of higher than preferred canopy cover, yet minimizing the duration of closed canopy conditions, is important not only to gopher tortoises but also commercial forests. Additionally, landscape considerations that provide for a matrix of structural conditions and connectivity or corridors linking gopher tortoise habitat are important to sustain populations in areas with production pine objectives. A National Council for Air and Stream Improvement (NCASI Inc.) survey of Member Companies revealed that open pine conditions are maintained over 47.2 percent of the life of a stand rotation (Weatherford et al. 2020, p. 4). Open pine in the above survey were limited to upland, xeric or mesic, pine dominated sites as coded by the USDA's Forest Inventory and Analysis program, further, open canopy was based on descriptions in Nordman et al. (2016, pp. 57–58), and Greene et al. (2019, p. 204).

Privately owned production pine forests are a dominant land use within the range of the gopher tortoise. Gopher tortoise persistence has been documented when suitable conditions occur on production pine forests (Diemer-Berish et al. 2012, pp. 51-52; Greene et al. 2019, p. 51). One study demonstrated positive responses in life history parameters four years following a clearcut on a pine plantation in northern Florida (Diemer-Berish and Moore 1993, p. 426). Most commercial timber operations grow loblolly or slash pine, rather than longleaf pine. Gopher tortoises may exploit appropriate stand conditions and other habitat characteristics, such as, stand structure conditions (e.g., basal area; overstory and midstory canopy closure) or suitable soil (Greene et al. 2020, pp. 52-53; Wigley et al 2012, p. 43), rather than a particular tree species. Common practices used in operational forestry such as stand establishment, thinning, and mid-rotation management can create similar structural conditions to fire-maintained conditions (NRCS 2020, p. 20). However, more information is needed, as there is no uniform method for tracking gopher tortoise activity on private lands. Additional research is needed to understand how management can further improve conditions, especially given the large area of private, working forests within gopher tortoise range. While some information regarding gopher tortoises is available (discussed in section 3.9.9), systematic surveys in managed forests across the range of the gopher tortoise are needed to properly assess populations on these lands and to allow for a more holistic assessment of the species range wide.

Contemporary management practices on private working lands have evolved in response to market demands that require conservation of biological diversity. Furthermore, development of diversified markets for forest products has increased forest management practices that benefit gopher tortoises (Greene et al. 2020, p. 55). Many corporate and non-corporate private landowners manage to high conservation standards to meet their objectives and in some cases to maintain important forest certifications such as Sustainable Forestry Initiative (SFI) or Forest Stewardship Council certification. Thinning and planting at lower densities, using herbicides to reduce midstory vegetation, and harvesting at an older stand age are more commonly used and provide vegetation conditions that gopher tortoises can occur and persist (Greene et al. 2019, p. 201; Greene et al. 2020, p. 55).

However, not all lands, public or private, are managed to these standards, and detrimental practices and lack of management continue to affect gopher tortoise habitat. Nearly complete groundcover weed control during site preparation or release treatments degrade habitat by removing forage plants. High seedling stocking rates quickly shade groundcover. Short timber rotations with a minimal proportion of the rotation being open canopied is problematic in that this practice may result in excessive shading, suppressed groundcover vegetation, and generally unsuitable conditions for gopher tortoises. Exclusion of prescribed fire and dense hardwood midstory encroachment within open canopied forests degrade habitat through suppression of groundcover and loss of open areas for burrowing and movement.

While we cannot quantify the extent to which detrimental practices occur and while these may not be practices utilized on certified forests, there is likely some percentage of habitat that has been impacted by these practices and therefore has influenced gopher tortoise viability. While we cannot account for all land management practices, there has been significant progress made between private landowners and conservation agencies, such as best conservation practices for gopher tortoises developed by states, and conservation incentive programs and partnerships that promote compatibility between timber and gopher tortoise management.

3.9. Conservation Measures

3.9.1. Federal and State Protections and Conservation

This section includes discussions of key protections and conservation efforts provided by various federal and state entities.

Federal

Natural Resources Conservation Service (NRCS)

The NRCS offers technical and financial assistance to help agricultural producers voluntarily conserve gopher tortoise habitat on private lands. This assistance helps producers plan and implement conservation activities and practices that provide benefits to several species, including the gopher tortoise while balancing conservation practices with natural resource and production goals.

The gopher tortoise is a nationally identified target species of the Working Lands for Wildlife (WLFW) partnership, which is a collaborative approach to conserving habitat on working lands. The NRCS works to restore longleaf pine across its historical range through the Longleaf Pine Initiative (LLPI). Additionally, NRCS conservation practices that benefit gopher tortoises include prescribed fire, forest stand improvements, herbicide applications, and brush management (NRCS 2020, pp. 22-23). Since 2012, NRCS has certified 943,740 acres (378,276 ha) in which private landowners have received assistance to implement management practices that benefit gopher tortoises and gopher tortoise habitat (Table 3.2). The WLFW program focused on promoting increased use of prescribed fire, improving vegetation management, re-establishing longleaf forests, supporting prescribed grazing management, and protecting existing quality habitat to benefit gopher tortoises across the range of the species (NRCS 2018, p. 1).

Table 3. 2-Gopher Tortoise Project Boundary: WLFW and LLPI Totals by Practice and Year. Data submitted by NRCS.

	Sum of Certified Acres by Year								
Practice and Priority	Sum of 2012	Sum of 2013	Sum of 2014	Sum of 2015	Sum of 2016	Sum of 2017	Sum of 2018	Sum of 2019	PRACTICE SUMS
Core Practices	**8,371.0**	**52,245.8**	**79,935.7**	**34,466.3**	**20,767.8**	**5,062.4**	**6,897.4**	**5,490.8**	**213,237.2**
Gopher Tortoise	**3,507.0**	**49,873.0**	**79,749.7**	**34,269.5**	**20,552.4**	**3,896.7**	**6,742.8**	**3,975.2**	**202,566.3**
Early Successional Habitat Development-Mgt	110.0	1,459.7	1,605.4	1,924.6	3,084.0	100.4	390.7	36.0	8,710.8
Restoration of Rare or Declining Natural Communities	1,781.3	7,396.9	11,057.0	4,936.3	5,368.9	1,178.3	672.3	37.0	32,428.0
Upland Wildlife Habitat Management	1,615.7	41,016.4	67,087.3	27,408.6	12,099.5	2,618.0	5,679.8	3,902.2	161,427.5
Longleaf Pine	**4,864.0**	**2,372.8**	**186.0**	**196.8**	**215.4**	**1,165.7**	**154.6**	**1,515.6**	10,670.9
Early Successional Habitat Development-Mgt	12.2	43.5	115.5	70.8	165.4	1,165.7	101.1	736.0	2,410.2
Restoration of Rare or Declining Natural Communities	4,788.4	2,312.3	37.0	59.0	0.0	0.0	40.0	0.0	7,236.7
Upland Wildlife Habitat Management	63.4	17.0	33.5	67.0	50.0	0.0	13.5	779.6	1,024.0
Supporting Practices	**35,548.6**	**86,491.5**	**98,111.2**	**84,904.3**	**76,495.7**	**95,342.5**	**119,531.7**	**134,077.5**	**730,503.0**
Gopher Tortoise	**12,009.9**	**68,810.3**	**74,879.2**	**48,179.6**	**47,051.8**	**55,407.8**	**72,806.5**	**81,932.1**	**461,077.2**
Brush Management	866.3	2,041.2	3,963.0	3,064.8	2,333.3	2,071.8	870.9	2,652.8	17,864.1
Forest Stand Improvement	5,653.7	7,356.4	4,567.4	4,751.0	5,436.8	5,010.7	3,823.6	6,815.9	43,415.5
Herbaceous Weed Treatment	1,224.2	2,410.2	3,875.9	3,518.1	921.2	2,465.1	3,320.8	3,417.8	21,153.3
Prescribed Burning	3,171.9	47,779.2	50,089.4	29,629.3	32,532.4	38,325.9	53,349.1	53,235.7	308,112.9
Prescribed Grazing	0.0	0.0	0.0	636.3	1,219.4	3,859.5	5,428.3	11,327.7	22,471.2
Tree/Shrub Establishment	1,093.8	9,223.3	12,383.5	6,580.1	4,608.7	3,674.8	6,013.8	4,482.2	48,060.2
Longleaf Pine	**23,538.7**	**17,681.2**	**23,232.0**	**36,724.7**	**29,443.9**	**39,934.7**	**46,725.2**	**52,145.4**	**269,425.8**
Brush Management	155.5	455.4	671.2	2,309.9	231.9	348.1	207.6	270.0	4,649.6
Forest Stand Improvement	447.5	29.0	267.9	1,019.1	830.6	406.1	1,022.3	1,414.4	5,436.9
Herbaceous Weed Treatment	240.8	487.7	1,366.6	1,226.3	1,717.1	1,968.1	3,283.6	4,682.2	14,972.4
Prescribed Burning	12,194.6	11,066.2	11,765.1	17,514.7	17,932.4	22,097.7	24,542.6	26,221.2	143,334.5
Tree/Shrub Establishment	10,500.3	5,642.9	9,161.2	14,654.7	8,731.9	15,114.7	17,669.1	19,557.6	101,032.4
Grand Total	**43,919.6**	**138,737.3**	**178,046.9**	**119,370.6**	**97,263.5**	**100,404.9**	**126,429.1**	**139,568.3**	**943,740.2**

U.S. Fish and Wildlife Service

The gopher tortoise population located west of the Tombigbee and Mobile Rivers in Alabama was federally listed as Threatened by the Service in 1987. Subsequently, the Service finalized a Recovery Plan (Service 1990, entire) which delineated actions required to recover and/or protect the species. The two primary objectives of the recovery plan were to prevent the listed population from becoming endangered and a long-term objective of delisting.

Sections 7 and 10 of the Act establish processes that allow the Service to review federal and non-federal actions that will affect species listed as endangered or threatened under the Act, and to provide exemptions to prohibitions outlined in section 9(a) of the Act. Section 7(a)(1) requires the Service to review programs administered and to utilize such programs in furtherance of the purposes of the Act. Section 7(a)(1) also requires all other federal agencies to implement programs for the conservation of listed species. Section 7(a)(2) requires that federal agencies consult with the Service to ensure that their actions are not likely to jeopardize the continued existence of listed species and are not likely to result in the destruction or adverse modification of designated critical habitat for listed species.

Section 10 of the Act allows a non-federal party to apply for and obtain a permit that authorizes the incidental take of federally listed wildlife or fish, subject to the development of a conservation plan. The Act defines incidental take as "[take that] is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity." Section 10(a)(1)(A) of the Act authorizes the Service to develop a Safe Harbor Agreement with an interested party and issue a permit to enhance the propagation or survival of a listed species. The Service must determine that the conservation measures to be implemented throughout the agreement will contribute to recovering the species by providing a net conservation benefit. Section 10(a)(1)(B) of the Act allows an applicant to apply for and obtain an incidental take permit for a listed species. Preparing a conservation plan, generally referred to as a Habitat Conservation Plan, is required for all Section 10(a)(1)(B) permits. Conservation plans developed for all section 10 incidental take permits must meet Service issuance criteria (50 CFR 17.22 and 50 CFR 17.32).

Recognizing that many species may spend at least part of their life cycle on non-federal lands, the Service implements conservation delivery tools and programs that aid in the conservation of listed and at-risk species, such as the gopher tortoise, on non-federal lands. The Cooperative Endangered Species Conservation Fund (Section 6) is a tool that provides grants to states to participate in a wide array of voluntary conservation projects for candidate, proposed, and listed species. Additionally, cooperative conservation programs such as the Safe Harbor Program and the Partners for Fish and Wildlife Program provide technical and financial assistance to private landowners and others for the conservation of wildlife and associated habitat. Partners for Fish and Wildlife Program projects implemented on private lands include landowner agreements terms ranging from 10 to 30 years depending on state and project specifics. Between 2010 and 2019, under the Partners for Fish and Wildlife Program, approximately 65,000 acres (26,305 ha) of restoration and enhancement activities were implemented in gopher tortoise habitat occurring on private lands in Alabama, Florida, Georgia, and Mississippi (Service 2020, unpaginated).

State Listing Protections

Each state within the historical range of the gopher tortoise provides some measure of protection for the species. The gopher tortoise is protected by regulation as a non-game species in Alabama, is state listed as threatened in Florida, Georgia, and Louisiana and is state listed as endangered in Mississippi and South Carolina. Gopher tortoise protections vary by state, however, laws within most states focus on prohibitions against the take, possession, export/sale, and killing of gopher tortoises. Alabama, Florida, Georgia, and Mississippi include specific prohibitions against gassing of wildlife burrows, including those of the gopher tortoise. South Carolina has prohibitions on the take of gopher tortoises and gopher tortoise burrows.

In Florida, through the Landowner Assistance Program, the FWC assists private landowners with plans to improve their wildlife habitat. In fiscal year 2017-2018, a typical planning year, this program planned beneficial management activities on 44,158 acres (17,870 ha) of gopher tortoise habitat in 34 Florida counties (FWC 2020a, p. 6). This program prepares 10-year plans for private land management activities and updates these plans on a 10-year interval. Over the next ten years, the FWC estimates that more than 440,000 acres (178,061 ha) of gopher tortoise habitat will have been managed with assistance from Landowner Assistance Program planning efforts(FWC 2020a, p.6).

3.9.2. Florida Gopher Tortoise Management Plan and Permitting Guidelines

Florida has developed a management plan and permitting guidelines to guide gopher tortoise recovery efforts. The primary goal of the Gopher Tortoise Management Plan (FWC 2007, revised 2012, entire) is to identify and conserve gopher tortoise populations through the implementation of conservation actions that include minimizing loss of tortoises, gopher tortoise population restoration and enhancement, and increasing and improving gopher tortoise habitat. While relocation activities (discussed below) are conducted in other states, Florida has also developed Gopher Tortoise Permitting Guidelines (FWC 2008, revised July 2020; entire) that direct regulatory actions, including mitigation, habitat management, and habitat acquisition objectives. Florida's regulations require that take of tortoises be authorized by a FWC permit and that the impacts be considered and mitigated.

3.9.3. Relocation, Translocation, Recipient Sites, and Headstarting

Relocation is the intentional movement of individuals to another location within its home range, or more frequently described as within the same site. Translocation describes the intentional capture and transfer of individuals (or groups of individuals) from one location to another. Gopher tortoises have been considered one of the most translocated species in the Southeast U.S. (Dodd and Seigel 1991, p. 340) and translocation is commonly used as a conservation strategy to mitigate the loss of tortoises from land slated for development. These displaced tortoises are often translocated to reestablish extirpated populations or augment existing populations (Griffith et al. 1989; p. 477). Due to its use for conservation, numerous studies have sought to evaluate the success of gopher tortoise translocation and improve its efficacy. However, tortoises are long lived, slow-growing, and are slow to reach maturity, making it difficult to determine if translocations result in viable tortoise populations without long-term monitoring.

Measures of translocation success in scientific literature include high site fidelity and survival rates as retention of tortoises on-site is imperative to establishment of stable populations. A population viability model for translocated tortoises concluded 90 percent annual retention of tortoises would be necessary to stabilize a translocated population (Siegel and Dodd 2000, p. 222). However, this model assumed retention rates were constant over time, which conflicts with findings in research studies. Emigration from recipient areas is high within the first-year post-translocation (Lohoefener and Lohmeier 1986, pp. 37-40; Burke 1989, p. 299; Diemer 1989, p. 2; Mushinsky et al. 2006, p. 366), but appears to decline over time (73 percent retention in first year following translocation; 92-100 percent retention 2-17 years post-translocation; Ashton and Burke 2007, p. 785). Apparent survival was found to be reduced the first 1-2 years post-translocation, but high in subsequent years; reduced apparent survival immediately post-translocation was primarily attributed to dispersal rather than mortality (Tuberville et al. 2008, pp. 2694-2695). High dispersal rates may be due to larger home ranges and greater long-distance movements post-translocation (Tuberville et al. 2005, p. 353; Bauder et al. 2014, p. 1449); these movements could relate to disorientation, attempts to return to their original home range, or exploration of their new environment (Bauder et al. 2014, p. 1450). Soft-release, or the temporary penning of gopher tortoises within a recipient area, is highly effective at limiting dispersal post-translocation. One study found a 76.9 percent dispersal rate when tortoises were not penned, a 38.5 percent dispersal rate when tortoises were penned for 9 months, and only an 8.3 percent dispersal rate when tortoises were penned for 12 months (Tuberville et al. 2005, p. 354).

Several considerations have been suggested to improve translocation success, such as: know and accommodate the biological constraints of the species, understand genetic factors, and minimize the risk of disease transmission (Dodd and Seigel 1991, pp. 344-346). Tortoise density and habitat condition should also be considered to ensure recipient sites provide sufficient space for foraging, reproduction, cover, and social interaction (Dodd and Seigel 1991, pp. 344-346). It has been recommended that relocations be conducted when: they are economically and logistically justified, have a high probability of success, include at least 100 individual tortoises, occur in areas of high-quality habitat, and take place where habitat management will occur after translocation (Ashton and Burke 2007, p. 786). Concerning disease transmission, it is recommended to not relocate tortoises showing clinical signs of disease and ensuring protection and management of recipient sites (Mushinsky et al. 2006, p. 369).

Studies have also sought to evaluate the impacts of translocation on body weight and habitat selection (Riedl et al. 2008, entire; Bauder et al. 2014, entire), disease risk and transmission (Hernandez et al. 2010, entire; Cozad et al. 2020, entire), translocation of tortoises to different latitudinal ranges (DeGregorio et al. 2012, entire; McKee et al. 2021, entire), mating systems (Tuberville et al. 2011, entire), social structure (Schulte 2020, entire), and interactions with resident populations (Riedl et al. 2008, entire).

While translocation is successful at removing tortoises from immediate danger due to development, there are still uncertainties about its efficacy. Additional research is needed to inform improvements to translocation methodology and may include: evaluating the efficacy and improvements to release methodology, the effect of habitat quality and size of resident populations on site fidelity of translocated animals, the relationship between cover type and quality on suitable site stocking densities, initial mortality rates post-translocation, disease risk, and long-term population demography of translocated populations (Tuberville et al. 2005, p. 356; Tuberville et al. 2008, p. 2695).

Gopher tortoise relocation and translocation practices are being implemented and included as regulatory agency guidance (Ginger 2010, personal communication; Service 2019 (84 FR 54732 54757)) in both the western and eastern portions of the range. The primary goals for recipient sites are to help prevent the loss of tortoises and retain the local or regional tortoise resource; and while habitat is lost on the development site, recipient sites can contribute to habitat conservation if sites receive long-term protection and subsequent habitat management. These sites can provide high conservation value by restocking tortoises to appropriately suitable lands where populations have previously been depleted. However, this practice could result in an overall net loss of habitat if not implemented in conjunction with acquisition and additional protection of habitat.

Florida's gopher tortoise permitting program includes the largest scale use of relocation and translocation practices in the range. When possible, FWC permits on-site relocation of tortoises to areas within the property boundaries of development sites, if an appropriate quantity and quality of habitat will be retained within the site boundary; this is part of an effort to retain the local populations of gopher tortoise in these areas. When habitat will not be retained on-site, tortoises are translocated to FWC-approved recipient sites. As of December 9, 2019, the FWC has permitted 39 long-term protected recipient sites (these sites are encumbered under a perpetual conservation easement that requires active management to ensure tortoise habitat suitability) comprising greater than 41,700 acres (16,875 ha), over 23,000 acres (9,308 ha) of which are permitted as gopher tortoise habitat. As of April 23, 2021, there is space for approximately 14,400 gopher tortoises available across long-term and short-term protected permitted recipient sites in Florida. This number fluctuates as reservations are made or released and is subject to change as new sites are permitted, recipient sites reach capacity, or when action is taken in the event that a permitted site falls out of compliance. For example, there are currently (as of April 23, 2021) greater than 20 sites in the pre-application stage or pending review by the FWC for consideration as potential recipient sites. In addition to long-term and short-term protected recipient sites, Florida also has several incidental take permitted recipient sites, such as Eglin Air Force Base (AFB) and Nokuse Plantation. To date, Eglin AFB has received over 1,200 gopher tortoises. Eglin AFB has established a goal of relocating 6,000 tortoises to the base. To continue efforts of re-establishing tortoises in the Florida Panhandle and alleviate constraints on recipient site capacity for other gopher tortoise translocation needs in Florida, Eglin AFB will accept tortoises from solar development sites under a Memorandum of Agreement (MOA) with FWC executed in 2020. Other recipient site options in Florida include restocking of public conservation lands, waif (tortoises of unknown origin) recipient sites, and research recipient sites.

Several other states are currently considering projects or have ongoing efforts to translocate tortoises, providing benefit to the species. For example, there is an ongoing effort to restock gopher tortoises on public lands where they are currently depleted in South Carolina using waif gopher tortoises (McKee et al. 2021, entire). More than 180 adult gopher tortoises from across the species' range have been translocated to the Aiken Gopher Tortoise Heritage Preserve in South Carolina; the total gopher tortoise population is approximately 300 tortoises. A 600 acre (243 ha) parcel in Mobile County, AL was purchased to conserve tortoises and serve as a recipient site for tortoises displaced by Alabama Department of Transportation sponsored projects. With implementation of appropriate management, this site has the capacity to support an estimated population of 346 tortoises (Federal Highways Administration 2010, p. 1). In Alabama, a plan will be developed for translocation and population augmentation with recommendations and protocol pertaining to donor and recipient sites.

In the western portion of the gopher tortoise's range, individual animals are typically translocated either to avoid mortality during land development activities or because they are considered waif tortoises by the state agencies and the Service (76 FR 45130). Tortoises suitable for these translocations include those brought in by the public, those that are reproductively isolated, or individuals determined to be in danger (e.g., crossing roads, burrows near road edges, etc.). At the time of capture, all waif tortoises and, for development projects, all tortoises at both the impact and relocation sites are evaluated to determine whether they have clinical signs of URTD through a physical examination and laboratory blood tests may also be completed. Tortoises that test positive for URTD antibodies are evaluated on a case-by case basis, but generally are not relocated to a URTD-negative tortoise population. Since some individual tortoises have tested seropositive and then tested seronegative upon re-testing months later (Wendland 2007, pp. 88-89), there are uncertainties about the utility of the testing protocol and whether impacts of translocation stress or seasonality play a role in affecting test results.

Headstarting, or the process of hatching and/or rearing juvenile turtles in captivity through their most vulnerable period (Spencer et al. 2017, p.1341) has shown success as a technique that could be used to boost depleted gopher tortoise populations (Holbrook et al. 2015, pp. 542-543; Tuberville et al. 2015, pp. 467-468; Quinn et al. 2018, p. 1552; Tuberville et al. 2021, p. 92). Headstarting turtles allows hatchlings to reach larger body size classes more quickly compared to their counterparts living under natural conditions, presumably making them less susceptible to predation (Heppell et al. 1996, p. 556; O'Brien et al. 2005, entire; Tuberville et al. 2021, p. 88). Natural predation rates of eggs and hatchling gopher tortoises are high (See section 3.6) and increasing survival of these life stages through headstarting or other measures could serve as a useful conservation tool. Eggs or hatchlings obtained from nests, when collected from robust populations, minimizes negative effects on donor populations (Quinn et al. 2018, p. 1554). The headstarting technique has historically garnered considerable controversy (Frazer 1992, entire; Seigel and Dodd 2000, entire; Burke 2015, entire), but there is increasing recognition of its potential role, particularly when used in concert with other management actions (Turtle Conservation Fund 2002, entire; Spencer et al. 2017, entire). Headstarting may be most beneficial to areas where gopher tortoise populations are severely depleted. However, headstarting is resource-intensive and can potentially pull limited resources away from land management activities or other conservation actions if implemented in areas with established populations or robust translocation and repatriation programs. Headstarting should be carefully considered, with specific conservation targets identified, prior to implementation.

Headstarting has only recently been explored as a management tool for the gopher tortoise. The gopher tortoise headstarting program at Camp Shelby in Forrest County, Mississippi (funded by the MS Army National Guard) has been ongoing since 2013 and is still active. It began as an experimental study to determine if tortoises could successfully be reared indoors for several years, and at what age they would reach a size that, when released, would have a high likelihood of survival (Holbrook et al. 2015, entire). These initial objectives have been met, as tortoises have successfully been reared indoors for several years with a very high (greater than 95 percent) survival rate; initial releases of 2- to 3-year old tortoises into the wild indicate that these juveniles have a much higher survival rate as well (70–80 percent versus some accounts of approximately 30 percent for wild 2- to 3-year old tortoises). Headstarted juveniles are often 2 to 3 times larger than wild cohorts. Plans for tortoises currently in the headstarting program will continue to be released into other areas within the installation where habitat has been restored and is either no longer occupied by tortoises or the tortoise population is lacking a juvenile size class. Due to the ongoing success of the Camp Shelby headstarting program, plans are now in development to expand the program into adjacent habitat located in DeSoto National Forest (M. Hinderliter 2021, Service, personal communication).

In Georgia and South Carolina, post release monitoring of head started yearling gopher tortoises opportunistically released at two protected sites has been reported (Tuberville et al. 2015, entire). Several years of the mark–recapture study revealed that head started gopher tortoises have the potential to experience post-release annual survival as high as 80 percent. A subsequent study used radiotelemetry to estimate survival and reported that 8- to 9-month head-started gopher tortoises exhibited 70 percent annual survival when predation risk during soft-release penning was mitigated (Quinn et al. 2018, entire). However, annual tortoise survivorship was observed to vary among release groups and across even small spatial scales because of variation in predation risk (Tuberville et al. 2005, p. 353; Quinn et al. 2018, p. 1548), which may confound perceived benefits of headstarting without a direct comparison to hatchlings. To account for spatial and temporal variability in survivorship and more explicitly quantify the benefits of headstarting, Tuberville et al. (2021, p. 89) released hatchling and head started yearling gopher tortoises as pairs directly into adult burrows and compared their post release movement and survival until winter dormancy. The study results indicated that yearling head started gopher tortoises experienced significantly higher survival to dormancy but exhibited similar movement patterns when compared to hatchlings released simultaneously (Tuberville et al. 2021, p. 90). Additional investigation is needed into the optimal duration of headstarting and whether longer headstarting periods confer an additional survival advantage (Tuberville et al. 2021, p. 92).

3.9.4. The Gopher Tortoise Conservation and Crediting Strategy

The Gopher Tortoise Conservation and Crediting Strategy is a conservation initiative designed to balance military mission activities and gopher tortoise conservation in Southeast installations (Service 2017, entire). The Crediting Strategy establishes the framework for determining credit for Department of Defense (DoD) conservation actions. The Crediting Strategy is an important instrument in providing for the conservation of the gopher tortoise across the candidate range and is intended to achieve a net conservation benefit to the species. The Crediting Strategy focuses on identification, prioritization, management, and protection of viable gopher tortoise populations and best remaining habitat, as well as increasing the size and/or carrying capacity of those viable populations while promoting the establishment of new, viable populations through increased connectivity or translocation and repatriation efforts (Service 2017, entire).

3.9.5. Conservation Agreements

A Candidate Conservation Agreement (revised 2018) for gopher tortoise conservation was developed as a cooperative effort among state, federal, non-governmental, and private organizations (e.g., The Longleaf Alliance, Joseph W. Jones Ecological Research Center, American Forest Foundation, etc.). The primary function of this agreement is to implement proactive gopher tortoise conservation measures across the candidate range.

In 2017, a Candidate Conservation Agreement with Assurances (CCAA) was established with the Camp Blanding Joint Training Center providing protections for approximately 17,000 acres (6,879 ha) of sandhill to be managed for the benefit of multiple at-risk species, including the gopher tortoise (Service et al. 2017a, entire).

In 2012 in Florida, FWC entered into a 30-year MOA with Mosaic Fertilizer, LLC (Mosaic) to facilitate the conservation of gopher tortoises and establish a long-term structure for tortoise relocations (implemented under the September 2012 Gopher Tortoise Permitting Guidelines). Mosaic land encompasses approximately 300,000 acres (121,405 ha) in Florida, approximately 1 percent of which are utilized in mining and reclamation operations but also includes forested, shrub, herbaceous, wetlands, upland communities; the area occupied by tortoises on Mosaic lands is unknown (FWC 2020a, p. 2). As part of this MOA, prior to mining operations, Mosaic relocates all gopher tortoises from the mine site to a certified recipient site, consistent with FWC Gopher Tortoise Permitting Guidelines (FWC 2020a, p. 2). Additionally, through this MOA, Mosaic promotes management of gopher tortoise habitat through payments to state agencies and non-governmental organizations to carry out controlled burns or other habitat management activities that benefit tortoises (FWC 2020a, p.2).

3.9.6. Conservation Strategies, Best Management Practices, and Other Conservation Initiatives and Guidelines

The Rangewide Conservation Strategy for the Gopher Tortoise was developed in 2013 by the Service to guide conservation of the gopher tortoise. Specifically, this Strategy is designed for partners, including the states within gopher tortoise range, the Service, and other public and private entities to collect and share information on gopher tortoise threats, outline highest priority conservation actions, and identify organizations best suited to undertake those conservation actions (Service 2013, entire).

In Florida, Forestry Wildlife Best Management Practices for State Imperiled Species were developed in 2014 to enhance silviculture's contribution to the conservation of wildlife and to provide guidance to landowners who chose to implement these voluntary practices (FDACS 2015, entire). As of 2020, the Florida Forest Service had received a Notice of Intent to implement conservation practices from 198 landowners on more than 3.7 million acres (1.5 million ha), ranging from small private non-industrial landowners to large working forest ownerships (FWC 2020, unpaginated). Subsequent to the Forestry Wildlife Best Management Practices, in 2015, Florida Department of Agriculture and Consumer Services and FWC collaboratively developed the Agriculture Wildlife Best Management Practices for State

Imperiled Species for other commodity groups to promote sound, agricultural land use, natural resource conservation, and reduce the potential for incidental take of State Imperiled Species (FDACS 2015, p. ii), including burrowing animals such as the gopher tortoise. As of 2021, Notice of Intent to implement conservation practices was provided by 28 landowners for approximately 425,031 acres (172,004 ha) of privately owned land (FWC 2021, p. 1). The FWC also provides recommendations to landowners annually. In fiscal year 2017-2018, the FWC recommended beneficial management and/or mitigation activities on 98 projects encompassing 29,495 acres (11,936 ha) of tortoise habitat across 40 counties (FWC 2021, p.1).

There are numerous other gopher tortoise conservation tools and guides, including the 2018 Best Conservation Practices for Gopher Tortoise Habitat on Working Forest Landscapes, that was collaboratively developed by partners including the Georgia Department of Natural Resources (GDNR) and the Service to assist in making recommendations for best conservation practices for creating and maintaining gopher tortoise habitat in the candidate portion of the range (GDNR et al. 2018, entire). GDNR developed the Forest Management Practices to Enhance Habitat for the Gopher Tortoise, which details the essentials of managing habitat for gopher tortoises including prescribed fire, timber harvest, and selective herbicide use (GDNR 2014, unpaginated) . The Georgia Gopher Tortoise Initiative is an extension of the GDNR's long-standing effort in conserving longleaf pine systems. The initiative is a collaborative effort between several public and private entities and is geared towards the protection, restoration, and long-term management of gopher tortoise habitat.

3.9.7. Conservation Lands

The conservation of multiple large, contiguous tracts of habitat is essential to the persistence of gopher tortoises. Gopher tortoise habitat occurs across a wide range of public ownerships with varying levels of management. An estimated 1.7 million acres (688,000 ha) of potential gopher tortoise habitat occurs on protected lands across a wide range of ownerships including federal, state, local government, non-governmental organizations (NGOs), and private lands (e.g., conservation easements) throughout the species' range (see Figure 4.11).

Land Acquisition and Management Planning

Land acquisition for conservation is a primary tactic in preventing habitat loss, fragmentation, and degradation. Each state within the historical range of the gopher tortoise has statutory authority to acquire land for conservation purposes. With the publishing of the 12-month finding (76 FR 45130) in 2011, all states within the historical range have made concerted efforts to protect gopher tortoise habitat via strategic land acquisition. Between 2011 and 2019, Alabama, Florida, Georgia, and South Carolina have reported fee-simple acquisition of approximately 42,000 acres (16,996 ha) of potential gopher tortoise habitat with an additional approximate 78,000 acres (31,565 ha) acquired in conservation easements (CCA 2019, pp. 52-73). Federal entities including the U.S. Air Force, the Forest Service, and the Service recorded an additional 2,740 acres (1,109 ha) of potential gopher tortoise habitat acquired and approximately 24,000 acres (9,712 ha) of conservation easements acquired (CA 2019, pp. 52-73).

Habitat improvement and management are vital factors in restoring and maintaining the structure and composition of vegetation within gopher tortoise habitat. As described in Chapter 2, over most of its range, the gopher tortoise inhabits open canopy pine ecosystems, scrub oak uplands, and flatwoods maintained by frequent growing season fire. Habitat management activities may include ecosystem restoration and enhancement, non-native and invasive plant and animal control, prescribed fire, chemical and mechanical vegetation management activities, and timber management. Habitat management occurring on public conservation lands is often accomplished via natural resource planning instruments (e.g., land management plans, comprehensive conservation plans, resource management plans, etc.).

Department of Defense

As part of the implementation of the Sikes Improvement Act (1997; 16 U.S.C. 670 et seq), the Secretaries of the military departments are required to prepare and implement Integrated Natural Resource Management Plans (INRMP) for each military installation in the United States. The INRMP must be prepared in cooperation with the Service and State fish and wildlife agencies and must reflect the mutual agreement of these parties concerning conservation, protection, and management of wildlife resources (16 U.S.C. 670a). The DoD must conserve and maintain native ecosystems, viable wildlife populations, Federal and State listed species, and habitats as vital elements of its natural resource management programs on military installations, to the extent that these requirements are consistent with the military mission (DoD Instruction 4715.3). Several installations (e.g., Eglin AFB) occur within the historical range of the gopher tortoise, providing important habitat for the species. Many of these installations specifically include gopher tortoise habitat and population management prescriptions and goals within their individual INRMPs. Most INRMPS also include species specific management for other upland species, likely benefiting gopher tortoises as well. Additionally, as part of their INRMPS, military installations across the Southeast complement state and federal laws by maintaining regulations on training restrictions in areas where rare species are found. According to an ArcGIS estimate, there is approximately 830,000 acres of gopher tortoise habitat occurring on military installations throughout the range. The condition of this habitat and the extent to which these areas are occupied by gopher tortoises is not fully understood.

U.S. Forest Service

The Forest and Rangeland Renewable Resources Planning Act (16 U.S.C. 36), as amended by the National Forest Management Act of 1976 (16 U.S.C. 1600-1614), requires that each National Forest (NF) be managed under a forest plan which is revised every 10 years. Forest plans provide an integrated framework for analyzing and approving projects and programs, including conservation of listed species. Several National Forests (e.g., Ocala NF, Desoto NF, Conecuh NF, Apalachicola NF, etc.) occur within the historical range of the gopher tortoise, providing important habitat conservation for the species. Identification and implementation of land management and conservation measures to benefit gopher tortoises vary among National Forests, but generally include habitat restoration and management objectives and maintaining buffers around gopher tortoise burrows during various forest management activities.

The Desoto NF recently completed 10 years of implementing a Collaborative Forest Landscape Restoration Program, in which they implemented longleaf pine restoration goals on approximately 374,000 acres of National Forest Land. Restoration goals included: pine thinning (30,716 acres), longleaf reestablishment (13,132 acres), prescribed burning (995,000 acres), hazardous fuel reduction and wildlife habitat improvement with herbicide (8,600 acres), non-native invasive species control (975 acres), pitcher plant bog restoration (775 acres), and road decommissioning (300 miles). Almost all of these conservation goals support gopher tortoise populations on Mississippi National Forest lands and have the potential to not only enhance but increase suitable habitat. With successful results and high support among partners, this Program was recently extended. In addition, the Desoto NF has prioritized any management treatment that contributes to improvement of habitat for federally listed species, including the gopher tortoise, as set forth in their Mission, Vision, and Operational Strategy (USFS 2020, entire).

U.S. Fish and Wildlife Service

The National Wildlife Refuge System Improvement Act of 1997 (16 U.S.C. 668dd) requires that each Refuge be managed under a Comprehensive Conservation Plan which is revised every 15 years. Additionally, this Act states that each Refuge shall be managed to, among other things, consider the needs of fish and wildlife first and to maintain the biological integrity, diversity, and environmental health of the Refuge System. Several National Wildlife Refuges (NWR) (e.g., Merritt Island NWR, Lake Wales Ridge, NWR, Lower Suwannee NWR, St. Marks NWR, etc.) occur within the historical range of the gopher tortoise, providing important habitat conservation for the species. Management activities included in NWR Comprehensive Conservation Plans that influence gopher tortoises include habitat restoration activities such as pine thinning and other mechanical vegetation management for restoring desired vegetative conditions in pine and scrub systems, and tortoise management and monitoring actions based on priorities of the refuge and available resources.

States

Through statute, the state of Florida requires that managers of lands that contain imperiled species consider the habitat needs of these species during preparation of management plans and that all land management plans include short-term and long-term goals to serve as the basis for land management activities; these goals include measurable objectives for imperiled species habitat maintenance, enhancement, restoration, or population restoration (253.034(5)). In Georgia, land management planning on state property is directed by policies contained within the Georgia Planning Act of 1989 (O.C.G.A. 12-2-28) and the Georgia Environmental Policy Act (O.C.G.A. 12-16-1). In South Carolina, the Heritage Trust Act (S.C. Code Section 51-17-80 and –90) requires a management plan, but does not require regular reviews or updates and while ongoing planning is not prescribed by state law, some timber harvest planning does occur under S.C. Code Section 50-3-510 et. seq. In Mississippi, while there are no statutes requiring resource management plans, MS Code Section 49-5-103 allows for annual appropriations for the General Fund for the management of nongame and endangered species.

3.9.9. Private Lands Conservation Efforts

Most forested land within the gopher tortoise range is privately owned. Privately owned lands account for approximately 80 percent of potential gopher tortoise habitat, of which approximately half are managed for forest production. (Greene et al. 2019, p. 201). As the human population continues to grow in the Southeast, development and related socioeconomic pressures will increasingly threaten forest resources, with effects such as forest conversion to non-forest uses and increasing fragmentation and degradation of forests. Forest loss may lead to loss of ecological function and connectivity essential for the dispersal of gopher tortoises across the landscape. With >90% of land in private ownership, couple with increasing numbers of urban and absentee landowners, forested lands within the range of the gopher tortoise are particularly susceptible to fragmentation and land-use conversion, It is important to strategically target forest-retention efforts, particularly as landscapes are subject to rapid conversion to development, and volatility in timber markets increase risk in private forestland timber production.

It is important to note, data included in our viability analysis (included in chapters 4 and 5) represents a subset of gopher tortoises likely to occur on the landscape, as the majority of data from private lands were lacking. Thus, population estimates in this SSA do not represent an assessment of all populations of gopher tortoises, but rather represent information that was provided by partners through much of the species' range. Most population estimates came from assessments of populations on lands managed for the conservation of biodiversity or natural resources.

Large Working Forest Lands

Coordinating with large working forest landowners and managers, NCASI provides technical information and scientific research needed to achieve environmental goals and principles, including species conservation. Across the entire range of the gopher tortoise, 12 large working forest ownerships in the listed range and 16 in the candidate portion of the gopher tortoise range account for over 6 million acres (2.4 million ha) (NCASI 2020, p. 3) of forest land, representing a significant land use with the potential to influence gopher tortoise resiliency in a multitude of ways across the range. While not all working forest lands include appropriate habitat conditions for gopher tortoises, approximately 2.78 million acres (1.12 million ha) of suitable soil types and 2.98 million acres (1.21 million ha) of open pine conditions are estimated to occur on private forest ownerships within the NCASI database (NCASI 2021, p. 1). Evidence of gopher tortoise occurrence from informal surveys and observations was reported by NCASI from Member Company lands in 107 counties between 1977 and 2019 (Figure 3.9). While the data reported does not cover all gopher tortoise habitat on Member Company land and does not include all lands under private forest management within range of the gopher tortoise, the information provided does reflect over 10,000 observations recorded between 2013 and 2019 (91 counties rangewide) (NCASI 2020, p. 9-11; Miller, pers. comm., 2021).

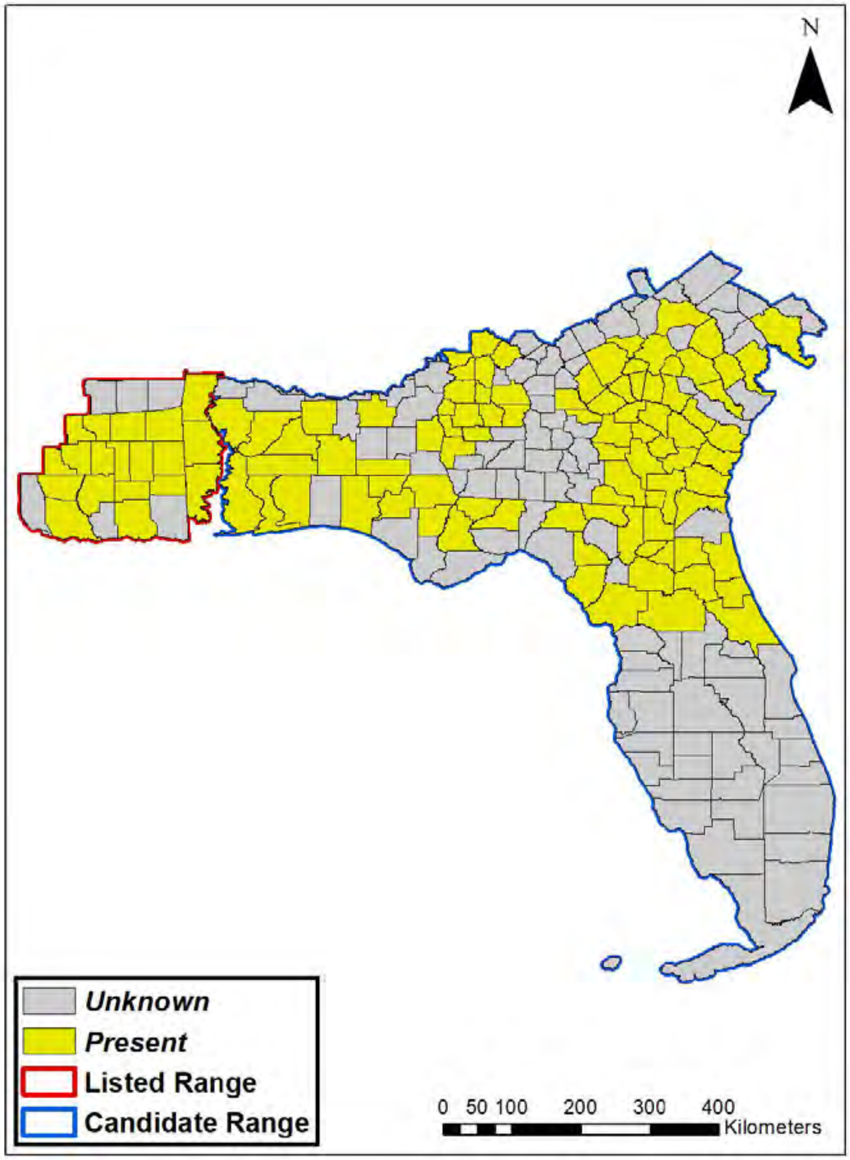

Figure 3. 9-Gopher tortoise known occurrence location (yellow) and unknown (gray) on NCASI Member Company lands. Data compiled here includes informal and formal surveys, burrow observations, presence at a stand level, and tortoise sightings. Unknown counties (gray) do not imply absence on NCASI Member Company lands as some counties do not contain Member Companies, some Member Company land in some counties may not include gopher tortoise habitat, and not all Member Company lands had survey data (NCASI 2020, p. 8).

While working to meet a range of objectives including timber production, many larger private working forests also accomplish conservation within a broad network (Figure 3.10) of collaboration with Federal, State and local government agencies, universities, and environmental non-governmental organizations (ENGOs). Forest certification is one method used to ensure forest lands are managed to provide habitat for wildlife, including gopher tortoises. Participants in forest certification programs such as the Sustainable Forestry Initiative (SFI), and Forest Stewardship Council, adhere to a set of principles that reflect a commitment to providing certain societal benefits, including conservation of biological diversity (NCASI 2020, p. 11). Certification is maintained through third party audits to demonstrate conformance with applicable standards. Standards applicable to gopher tortoise conservation include: 1) having a program to incorporate conservation of native biological diversity, including species, wildlife habitat, and ecological community types at stand and landscape scales; 2) developing criteria and implementing practices to retain stand-scale wildlife habitat elements; and 3) working individually or collaboratively to support diversity of native forest cover types and age or size classes that enhance biological diversity at the landscape scale. An estimated 13.7 million acres (5.5 million ha) within states where gopher tortoises occur are certified through SFI (SFI 2021, unpaginated), though the proportion of certified acres that occur within the range of the gopher tortoise is unknown. Additionally, the proportion of certified acres that include gopher tortoises or gopher tortoise habitat is also unknown.

Across the range of the gopher tortoise, master logger programs are available in each state. These programs include training that meets SFI program standards and in addition to increasing safety and efficiency within the profession, provides professional loggers with environmental training, Environmental training includes BMPs, the ESA, and threatened and endangered species management, including gopher tortoise. Trained master/professional loggers supervise most forest harvesting operations to meet the requirements of the SFI.

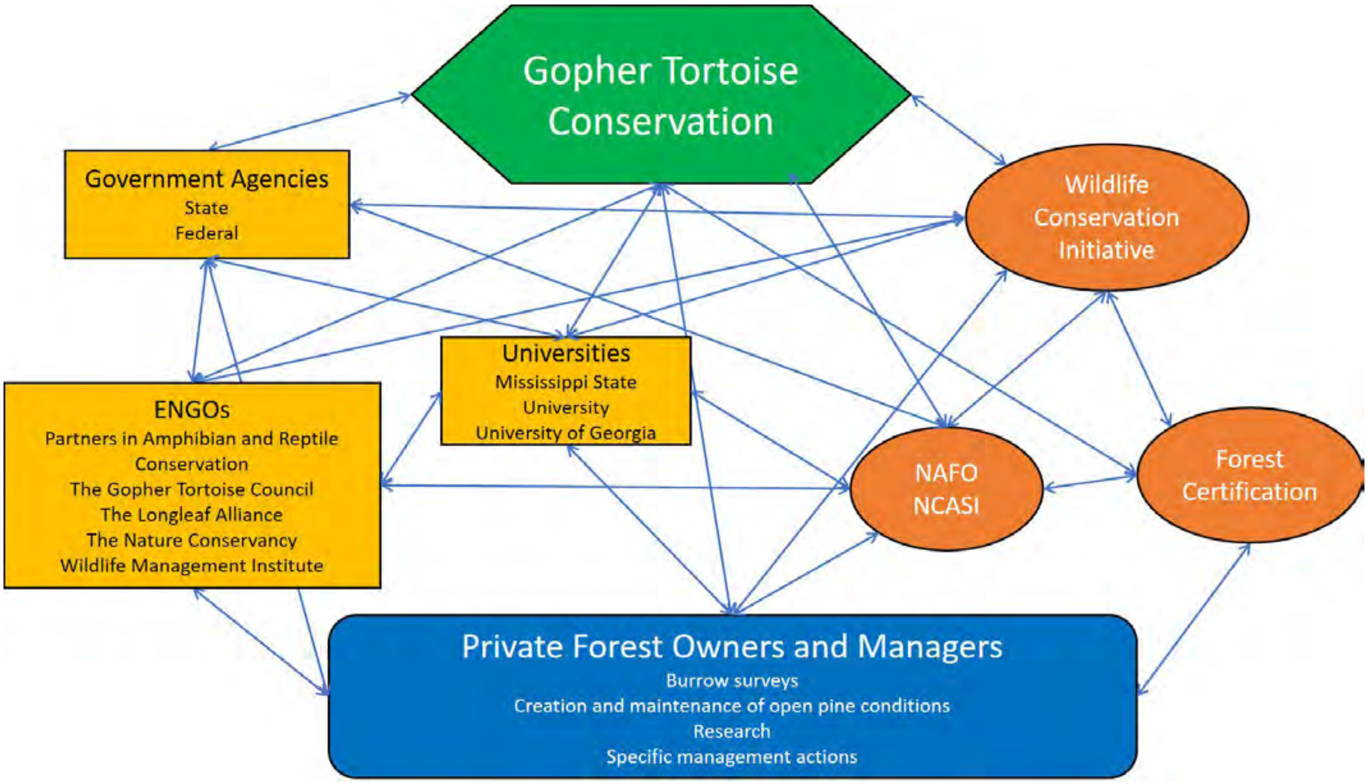

Figure 3. 2-Gopher tortoise conservation occurs through collaboration among several entities. Large private working forest owners and managers (blue) complete gopher tortoise conservation within their own organizations but also collaborate with environmental non-governmental organizations (ENGOs), government agencies, and universities (yellow). Furthermore, private forest owners and managers cooperate with each other via the National Alliance of Forest Owners, NCASI, and the Wildlife Conservation Initiative (orange) to ensure gopher tortoise conservation efforts happen throughout the species' range. Lastly, forest certification programs (orange) provide further assurances that at-risk species conservation (including gopher tortoise conservation) will continue to be a priority on private forests. Entities listed do not represent an exhaustive list of cooperators and partners. Source: NCASI

Family Forests

The largest forest landowner group in the United States is the family forest landowners, controlling 36 percent of forest lands in the country (Butler et al. 2016, p. 641) and in the south, private ownerships account for 87 percent of forest land (Oswalt 2014, p. 6). Similar to large working forest landowners, family forest landowners accomplish conservation through a broad network of conservation partners (Figure 3.11). Conservation values are important and family forest landowners rank beauty, wildlife, nature, and legacy as top reasons for owning land, and timber production as not one of the top ten reasons (Butler et al. 2016, p. 644). Working with smaller, family forest landowners, the American Forest Foundation (AFF) works to increase sustainable wood supplies on family forests while protecting and enhancing habitat for at-risk species, including the gopher tortoise. In accomplishing this objective, in 2017 the AFF has partnered with the Service's Partners for Fish and Wildlife Program to support conservation of at-risk species on private lands within the Southeast. Participating landowners work with Partners biologists to develop habitat improvement plans that meet their long-term objectives for the property, receive cost share for habitat improvement projects and commit to actively managing the project area. Consistent with the Partners program requirements, landowners enter into formal agreements with the Service and AFF for a minimum of 10 years. Since 2017, the partnership has engaged landowners with over 3,500 acres (1,416 ha) under agreement where habitat improvement projects have included approximately 2,000 acres (809 ha) of longleaf pine establishment and the introduction of prescribed fire to more than 1,400 acres (566 ha) of existing pine forests. An additional focus of this partnership is the implementation of wildlife surveys, including gopher tortoise. Since 2017, gopher tortoise surveys on participating forests have identified 762 gopher tortoises, including 2 populations that meet the MVP criteria (AFF 2021, unpaginated). As with the large working forests, family forest landowners may participate in forest certification programs such as the American Tree Farm System (ATFS). The ATFS has certified more than one million acres of private lands in each of the Southeast states and requires landowners and managers to implement BMPs, identify and protect state and federal listed species, and to protect soil and water resources. ATFS certification, as are most forest certifications, is a third-party audited certification system authorized by the Program for the Endorsement of Forest Certification (PEFC). It is unknown how many acres of ATFS certified lands occur within the gopher tortoise range, include gopher tortoise habitat, or support gopher tortoise populations.

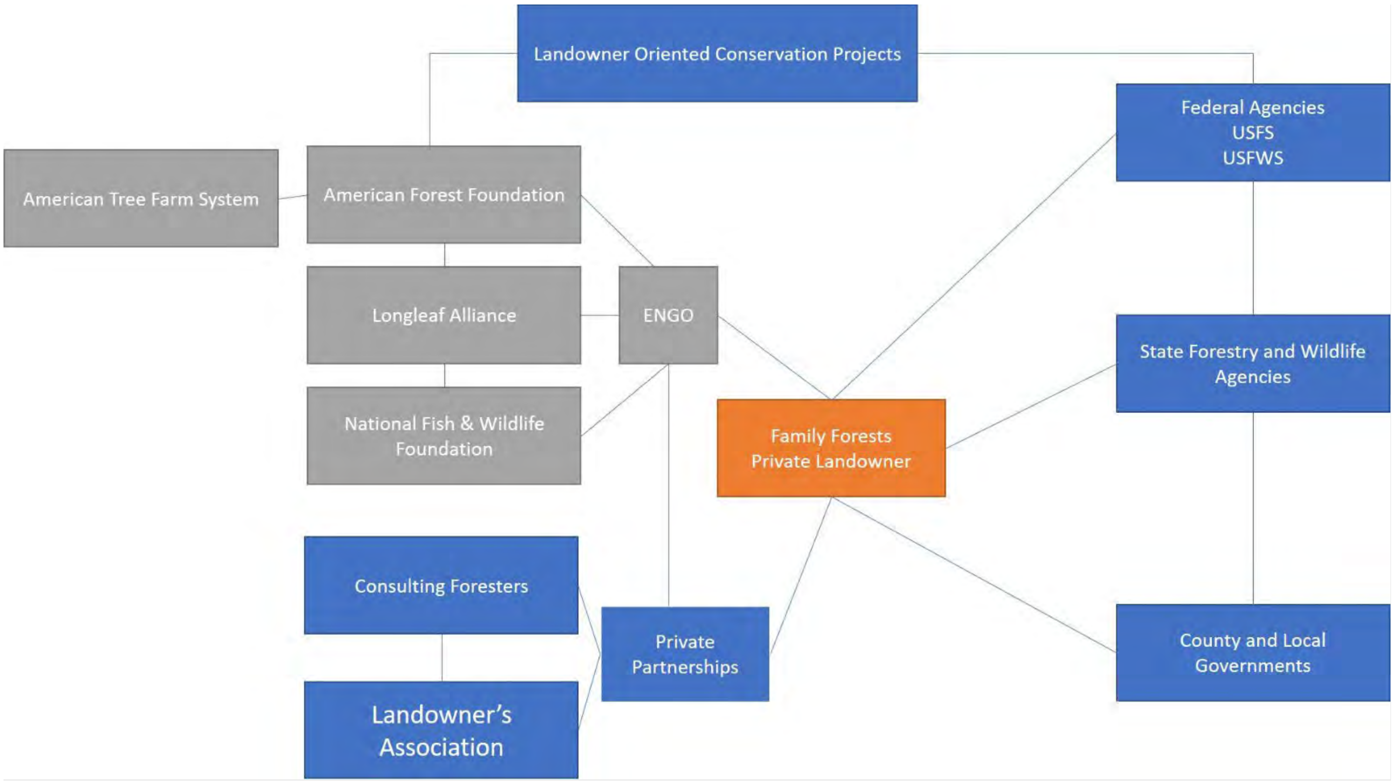

Figure 3. 11-Gopher tortoise conservation delivery network for small family forests. Entities listed are not exhaustive of all potential partners and stakeholders. Source: AFF

Additionally, The Longleaf Alliance works with private landowners and other partners across the range of the gopher tortoise to restore and maintain habitat as an essential part of their larger focus in restoring the longleaf pine ecosystem. In providing technical and financial assistance, the Longleaf Alliance in 2019, assisted landowners with the implementation of over 55,000 acres (22,258 ha) of prescribed fire within gopher tortoise habitat in addition to assistance with longleaf pine plantings, groundcover restoration, and invasive plant management efforts (SERPPAS 2020, p. 17).

Conservation Banks

Several privately-owned tracts of land are managed as mitigation/conservation areas for gopher tortoises in both Mississippi and Alabama, providing suitable habitat, protection, and habitat management. In Greene County, MS, the 1,230-acre Chickasawhay Gopher Tortoise Conservation Bank was established in 2009 to accept tortoises displaced by development within the Bank's service area and to compensate impacts to tortoises. As the only official mitigation bank for the gopher tortoise, the national mitigation banking guidelines are followed for maintaining optimal habitat, including aggressive prescribed fire and longleaf restoration programs.

In Mobile County, AL, four gopher tortoise conservation areas are managed through HCPs with the Service. These areas serve as a relocation site for tortoises impacted by utility and county construction and maintenance and are required to follow habitat plans which include restoration and management of the open-canopied, upland longleaf pine habitat used by gopher tortoises. However, they are all less than 700 acres and primarily surrounded by urban landscapes with incompatible habitat.

3.10. Summary of Factors Influencing Viability

The best available information regarding the gopher tortoise and gopher tortoise habitat indicates that habitat loss, degradation, and fragmentation (due to land use changes from urbanization), climate change, and habitat management are the most significant factors influencing gopher tortoise viability. Urbanization results in a range of impacts that either remove or degrade/fragment remaining habitat, or impact gopher tortoises directly through development. Urbanization brings road construction and expansion, which may cause direct mortality of gopher tortoises. In addition, this type of development may also create conditions beneficial to invasive species, increase predators and inadequate conditions for fire management. Temperature increases associated with long term climate change are likely to further constrain use of prescribed fire through a decrease in the number of suitable burn days. Habitat loss resulting from sea level rise associated with climate change is a risk for coastal populations of gopher tortoise. These factors are considered to have population level effects and were evaluated further in the current condition and future condition analysis.

CHAPTER 4 – POPULATION AND SPECIES NEEDS AND CURRENT CONDITION

4.1. Introduction

In this chapter, we consider the gopher tortoise's current distribution, species needs, and how the species needs influence the 3 Rs. We first define populations of the species. Next, we characterize population and habitat factors for the species in terms of the 3 Rs. Finally, we estimate the current condition of the gopher tortoise using population metrics used to characterize the 3 Rs.

Survey methodologies

We received a variety of data to assess resiliency factors for the gopher tortoise, including information from state and federal agencies, local governments, and private lands. These data represent a subset of gopher tortoises likely to occur on the landscape due to the lack of a comprehensive private lands data set. Data were collected using burrow surveys of various methodologies and included burrow surveys (comprehensive and area-constrained) both with and without burrow scoping incorporated, and line transect distance sampling (LTDS; Buckland et al. 1993, entire; Thomas et al. 2010, entire); some burrow data were submitted with unknown methodology. Comprehensive burrow surveys, sometimes called 100 percent surveys, involve a team of researchers searching a site to count the total number of gopher tortoise burrows present. Area-constrained surveys, also referred to as belt transect surveys, use a similar methodology as comprehensive surveys. However, these surveys are restricted to a transect of pre-delineated length and width, and population estimates are extrapolated site-wide based on the proportion of the site that was surveyed (Auffenberg and Franz 1982, pp. 95-96; Cox et al. 1987, p. 39). As counting burrows alone during these surveys results in unknown occupancy estimates, an occupancy rate (or correction factor), is often used to estimate population size for comprehensive and belt transect surveys (0.614, Auffenberg and Franz 1982, p. 96; 0.5, Ashton and Ashton 2008, p. 158; 0.40, Guyer et al. 2012, p. 132).

Biologists also sometimes use burrow-scope cameras in conjunction with burrow surveys to directly estimate abundance of local populations by counting individuals within burrows; this method assumes that all potentially occupied gopher tortoise burrows were detected at sites and that only a single gopher tortoise is present in a burrow. Line transect distance sampling is a survey method to derive estimates of abundance where a research team walks transects, observes gopher tortoise burrows, searches the burrow for a gopher tortoise with a burrow scope, records the precise spatial location of occupied burrows, and measures the perpendicular distance of each occupied burrow to the transect line (Smith et al. 2009a, entire). Invariably, burrows and individuals are imperfectly sampled because detection probability of burrows is less than one. However, analysis of LTDS data generates functions estimating the decay of the detection rate with increasing distance from the transect line, and this detection function can then be used to account for undetected burrows and therefore estimate the total number of occupied burrows in the search area (i.e., total population size). Because juvenile gopher tortoises have small burrows that are difficult to observe, detection of juveniles during all burrow survey types (comprehensive, belt transect, LTDS) is lower than adults; thus, surveys may underrepresent smaller size classes in the population estimates (Smith et al. 2009a, p. 356; Gaya 2019, pp.13-31).

Because data were provided by a variety of sources, contained disparate levels of data resolution, and were collected in various ways, we could not reliably determine abundance, density, habitat availability, or other metrics for all populations. All population data provided are integral to evaluating the current condition of the gopher tortoise, although different data types come with different assumptions and limitations as described below.

Spatially explicit data

The most useful data, from an analysis perspective, are those data that come from standardized and systematic surveys which result in spatially explicit burrow locations and subsequent population estimates. There are several advantages to spatially explicit data, including the ability to make more reliable estimates of populations size; use of spatial buffering to delineate populations based on species biology (see Delineating Populations section below); ability to tie site-specific factors, such as habitat and management factors, to locations of gopher tortoises; and, ability to estimate future parameters, such as probability of persistence and estimated future abundance of gopher tortoise populations.

Due to discrepancies in historical data collection, surveys have recently been performed using LTDS (Buckland et al. 1993, entire; Thomas et al. 2010, entire) when possible and applicable. This methodology is believed to be the most statistically reliable to assess accurate measurements of gopher tortoise populations (Smith et al. 2009b, p. ii). Surveys using this methodology have been done across the range of the gopher tortoise and have been providing more comprehensive data on the status of the species, at least in conservation lands where it has been mostly used. Some belt transect survey data submitted were incomplete and the proportion of habitat surveyed, and therefore the proportion of burrows or tortoises, was unknown. Also, population estimates derived from the belt transect method tend to be less accurate than LTDS; unlike LTDS, the belt transect method involves an area-constrained survey and assumes that burrows occur uniformly and independent of space. Moreover, LTDS analyses yield estimates of precision and detectability that cannot by calculated using the belt transect methodology. Some burrow data were included with unknown survey methodology. In these instances, it is likely that these data do not represent the true population sizes for these sites.

County level information

Private landowners, large and small, play a vital role in conserving habitat for fish, wildlife, and plants, highlighted by the fact that more than two-thirds of the nation's threatened and endangered species use habitat found on private land. The gopher tortoise is no different, where a large percentage of potential habitat is located on land that is privately owned. This highlights the importance of including data from private lands when assessing species viability. The vast majority of the private lands data obtained for this assessment lack a spatial component because of issues associated with confidentiality of location data; this does not preclude the utility and importance of these data in the species status assessment. To this end, we created a landowner questionnaire and utilized responses to estimate population, habitat, and management factors at a county scale to ensure privacy for respondents (Appendix A). We received 167 responses to the landowner questionnaire, with respondents owning properties covering much of the range of the gopher tortoise (Figure 4.1). Responses likely represent a small percentage of private lands that currently support gopher tortoises, particularly given the reluctance many private landowners have sharing occurrence data for at risk species. In addition to these responses, the Florida Forestry Association (FFA) sent out their own questionnaire to additional landowners in the state of Florida, with an additional 34 respondents. Although the FFA questionnaire was similar to the one found in Appendix A, a key difference was that we were not able to obtain population estimates from the 34 responses, thus are unable to estimate current resiliency for populations on these properties.

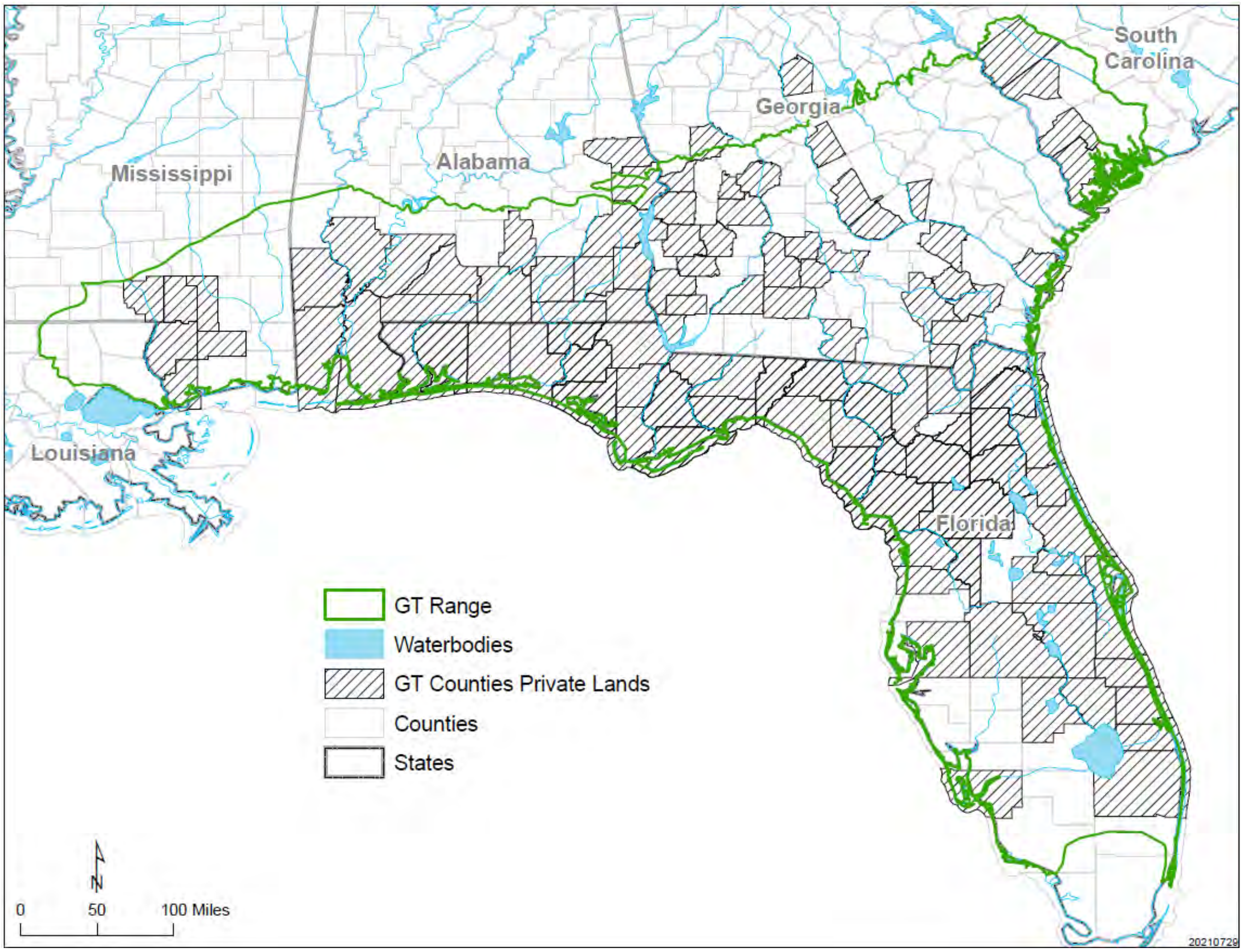

Figure 4. 1-Location of counties with responses to the private landowner questionnaire (with hatching).

Because data received from these questionnaires are not spatially explicit, there are limitations to the applicability of the data as it relates to delineation of populations, assessment of site-specific factors such as habitat quality and quantity, and management regimes, and use of abundance data in projections of future scenarios. Due to these limitations, we present results for current conditions for both types of data (spatially explicit and county level) separately. As will be discussed in Chapter 5 (Future Conditions), we only used spatially explicit data to inform the population model used to forecast future scenarios for the gopher tortoise, which introduces a degree of uncertainty into future projections, given we were only able to use a subset of populations that likely occur on the landscape.

4.2. Delineating populations

As the population is a biologically meaningful unit in an analysis of resiliency, which is then scaled up to redundancy and representation at the species scale, appropriately defining and delineating populations is a crucial step to assess species viability. Below we discuss the challenges of delineating populations for the gopher tortoise and outline our approach.

For this assessment, we defined populations for the species as contiguous areas surrounding known gopher tortoise burrows with habitat conducive to survival, movement, and inter-breeding among individuals within the area. To delineate populations, we compiled and used all records with spatially explicit information, as detailed previously. In addition to naturally occurring gopher tortoise populations, we also included long-term recipient sites in Florida and South Carolina (hereafter, recipient sites) that currently support translocated individuals. A detailed discussion of recipient sites can be found in Chapter 3 (3.9.3 Translocation, Relocation, Recipient Sites and Headstarting). We could not delineate populations for county records that were lacking coordinates, thus we placed these records at the county's centroid and summarized population and habitat factors separately.

Using spatial survey data from across the range of the gopher tortoise, we sought to operationally identify populations at two spatial scales: local populations and landscape populations (Figure 4.2). Local populations can be considered groupings of individuals discovered by demographic or spatial analysis (Smallwood 2001, entire; Goessling et al. 2021, p. 141), whereas landscape populations can refer to the assemblage of individuals found within a property or region of interest (Goessling et al. 2021, p. 141). We defined local populations as geographic aggregations of individuals that interact significantly with one another in social contexts that make reproduction significantly greater between individuals within the aggregation than with individuals outside of the aggregation (sensu Smallwood 1999). We operationally delineated local populations by identifying aggregations of individuals or burrows where individuals were clustered together within a 1,968 feet (600 m) buffer to the exclusion of other adjacent individuals or burrows. Studies of gopher tortoise populations in Alabama (Conecuh NF; C. Guyer, unpublished data), Georgia (Ft. Stewart Army Reserve; E. Hunter and D. Rostal, unpublished data), and Florida (Boyd Hill Nature Preserve; J. Goessling and G. Heinrich, unpublished data) have found that greater than 80 percent of gopher tortoise movements within and among years were less than 1,640 feet (500 m). We recognize that although gopher tortoise interactions may primarily occur within 600 meters of a burrow cluster, the extent to which a tortoise will travel and interact with other tortoises varies by population, and this is likely influenced by many factors, including demographics (sex and size class ratios), population density, whether the population is naturally occurring or a translocated population, habitat type, management, nearby urbanization, and degree of habitat fragmentation.

We selected a 1,968 feet (600 m) distance to buffer populations to encompass typical movement distances and adjacent habitat around surveyed populations that might include gopher tortoises. Because gopher tortoise habitat and demography vary across the range, the 1,968 feet (600 m) buffer represents a compromise across geography and habitat based on a thorough literature search and species expert input. We assumed that areas unsuitable for gopher tortoises were unsuitable for gopher tortoise movement or survival and considered those strict barriers when delimiting local populations. Thus, movement barriers included interstates, freeways, and expressways (HPMS 2019); major rivers and lakes (Sciencebase.org); wetlands, and highly urbanized areas as determined by visual inspection with ESRI imagery.

Local populations can be connected to other, nearby local populations by dispersal; together, connected local populations may form landscape populations. Gopher tortoises infrequently move long distances from established core home range areas, and such movements can result in permanent emigration and immigration into other populations. Local populations that are spatially proximate to other local populations might receive immigrants that bolster population size. While little quantitative information is available describing the frequency or success of immigration, one study found that 2 percent of adults emigrated from local populations each year (Ott-Eubanks et al. 2003, p.319). It is important to note that this emigration estimate was based on only 2 individuals and may underestimate true immigration. We identified instances of two or more local populations that may be connected by dispersal through gopher tortoise habitat as landscape populations.

Although the term landscape population has been used to identify areas where individuals are located within a human defined boundary (Goessling et al. 2021, p. 141), such as a property line, we define a landscape population as a series of local populations that are connected by some form of movement; individuals within a landscape population are significantly more likely to interact with other individuals within the landscape population than individuals outside of the landscape population. Gopher tortoises have been shown to move over 4,921 feet (1,500 m) throughout multiple years, with distances as large as 8,802-15,220 feet (2,683-4,639 m) (McRae et al. 1981, p.172; Diemer-Berish et al. 2012, p. 52; Guyer et al 2012, entire; Castellon et al 2018, p. entire; unpublished data from Goessling and Rostal and Hunter). We operationally delineated landscape populations by identifying local populations connected by habitat within 8,202 feet (2.5 km) buffer around each local population; habitat was considered any areas other than open water, wetlands, paved roads (interstates, freeways, and expressways), and urbanized areas. Landscape populations could comprise multiple local populations or a single local population if no other local populations were within 8,202 feet (2.5 km) buffer, or otherwise separated by a barrier to gopher tortoise movement.

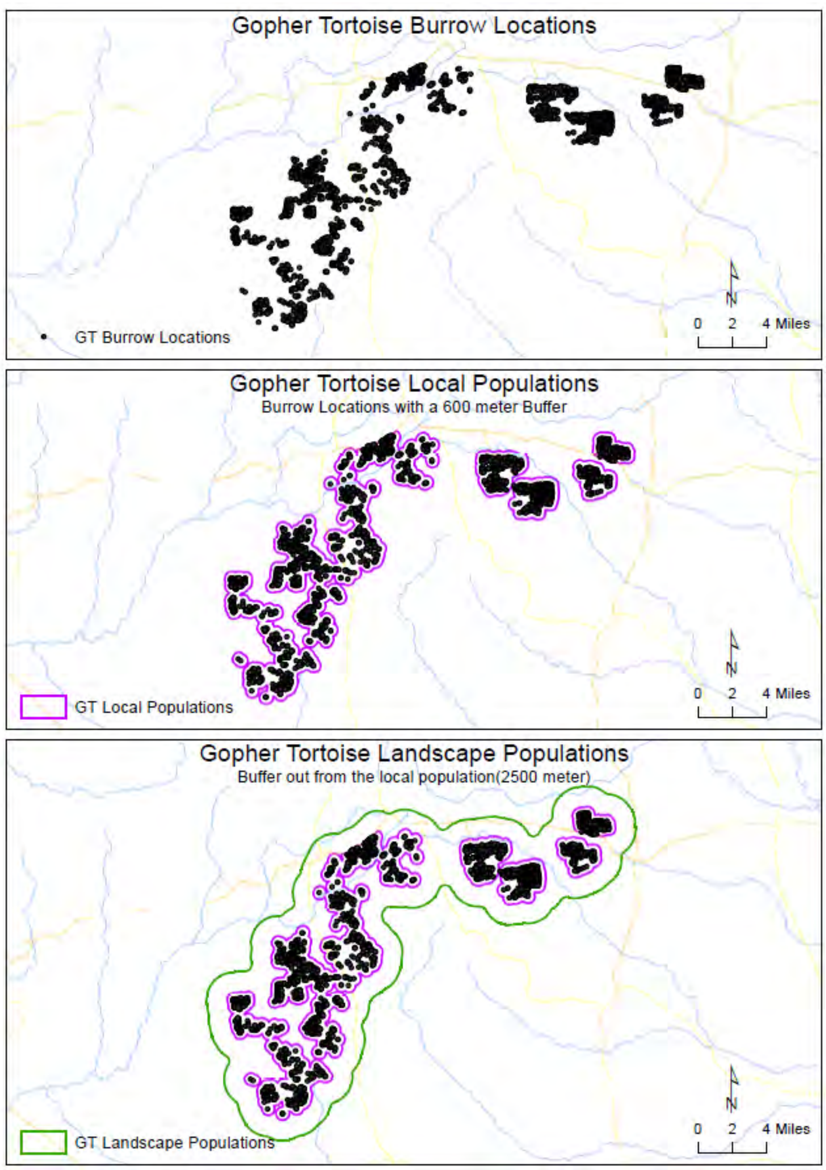

Figure 4. 2-Process for delineating local (0.37 miles/600 m buffer) and landscape populations (1.55 miles/2500 m buffer) using burrow locations for gopher tortoises.

Our process of spatially delineating local populations and landscape populations resulted in a dataset of 656 local populations from 253 landscape populations (Figure 4.3); Florida had the greatest number of local (316) and landscape populations (161), followed by Georgia (151, 63, respectively), Mississippi (99, 7), Alabama (77, 14), Louisiana (7, 5), and South Carolina (6, 4).

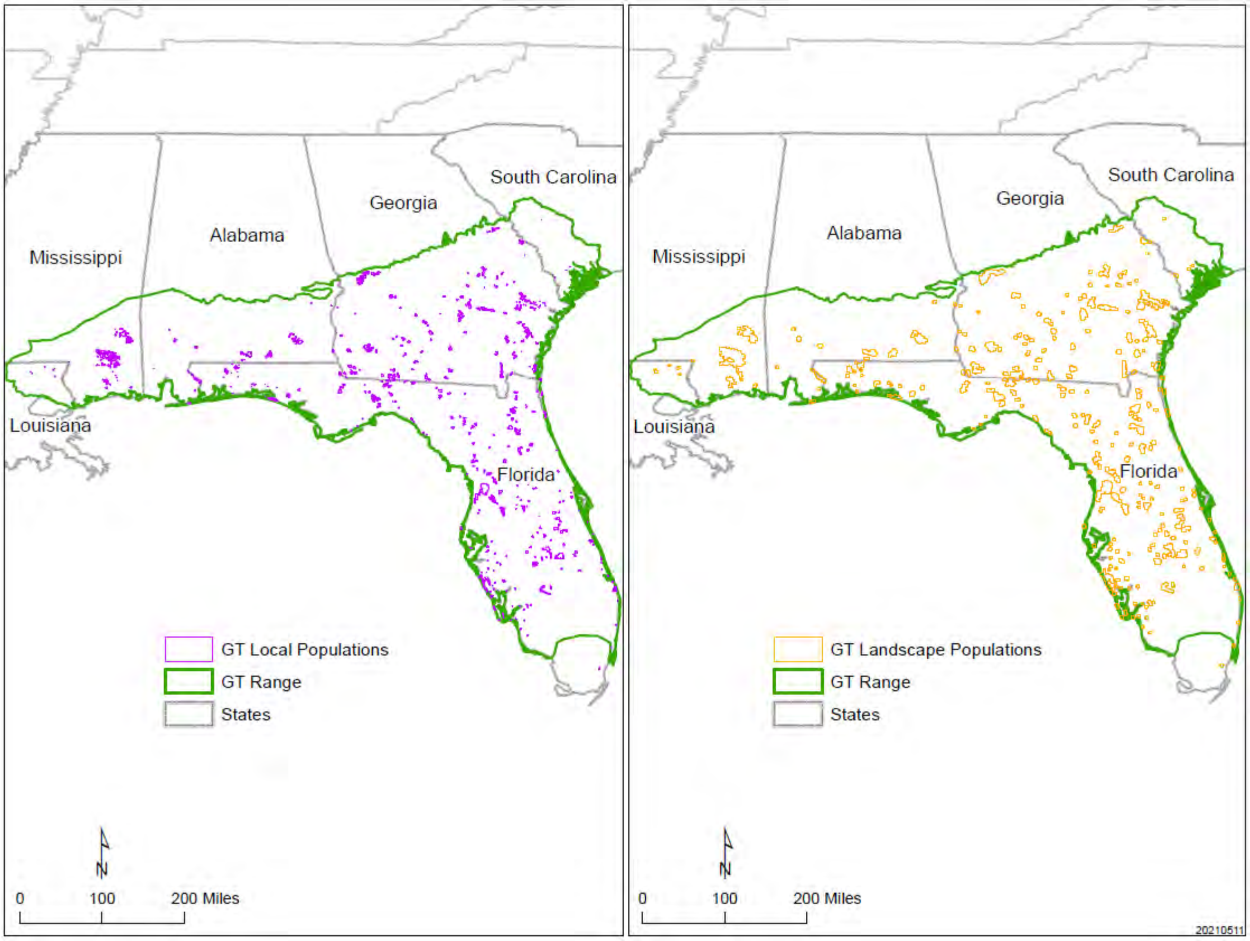

Figure 4. 3-Location of spatially delineated local populations (left panel) and landscape populations (right panel) across the range of the gopher tortoise.

4.3. Delineating representative units

Representation refers to the breadth of genetic and environmental diversity within and among populations, which influences the ability of a species to adapt to changing environmental conditions over time. Differences in life history traits, habitat features, and/or genetics across a species range often aid in the delineation of representative units, which are used to assess species representation. Representation improves with the persistence of populations spread across the range of genetic and/or ecological diversity within the species.

Drawing conclusions about genetic subdivisions and unique genetic assemblages based on available data are difficult because methodologies varied among studies, sample sizes were small in some areas, distances among samples were large in some cases, and areas covered by each study varied. While there is molecular support for recognizing the western portion of the range as genetically distinct, other research has suggested that additional structure exists at both rangewide and regional scales (Ennen et al. 2010, entire; Clostio et al. 2012, entire; Ennen et al. 2012, entire; Galliard et al. 2017, entire). A recent study investigating genetic structure at multiple scales found five genetic regions (Western, Central, West Georgia, East Georgia, and Florida), loosely delineated by biogeographical features including the Tombigbee-Mobile Rivers, Apalachicola-Chattahoochee Rivers, and transitional areas between physiographic provinces of the Coastal Plains (Figure 4.4; Galliard et al. 2017, pp. 503-507). The Tombigbee-Mobile Rivers separate the Western region from the rest of the range, which corresponds to the listed portion of the range of the species. The Apalachicola-Chattahoochee Rivers divide the Central and West Georgia regions, although there is a high degree of admixture at the border of these two regions. The rest of the genetic groups are associated with transitional zones between the Eastern Gulf, Sea Island, and Floridian physiographic province sections of the Coastal Plains, with high amounts of admixture between adjacent genetic groups (Figure 4.4; Galliard et al. 2017, pp. 503-507).

With respect to gene flow, levels of gene flow have been found to be asymmetric from central to peripheral regions, with the highest levels from the Central to Western Regions, and the lowest between the Florida and Western Georgia groups (Galliard et al. 2017, p. 509). Finally, significantly lower genetic diversity is found at the periphery of the range, with low diversity in the Western and East Georgia regions (Ennen et al. 2010; Clostio et al. 2012; Galliard et al. 2017, p. 509).

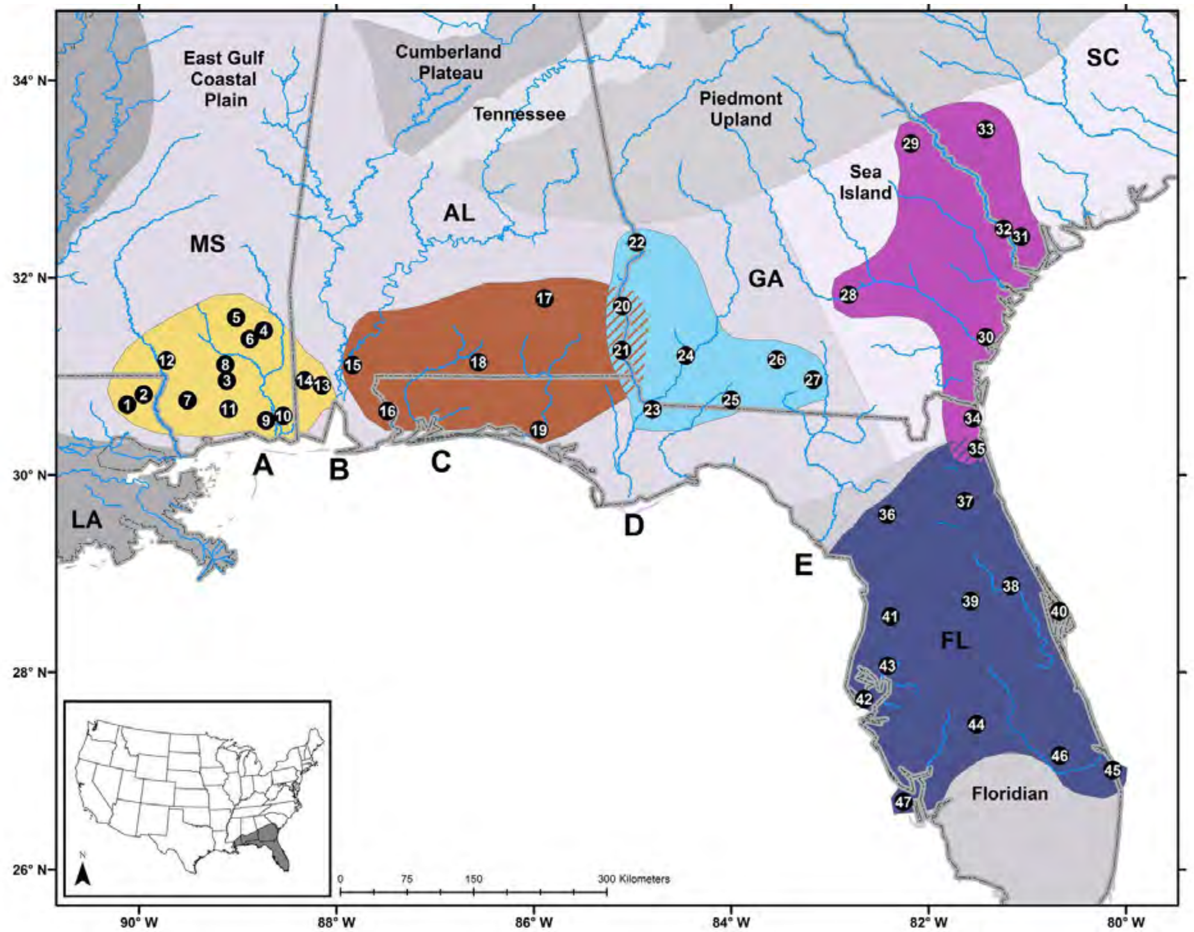

Figure 4. 4-Sampling locations and subsequent genetics units from genetics study by Galliard et al. 2017. The colored shaded areas around sampling sites represent their assignment to one of the five genetic groups (regions) as follows: yellow (Western), brown (Central), light blue (West Georgia), magenta (East Georgia), and dark blue (Florida).

For this assessment, we delineated five representative units (hereafter analysis units) based on the results of Galliard et al. (2017, entire), physiographic regions, and the input of species experts (Figure 4.5). We used the Tombigbee-Mobile Rivers and Apalachicola-Chattahoochee Rivers as boundaries between the Western (Unit 1), Central (Unit 2), and West Georgia (Unit 3) analysis units. Because of the high degree of admixture and lack of well-defined boundaries found within transitional zones of physiographic regions, we used other biogeographic barriers and expert input to delineate boundaries between West Georgia, East Georgia (Unit 4), and Florida (Unit 5) analysis units. We used U.S. Environmental Protection Agency (EPA 2013, unpaginated) Level IV ecoregions to delineate the boundaries between the two Georgia units, and the East Georgia and Florida unit. We used the Suwanee River to separate the West Georgia and Florida units, as this river represents a significant barrier to dispersal, and gene flow between these 2 units is known to be low (Galliard et al. 2017, p. 509).

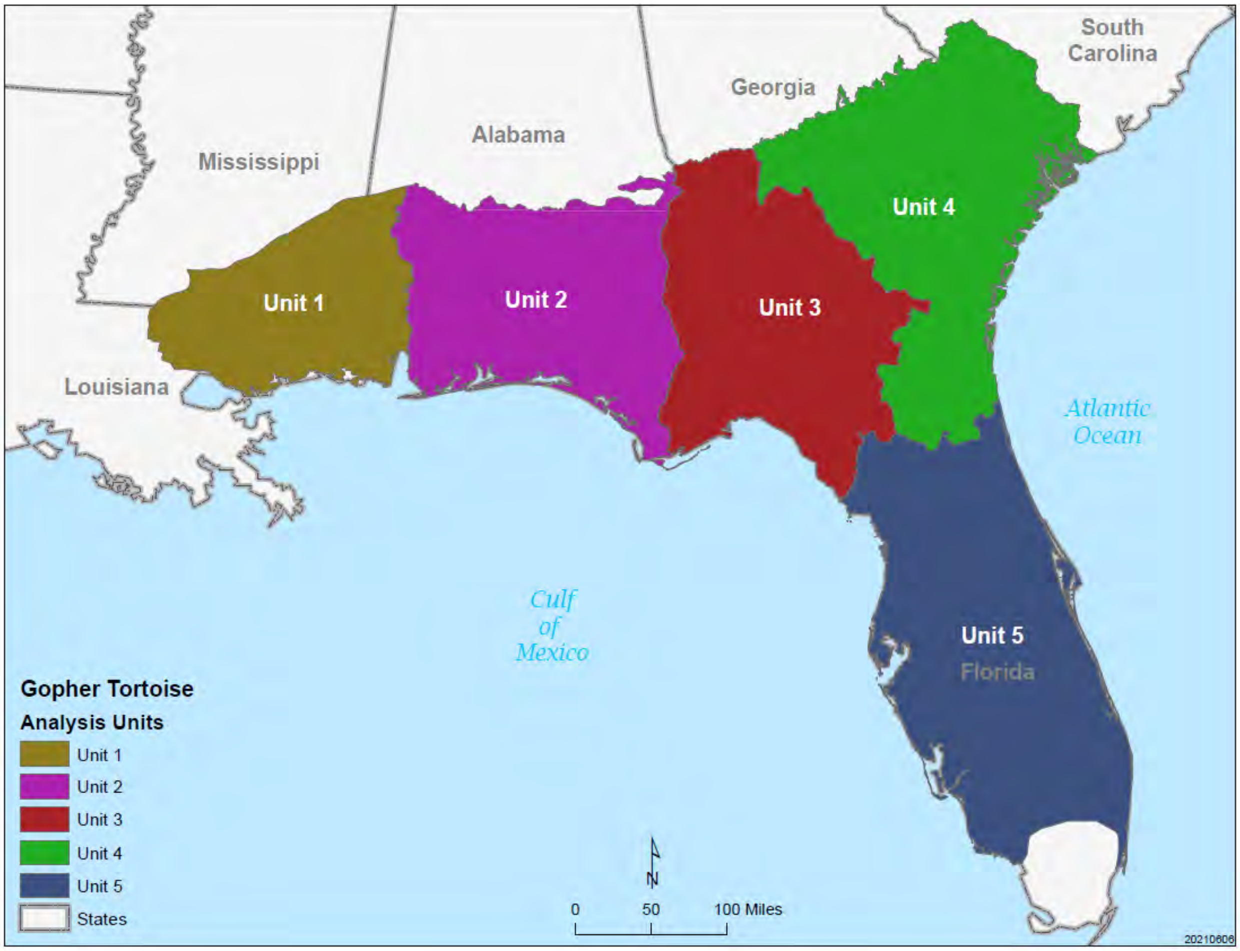

Figure 4. 5-Analysis units used as units of representation for the gopher tortoise in this Species Status Assessment. Analysis units include Western (Unit 1), Central (Unit 2), West Georgia (Unit 3), East Georgia (Unit 4), and Florida (Unit 5).

4.4. Current resiliency

Resiliency describes the ability of a species to withstand low-level stochastic events and is associated with population size, growth rate, and habitat quality. Highly resilient populations are more likely to withstand disturbances such as random fluctuations in fecundity (demographic stochasticity), variation in mean annual temperature (environmental stochasticity), or the effects of anthropogenic activities, such as local development projects. Viability denotes a species' ability to sustain populations over a determined time frame and is closely tied with population resiliency. Below, we describe population, habitat, and management factors that contribute to resiliency of gopher tortoise populations.

4.4.1. Population factors

For gopher tortoise populations to persist for a biologically meaningful timeframe, they must have an adequate number of individuals (population size), be above a particular density (population density), and have sufficient genetic exchange between local populations to maintain genetic diversity (Figure 4.6). There must also be sufficient habitat to support individual and population needs, which we discuss in the next section (Habitat and Management Factors). Population size and density are driven by a variety of underlying demographic parameters, including fecundity, sex ratio, and survival at various life history stages (egg, nest, hatchling, juvenile, and adult survival). Genetic diversity is primarily driven by rates of emigration and immigration between local populations.

It is important to note that populations of gopher tortoises experience great variation in abiotic characteristics across the species' range, and variation in abiotic characteristics influences demographic rates among populations. At southern latitudes, populations experience significantly warmer mean annual temperature, which may afford greater overall opportunity for thermoregulation, energy acquisition, and metabolism when compared to northern populations. As a result, southern populations of gopher tortoises experience faster growth rates, younger ages of sexual maturity (hereafter, maturity age), and increased clutch size (Ashton et al. 2007; Moore et al. 2009, pp. 387-392; Meshaka Jr. et al. 2019, entire).

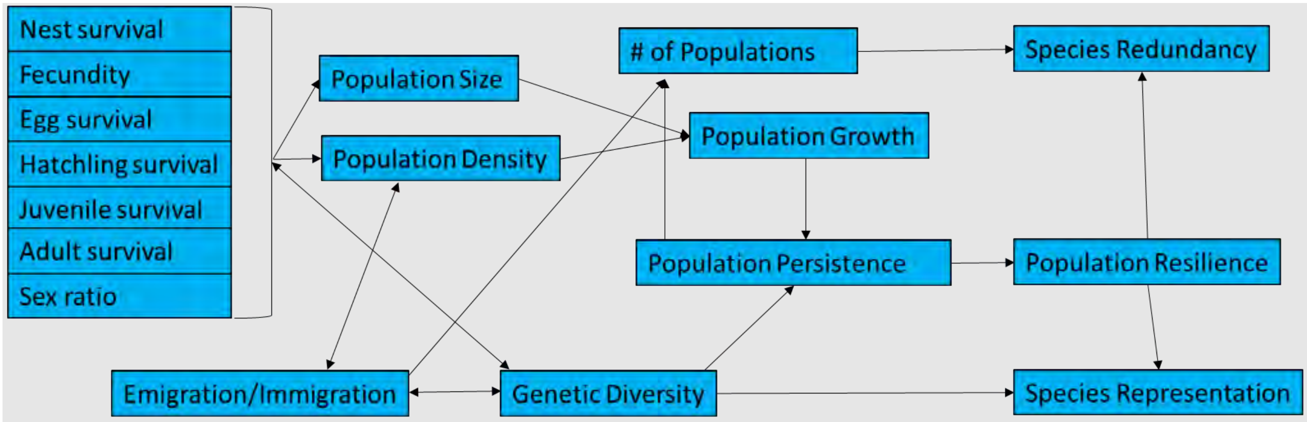

Figure 4. 6-Influence diagram depicting population factors contributing to viability of gopher tortoise.

Minimum viable population (MVP) size is a benchmark used to identify the smallest population size that will reliably persist through a biologically appropriate time frame. The purpose of establishing MVP parameters is to provide acceptable benchmarks for conservation and recovery efforts and is not to determine absolute minimum thresholds that if not met, will result in certain population demise, or that meeting targets implies viability. To reach scientific consensus on appropriate MVP parameters for the gopher tortoise, the GTC convened the Minimum Viable Population and Minimum Reserve Size Working Group in July 2013 and October 2014 (GTC 2013, 2014; entire); this working group determined an MVP includes at least 250 adult gopher tortoises. This abundance criterion was informed by population viability analyses which found populations of 250 or more individuals were most likely to withstand stochastic events and persist for 100 years (Miller et al. 2001, p. 28) or 200 years under favorable habitat conditions (Tuberville et al. 2009, p. 19). The working group also determined an MVP contains a density of no less than 0.4 gopher tortoises per hectare (approximately 0.16 gopher tortoises per acre); this criterion was based on Guyer et al. (2012, pp. 130-131) which found populations with densities below this threshold exhibited altered movement patterns that could negatively impact gene flow and viability. The working group also concluded that at least 247 acres (100 hectares) of high quality, managed habitat was required for a population to persist (McCoy and Mushinsky 2007, p. 1404; GTC 2013, pp. 2-3). Additional MVP criteria included an approximate 1:1 ratio of males to females, evidence of recruitment into the population, variability in size and age classes, and no major constraints to gopher tortoise movement (GTC 2013, pp. 2-3).

The MVP working group recognized populations of less than 250 adults as support populations with two categories, primary and secondary support. Primary support populations contain between 50-249 adult individuals, and secondary support populations are those with less than 50 adults (GTC 2014, p. 4). These support populations may persist for a long period of time under high-quality habitat conditions (Folt et al. 2021, p. 13), but are likely more vulnerable to stochastic events than MVPs (Miller et al. 2001, p. 28; GTC 2014, p. 4). Thus, viability can be evaluated as a measure of the likelihood that a species will sustain populations over time, rather than as a specific state of viable or not viable.

Because we lack consistent and reliable estimates of density, sex ratios, recruitment, dispersal, habitat, and management effort for all sites with available spatial occurrence data, we qualitatively assessed resiliency at the population level by evaluating the estimated current abundance of local populations and creating ordinal resiliency categories. Population estimates for this assessment include data on State, Federal, local government, and private lands, collected in various ways, ranging from standardized survey techniques including belt transect surveys and LTDS (Spatially Explicit), to private lands population information provided at the county level (County Level), to long-term recipient sites (Spatially Explicit). Data were provided by a variety of sources and contain disparate levels of data resolution; thus, we could not reliably determine abundance, density, or other metrics used to identify MVPs (see above) for all populations. All population data provided are integral to evaluating the current condition of the gopher tortoise. Therefore, we used a burrow conversion factor for properties that provided burrow counts and locations but did not have a corresponding abundance estimate from a LTDS survey. Although there is no single burrow conversion factor that would be appropriate for all population across the range of the species, we used a conventional burrow conversion factor of 0.4 individuals/burrow (Guyer et al. 2012, pp. 130-131) to calculate an estimated current population size based on the literature and expert input.

We used estimated abundance of adult gopher tortoises as a metric for categorical levels of resiliency: high (greater than or equal to 250), moderate (51-249), and low (less than 50). These resiliency levels align with the MVP working group’s categories for minimum viable (high resiliency), primary support (moderate resiliency), and secondary support (low resiliency) populations (GTC 2014, p. 4). Landscape populations likely provide a higher level of resiliency than local populations, assuming gopher tortoises are able to disperse at a landscape scale, although we do not quantify this explicitly in our resilience assessment. Resiliency categories for local populations are defined as follows:

- High-local population highly likely to persist through a biologically appropriate time frame.
- Moderate-local population likely to persist for a long period of time under high-quality habitat conditions, although more vulnerable to stochastic disturbances compared to highly resilient populations.
- Low-local population may persist for a long period of time under high quality habitat conditions and high levels of management, but highly vulnerable to stochastic disturbances.

Population Factors: Results

Table 4.1 and Figure 4.7 summarize the results of the resiliency analysis for spatially delineated populations of gopher tortoises. It is important to note that abundance estimates are only from spatially delineated populations (i.e., do not contain county level data or gopher tortoises that are present, but not reported), and that these estimates likely significantly underestimate the true number of gopher tortoises present across the species' range. Based on available data, there are an estimated 149,152 gopher tortoises from 656 spatially delineated local populations across the range of the species, with local abundance categories as follow: 360 low, 169 moderate, and 127 high. Most gopher tortoises are found in the eastern portion of the range with Unit 5 supporting 47 percent of the estimated rangewide population total, and Units 3 and 4 supporting 26 percent and 19 percent, respectively. Units 1 and 2 support much smaller numbers of gopher tortoises, with 2 percent and 6 percent of the estimated rangewide population total, respectively, likely driven by differences in soils, as discussed earlier in Chapter 2: Species Biology.

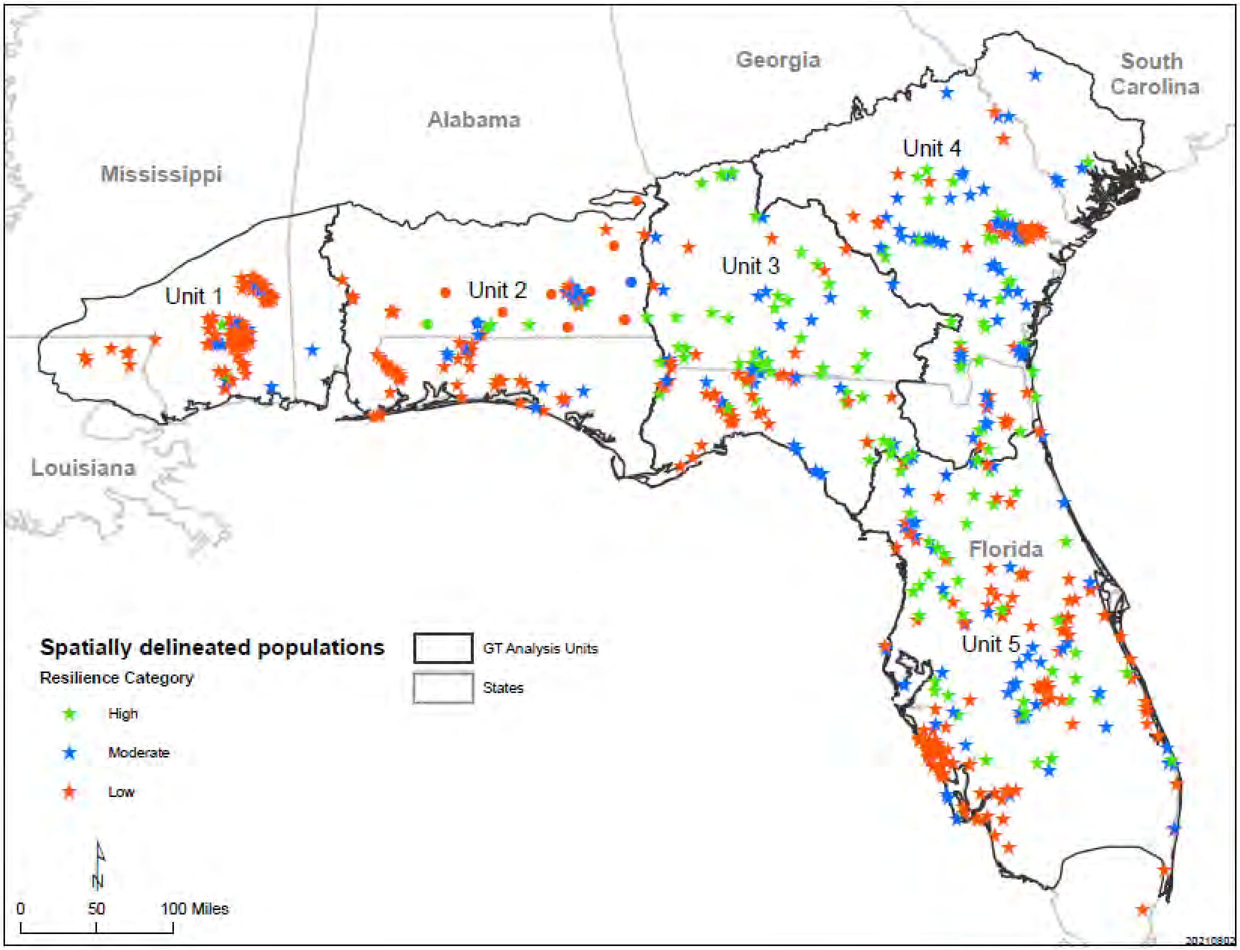

Figure 4.7-Location and associated resiliency (red = low; blue = moderate; green = high) for spatially delineated local populations of gopher tortoise.

Table 4.1-Site specific data population factors and current resiliency for spatially delineated local populations of gopher tortoise.

Analysis unit	# of burrows	# of landscape pops	# of local pops	Abundance	Current Resiliency
1	8,815	13	106	3,100	Low (94)
					Moderate (10)

					High (2)
2	5,809	30	106	8,642	Low (71)
					Moderate (27)
					High (8)
3	17,867	55	109	38,947	Low (42)
					Moderate (24)
					High (43)
4	20,216	46	124	28,408	Low (35)
					Moderate (58)
					High (31)
5	24,783	109	211	70,055	Low (118)
					Moderate (50)
					High (43)
Rangewide	**77,490**	**253**	**656**	**149,152**	**Low (360)**
					Moderate (169)
					High (127)

Table 4.2 summarizes the county location and results of the population factors we were able to obtain from the landowner questionnaire. We received responses from 167 properties across all analysis units, which represents approximately 25 percent of all data available for this report. Ninety-one (91) of these properties reported juveniles present, meaning approximately 55 percent of properties show evidence of reproduction. Although respondents only provided categories of abundance on the questionnaire, as opposed to precise abundance estimates, we provide estimates of low, moderate, and high condition classes for abundance as with the spatially delineated populations as follows: 63 low, 11 moderate, and 11 high. As with the spatially delineated populations, most of the properties classified as moderate or high abundance are in the eastern portion of the range, with the western portion supporting many populations

with low abundance. The results reported here for the landowner questionnaire do not include over 10,000 observations recorded between 2013 and 2019 (91 counties rangewide) by an informal NCASI survey (NCASI 2020, p. 9-11; Miller, pers. comm., 2021). Thus, results are assuredly an underestimate of gopher tortoise occurrences on private forests as they are derived from mostly informal surveys, do not cover all possible locations of gopher tortoises across the properties, and only includes a subset of acres under private forest management within gopher tortoise range.

Table 4. 2-County level data population factors (presence of juveniles, estimated number of burrows, and estimated abundance) derived from landowner questionnaire, organized by analysis unit.

Analysis unit	**# of properties**	**Juveniles present?**	**Estimated # of burrows**	**Estimated abundance**
1	17	Yes (7) No (10) Unknown (0)	Unknown (4)	Unknown (4)
			1-50 (13)	1-50 (13)
			50-250 (0)	50-250 (0)
			>250 (0)	>250 (0)
2	32	Yes (17) No (6) Unknown (9)	Unknown (27)	Unknown (29)
			1-50 (5)	1-50 (3)
			50-250 (0)	50-250 (0)
			>250 (0)	>250 (0)
3	48	Yes (21) No (8) Unknown (19)	Unknown (31)	Unknown (31)
			1-50 (12)	1-50 (12)
			50-250 (1)	50-250 (2)
			>250 (4)	>250 (3)
4	22	Yes (11) No (8) Unknown (3)	Unknown (2)	Unknown- (6)
			1-50 (9)	1-50 (10)
			50-250 (8)	50-250 (5)
			>250 (3)	>250 (1)
5	48	Yes (35) No (6) Unknown (7)	Unknown (12)	Unknown (12)
			1-50 (18)	1-50 (25)
			50-250 (11)	50-250 (4)
			>250 (7)	>250 (7)

4.4.2. Habitat and management factors

The Minimum Viable Population and Minimum Reserve Size Working Group discussed the influence of habitat size, quality, and management on the viability of gopher tortoise populations and concluded that the minimum reserve size to support a viable gopher tortoise population was 247 acres (100 ha), if that site is of superior quality and will be maintained at that quality (GTC 2013, p. 2). Persistence is believed to increase with habitat quality, and previous efforts involving expert workshops and habitat suitability modeling has shown that habitat suitability for gopher tortoises increases with the amount of well-drained soil, compatible land cover (e.g., evergreen forests, shrub), and fire frequency (Figure 4.8 and 4.9; Crawford et al. 2020, pp. 134-136).

Gopher tortoises may be found in a variety of vegetative community types, including upland pine systems such as sandhill and mesic flatwoods, scrub, xeric hammock, dry prairie, coastal grasslands and dunes, mixed hardwood-pine communities, and ruderal communities, with the primary determinants of gopher tortoise habitat suitability being well-drained sandy soils and the presence of an open savanna-like vegetation community. Given the gopher tortoise's affinity for open savanna conditions, maintenance of an open canopy and mid-story is the primary focus of management. Historically, frequent surface fires on the order of every 1-5 years were the primary driver that maintains savanna-like vegetation communities on most sites occupied by the gopher tortoise, although some extremely xeric sites may be maintained largely by moisture limitation. Today, this fire regime is best maintained through prescribed fire, as fragmentation of the landscape by roads and other fire barriers, and social/societal constraints (i.e., suppression efforts) prevents the spread of fire from natural lightning ignitions. Loss and alteration of gopher tortoise habitat from fire exclusion or fire suppression has a significant effect on survival of the gopher tortoise (Boglioli et al. 2000, p. 704), and increased urbanization has limited its use in many locations (Ashton and Ashton 2008, p. 78). Mechanical and chemical treatments to reduce midstory vegetation can also be effective techniques, particularly in areas with constraints to conducting prescribed fire (e.g., at wildlife urban interfaces where smoke management and liability can severely limit the ability to conduct prescribed fire).

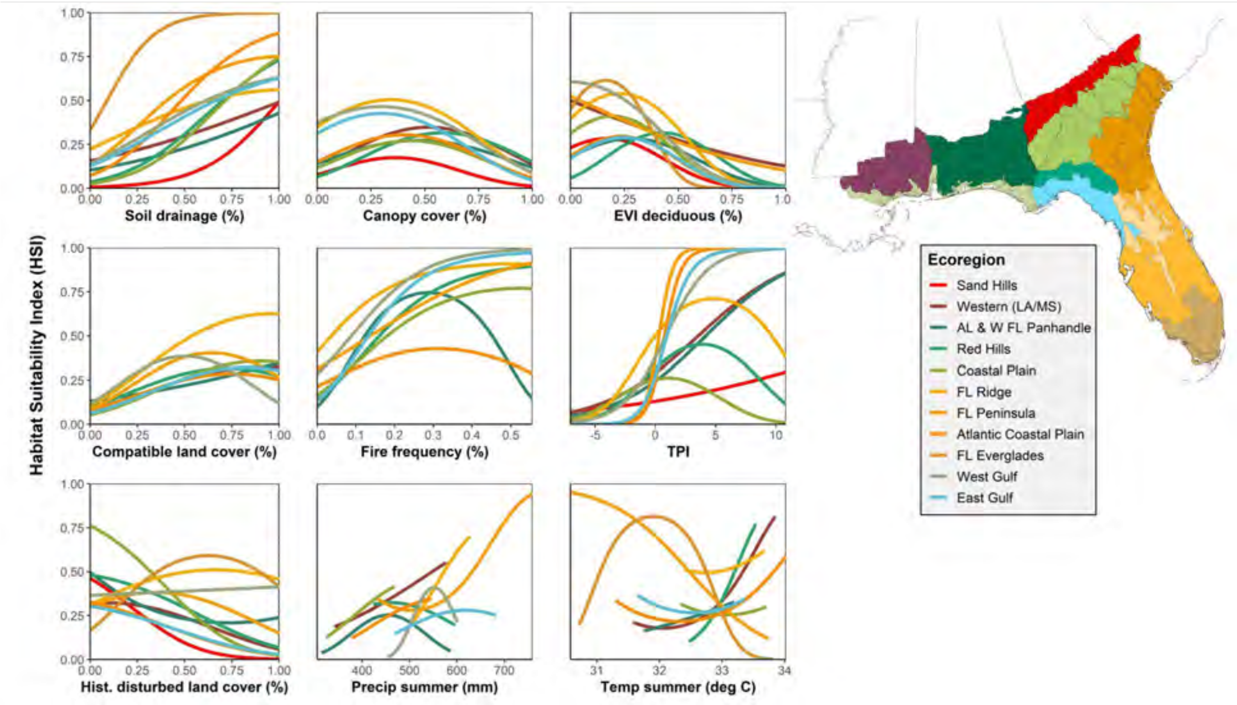

Figure 4. 8-*From Crawford et al. 2020:* Relationships from the best-fitting model between habitat suitability and environmental predictors, by ecoregion group (top right), for the gopher tortoise. Although relationships varied by ecoregion, gopher tortoise habitat suitability tended to increase with the amount of well-drained soil, compatible land cover (e.g., evergreen forests, scrub/shrub), and fire frequency.

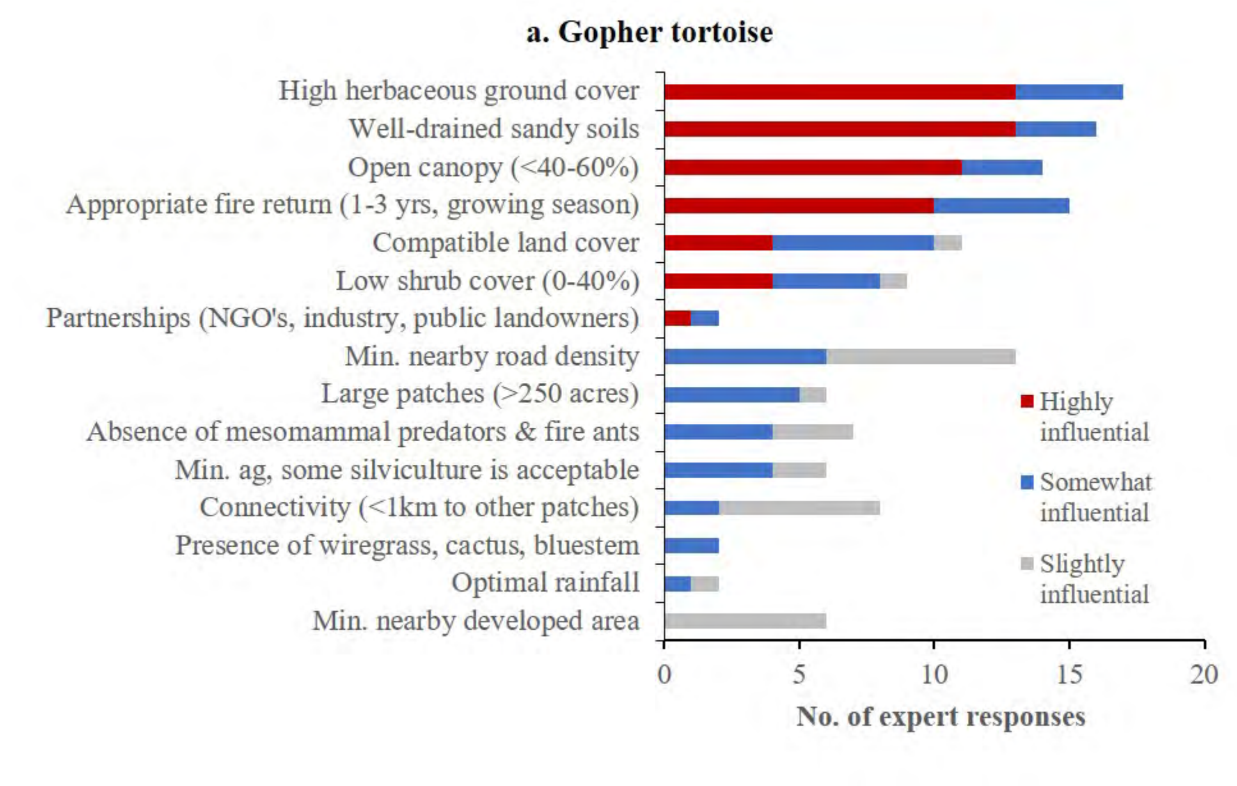

Figure 4. 9-*From Crawford et al. 2020, p. 68:* Influential environmental, landscape, and biophysical attributes for gopher tortoise habitat and presence at a site, as identified in questionnaires of 16 experts. Attributes are generally ordered from highest (top rows) to lowest (bottom rows) influence on habitat suitability and species presence. Definitions for attribute rankings: Highly – attributes must occur at a site for the species to be present; Somewhat – attributes occurring on the landscape greatly increase the likelihood of species being present, but species may occasionally use landscapes without these attributes; Slightly – attributes occurring on the landscape slightly or variably increase the likelihood of species being present, but species may use landscapes without these attributes.

Habitat Factors: Results

Because habitat data were provided by a variety of sources and contain disparate levels of data resolution, we could not reliably determine estimates of habitat within all populations across the range of the gopher tortoise. Thus, we summarize the spatially delineated populations and county level information separately, and estimates of habitat were not used to assess resiliency of gopher tortoise populations; only abundance was used to assess resiliency Estimates of occupied habitat are derived from the Habitat Suitability Index (HSI) model described below (Figure 4.10), and include all suitable habitat found within the 1,968 feet (600 m) buffers used to delineate local populations (Table 4.3). We also calculate estimates of potential habitat by calculating the amount of suitable habitat as predicted by the HSI model, which is located outside of the 1,968 feet (600 m) buffers used to delineate local populations (Table 4.3). Finally, we summarize the amount of low, medium, and high quality habitat as provided by landowners from the questionnaire described earlier (Table 4.4).

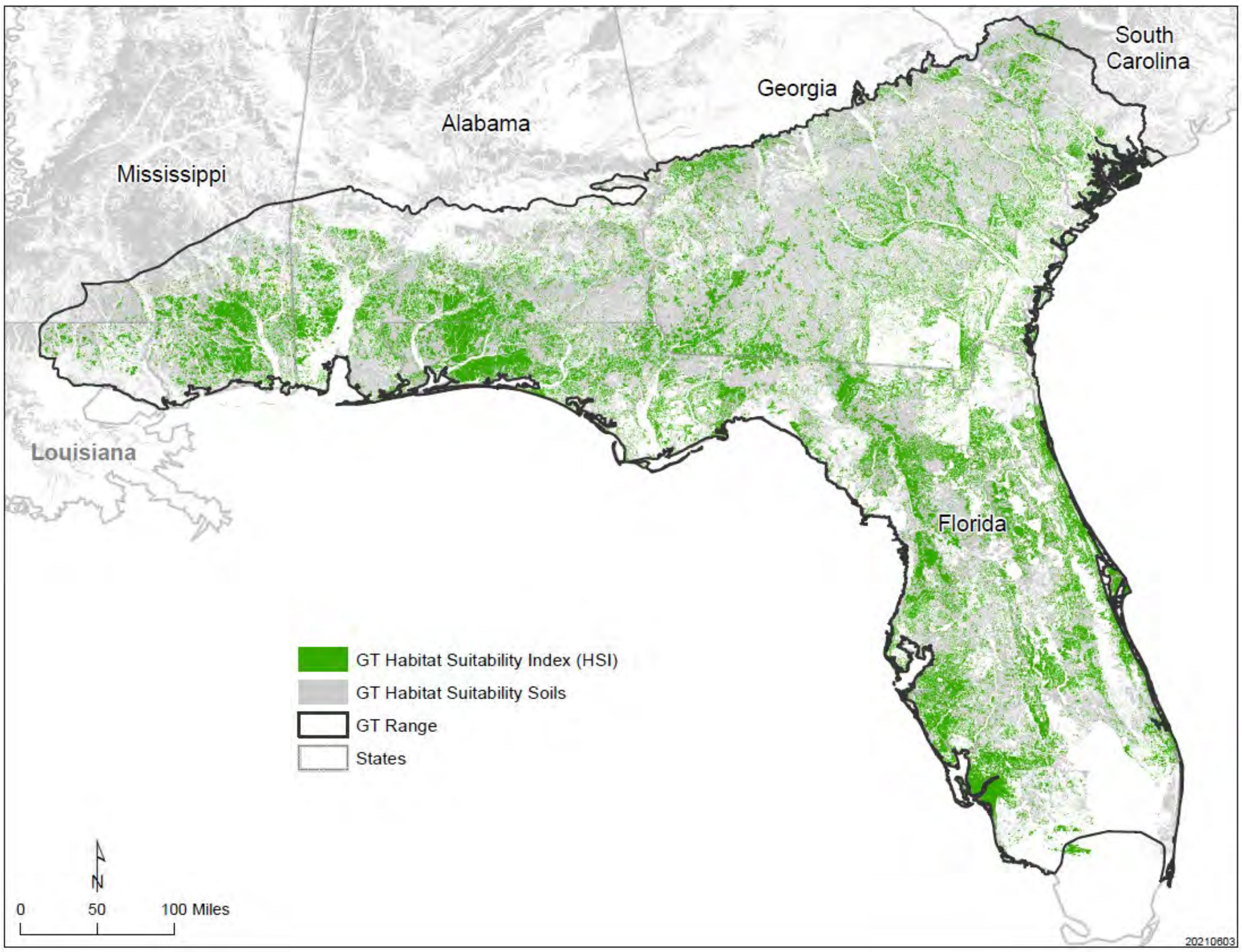

Figure 4. 10-Location of suitable habitat (green) from the HSI model (Crawford et al. 2020) and suitable soils (grey).

Table 4. 3-Estimates of known occupied habitat (habitat included within local population boundaries) and potential habitat (habitat located outside of local population boundaries), by analysis unit, as predicted by the HSI model. Total habitat is the sum of occupied and potential habitat.

Analysis Unit	Occupied Habitat	Potential Habitat	Total Habitat
1	103,582 acres	1,937,559 acres	2,041,141 acres
2	68,430 acres	3,416,877 acres	3,485,307 acres
3	220,127 acres	2,932,265 acres	3,152,392 acres
4	149,146 acres	2,768,120 acres	2,917,266 acres
5	303,627 acres	5,284,111 acres	5,587,738 acres
Rangewide Total	**844,912 acres**	**16,338,932 acres**	**17,183,844 acres**

Table 4. 4-Estimates of low, moderate, and high suitability habitat based on responses to landowner survey. Total habitat is the sum of low, moderate, and high suitability habitat.

Analysis Unit	Low Suitability Habitat	Moderate Suitability Habitat	High Suitability Habitat	Total Habitat
1	4,599 acres	10,943 acres	9,153 acres	24,695 acres
2	18,246 acres	84,004 acres	18,251 acres	120,501 acres
3	18,195 acres	21,356 acres	54,615 acres	94,167 acres
4	30,118 acres	38,131 acres	28,813 acres	97,063 acres
5	37,807 acres	33,208 acres	39,898 acres	110,914 acres
Rangewide	**108,965 acres**	**187,642 acres**	**150,730 acres**	**447,340 acres**

Management Factors: results

To assess gopher tortoise management, we used several data sets available from multiple sources and at multiple spatial scales and these data may include some overlap. First, we used the Tall Timbers Southeast fire history dataset, derived from the U.S. Geological Survey Burned Area (v2) Products (Hawbaker et al. 2020, entire) representing years 1994-2019, which allowed for estimates of acres burned (prescribed fire and wildfire) within gopher tortoise populations across multiple years. The advantages of these data are that they cover the entire range of the species and can be summarized by habitat acreage estimates for the gopher tortoise; however, we are unable to estimate other midstory management techniques such as chemical and mechanical treatments with these data. Acres burned across all units has generally increased over time, with significantly more burning occurring in Unit 5 (Table 4.5). It should be noted that we did not use any management metrics in our resiliency assessment; only abundance was used to assess population resiliency.

Table 4. 5-Acres burned (prescribed fire and wildfire), rangewide, and by analysis unit, for the years 1994-2019. Data obtained from the Tall Timbers Southeast fire history dataset.

Year	**Unit 1 fire acres**	**Unit 2 fire acres**	**Unit 3 fire acres**	**Unit 4 fire acres**	**Unit 5 fire acres**	**Total acres**
1994	17064	29580	22325	28969	41777	139716
1995	17351	23740	32089	29225	56752	159157
1996	14663	33233	68453	67842	103565	287756
1997	23548	28191	39641	47278	65203	203861
1998	22581	35007	60527	72085	99443	289644
1999	42810	76413	107046	94854	174827	495949
2000	70032	88929	134093	92035	163276	548366
2001	51095	68601	123032	102376	174164	519268
2002	45423	60584	71056	71704	104606	353374
2003	28963	43311	44151	45206	80722	242353
2004	40680	64721	85354	77782	145806	414342
2005	29955	59132	52668	61542	130292	333590
2006	89316	111019	102895	90224	249825	643279
2007	73774	90137	152646	161408	192678	670643
2008	53711	73615	104675	104038	140159	476199
2009	50212	79730	108016	93087	167332	498377
2010	38619	67389	85344	68852	129831	390035
2011	54290	101537	188435	292767	210675	847704
2012	16508	54169	68760	135385	117246	392067
2013	50671	106243	164417	106302	135898	563532
2014	69394	113388	162379	183892	218601	747655
2015	68604	105771	112364	102538	177518	566795
2016	89220	156954	193986	112830	188606	741597
2017	88513	197421	340685	331213	415134	1372965
2018	70181	149963	346703	213304	516060	1296210
2019	35795	106202	194682	161009	582368	1080058

We also used summary data for prescribed fire and other midstory maintenance activities available from America's Longleaf Restoration Initiative (ALRI) FY2019 annual report. An advantage of these data is the inclusion of management practices beyond prescribed fire, although the spatial scale of the data is the historical range of longleaf pine, thus estimates of management, include areas outside of gopher tortoise habitat. Also, gopher tortoises use a variety of pine communities, so by limiting reported management actions to longleaf stands, data reported by ALRI excludes some areas within the species range where gopher tortoises are likely present. Florida reported by far the most acres of habitat managed for longleaf by fire and other methods, with nearly 600,000 acres (242,811 ha) treated between October 2018-September 2019. Much of the management implemented by partners under the ALRI umbrella is likely to benefit gopher tortoise.

Table 4. 6-Midstory management, including acres burned and acres managed by other means (e.g., chemical and mechanical) between October 2018-Septemeber 2019, as reported by ALRI (2019).

State	Acres burned	Acres treated (other)	Total acres treated
Alabama	141,054	7,788	148,842
Florida	529,086	58,330	587,416
Georgia	133,019	503	133,522
Mississippi	52,941	3,505	56,446
Louisiana	53,716	9,135	62,851
South Carolina	64,276	5,170	69,446

Next, we summarize management practices as detailed in the gopher tortoise CCA 2021 annual report, which covers management actions implemented during FY2021 (Table 4.7). The goal of the CCA is to organize a cooperative approach to gopher tortoise management and conservation in the eastern portion of its range, and the standardized report generated by partners helps to support this approach and encourages uniform actions and reporting, integrating monitoring and research efforts, and support partner formation. Advantages of the CCA management data are they are specific to sites known to support gopher tortoises and include both prescribed fire and other beneficial practices such as chemical and mechanical treatments, and invasive species control. Unfortunately, the CCA data are limited to the eastern portion of the range, thus does not include information for the western portion.

Table 4. 7-Midstory management, including acres burned and acres managed by other means (e.g., chemical and mechanical), by agency, for FY2021, as reported by the gopher tortoise CCA report (2021). Data cover only the candidate portion of the gopher tortoise range. *Other includes Poarch Band of Creek Indians, Longleaf Alliance, Jones Center, Alabama Forestry Commission, National Park Service, and Georgia Power.

Agency	Acres burned	Acres treated (other)	Total acres restored or maintained
DoD	75,505	13,636	89,141
Forest Service	48,548	3,606	52,154
USFWS	20,362	1,639	22,001
Alabama	6,030	7,229	13,259
Florida	111,891	146,230	258,121
Georgia	33,209	2,530	35,739
South Carolina	431	100	531
Other*	98,513	3,233	101,746

Finally, Table 4.8 summarizes the results provided by respondents to the landowner questionnaire, including total acres burned on the property using prescribed fire, estimated burn frequency in years, and whether other practices beneficial to gopher tortoises are implemented on the property. A total of 228,454 acres (92,452 ha) were burned by private landowners that responded to the questionnaire, with most of this prescribed burning occurring in analysis units 3 and 5. Although there is some variance by analysis unit, many property owners are implementing prescribed fire on a 1-3 year cycle, with few landowners burning on a cycle of greater than 5 years. Finally, many landowners are implementing additional beneficial practices, including chemical and mechanical midstory treatments, invasive species control, and flagging of burrows prior to thinning of forest stands.

Table 4. 8-Results provided by respondents to the landowner questionnaire, by analysis unit, including acres burned, estimated burn frequency in years, and whether other practices beneficial to gopher tortoises are implemented on the property.

Analysis Unit	Acres burned	Burn frequency in years (# of respondents)	Other beneficial practices Y/N (# of respondents)
1	11,605	1-3 (14)	Y- (17) N- (0)
		3-5 (0)	
		>5 (1)	
2	33,562	1-3 (9)	Y- (23) N- (9)
		3-5 (5)	
		>5 (1)	
3	66,299	1-3 (14)	Y- (21) N- (27)
		3-5 (7)	
		>5 (0)	
4	12,361	1-3 (8)	Y- (17) N- (5)
		3-5 (4)	
		>5 (3)	
5	104,627	1-3 (7)	Y- (40) N- (8)
		3-5 (13)	
		>5 (11)	

4.5. Current resiliency results

Below, we summarize the results of the current condition analysis for both spatially delineated and county level local populations, by analysis unit (Table 4.9 and Figure 4.11). Current resiliency is derived from the estimated abundance at each local population (except for county level data which did not have an estimated abundance; these were labeled as unknown); although our resiliency assessment was limited to abundance within each population, habitat and management factors are also summarized for each analysis unit.

Table 4. 9-Number of local populations and current resiliency of gopher tortoise, by analysis unit; includes spatially explicit and county level data.

Analysis unit	# of local populations	Current Resiliency
1	123	Low (107)
		Moderate (10)
		High (2)
		Unknown (4)
2	138	Low (74)
		Moderate (27)
		High (8)
		Unknown (29)
3	157	Low (54)
		Moderate (26)
		High (46)
		Unknown (31)
4	146	Low (45)
		Moderate (63)
		High (32)
		Unknown (6)
5	259	Low (143)
		Moderate (54)
		High (50)
		Unknown (12)
Rangewide	**823**	**Low (423)**
		Moderate (180)
		High (138)
		Unknown (82)

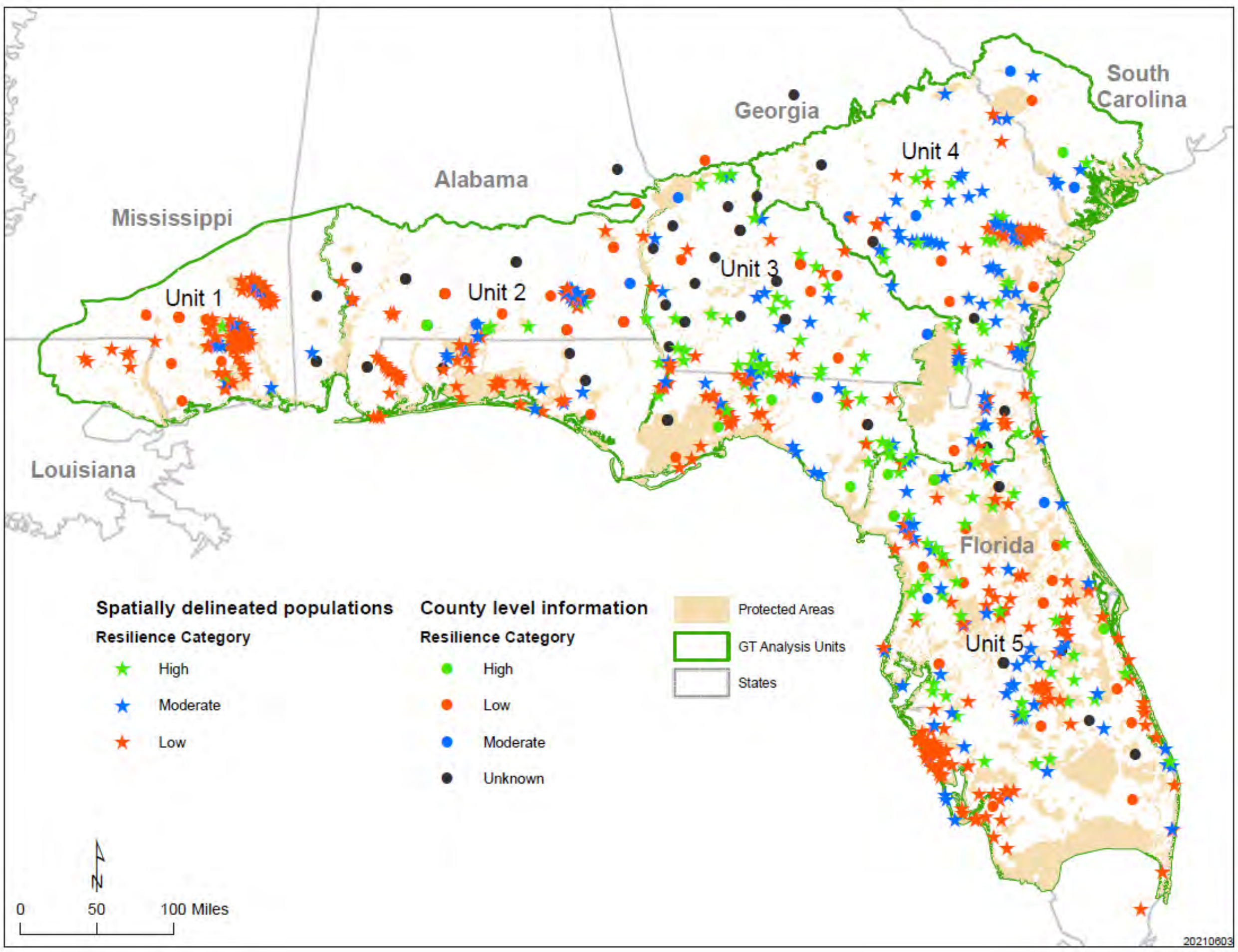

Figure 4. 11-Location of protected areas and local gopher tortoise populations with associated current resiliency, by analysis unit; includes spatially explicit and county level data.

<u>Unit 1</u>

Based on available data, analysis unit 1 is composed of many small, disconnected populations, and very few larger populations (123 local populations; 13 landscape populations), spread across private and public land. Based on current abundance, there are 107 low, 10 moderate, and 2 high resiliency populations within this unit; 4 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.12). Camp Shelby, a DoD property, is the stronghold of the unit with a local population having an estimated 1,003 individual gopher tortoises. Seventeen properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 7 properties reporting signs of reproduction.

Although over 103,000 acres (41,682 ha) of habitat are currently known to be occupied by gopher tortoises, there is nearly 2 million acres (809,371 ha) of estimated habitat where gopher tortoise occupancy is unknown and where future surveys may reveal more gopher tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that over 35,795 acres (14,485 ha) were burned within this unit in 2019, over a 2 times increase over time since 1994. Over 90 percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with all respondents reporting implementing additional beneficial practices for gopher tortoises.

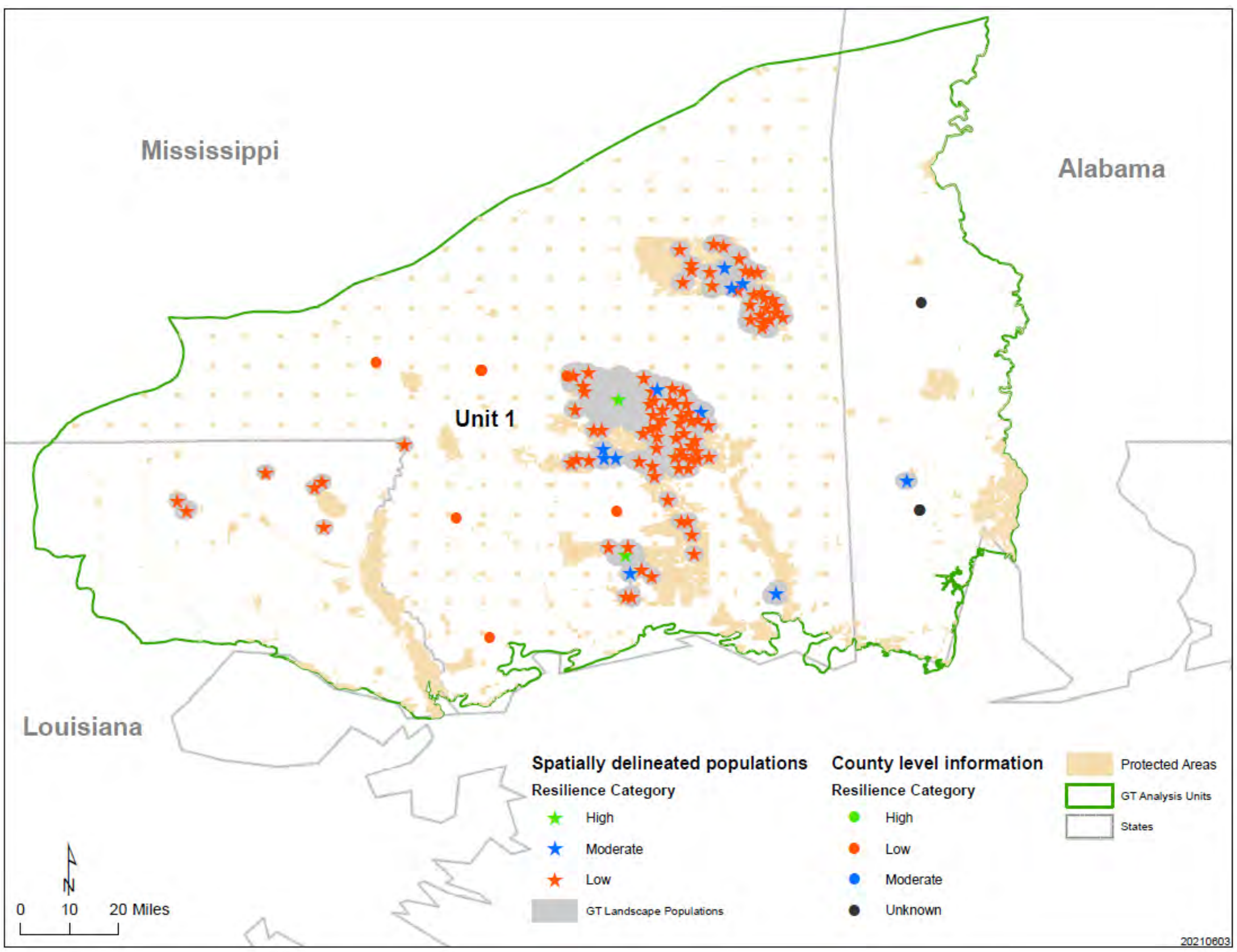

Figure 4. 12-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 1.

Unit 2

Based on available data, analysis unit 2 has 138 local populations and 30 landscape populations. Based on current abundance estimates, this unit is composed of 74 low, 27 moderate, and 8 high resiliency local populations; 29 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.13). The 8 highly resilient populations are found on Fort Rucker, Conecuh NF, Apalachee WMA, Perdido WMA, Geneva State Forest, and an unnamed private property. Thirty-two properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 17 properties reporting signs of reproduction.

Although over 68,000 acres (27,518 ha) of habitat are currently known to be occupied by gopher tortoises, there is nearly 3.4 million acres (1.37 million ha) of estimated habitat where gopher tortoise occupancy is unknown and where future surveys may reveal more tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that approximately 106,000 acres (42,896 ha) were burned in 2019, just over a 3 times increase since 1994. Sixty percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with 72 percent of respondents reporting implementing additional beneficial practices for gopher tortoises.

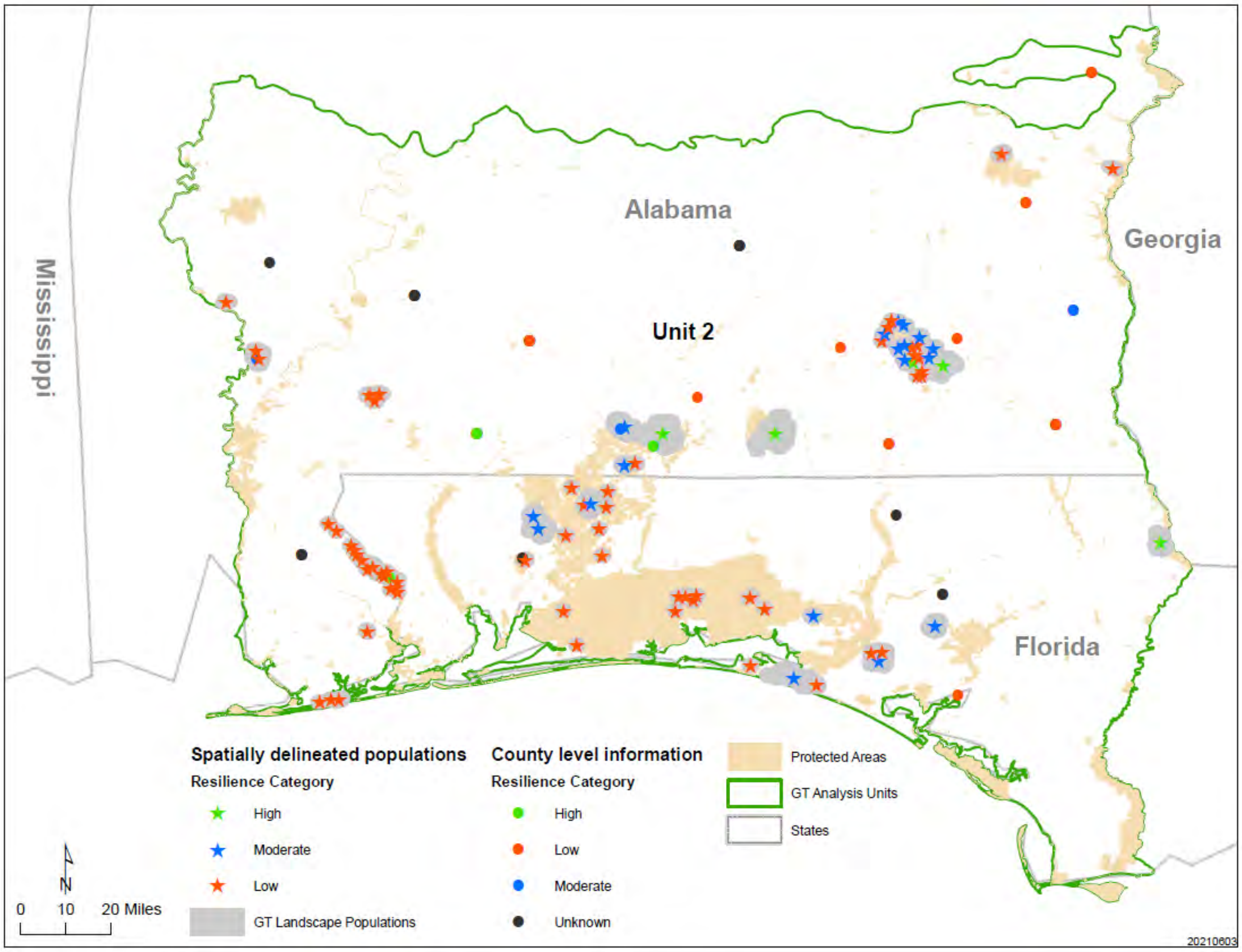

Figure 4. 13-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 2.

Unit 3

Based on available data, analysis unit 3 has 157 local populations and 55 landscape populations. Based on current abundance estimates, analysis unit 3 is composed of 54 low, 26 moderate, and 46 high resiliency populations; 31 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.14). Of the 46 highly resilient populations, 7 populations have estimates exceeding 1,000 individuals, including Twin Rivers State Forest, Chattahoochee Fall Line WMA, River Bend, Alapaha River WMA, Apalachicola NF, and the Jones Center at Ichauway. Forty-eight properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 21 properties reporting signs of reproduction.

Although over 220,000 acres (89,030 ha) of habitat are currently known to be occupied by gopher tortoises, there is over 2.9 million acres (1.17 million ha) of estimated habitat where gopher tortoise occupancy is unknown, and where future surveys may reveal more tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that over 194,000 acres (78,509 ha) were burned in 2019, almost a 10 times increase since 1994. Sixty-seven percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with 44 percent of respondents reporting implementing additional beneficial practices for gopher tortoises.

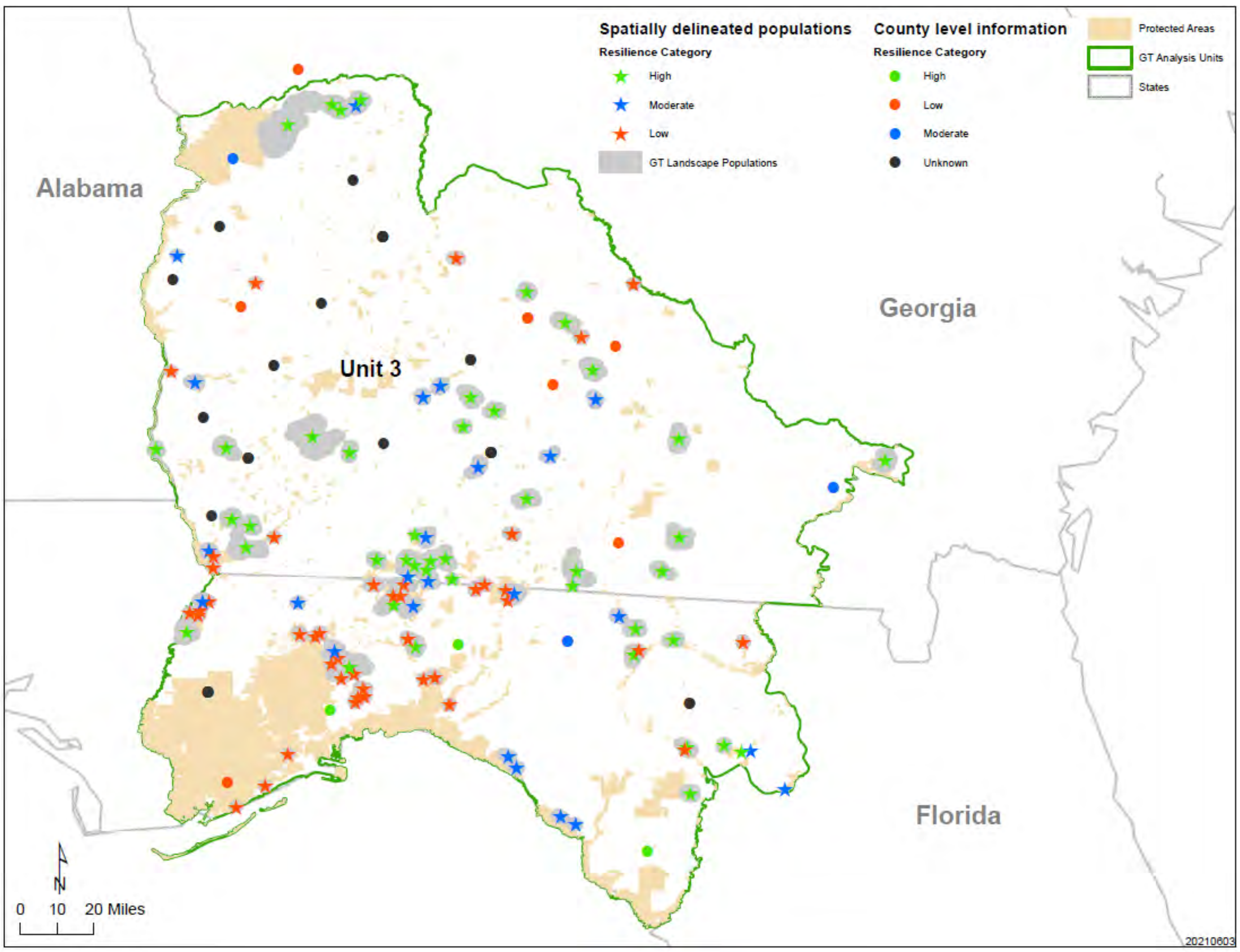

Figure 4. 14-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 3.

Unit 4

Based on available data, analysis unit 4 has 146 local populations and 46 landscape populations. Based on current abundance estimates, analysis unit 4 is composed of 45 low, 63 moderate, and 32 high resiliency populations; 6 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.15). Of the 32 highly resilient populations, 5 populations have estimates exceeding 1,000 individuals, including Ohoopee Dunes WMA, Ralph E. Simmons State Forest, Jennings State Forest, and Fort Stewart. Twenty-two properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 11 properties reporting signs of reproduction.

Although over 149,000 acres (60,298 ha) of habitat are currently known to be occupied by gopher tortoises, there is over 2.7 million acres (1.09 million ha) of estimated habitat that is currently not known to be occupied where future surveys may reveal more gopher tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that over 161,000 acres (65,154 ha) were burned in 2019, over a 7 times increase since 1994. Fifty-three percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with 77 percent of respondents reporting implementing additional beneficial practices for gopher tortoises.

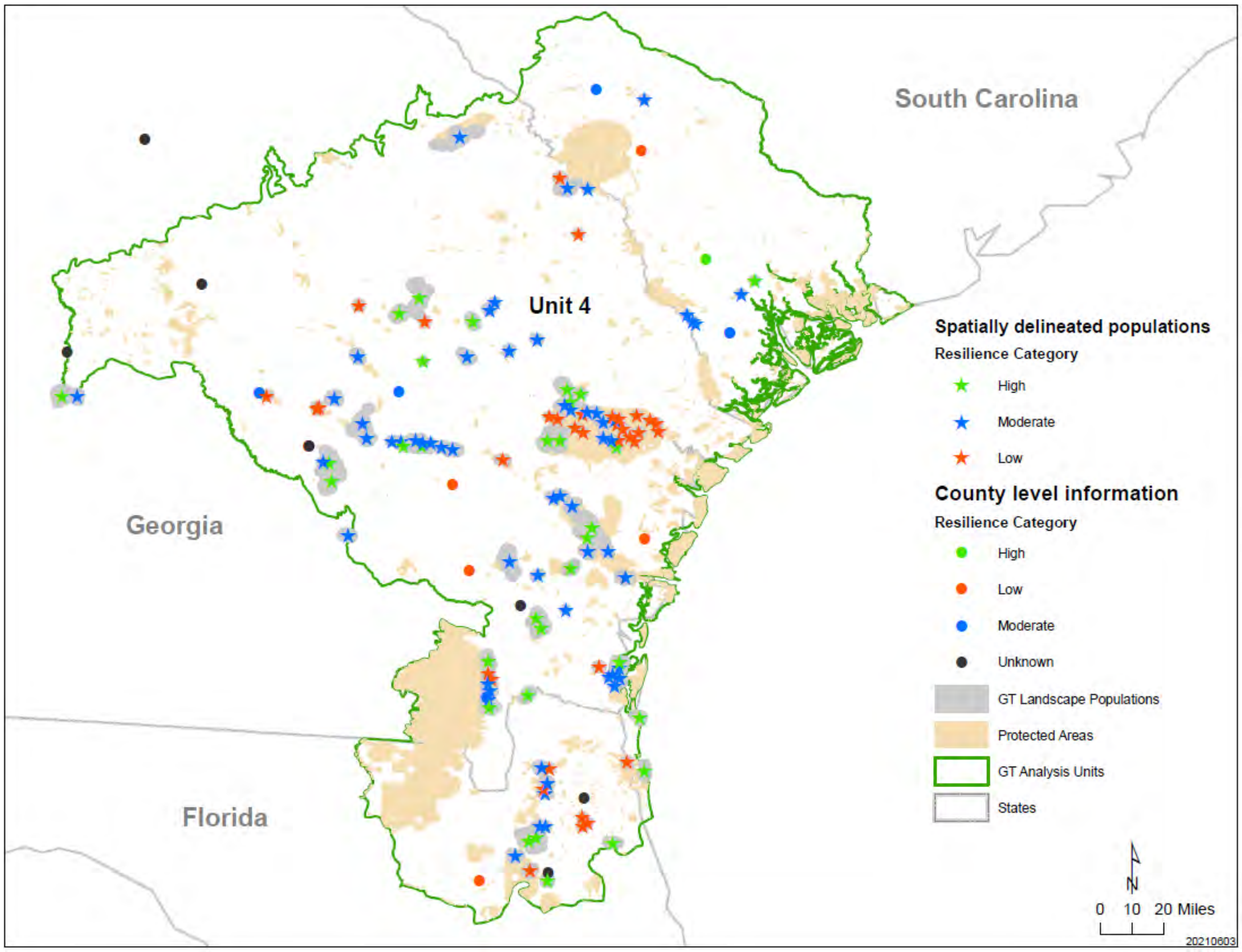

Figure 4. 15-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 4.

Unit 5

Based on available data, analysis unit 5 has 259 local populations and 109 landscape populations. Based on current abundance estimates, analysis unit 5 is composed of 143 low, 54 moderate, and 50 high resiliency populations; 12 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.16). Of the 47 highly resilient populations, 12 populations have estimates exceeding 1,000 individuals, including Camp Blanding and Goldhead Branch State Park; Ocala NF; Chassahowitzka WMA; Ichetucknee Springs State Park; Bell Ridge Wildlife and Environmental Area; Etoniah Creek State Forest; Halpata Tastanaki and Cross Florida Greenway; Lake Louisa State Park; Kissimmee Prairie Preserve State Park; Green Swamp West Unit WMA; Withlacoochee State Forest's Citrus Tract;

and Perry Oldenburg Wildlife and Environmental Area and Withlachoochee State Forest's Croom Tract. Forty-eight properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 35 properties reporting signs of reproduction.

Although over 300,000 acres (121,405 ha) of habitat are currently known to be occupied by gopher tortoises, there is nearly 5.3 million acres (2.14 million ha) of estimated habitat where gopher tortoise occupancy is unknown and where future surveys may reveal more gopher tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that over 582,368 acres (235,675 ha) were burned in 2019, a nearly 14 times increase over time since 1994. Twenty-three percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with 83 percent of respondents reporting implementing additional beneficial practices for gopher tortoises.

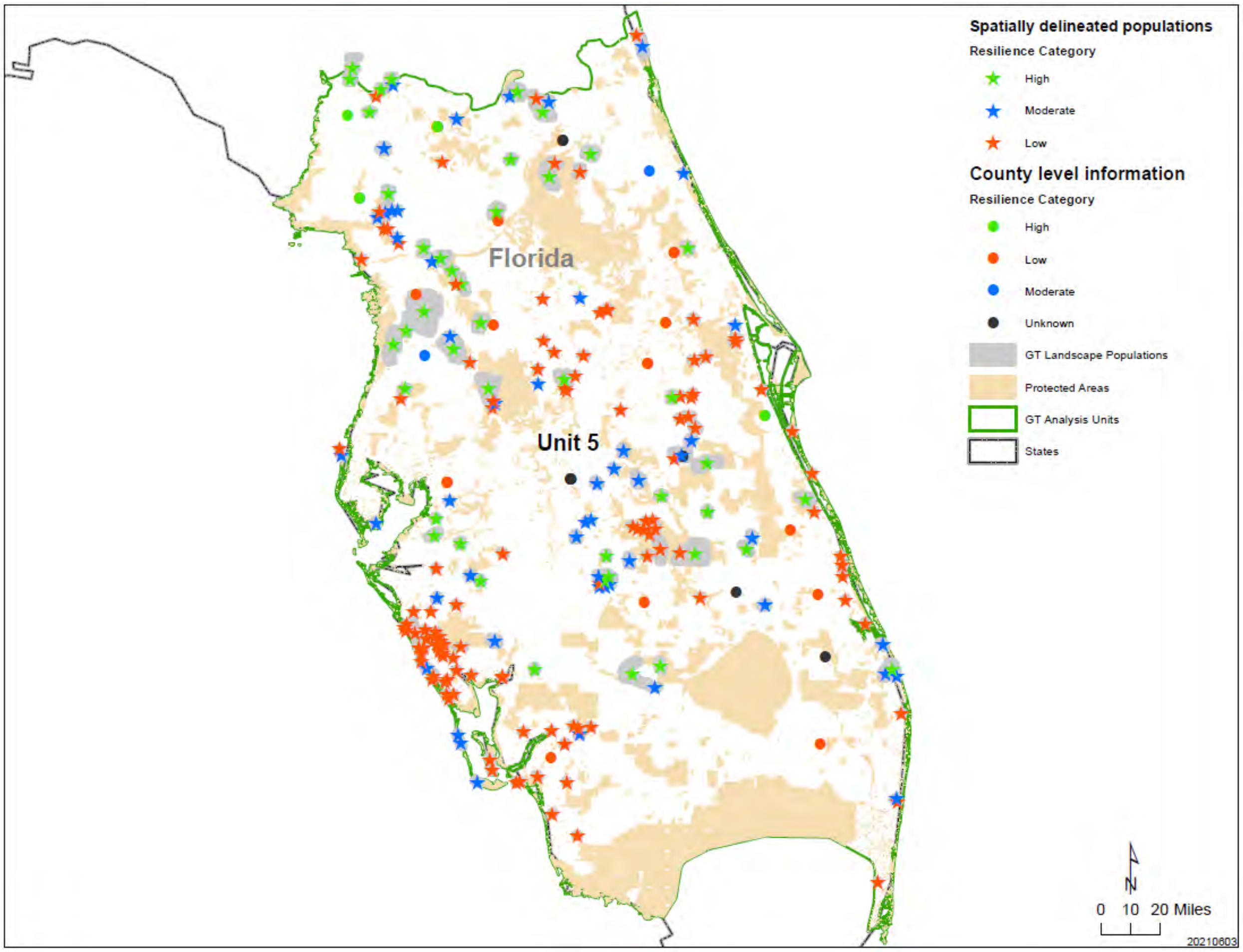

Figure 4. 16-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 5.

4.6. Current representation and redundancy

As described previously in this chapter, representation for this species is assessed primarily based on genetic variation across the range of the species (5 analysis units; Galliard et al. 2017, entire). We evaluated current representation by examining the number of populations and their associated resiliency within the five population analysis units across the species' range (Gaillard et al. 2017, entire). We report redundancy for gopher tortoise as the total number and resiliency of populations and their distribution within and among representative units.

Although gopher tortoises occupy vegetative communities with a variety of pine types, the species was historically associated with longleaf pine systems, which once covered an estimated 92 million acres (37.2 million ha) (Frost 1993, p. 20), but has declined significantly due to forest clearing and conversion for agriculture and development (Landers et al. 1995, p. 39). Due to loss of open pine conditions, gopher tortoise representation and redundancy have likely decreased significantly from historical levels. Currently, all five analysis units are occupied by multiple local populations, although the resiliency of these populations varies across the range (Figure 4.17). Unit 1, in the far western portion of the species range, is comprised of many small, isolated populations (although there is uncertainty in whether currently unknown populations are present on private lands which could ultimately connect these small populations into larger more resilient populations; future surveys and data from private lands would help elucidate this uncertainty), with only 10 percent of the populations having at least moderate resiliency (calculated as 100% x (moderate + high)/(total - unknown)), and only 2 populations with high resiliency, leaving portions of this unit potentially vulnerable to catastrophic events. These results are confounded by the fact that Unit 1 is the western extent of the species range, and spatial gradients in environmental factors often produce predictable patterns in which habitat quality is highest in the centers of species' ranges and becomes more unsuitable as the range edge is approached; thus, apparent lower levels of abundance seen in the western portion of the range might be driven by natural variation in climate and soils found at the edge of the species' range. Also, there are likely many populations that are unaccounted for with the limited data we had available, which if accounted for, would infer a higher degree of redundancy (i.e., more populations and greater spatial distribution).

Similarly, for Unit 2, in the western-central portion of the range, only 32 percent of the populations are of moderate or greater resiliency, but 8 populations are classified as highly resilient, potentially buffering against the potential of catastrophic events. The central (Unit 3) and eastern (Units 4 and 5) have many populations (67 percent of the total number of populations assessed), and the resiliency of many of the populations is of moderate or high condition (Unit 3 = 57 percent; Unit 4 = 68 percent; Unit 5 = 50 percent). In addition to a relatively high number of highly resilient populations within the 3 eastern analysis units, the populations are well distributed across each unit, potentially buffering against the impacts of potentially catastrophic events. The fact that there are more resilient populations in the eastern portion of the range compared to the western portion is not surprising, as the soils are not as suitable in the western portion, an important component of habitat driving habitat quality, and ultimately abundance and density.

From a rangewide perspective, although representation and redundancy have likely decreased significantly relative to the historical distribution of the species, there are still many resilient populations distributed across the range of the species, contributing to future adaptive capacity (representation), and buffering against the potential of future catastrophic events. Because the species is widely distributed across its range, it is highly unlikely any single event would put the species as a whole at risk. However, portions of analysis unit 1 are likely more vulnerable to such catastrophes given that most of the populations present in this unit are of low resiliency.

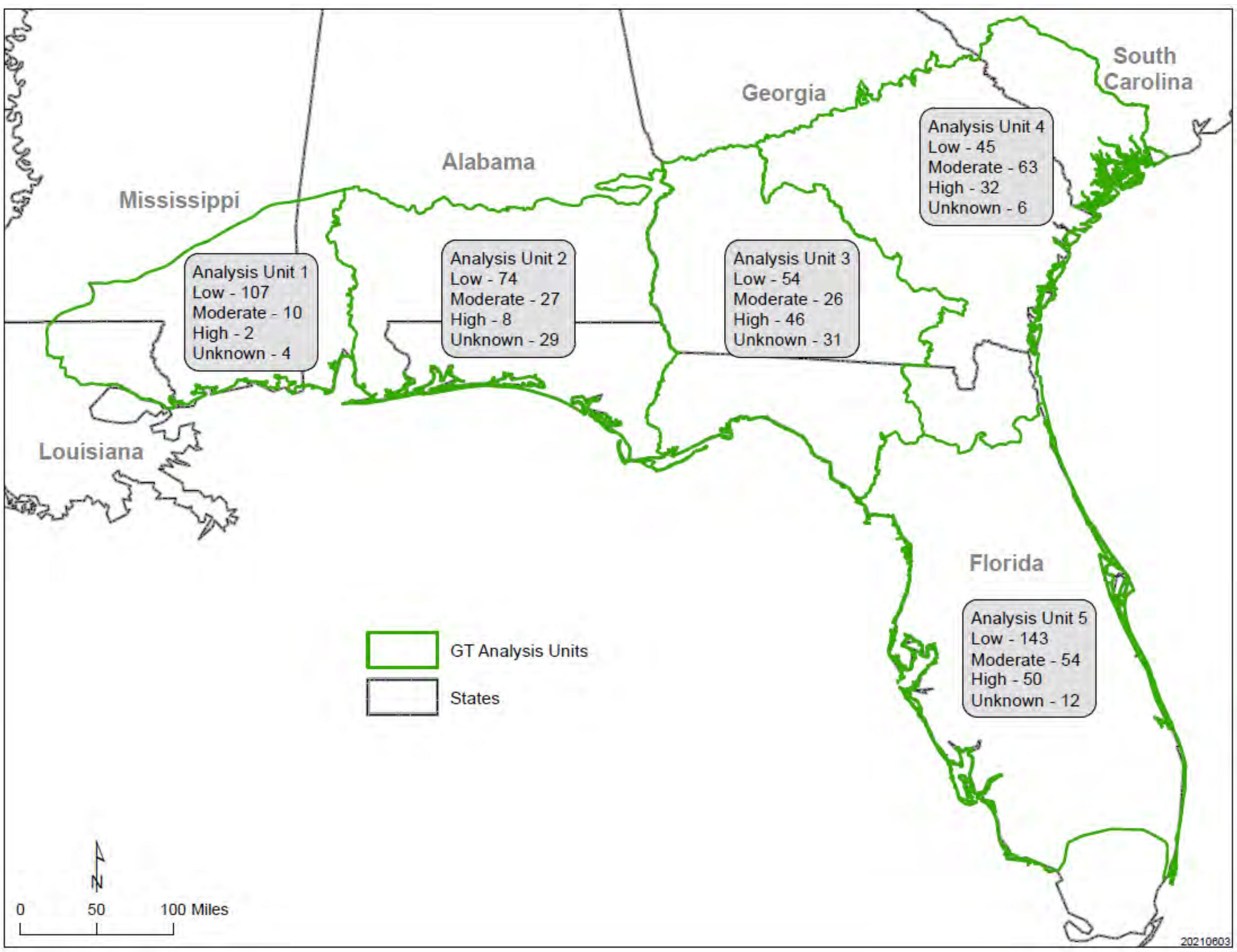

Figure 4. 17-Resiliency of gopher tortoise local populations summarized by analysis unit.

CHAPTER 5 – FUTURE CONDITIONS AND VIABILITY

We have considered what the gopher tortoise needs for viability and the current condition of those needs (Chapters 2 and 4), and we reviewed the influencing factors that are driving the current, and future conditions of the species (Chapter 3). We now consider what the species' future condition might be by projecting populations that occur on protected conservation lands. We apply our future forecasts to the concepts of resiliency, representation, and redundancy to describe the future viability of the gopher tortoise.

To assess viability for the gopher tortoise, we developed an analytical framework that integrates projections from multiple models of future anthropogenic and climatic change to project future trajectories/trends of gopher tortoise populations and identify stressors with the greatest influence on future population persistence. The modeling framework was built to support the future conditions analysis by estimating the change in population growth and persistence probability of populations while accounting for geographic variation in life history. The model links intrinsic factors (demographic vital rates) to four extrinsic anthropogenic factors that are hypothesized to threaten gopher tortoise population persistence (climate warming, sea-level rise, urbanization, and shifts in habitat management). We used published models describing extrinsic factors in the future to project gopher tortoise demographics under six future scenarios varying in threat magnitude and presence. A regression analysis of model outputs was used to identify threats that are predicted to have the greatest impact on population persistence. A detailed model description is included in Appendix B.

5.1 Models and scenarios

5.1.1. Model Structure

A population viability analysis (PVA) framework was used to predict population growth and extinction risk for the gopher tortoise. The PVA is a stage-based population model (i.e., Lefkovitch model) used to project population size and structure forward in time with simulations. For the PVA, local population demography of gopher tortoises was conceptualized in a multi-stage, female-only model, with two discrete life stages: juveniles and adults. During a given time-step, both stages had a probability of individuals surviving and staying within the stage, juveniles had a probability of maturing to become adults, and adults had a probability of reproducing and potentially recruiting individuals into the juvenile stage. Individuals that did not survive during a time-step were assumed to have either died or permanently emigrated from the population. Recruitment into the adult stage by immigration was also modeled. In the following sections of Chapter 5, we describe the methods and results of the future conditions analysis; we note that a detailed description of the model structure can be found in Appendix B.

5.1.2. Demographic parameters

We constructed a baseline population model that approximated demographic conditions experienced by gopher tortoise populations in recent decades across the species' range. However, populations of gopher tortoises experience great variation in abiotic characteristics across the species' range, and variation in abiotic characteristics influences demographic rates among populations. At more southern latitudes, populations experience significantly warmer mean annual temperature, which may afford greater overall opportunity for thermoregulation, energy acquisition, and metabolism when compared to northern populations. As a result, southern populations of gopher tortoises experience faster growth rates, younger ages of sexual maturity (hereafter, maturity age), and increased clutch size (Mushinsky et al. 1994, p. 123; Ashton et al. 2007, entire; Meshaka Jr. et al. 2019, p. 105-106). Because the goal was to predict population growth and extinction risk of populations across the species' range and predictive population models are most useful when demographic parameters are modeled specific to populations of interest (Ralls et al. 2002, entire), we extended the model to accommodate for geographic variation in demographic rates by estimating parameters specific to the geographic location of populations.

Demographic parameters used to model and project baseline population demographics of gopher tortoises are shown in Table 5.1. For parameters thought to vary substantially by abiotic features among sites, linear regression models were fit to estimate relationships between demographic rates and mean annual temperature (hereafter, MAT; degrees C) sourced from the 'WorldClim' database (Hijmans 2020, entire). If parameters were not known to vary geographically, mean values were modeled as invariant among populations. In the following subsections, we describe how parameters describing recruitment, maturity age, survival, immigration, and initial population size, were modeled.

Table 5. 1-Demographic parameters, mean estimates, and distribution shapes used to model and project baseline population demographics of gopher tortoises in conservation lands across the species' range.

Parameter	Distribution shape	Mean (SE)
Probability of breeding	Beta	0.97 (0.01)
Fecundity	Log normal	-3.54 (2.42) + 0.48 (0.12) * MAT
Nest survival	Beta	0.35 (0.10)
Probability of viable eggs	Beta	0.85 (0.05)
Probability of female	Beta	0.50 (0.04)
Hatchling survival	Beta	0.13 (0.03)
Juvenile survival	Beta	0.75 (0.06)
Adult survival	Beta	0.96 (0.03)
Maturity age	Log normal	43.52 (11.31) – 1.41 (0.53) * MAT
Juvenile abundance	Log normal	Varying by population
Adult abundance	Log normal	Varying by population
Immigration rate	Beta	0.01 (0.001)
Percent of winter days for burning	Beta	0.77 (0.05)
Percent of spring days for burning	Beta	0.80 (0.05)
Percent of summer days for burning	Beta	0.65 (0.05)
Change in winter days for burning	Beta	Varying by projection scenario
Change in spring days for burning	Beta	Varying by projection scenario
Change in summer days for burning	Beta	Varying by projection scenario
Burn probability	Beta	0.4 (0.015)
Fire effect on survival	Beta	0.96 – 0.027 (0.003) * YSB

Recruitment

We modeled the proportion of breeding females in a given year as 0.97; this estimate has recently been validated by two independent field studies (J. Goessling unpubl. data, 2021; E. Hunter unpubl. data, 2021). Because fecundity varies widely among populations and is likely driven by a north-to-south latitudinal gradient in temperature (Ashton et al. 2007, p. 360), we used linear regression to estimate the relationship between MAT and estimates of mean clutch size from the literature and then used regression coefficients to simulate mean values for populations, given the geographic location and MAT of a population. We modeled the proportion of nests that survive predation as 0.35 using an estimate from unmanipulated nests (Smith et al. 2013, p. 355). We modeled the probability of eggs being viable and hatching as 0.85, an average from reviews of field hatching rates (Landers et al. 1980, p. 359; Rostal and Jones 2002, p. 7). To account for males (and remove them) during projections, we assumed that sex ratios of eggs were even within populations and modeled the probability of eggs being female as 0.5. We modeled hatchling survival from nest emergence until the following survey period as 0.13 (0.04–0.34, 95 percent confidence interval [CI]), given results from a meta-analysis of hatchling survival of gopher tortoises (Perez-Heydrich et al. 2012, p. 342).

Maturity age

Age at maturity varies along a latitudinal gradient across gopher tortoise populations (Mushinsky et al. 1994, p. 123; Meshaka Jr. et al. 2019, p. 105-106). We used linear regression to estimate the relationship between MAT and maturity age estimates of females from the literature, then used regression coefficients to simulate mean maturity ages for populations, given the population's geographic location and MAT. Given a predicted maturity age for a population, we then calculated the probability that a juvenile will transition to adulthood during a given year.

Survival Rates

Survival rates are difficult to measure for gopher tortoises because individuals are long-lived, challenging to recapture, may become unavailable for resurvey by emigrating away from study populations, or may die. When individuals disappear from a study population, mark-recapture analyses are often unable to estimate whether individuals died or emigrated away. To this end, most mark-recapture studies of gopher tortoise seeking to understand survival have estimated apparent annual survival, which is the probability that individuals survived and stayed within a study area. Studies have found apparent annual survival to vary between adults and juveniles, with adults having higher survival than juveniles (Tuberville et al. 2014, p. 1155; Howell et al. 2020, p. 60; Folt et al. 2021, p. 624-625). We reviewed the literature for apparent annual survival estimates for gopher tortoises and performed a linear regression analysis testing for effects of age and MAT on survival, which confirmed that adults have greater survival than juveniles but failed to recover an effect of MAT on survival; rather, survival is likely most strongly influenced by habitat quality and management at sites (Howell et al. 2020, entire; Folt et al. 2021, p. 627;

Hunter and Rostal 2021, p. 661). We modeled adult survival as 0.96 and juvenile survival as 0.75 (Folt et al. 2021, p. 624-625), with a density-dependent limit on population growth where for each time-step when density increased above 2 females/ha, we prevented recruitment into the adult age class. Field studies have estimated tortoise density to range from 0.02–1.50 individuals/ha among northern populations (Guyer et al. 2012) and from 4.2–24.9 individuals/ha in southern Florida. We selected a threshold of 2 females/ha (i.e., 4 tortoises/ha, assuming even sex ratios) as a limit for density dependence because there is a considerable uncertainty when estimating tortoise density and 2 females/ha was a conservative intermediate estimate of maximum density among populations across the species' range.

Immigration

Gopher tortoises infrequently move long distances from established core home range areas; such movements can result in permanent emigration and immigration into other populations. We implicitly modeled losses to local populations due to emigration because the estimates of apparent annual survival accounts for individuals that emigrate from local populations. Given ongoing emigration, local populations within the same landscape population might receive immigrants that bolster population size. While little quantitative information is available describing the frequency or success of immigration, one study found that 2 percent of adults emigrated from local populations each year (Ott-Eubanks et al. 2003, p. 319). Given it is unlikely that all emigrants successfully immigrate into another population, the number of immigrants into local populations was modeled as a product of a randomly-drawn immigration rate (mean = 1 percent) multiplied by the total number of adult tortoises in adjacent populations (i.e., landscape population size) divided by the number of nearby local populations. Immigration rate was constrained during each time step so that the sum of immigration rate and survival rate could not exceed 1.

Initial population size

To estimate population growth and extinction risk of gopher tortoise populations across the species' range, we initialized the model with estimates of population size from spatially delineated populations. Population estimates were collected by a diverse partnership of cooperating State and Federal agencies, private organizations, and academic institutions. As discussed previously, only spatially explicit data were used in the future projection modelling. Because initial population sizes used in this analysis are the same dataset that were included in Chapter 4, the same assumptions and data limitations apply, including factors that may result in underrepresentation of initial population sizes and thus, future projections. It is important to note, data included in future condition modelling represents a subset of gopher tortoises likely to occur on the landscape, as data from private lands were lacking due to the absence of spatial information. Population estimates do not represent an assessment of all local populations of tortoises that exist in southeastern North America, but rather represent information that was provided by partners through much of the species' range. Most population estimates came from assessments of local populations on lands managed for the conservation of biodiversity or natural resources. Future inclusion of additional spatially explicit populations, particularly from private lands, would provide projections that better describe the species as a whole; our current model only makes projections about a subset of the species' populations.

We initialized starting population size using population estimates derived from data collected using burrow surveys and LTDS. Using spatial survey data associated with population estimates, we identified populations at two spatial scales as described in Chapter 4: local populations and landscape populations. We received some population estimates in aggregate from properties that were delineated to have two or more local populations of gopher tortoises; in these instances, we multiplied the population estimate (and confidence limits) by the area of each delineated local population and divided by the total survey area of the original survey. We assumed that population estimates being delineated into two or more local populations through this process would have even population densities and this process spread the population assessment evenly among local populations delineated by in the dataset. Some delineated local populations assessed in current conditions have less than 2 individuals; we removed these local populations from the future condition analysis.

The process of delineating local populations and landscape populations resulted in a dataset of 626 local populations that formed 244 landscape populations. We used population estimates from local populations to parameterize initial population size of adults and juveniles during simulated population projections. We assumed a 1:1 sex ratio and a 3:1 adult:juvenile ratio in populations (Folt et al. 2021, p. 626) and used the ratios to isolate and separate the female population into juvenile and adult components.

5.1.3. Modeling threats

We sought to model how predicted future changes to abiotic and biotic features may threaten future population growth and viability of gopher tortoises. We engaged scientists with expert knowledge in both gopher tortoise population biology and habitat management and identified a series of factors that experts considered to have high likelihood of influencing gopher tortoise demographics in the future (hereafter, threats). Using the list of threats, we reviewed the literature to identify research describing quantitative effects of how threats (or similar mechanisms) influence specific demographic parameters in the conceptual model for gopher tortoises. Below, we describe hypotheses for how four threats (climate warming, sea-level rise, urbanization, and climate-change effects on habitat management) may influence gopher tortoise demographics, and how we used quantitative estimates of the threats from the literature to parameterize and simulate how threats may influence future population growth and viability of gopher tortoises.

Climate warming

Climate change is predicted to drive warming temperatures and seasonal shifts in precipitation across Southeastern North America (Carter et al. 2018, entire). Of these two effects, warming temperatures may have the greater impact on gopher tortoises, because gopher tortoise demography is known to be sensitive to temperature gradients across the species' range. Specifically, maturity age and fecundity vary along a north-south latitudinal gradient, where warmer, southern populations have faster growth rates, younger maturity ages, and increased fecundity relative to cooler, northern populations (Ashton et al. 2007, p. 123; Meshaka Jr. et al. 2019, p. 105-106). As climate warming increases temperatures in the region, individuals in populations may experience more favorable conditions for growth and reproduction across the species' range. Because no studies have linked gopher tortoise growth or fecundity to interannual or interpopulation variation in precipitation, it seems less likely that climate-driven shifts in precipitation will influence gopher tortoise demography. Although the gopher tortoise exhibits temperature-dependent sex determination, we did not include this effect in the model as gopher tortoises can modify nest site selection and timing of nesting, as discussed in Chapter 3. We also did not model any potential range expansion or contraction that could occur due to long term climate change because there is no consensus or projection framework that we are aware of related to vegetative community changes and climate change projections; also, any significant expansion or contraction of the gopher tortoise range is likely to occur beyond our projection timeframe of 80 years.

We modeled how climate warming may influence gopher tortoise demography by using the estimated linear relationships of MAT with maturity age and fecundity to predict how warming temperatures experienced by populations in the future will drive concurrent changes in demography. For each population, we used historical estimates of MAT using the 'WorldClim' database (Hijmans 2020, entire) and then simulated step-wise climate-warming effects on MAT each year in the future where warming rates were parameterized by three treatments of climate warming: (1) a 1.0 °C (1.8 °F) increase in MAT over the next 80 years, (2) a 1.5 °C (2.7 °F) increase in MAT over the next 80 years, and (3) a 2.0 °C (3.6 °F) increase in MAT over the next 80 years (IPCC 2013, entire). The three scenarios (1.0 °C, 1.5 °C, and 2.0 °C) related to an optimistic prediction of RCP2.6, an intermediate prediction between RCP2.6 and RCP4.5, and a prediction for RCP4.5, respectively. Each year in the future, we used simulated changes in MAT to calculate mean maturity age and fecundity at sites. This analysis assumes that: (i) all local populations will respond homogeneously to warming temperatures, and (ii) there are no potential climatic ceilings that would limit growth and reproduction.

<u>Habitat management</u>

Prescribed fire is the most common management technique to maintain high-quality, open canopy conditions for gopher tortoises (Landers and Speake 1980, entire; Diemer 1986, p. 130; Yager et al. 2007, entire; Ashton et al. 2008, entire); however, when fire is not present in sufficient intervals or intensity to maintain open canopy conditions on the landscape, apparent survival of gopher tortoises decreases (Hunter and Rostal 2021, p. 661), potentially to levels that are insufficient for maintaining population viability (Folt et al. 2021, p. 627). However, wildlife managers tasked with maintaining high-quality habitat for gopher tortoises and other fire-dependent upland plant and animal species (Guyer and Bailey 1993,entire) may be challenged because regional climate warming may make habitat management with prescribed fire more difficult to accomplish. Managers require suitable fuel and weather conditions (e.g., relative humidity, temperature, wind speed; i.e., the ‘burn window’) to facilitate manageable fire behavior that will accomplish intended goals while limiting risk toward human communities. However, climate-change models predict the availability of burn window conditions to shift over future decades, with available conditions for fire management increasing in the winter but decreasing in the spring and summer (Kupfer et al. 2020, p. 769-770); summed together, seasonal shifts in the burn window conditions will decrease overall opportunity for management with prescribed fire. If managers become limited in the use of prescribed fire, resulting decreases in habitat quality may drive decreases in gopher tortoise survival. Alternatively, managers will need to rely on alternative tools to control midstory, such as chemical and mechanical treatments, which can be economically costly. Also, it should be noted that, although the ability to implement prescribed fire will likely be greatly constrained in the future, modelling for the southeastern United States suggests increased wildfire risk and a longer fire season, with at least a 30 percent increase from 2011 in lightning-ignited wildfire by 2060 (Vose et al. 2018, p. 239). It is possible that more frequent wildfires may help to mitigate predicted decreases in suitable burn days.

We estimated how habitat management influences gopher tortoise population growth by modeling habitat management of populations and linking the frequency of management to adult survival (see Appendix B for more information). We assumed that a baseline fire-return interval of 1-4 years (mean = 2.5 years) maintains high-quality habitat for the species (Guyette et al. 2012, p. 330; Crawford et al. 2020, p. 141) and then modeled the probability that the habitat associated with a population is burned during a given year (burn probability) as the inverse of the fire-return interval. Next, using historical baseline data describing average seasonal burn opportunity across southeastern North America (Kupfer et al. 2020, p. 769-771), we modeled the number of available burn days (i.e., days within the burn window) in winter (January–February), spring (March–May), and summer (June–July) as a product of the total days per season (59, 92, and 61 days, respectively) and the percentage of days historically available for burning (0.766, 0.800, and 0.645, respectively). We modeled four treatments for how the number of days available for prescribed fire may change in the future (Kupfer et al. 2020, p. 769-771): (1) ‘decreased fire’ - prescribed fire use will decrease consistent with climate shifts projected by

RCP4.5, (2) ‘very decreased fire’ - prescribed fire use will decrease with climate projections RCP8.5, (3) ‘increased fire’ - prescribed fire use will increase opposite of the effect projected by RCP4.5, and (4) ‘status quo’ - prescribed fire use will remain at current levels.

For each treatment, we modeled effects of climate change on the percentage of available burn days over the next 80 years using average effects from across southeastern North America (Kupfer et al. 2020, p. 769-771): 0.016 increase in winter, 0.040 decrease in spring, and 0.239 decrease in summer (‘decreased fire’ treatment); 0.030 increase in winter, 0.105 decrease in spring, and 0.436 decrease in summer (‘very decreased fire’ treatment); 0.016 decrease in winter, 0.040 increase in spring, and 0.239 increase in summer (‘increased fire’ treatment), and no effects on burn days (‘status quo’ treatment). The increased fire and status quo treatments could result if habitat managers can offset effects of climate change by benefiting from methodological advances in fire management or by using alternative methods rather than prescribed fire, such as mechanical or chemical treatments, to achieve similar management goals.

Urbanization

Human development of the landscape (i.e., urbanization) threatens terrestrial wildlife communities in the southeastern United States, including gopher tortoise populations that often rely on upland habitats that are popular sites for urban development or agriculture. While the local gopher tortoise populations we modeled are largely on conservation lands intended for wildlife conservation, urbanization threatens to surround these conservation lands, disrupt habitat connectivity, and decrease metapopulation dynamics that maintain connectivity and gene flow both among local populations and within landscape populations. Additionally, urbanization can disrupt habitat management by decreasing the ability of managers to use prescribed fire, with the caveat that managers have the alternative to implement other tools, such as mechanical and chemical treatments. We sought to model effects of urbanization pressure on gopher tortoise populations by linking urbanization projections from the SLEUTH urbanization model (Terando et al. 2014, entire) to habitat management of local populations with prescribed fire and with baseline immigration rates of gopher tortoises across landscape populations.

First, we modeled an effect of urbanization on habitat management by making burn probability a function of each population's distance to the nearest urban area. Studies have found evidence of fire exclusion/suppression in habitats within 600 m to 5 km (0.4 to 3.1 miles) of urban areas (Theobald & Romme, 2007, entire; Pickens, et al., 2017, p. 105). Therefore, we chose a moderate value of 10,498 feet (3.2 km) to capture the interaction between urbanization and fire frequency. Specifically, we assumed that local populations immediately adjacent to urban areas (distance less than 328 feet [0.1 km]) are unable to manage with prescribed fire. We also assumed management is uninfluenced for populations far from urban areas (greater than 10,498 feet [3.2 km]; no effect), and management of populations between 328-10,498 feet (0.1–3.2 km) from an urban area experience a negative effect on fire management with burn probability declining as a linear function of the population's proximity to the urban area (i.e., populations closer to urban areas experience less prescribed fire).

To model effects of urbanization on migration dynamics among local populations within landscape populations, we first estimated the total area and urbanized area within landscape populations in year 2020 using the SLEUTH model. Next, we estimated future urbanization and its effect on dispersal for gopher tortoises by estimating future urbanized areas using the SLEUTH model projections for 40, 60, and 80 years in the future. We then calculated the predicted change in proportion of habitat due to future urbanization for landscape populations. For each year greater or equal to 3 during population projections, we modeled the number of adult immigrants into local populations in each year as a function of the total number of individuals in the landscape population available for immigration to the local population during the previous year divided by the total number of local populations in the landscape population; this estimated a number of migrants from the landscape population that would be available to immigrate into a local population being modeled during a given timestep. We then multiplied the number of dispersing tortoises during a timestep by the proportion of non-urbanized habitat across the landscape, assuming that urbanized habitat prevented dispersal by causing mortality of dispersing tortoises (i.e., road mortality). Next, we assumed that the likelihood of a population is managed with prescribed fire varies by its distance to the nearest urban area. We first estimated the distance of each local population to the nearest urban area in the current conditions (i.e., year 2020) and in the future using the SLEUTH model by measuring the distance to urban area from the geometric center of local populations to the edge of the nearest neighbor urban area. We assumed that local populations immediately adjacent to urban areas (distance < 0.1 km) are unable to be managed with prescribed fire and forced burn probability to 0 for those populations; that management is uninfluenced for populations far from urban areas (> 3.2 km; no effect on burn probability); and that populations between 0.1–3.2 km from an urban area experience a negative effect on fire management where burn probability declined as a linear function of the population's proximity to urban area. We explain how we modeled urbanization in greater detail in Appendix B.

We estimated predicted effects of urbanization on local and landscape populations by modeling three treatments from the SLEUTH urbanization model that corresponded to different probability thresholds of urbanization:
(1) a 'low urbanization' treatment where future urbanization was limited to cells with urbanization probability greater or equal to 0.95,
(2) a 'moderate urbanization' treatment with urbanization predicted by probability greater or equal to 0.50, and
(3) a 'high urbanization' treatment with urbanization probability greater or equal to 0.20.
We assumed that: (i) immigration was limited to adults and that no juveniles successfully migrate among populations, and (ii) immigrants cannot survive or move through urbanized areas (e.g., due to road mortality) but can survive while moving through unurbanized areas.

<u>Sea level rise</u>

Because gopher tortoises are a terrestrial species and not suited for wetlands, sea-level rise may negatively affect gopher tortoise populations in low-lying coastal areas, such as coastal sand-dune environments (Blonder et al. 2021, p. 6-8). Projected sea-level rise scenarios provide a range of coastal inundation scenarios that vary in severity. We modeled effects of sea-level rise on gopher tortoises using three scenarios of sea-level rise predicted by the U.S. National Oceanic and Atmospheric Administration (NOAA), the 'intermediate-high', 'high', and 'extreme' scenarios, which correspond to projections from two of the most likely global emission scenarios, RCP6 and RCP8.5 (IPCC 2013, entire; NOAA 2020, entire). Local projections for the two scenarios are available from U.S. Geological Survey sea-level monitoring stations across the southeastern United States, providing estimates of sea-level rise for stations at decadal time steps in the future to year 2100.

We modeled three treatments of sea-level rise using projections from NOAA:
(1) the ‘intermediate-high’ scenario derived from RCP6.0, which projects approximately 6.0 feet (1.83 m) of sea-level rise over the next 80 years;
(2) the ‘high’ scenario which projects approximately 8.37 feet (2.55 m) of sea-level rise over the next 80 years; and,
(3) the ‘extreme’ scenario derived from RCP8.5, which projects approximately 10.37 feet (3.16 m) of sea-level rise over the next 80 years (NOAA 2020, entire).

We modeled sea-level rise effects on populations in two ways. First, assuming that gopher tortoise populations cannot persist when oceanic levels encroach too close upon their habitat, we simulated decreasing elevation of gopher tortoise populations due to sea-level rise. We extracted historical estimates of elevation Above Sea Level (ASL; in feet/m) using the centroid geographic coordinates of each local population using the ‘WorldClim’ database (Hijmans 2020, entire). Given the total predicted sea-level rise of each treatment over the next 80 years, we simulated incremental sea-level rise at each population in each year in the future and subtracted this incremental oceanic rise from the site’s elevation through time. When the site elevation of populations decreased to less than 5.56 feet (2 m) ASL, we considered the populations functionally extirpated. Second, we assumed that habitat inundated by sea-level rise adjacent to local populations would decrease connectivity and dispersal dynamics of individuals among populations within landscape populations. We used spatial projections from NOAA to estimate future inundation area due to sea-level rise for each landscape population, and then modeled immigration to decline as a function of decreasing habitat available for dispersal at the landscape scale. The analysis of sea-level rise effects assumes that: (i) sea-level rise throughout the Southeast will be homogeneous and characterized by NOAA projections derived from data from Ft. Myers, Florida, (ii) populations less than 5.56 feet (2 m) ASL are unable to persist, and (iii) populations are unable to migrate away from sites because coastal areas are often heavily developed and there is no guarantee that adjacent properties would be available for entire populations to migrate.

5.1.4. Scenarios and population projection structure

To understand how gopher tortoise populations will respond to scenarios with multiple concurrent factors, we created a set of six scenarios with varying levels of threat magnitude and combination (Table 5.2). Specifically, we created three scenarios with different levels of stressors (low stressors, medium stressor, and high stressors) that experienced habitat management consistent with contemporary target management goals. We then used the medium stressor values and built three additional models that varied in habitat management treatments, ranging from 'more management' conditions to worsening ('less management') and much worse ('much less management') conditions (Table 5.2). Appendix B describes how uncertainty in future states of factors and scenarios were addressed, including geographic variation among populations, parametric uncertainty, and temporal stochasticity.

Table 5. 2-Six scenarios of future climate warming, sea-level rise, urbanization, and habitat management used to simulate population growth and extinction risk for gopher tortoises for 80 years into the future. Scenarios vary in the magnitude of threat influences on gopher tortoise demography; threat levels included three levels of climate warming (1.0, 1.5, and 2.0 degrees C increase; 1.8, 2.7, 3.6 degrees F, respectively), three levels of sea-level rise (intermediate-high [6.00 feet/1.83 m], high [8.37 feet/2.55 m], and extreme [10.37 feet/3.16 m] scenarios), three levels of urbanization scenarios predicted by the SLEUTH model (Terando et al. 2014, entire) at probability thresholds of 0.9 (conservative projection), 0.5 (moderate projection), and 0.1 (aggressive projection), and four levels of changes in habitat management (no changes, less management predicted by RCP4.5 [Kupfer et al. 2020, p. 769-770], much less management predicted by RCP8.5 [Kupfer et al. 2020, p. 769-770], and improved management [the opposite of the effect predicted by RCP4.5 in Kupfer et al. 2020, p. 769-770]).

Scenarios	Climate warming (deg C)	Sea-level rise (m)	Urbanization	Management
Low stressors	1.0	0.54 m	P = 0.95	Status quo
Medium stressors	1.5	1.83 m	P = 0.50	Status quo
High stressors	2.0	3.16 m	P = 0.20	Status quo
More management	1.5	1.83 m	P = 0.50	More

Less management	1.5	1.83 m	P = 0.50	Less
Much less management	1.5	1.83 m	P = 0.50	Much less

Little to no data exist describing gopher tortoise immigration rates (γ) in wild populations. Given uncertainty associated with this parameter, we sought to include a sensitivity analysis to understand the effects of γ on our results. We crafted three additional scenarios: a 'no immigration' scenario with γ = 0, a 'high immigration' scenario with γ = 0.02, and a 'very high immigration' scenario with γ = 0.04. We simulated these scenarios with stressor and habitat management values from the 'medium stressors' scenario with a projection interval of 80 years, and we compared the resulting immigration scenarios to the 'medium stressors' scenario results that were simulated with γ = 0.01.

To assess future redundancy, resiliency, and representation of the gopher tortoise, we used population projections to estimate changes in gopher tortoise populations in the future under each of the six scenarios (Table 5.2). We assessed redundancy by measuring predicted changes in the total number of individuals, local populations, and landscape populations in the future. We summarized population trends by estimating population growth rate as increasing (greater than 1.00), stable (equals 1.00), or decreasing (less than 1.00). We measured population growth of total population size, the number of local populations, and the number of landscape populations across the species' range during the projection interval by dividing the value from year 2020 by the model-predicted value at the end of the projection interval.

We assessed the resiliency of future populations to changing environments by estimating extinction risk. We chose 3 females as a lower threshold to approximate functional extinction because populations with fewer than three females are extremely likely to be inbred and at great risk of extirpation (Chesser et al. 1980, entire; Frankham et al. 2011, p. 466). For each population, we estimated persistence probability, and then categorized populations as 'extremely likely to persist' (persistence probability greater or equal to 0.95), 'very likely to persist' (P greater than or equal to 0.80 and less than 0.95), 'more likely than not to persist' (P greater than or equal to 0.50 and less than 0.80), and 'unlikely to persist' (i.e., extirpated; persistence probability less than 0.50). We then simulated the number of populations predicted to persist at the end of the projection. For each landscape population, we estimated resiliency by selecting the constituent focal population with the greatest persistence probability and used that value to categorize landscape population persistence and simulated landscape population survival.

We evaluated how representation is predicted to change in the future by examining how population growth of total population size (number of individual females), number of populations, and number of landscape populations will vary by the five population genetic groups of tortoises across the species' range (Gaillard et al. 2017, p. 501-504). For each scenario, we summarized the results among all populations across the species' range, but also by genetic units (five units; see Gaillard et al. 2017, p.501-504). All analyses were performed in the statistical program R (R Core Team 2018, entire). A more detailed methodological summary of the future conditions analysis is included in Appendix B.

5.2 Model results

Linear regression analysis of three demographic parameters reviewed in the literature (fecundity, maturity age, and apparent annual survival probability) found that fecundity and maturity age vary significantly by MAT across the species' range (Figure 5.1). For each 1 °C (1.8 °F) increase in MAT, we found that maturity age decreased by 1.41 years (0.18–2.62, 95 percent CI), which was a statistically significant effect ($P = 0.029$). For each 1 °C (1.8 °F) increase in MAT, we found that fecundity increased by 0.52 eggs per clutch (0.27–0.77, 95 percent CI), which was statistically significant (P less than 0.001). Survival probability showed no significant trend with respect to MAT.

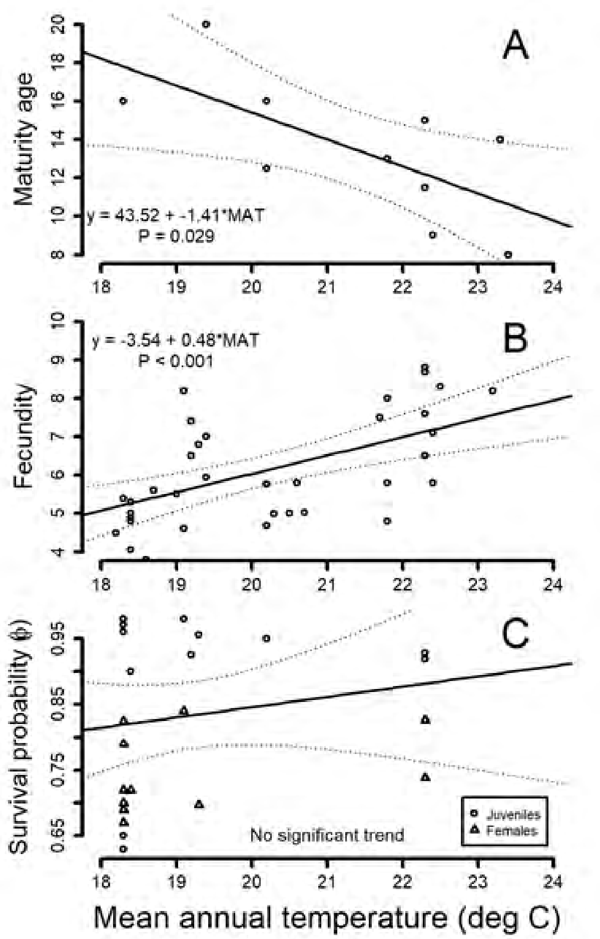

Figure 5. 1-Effect of mean annual temperature (MAT; degrees C) on (A) maturity age (MA), (B), fecundity, and (C) annual apparent survival probability of gopher tortoise (Gopherus polyphemus) populations. Geographic variation in biotic conditions (e.g., MAT) predict significant variation in maturity age and fecundity (P less than 0.05) but not in annual apparent survival probability.

We simulated population growth of 626 local populations and 244 landscape populations that were estimated to comprise approximately 70,600 individual (female) gopher tortoises. Population projections under six scenarios of future change during 40, 60, and 80-year projection intervals predicted declines in the number of gopher tortoise individuals, local populations, and landscape populations of gopher tortoises (Table 3). Relative to current levels of total population size, projections for total population size suggested declines by 2060 (λ = 0.65–0.67 among scenarios; i.e., 33–35 percent declines), 2080 (λ = 0.66–0.70 among scenarios; 30–34 percent declines), and 2100 (λ =

0.67–0.72 among scenarios; i.e., 28–33 percent declines). The six scenarios varied little in their effects on the total number of individuals, local populations, and landscape populations; but scenario effects become more magnified in each successive timestep. However, 95 percent confidence intervals for projections of future population growth overlapped with 1.00 in all scenarios and timesteps, indicating significant uncertainty in projections for each scenario at each projection interval.

Among the simulated populations, the number of local populations and landscape populations also were predicted to decline in each projection interval (Table 5.3). Declines in local populations and landscape populations were modest at the 40-year timestep (47–48 percent and 25–27 percent declines among scenarios, respectively) but were exacerbated at the 60-year (60–61 percent and 41–43 percent declines, respectively) and 80-year (68–70 percent and 53–57 percent declines, respectively) timesteps. Scenarios did not vary strongly in their effect on the predicted number of persisting local populations and landscape populations within each projection interval.

Table 5. 3-Simulated population projections for female gopher tortoises under six scenarios of future change. Columns summarize the initial number (in 2020), future predicted number, and population growth rate (λ) for the total population size, number of populations, and number of landscape populations for six scenarios projected 40, 60, and 80 years into the future. See Table 5.2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of landscape populations		
	Initial	Future	λ	Initial	Future	λ	Initial	Future	λ
Year 2060									
Low stressors	70610	47468	0.67 (0.30–1.80)	626	332	0.53 (0.51–0.55)	244	179	0.73 (0.63–0.81)
Medium stressors	70614	47630	0.67 (0.30–1.91)	626	331	0.53 (0.51–0.54)	244	183	0.75 (0.61–0.80)
High stressors	70582	45998	0.65 (0.28–1.84)	626	329	0.53 (0.51–0.55)	244	177	0.73 (0.64–0.80)
More management	70611	46646	0.66 (0.29–1.84)	626	329	0.53 (0.51–0.55)	244	178	0.73 (0.61–0.80)
Less management	70610	46826	0.66 (0.29–1.79)	626	328	0.52 (0.50–0.54)	244	180	0.74 (0.62–0.80)
Much less management	70600	46495	0.66 (0.29–1.80)	626	323	0.52 (0.50–0.54)	244	178	0.73 (0.60–0.79)
Year 2080									
Low stressors	70609	49281	0.70 (0.36–1.77)	626	249	0.40 (0.38–0.41)	244	143	0.59 (0.44–0.73)
Medium stressors	70636	48924	0.69 (0.37–1.79)	626	250	0.40 (0.38–0.41)	244	142	0.58 (0.45–0.73)
High stressors	70592	46674	0.66 (0.34–1.70)	626	246	0.39 (0.37–0.41)	244	138	0.57 (0.43–0.70)

More management	70598	49246	0.70 (0.35–1.86)	626	250	0.40 (0.38–0.42)	244	145	0.59 (0.45–0.74)
Less management	70604	48754	0.69 (0.34–1.80)	626	247	0.39 (0.38–0.41)	244	138	0.57 (0.44–0.72)
Much less management	70569	48592	0.69 (0.35–1.69)	626	243	0.39 (0.37–0.42)	244	142	0.58 (0.42–0.72)
<u>Year 2100</u>									
Low stressors	70614	50846	0.72 (0.37–1.77)	626	198	0.32 (0.30–0.33)	244	114	0.47 (0.36–0.62)
Medium stressors	70594	48366	0.69 (0.36–1.74)	626	196	0.31 (0.29–0.33)	244	108	0.44 (0.35–0.59)
High stressors	70578	47378	0.67 (0.35–1.70)	626	194	0.31 (0.29–0.33)	244	109	0.45 (0.33–0.60)
More management	70584	49114	0.70 (0.36–1.73)	626	196	0.31 (0.30–0.33)	244	110	0.45 (0.33–0.62)
Less management	70596	47202	0.67 (0.37–1.75)	626	193	0.31 (0.29–0.33)	244	106	0.43 (0.34–0.61)
Much less management	70608	48520	0.69 (0.37–1.67)	626	188	0.30 (0.28–0.32)	244	106	0.43 (0.34–0.59)

Categorization of populations by persistence probability revealed finer-scale variation of how scenarios varying in magnitude of stressors and management influenced persistence probability of populations (Table 5.4). Among the three projection intervals, the ‘low stressors’ scenario tended to predict higher percentages of Extremely Likely Extant populations and lower percentages of Unlikely Extant (i.e., Extirpated) populations relative to the ‘medium stressors’ and ‘high stressors’ scenarios. Similarly, the ‘more management’ scenario tended to predict higher percentages of Extremely Likely Extant populations and lower percentages of Unlikely Extant (i.e., Extirpated) populations relative to the ‘less management’ and ‘much less management’ scenarios. Figure 5.2 illustrates persistence probabilities among populations and landscape populations predicted by the ‘less management’ scenario.

Table 5. 4- Predicted population persistence probabilities categories for gopher tortoise populations in year 2100 under six future scenarios varying in the magnitude of future stressors; numbers represent number of local gopher tortoise populations, whereas numbers in parentheses represent the percentage of populations that fall into each category; persistence categories are Extremely Likely Extant (P > 95.0 percent), Very Likely Extant (P = 80.0–94.9 percent), More Likely Than Not Extant (P = 50.0–79.9 percent), and Unlikely Extant (P < 50.0 percent; i.e., extirpated). See Table 5.2 for descriptions of scenarios and their parameters.

Population persistence category	Scenario					
	Low stressors	Medium stressors	High stressors	More management	Less management	Much less management
Year 2060						
Extremely Likely Extant	104 (16.6%)	103 (16.5%)	101 (16.1%)	99 (15.8%)	102 (16.3%)	104 (16.6%)
Very Likely Extant	102 (16.3%)	97 (15.5%)	108 (17.3%)	108 (17.3%)	98 (15.7%)	91 (14.5%)
More Likely Than Not Extant	135 (21.6%)	145 (23.2%)	135 (21.6%)	134 (21.4%)	141 (22.5%)	141 (22.5%)
Unlikely Extant (i.e., Extirpated)	285 (45.5%)	281 (44.9%)	282 (45%)	285 (45.5%)	285 (45.5%)	290 (46.3%)
Year 2080						
Extremely Likely Extant	78 (12.5%)	74 (11.8%)	71 (11.3%)	79 (12.6%)	74 (11.8%)	76 (12.1%)
Very Likely Extant	35 (5.6%)	44 (7%)	41 (6.5%)	36 (5.8%)	41 (6.5%)	31 (5%)
More Likely Than Not Extant	122 (19.5%)	116 (18.5%)	117 (18.7%)	128 (20.4%)	103 (16.5%)	114 (18.2%)
Unlikely Extant (i.e., Extirpated)	391 (62.5%)	392 (62.6%)	397 (63.4%)	383 (61.2%)	408 (65.2%)	405 (64.7%)
Year 2100						
Extremely Likely Extant	76 (12.1%)	72 (11.5%)	70 (11.2%)	71 (11.3%)	70 (11.2%)	70 (11.2%)
Very Likely Extant	21 (3.4%)	20 (3.2%)	25 (4%)	24 (3.8%)	24 (3.8%)	24 (3.8%)
More Likely Than Not Extant	65 (10.4%)	62 (9.9%)	55 (8.8%)	58 (9.3%)	57 (9.1%)	54 (8.6%)
Unlikely Extant (i.e., Extirpated)	464 (74.1%)	472 (75.4%)	476 (76%)	473 (75.6%)	475 (75.9%)	478 (76.4%)

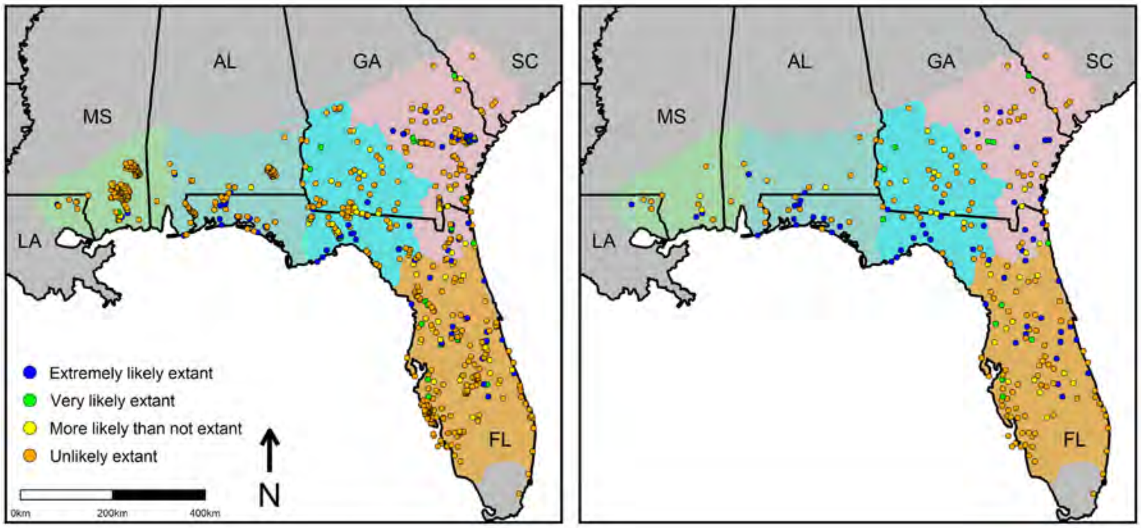

Figure 5. 2- Persistence probabilities of gopher tortoise (*Gopherus polyphemus*) local populations (left) and landscape populations (right) predicted by a future scenario of less habitat management with medium stressor (Table 2) projected 80 years into the future. Symbols are colored by persistence probability categories: Extremely Likely Extant (≥ 95.0 percent), Very Likely Extant (= 80.0–94.9 percent), More Likely Than Not Extant (= 50.0–79.9 percent), and Unlikely Extant (< 50.0 percent; i.e., extirpated). See Table 5.2 for descriptions of scenarios and their parameters.

Our analysis of representation revealed that changes in the number of individuals, local populations, and landscape populations varied by analysis unit (Figure 5.3); we provide the projections for the 80-year projection interval in Table 5.5. Among the five analysis units projected 80 years into the future, units 1, 3, and 5 were predicted to decline overall, with mean λ values ranging between 0.60–0.73, 0.47–0.49, and 0.52–0.58 among scenarios for each unit, respectively (i.e., 27–40 percent, 51–53 percent, and 42–48 percent declines, respectively); however, 95 percent CI of λ values overlapped with 1.00 in all scenarios for each of the three units, indicating uncertainty in future abundance. Unit 4 was predicted to experience more modest declines in total abundance (λ = 0.86–0.98; i.e., 2–14 percent decrease), but 95 percent CI of λ also overlapped 1.00, indicating uncertainty in predicted future abundance. Alternatively, total abundance in Unit 2 was predicted to increase substantially (λ = 2.37–2.53; i.e., 137–153 percent increase); 95 percent CI of λ exceeded 1.00, indicating a significant predicted increase.

Scenarios predicted substantial declines in the number of local populations among all units. Predicted reductions in populations were greatest in Unit 1 (λ = 0.22–0.23), Unit 2 (λ = 0.23–0.26), and Unit 5 (λ = 0.28–0.30), and slightly weaker (but still strong) in Unit 3 (λ = 0.37–0.39) and Unit 4 (λ = 0.39–0.41). The number of landscape populations was predicted to decline among all scenarios in each analysis unit, with the strongest loss of landscape populations in Unit 5 (λ = 0.36–0.41 among scenarios) and the weakest loss of landscape populations in Unit 3 (λ = 0.48–0.53 among scenarios).

Table 5. 5- Simulated population projections for gopher tortoises populations in each of the five analysis units. Six scenarios of predicted future change were projected 80 years into the future; results are summarized by the initial number, future predicted number, and population growth rate (λ) for the total population size, number of local populations, and number of landscape populations in each genetic unit. See Table 2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of landscape populations		
	Initial	Future	λ	Current	Future	λ	Initial	Future	λ
Unit 1									
Low stressors	1571	1151	0.73 (0.22–3.55)	102	23	0.23 (0.18–0.27)	13	6	0.46 (0.46–0.46)
Medium stressors	1573	1066	0.68 (0.22–3.50)	102	23	0.23 (0.18–0.27)	13	6	0.46 (0.46–0.54)
High stressors	1572	990	0.63 (0.22–3.86)	102	23	0.23 (0.18–0.26)	13	6	0.46 (0.46–0.54)
More management	1572	1066	0.68 (0.21–4.01)	102	23	0.23 (0.19–0.27)	13	6	0.46 (0.44–0.54)
Less management	1573	1026	0.65 (0.22–3.79)	102	22	0.22 (0.18–0.26)	13	6	0.46 (0.46–0.54)
Much less management	1572	947	0.60 (0.22–3.42)	102	22	0.22 (0.18–0.26)	13	6	0.46 (0.46–0.54)
Unit 2									
Low stressors	2896	7316	2.53 (1.49–4.08)	81	21	0.26 (0.21–0.30)	29	16	0.55 (0.48–0.66)
Medium stressors	2896	7022	2.42 (1.24–3.94)	81	19	0.23 (0.20–0.27)	29	15	0.52 (0.45–0.59)
High stressors	2894	6868	2.37 (1.50–4.04)	81	19	0.23 (0.20–0.28)	29	14	0.48 (0.45–0.59)
More management	2896	7086	2.45 (1.39–3.95)	81	20	0.25 (0.21–0.28)	29	15	0.52 (0.45–0.59)
Less management	2898	7007	2.42 (1.58–4.10)	81	20	0.25 (0.20–0.28)	29	15	0.52 (0.45–0.59)
Much less management	2898	7084	2.44 (1.44–3.92)	81	19	0.23 (0.20–0.27)	29	14	0.48 (0.45–0.52)
Unit 3									
Low stressors	19432	9468	0.49 (0.31–1.08)	110	42	0.38 (0.34–0.44)	55	29	0.52 (0.36–0.73)
Medium stressors	19428	9125	0.47 (0.31–1.04)	110	42	0.38 (0.34–0.44)	55	27	0.49 (0.32–0.68)
High stressors	19419	9406	0.48 (0.30–1.02)	110	42	0.38 (0.34–0.44)	55	28	0.50 (0.35–0.72)
More management	19426	9338	0.48 (0.30–1.11)	110	43	0.39 (0.35–0.45)	55	29	0.53 (0.38–0.76)
Less management	19430	9224	0.47 (0.31–1.06)	110	42	0.38 (0.33–0.43)	55	28	0.51 (0.35–0.75)

Much less management	19432	9332	0.48 (0.31–1.03)	110	41	0.37 (0.33–0.43)	55	27	0.48 (0.35–0.70)
Unit 4									
Low stressors	14032	13793	0.98 (0.55–2.20)	123	50	0.37 (0.33–0.43)	46	21	0.46 (0.35–0.65)
Medium stressors	14030	13368	0.95 (0.55–2.28)	123	50	0.39 (0.35–0.45)	46	22	0.48 (0.37–0.64)
High stressors	14040	12013	0.86 (0.42–1.98)	123	48	0.41 (0.37–0.46)	46	20	0.43 (0.35–0.62)
More management	14036	13325	0.95 (0.54–2.11)	123	51	0.40 (0.36–0.44)	46	22	0.48 (0.35–0.66)
Less management	14034	13109	0.93 (0.54–2.09)	123	49	0.41 (0.37–0.46)	46	22	0.48 (0.35–0.67)
Much less management	14039	13118	0.93 (0.56–2.11)	123	49	0.39 (0.35–0.43)	46	20	0.43 (0.36–0.63)
Unit 5									
Low stressors	32684	19120	0.58 (0.25–1.70)	210	62	0.30 (0.27–0.32)	103	41	0.40 (0.30–0.52)
Medium stressors	32666	17786	0.54 (0.24–1.65)	210	60	0.29 (0.26–0.31)	103	43	0.41 (0.27–0.53)
High stressors	32653	18102	0.55 (0.25–1.66)	210	60	0.29 (0.26–0.32)	103	39	0.38 (0.25–0.58)
More management	32655	18300	0.56 (0.24–1.64)	210	60	0.29 (0.26–0.31)	103	41	0.40 (0.26–0.57)
Less management	32662	16836	0.52 (0.23–1.71)	210	60	0.29 (0.25–0.32)	103	37	0.36 (0.27–0.54)
Much less management	32666	18038	0.55 (0.24–1.59)	210	58	0.28 (0.25–0.30)	103	40	0.38 (0.27–0.51)

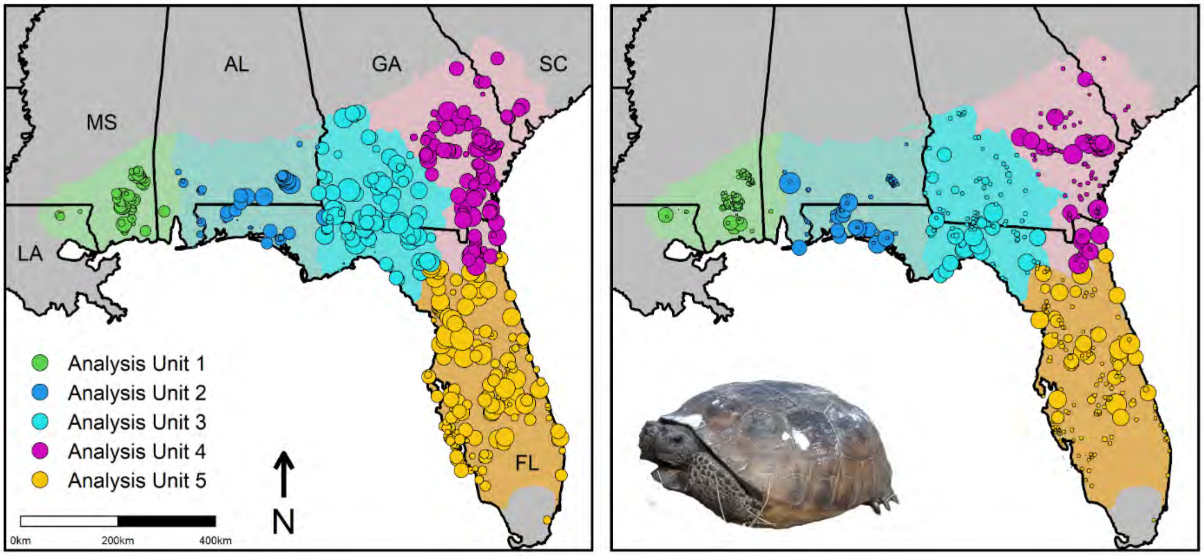

Figure 5. 3-Current (left) and future predicted abundance (right) of gopher tortoise (*Gopherus polyphemus*; right inset) populations in the southeastern United States that were modeled to predict future population growth and extinction risk for the species under scenarios of global change. Each circle represents a local population and circles are colored by analysis units. Symbol size reflects a log-transformed scale of population size; the left panel shows population size estimated during a survey during 2010–2020; the right panel shows predicted population size under a future scenario of 'medium stressors with less management' (Table 5.2). Abundance of populations during 2010–2020 was estimated from analysis of data from burrow surveys or Line Transect Distance Sampling (LTDS) at each the site within the last ten years.

We found that model projections were sensitive to input values for immigration rate (Table 5.6). The population declines predicted by the 'medium stressors' scenario were exacerbated substantially when simulated with an immigration rate of 0; conversely, elevated values for immigration produced population projections that substantially increased the total population size above initial starting population size and decreased declines in local populations and landscape populations.

Table 5. 6- Simulated population projections for gopher tortoises under scenarios varying in immigration rate (γ): no immigration ($\gamma =$ 0), intermediate immigration (γ = 0.01), high immigration (γ = 0.02), and very high immigration (γ = 0.04). Columns summarize the initial number (in 2020), future predicted number, and population growth rate (λ) for the total population size, number of populations, and number of landscape populations for four scenarios projected 80 years into the future. Each scenario models stressors and management actions using input values from the 'medium stressors' scenario from Table 2, and the 'intermediate immigration' scenario has the same input values the 'medium stressors' scenario from Table 2; see Table 2 for more information about input parameters.

Scenarios	Total population size			Number of local populations			Number of landscape populations		
	Initial	Future	□	Initial	Future	□	Initial	Future	□
No immigration	70602	1566	0.02 (0.01–0.18)	626	81	0.13 (0.11–0.15)	244	46	0.19 (0.09–0.36)
Intermediate immigration	70594	48366	0.69 (0.36–1.74)	626	196	0.31 (0.29–0.33)	244	108	0.44 (0.35–0.59)
High immigration	70600	91805	1.30 (0.71–2.76)	626	247	0.39 (0.38–0.41)	244	124	0.51 (0.39–0.66)
Very high immigration	70600	151320	2.14 (1.18–4.44)	626	312	0.50 (0.48–0.52)	244	144	0.59 (0.48–0.68)

With each 50-female increase in starting population size, populations were 1.029 (1.027–1.03; 95 percent CI) times as likely to persist, which was statistically significant ($P < 0.0001$). With each 1 local population increase in landscape populations, local populations were 0.987 (0.986–0.987; 95 percent CI) times as likely to persist (i.e., 1.013 times less likely), which was statistically significant ($P < 0.0001$). For each 500-ha increase in area, populations were 1.002 (1.001–1.003; 95 percent CI) times as likely to persist, which was statistically significant ($P = 0.044$). With each 10 m increase in elevation, populations were 0.901 (0.899–0.904; 95 percent CI) times as likely to persist (i.e., 1.109 times less likely), which was statistically significant ($P < 0.0001$). For each 0.5 degree increase in latitude, populations were 1.122 (1.119–1.125; 95 percent CI) times as likely to persist, which was statistically significant ($P < 0.0001$). With each 0.01 proportional loss in landscape area due to sea-level rise, local populations were 0.57 (1.67–1.82; 95 percent CI) times as likely to persist (i.e., 1.747 times less likely), which was statistically significant ($P < 0.0001$). With each 0.1 proportional loss in landscape area due to urbanization, local populations were 0.96 (0.955–0.965; 95 percent CI) times as likely to persist (i.e., 1.042 times less likely), which was statistically significant ($P < 0.0001$). With each categorical increase in fire management (from ‘very less’ to ‘less’ to ‘status quo’ to ‘increased’), local populations were 1.021 (1.014–1.029; 95 percent CI) times as likely to persist, which was statistically significant ($P < 0.0001$).

5.3. Summary of future conditions and viability

We synthesized literature describing gopher tortoise life history and built a predictive population model that accounted for geographic variation in demography to estimate growth of gopher tortoise populations across the species range on conservation lands. We then identified a series of influences (climate warming, sea-level rise, urbanization, and habitat management) that have been hypothesized to have significant current and future effects on gopher tortoise populations. Then, using estimates of these effects on gopher tortoise demography and/or reasonable assumptions, we linked influences to specific demographic rates and used published model projections of their prevalence in the future (Terando et al. 2014, entire; IPCC 2013, entire; Kupfer et al. 2020, entire; NOAA 2020, entire) to simulate how gopher tortoise populations will respond to future conditions across the species’ range.

Using this integrative modeling framework, we simulated future resiliency, representation, and redundancy of gopher tortoise populations under six scenarios varying in the magnitude of influences at 40, 60, and 80 years in the future. Simulated growth of approximately 70,600 individuals (females) from 626 local populations and 244 landscape populations predicted future declines in the number of individuals, local populations, and landscape populations among all scenarios and projection intervals. Scenarios did not vary strongly in their effect on λ of individuals, populations, and landscape populations; no single stressor scenario or management scenario was sufficient to prevent population declines, and 95 percent confidence intervals of projections overlapped significantly among all scenarios, indicating statistical insignificance of scenario effects.

While scenarios did not have strong effects on overall trends in abundance and population redundancy, categorization of populations by persistence probabilities suggested that the 'increased management' and 'low stressors' scenarios performed better at increasing population persistence and reducing extirpation than other management and stressor scenarios. Increased habitat management promoted greater population persistence relative to decreased management scenarios because of positive effects of management on survival in local populations, which increases population growth and persistence probability of populations. While populations may experience reproductive benefits from warming temperatures in the future (i.e., positive effects with increased stressors), the 'low stressors' scenarios outperformed the elevated stressor scenarios because the negative effects of urbanization and sea-level rise on survival and immigration were stronger than the positive effects of warming on reproduction.

The regression analysis identified significant effects of initial abundance, number of populations per landscape population, area, elevation, urbanization, sea-level rise, and habitat management to influence persistence probabilities of local populations. For groups and agencies seeking alternatives to buffer tortoise populations from anthropogenic effects, these factors represent opportunities for management and/or conservation. We observed positive effects of initial population size, area, and fire management on population persistence. Because large areas of land support larger local populations of tortoises experience increased persistence probabilities (Fahrig and Merriam 1985, entire), management actions to conserve large tracts of land with abundant and well-connected populations on high-quality habitat might be prioritized, as well as actions to increase population size of local populations or increase the number of local populations within landscape populations (i.e., translocation and repatriation, respectively; e.g., Tuberville et al. 2008, entire; McKee et al. 2021, entire). Similarly, increased urbanization will decrease immigration and habitat management among populations, and conservation planning strategies could emphasize securing connectivity of existing local populations through strategic land acquisitions or partnerships (Ashrafzadeh et al. 2020, entire). We observed particularly strong negative effects of both sea-level rise and elevation on persistence probability. The sea-level rise effect was due in large part because we set an extinction threshold where local populations that fell to less than 2 m asl due to sea-level rise were forced to extinction. Gopher tortoise populations in low-elevation, coastal areas at risk of sea-level rise might be doomed, and future conservation actions might include assisted migration (Vitt et al. 2010, entire) to suitable areas less at risk to sea-level rise and coastal inundation (Blonder et al. 2020, entire). The effect of decreased persistence at higher elevations was likely due to increased urbanization pressure in high-elevation areas; urbanization was also predicted to have a significant negative effect on persistence of local populations, and urbanization tends to focus on upland, high-elevation habitats that are occupied by tortoise populations (Diemer 1986, entire).

The large declines in number of local populations occurred, in part, because many local populations (N = 174; 27.8%) delimited in our surveys had very few individuals to start with in the current conditions. Assuming a 3:1 adult to juvenile ratio and an even sex ratio, local populations with less than 8 individuals were functionally extirpated at the start of projections, given our quasi-extinction probability (< 3 adult females). This also likely explains the negative effect of landscape population size on population persistence we observed in our regression analysis; for example, a few extremely large landscape populations (e.g., six landscape populations contained 13–50 local populations) were dominated by local populations with <8 individuals, thus driving down mean persistence probability in the large landscape populations. This also likely explains the negative effect of landscape population size on population persistence we observed in our regression analysis; a few extremely large landscape populations (e.g., six landscape populations had 13–50 local populations) were dominated by local populations with <8 individuals, thus driving down mean persistence probability in large landscape populations.

Our analysis simulated the fate of known populations largely on protected, conservation lands that should be managed for natural resource conservation in the future. We expect populations on managed, conservation lands to be characterized by greater demographic rates and persistence probabilities relative to populations not existing on conservation lands (i.e., populations that we were unable to model in our framework). To this end, we did not project the abundance of existing populations not included in our dataset or estimate the formation of new populations outside of conservation lands. While other tortoise populations exist outside of the ones we simulated with our projection model and new tortoise populations may form due to natural dispersal and colonization dynamics, they may occur on lands lacking long-term protection from development, their demographic rates are likely reduced relative to populations on conservation lands, and we did not feel comfortable projecting those populations into the future under assumptions of land management and protection for wildlife conservation. Similarly, we could not estimate the formation of new populations outside of the sites we projected, or the migration of entire populations to new areas, because there is no guarantee that land would be available for populations to form on or migrate to.

Previous demographic models for gopher tortoises have not used immigration parameters (e.g., Tuberville et al. 2009, entire; Folt et al. 2021, entire) and modeled gopher tortoise demography as closed to immigration, perhaps due to the paucity of field estimates of immigration in wild populations. Previous models found no scenarios where populations were stable or increasing, although recent studies have documented situations where stability and population growth are achieved in the field (Folt et al. 2021, p. 624-626; Goessling et al. 2021, p. 141). This discrepancy suggests a disconnect between demographic projections that are largely influenced by apparent survival projections and actual trends occurring in populations, a discrepancy that may be resolved by incorporating immigration during projection analyses. To this end, we incorporated an immigration parameter for local populations and found projections were sensitive to inputs for this parameter. This was supported by the fact that persistence probabilities were sensitive to threats that influenced immigration rates and two scenarios of ‘no immigration’ and ‘high immigration’ produced results that strongly deviated from results of the stressor and management scenarios. Together, these lines of evidence suggest that immigration is an important parameter in gopher tortoise demography that may deserve future attention when studying gopher tortoises in the field and building models of gopher tortoise demography in the laboratory. Due to the uncertainty of true immigration rates, and the use of a small sub-set of populations used in this model relative to the true number of tortoises on the landscape, it is likely that immigration is underrepresented in this model, resulting in uncertainty in future projections.

It is important to note that we included long-term recipient sites in our population projections, although there are several assumptions that we made when including these data. While translocation is successful at removing gopher tortoises from immediate danger due to development, there are still uncertainties about its efficacy, and additional research is needed to inform improvements to translocation methodology. Gopher tortoises are long-lived, slow-growing, and are slow to reach maturity, making it difficult to determine if translocations result in viable gopher tortoise populations without long-term monitoring. Additionally, many of the recipient sites included in this analysis have not reached their permitted capacity, potentially resulting in greater uncertainty in the future condition estimates for these populations.

We modeled some parameters in our simulation exercise as invariant among populations across the species' range, largely for variables which we found lacked substantial data describing geographic variation. For example, we modeled a density-dependent limit on recruitment to the adult age class of 2.0 females/hectare and a fire-return interval of 1–4 years as necessary to create high-quality habitat for tortoises in all populations. However, tortoise populations may have different mechanisms across the species range; in Florida, populations may reach greater densities before density-dependent effects influence life history, and fire may be less important in regulating quality habitat in some areas with deep sandy soils (Hunter and Rostal 2021). More research describing geographic variation in life history, particularly how Florida populations differ from northern populations, would be useful to update and improve the utility of the model framework we used.

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APPENDIX A

GOPHER TORTOISE PRIVATE LANDOWNER QUESTIONNAIRE

Gopher Tortoise Data Request

To support the development of a Species Status Assessment (SSA) for the gopher tortoise, the U.S. Fish and Wildlife Service (Service) is collecting, compiling, synthesizing, and analyzing the best available science on habitat and management of the species. This form is being used to gather data and information for the gopher tortoise SSA, which will be used to inform the classification decision for the gopher tortoise. Classification decisions are based only on the best available science. Multiple groups have requested additional clarification in the type of information that the Service will need to do the evaluation for this species, and therefore, we are providing this form for you to consider. However, the Service will accept information in any format that you can provide.

Please answer the below questions to the best of your ability. If there is other important information you think we should know about your property, please feel free to provide that in the last question on the form. We appreciate your time and effort! We would appreciate your response by September 15, 2019, if possible, to ensure we have adequate time to consider the information during our status review, but we will accept information throughout the entire process. All data and information submitted to us, including names and addresses, would become part of the administrative record.

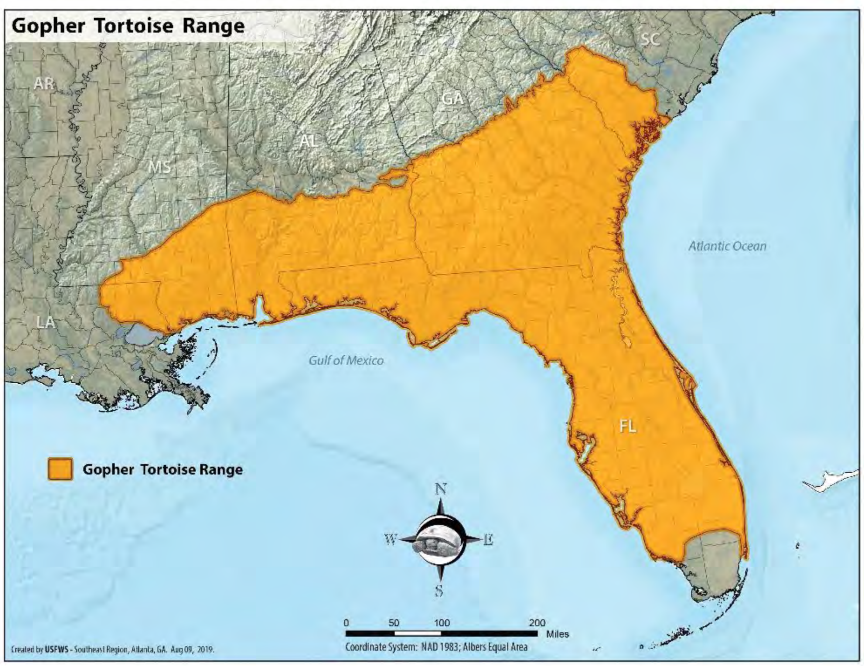
In order to avoid duplication, please submit this form only once (via internet or PDF version). If PDF version, please provide to the Service at gophertortoise@fws.gov or through your respective association to provide to the Service.

Gopher Tortoise Data Request

Basic Property Information

Please provide as much information about your property as you feel comfortable. If you would like to submit additional information or data, please do so at gophertortoise@fws.gov.

State



County (if you own property in multiple counties, please fill out separate forms for each county). [ ]

Counties with Gopher Tortoises

Alabama: *Baldwin, Choctaw, Clarke, Marengo, Mobile, Sumter, Washington, Baldwin, Barbour, Bullock, Butler, Choctaw, Clarke, Coffee, Conecuh, Covington, Crenshaw, Dale, Dallas, Escambia, Geneva, Henry, Houston, Lee, Lowndes, Macon, Marengo, Mobile, Monroe, Montgomery, Pike, Russell, Washington, Wilcox*; **Louisiana**: *Livingston, St. John the Baptist, St. Tammany, Tangipahoa, Washington*; **Mississippi**: *Clarke, Covington, Forrest, George, Greene, Hancock, Harrison, Jackson, Jasper, Jefferson Davis, Jones, Lamar, Lawrence, Marion, Pearl River, Perry, Pike, Stone, Walthall, Wayne*; **Georgia**: *Appling, Atkinson, Bacon, Baker, Ben Hill, Berrien, Bleckley, Brantley, Brooks, Bryan, Bulloch, Burke, Calhoun, Camden, Candler, Charlton, Chatham, Chattahoochee, Clay, Clinch, Coffee, Colquitt, Cook, Crawford, Crisp, Decatur, Dodge, Dooly, Dougherty, Early, Echols, Effingham, Emanuel, Evans, Glascock, Glynn, Grady, Houston, Irwin, Jeff Davis, Jefferson, Jenkins, Johnson, Lanier, Laurens, Lee, Liberty, Long, Lowndes, McDuffie, McIntosh, Macon, Marion, Miller, Mitchell, Montgomery, Muscogee, Peach, Pierce, Pulaski, Quitman, Randolph, Richmond, Schley, Screven, Seminole, Stewart, Sumter, Talbot, Tattnall, Taylor, Telfair, Terrell, Thomas, Tift, Toombs, Treutlen, Turner, Twiggs, Ware, Washington, Wayne, Webster, Wheeler, Wilcox, Wilkinson, Worth*; **Florida**: *Alachua, Baker, Bay, Bradford, Brevard, Broward, Calhoun, Charlotte, Citrus, Clay, Collier, Columbia, DeSoto, Dixie, Duval, Escambia, Flagler, Franklin, Gadsden, Gilchrist, Glades, Gulf, Hamilton, Hardee, Hendry, Hernando, Highlands, Hillsborough, Holmes, Indian River, Jackson, Jefferson, Lafayette, Lake, Lee, Leon, Levy, Liberty, Madison, Manatee, Marion, Martin, Miami-Dade, Monroe, Nassau, Okaloosa, Okeechobee, Orange, Osceola, Palm Beach, Pasco, Pinellas, Polk, Putnam, St. Johns, St. Lucie, Santa Rosa, Sarasota, Seminole, Sumter, Suwannee, Taylor, Union, Volusia, Wakulla, Walton, Washington*; **South Carolina**: *Aiken, Allendale, Barnwell, Bamberg, Colleton, Dorchester, Hampton, Jasper*

Is your property subject to a conservation easement?

◯ Yes ◯ No

Is your property third party certified (e.g., SFI, FSC, ATFS)?

◯ Yes ◯ No

Do you implement any wildlife conservation or land best management practices?

◯ Yes ◯ No

Gopher Tortoise Data Request

Gopher Tortoise Habitat Type Information

How many acres of potential gopher tortoise type habitat are on your property? Potential gopher tortoise habitat includes well-drained, sandy soils, and can be found in a variety of habitats such as longleaf pine forests/ sandhills, xeric oak hammocks, scrub, pine flatwoods, dry prairies, coastal dunes, and pastures. This number will be called your "GT Acres", and can either be an exact number or a high and low estimate.

Which of the following community types best describes your GT acres? (choose all that apply)

☐ Pine ☐ Hardwood ☐ Mixed-pine hardwood

☐ Pasture/Open ☐ Other

We can describe gopher tortoise habitat suitability as low, moderate, or high depending on the condition of the canopy, mid-story/shrub layer, and herbaceous ground cover. Please estimate the approximate amount of your GT acres that fall in the Low suitability class as described below:

How many acres do you have that meet the Low Suitability as described below?

Description and examples of low suitability

Low	Dense canopy; uniform stand condition, characterized by minimal herbaceous groundcover	Metric	
		Pine Basal Area (ft^2/acre)	Less than 10 or greater than 105 (ft^2/acre)
		Pine Canopy Cover	Less than 10% or more than 85%
		Mid-story Cover	More than 40%
		Native Herbaceous Ground Cover	Less than 20%

Please estimate the approximate amount of your GT acres that fall in the Medium suitability class as described below:

How many acres do you have that meet the Medium Suitability as described below?

Description and examples of Medium suitability

Medium	**Fairly open canopy, with low to dense mid-story/shrub layer so only a few areas have adequate light reaching the ground to support herbaceous groundcover**	**Metric**	
		Pine Basal Area (ft^2/acre)	10 to 20 or 90 to 105
		Pine Canopy Cover	10 to 20 % or 75 to 85%
		Mid-story Cover	30 to 40%
		Native Herbaceous Ground Cover	20 to 30%

Please estimate the approximate amount of your GT acres that fall in the High suitability class as described below:

How many acres do you have that meet the High Suitability as described below?

Description and examples of high suitability

High	Open canopy; minimal shrub/mid-story layer; abundant native herbaceous groundcover	Metric	
		Pine Basal Area (ft^2/acre)	20 to 90
		Pine Canopy Cover	20 to 75%
		Mid-story Cover	Less than 30%
		Native Herbaceous Ground Cover	30 to 98%

Land Management Information

If prescribed fire is used on the GT acres, how many acres are treated with fire?

If prescribed fire is used on the GT acres, what is the prescribed burning frequency?

- ○ 1 to 3 years
- ○ 3 to 5 years
- ○ 5 to 7 years
- ○ More than 7 years
- ○ Other:

What other beneficial management practices do you use on your property? check all that apply

- ☐ Herbicide application for hardwood control
- ☐ Roller Chopping
- ☐ Mowing/Mulching
- ☐ Thinning
- ☐ Longleaf planting
- ☐ Invasive species control
- ☐ Marking/flagging burrows before thinning or disruptive practices
- ☐ Other:

On how many GT acres do you manage mid-story woody vegetation by methods other than prescribed fire (e.g. mechanical or herbicide)?

Do you anticipate the land use, management objectives, or fire regime to change in the next 20-30 years?

- ○ Yes
- ○ No

If yes, explain how.

Gopher Tortoise Information

Have there been gopher tortoises observed on your property in the last 5 years?

○ Yes ○ No

Has a complete survey of the property been done?

○ Yes ○ No

If Yes, what was the type of survey conducted?

- ☐ Line-transect distance sampling
- ☐ 100% survey method
- ☐ Opportunistic
- ☐ Other: ____________________

What is the estimated number of individual tortoises on your property?

○ 1 to 25	○ 50 to 100	○ 250 or more
○ 25 to 50	○ 100 to 250	○ Unknown

What is the estimated number of tortoise burrows on your property?

○ 1 to 25	○ 50 to 100	○ 250 or more
○ 25 to 50	○ 100 to 250	○ Unknown

Have juvenile gopher tortoises or juvenile burrows (i.e. burrow opening <5 inches) been seen on your property?

◯ Yes

◯ No

No (image NOT of a gopher tortoise burrow)

Examples of juvenile burrows. You can go here (https://www.outdooralabama.com/sites/default/files/GT%20vs%20other%20burrows%20Identification%20Guide%20Handout.pdf) for additional examples.

Anything important you think we should know about your property and conservation practices for gopher tortoises?

APPENDIX B

Gopher Tortoise Population Modelling

Predicting Population Growth of Gopher Tortoises (*Gopherus polyphemus*) under Future Scenarios of Climate Warming, Sea-level Rise, Urbanization, and Habitat Management

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Introduction

In this paper, I describe an analytical framework that integrates predictions from multiple models of future anthropogenic change to: (1) predict future population growth of an imperiled, ecologically significant species, (2) identify stressors with the greatest influence on future population persistence, and (3) support decisions about conservation and management during, for example, a Species Status Assessment for the gopher tortoise (*Gopherus polyphemus*). I reviewed the literature describing gopher tortoise life history and adapted a previously published population model for gopher tortoises (Folt et al. 2021) to estimate population growth and persistence probability of populations while accounting for geographic variation in life history. I expanded the model to link intrinsic factors (demographic vital rates) to four extrinsic anthropogenic factors that are hypothesized to threaten gopher tortoise population persistence (climate warming, sea-level rise, urbanization, and shifts in habitat management). I used published models describing predictions for extrinsic factors in the future to project gopher tortoise demographics under six future scenarios varying in threat magnitude and presence. I performed a regression analysis of model outputs to identify threats that are predicted to have the greatest impact on population persistence.

Methods

I sought to predict population growth and extinction risk for the gopher tortoise in a population viability analysis (PVA) framework. I built a stage-based population model (i.e., Lefkovitch model) (Lefkovitch 1965) and used the model to project population size and structure forward in time with simulations. For the PVA, I conceptualized local population demography of tortoises in a multi-stage, female-only model with two discrete life stages: juveniles and adults (Figure 1). During a given time-step, both stages had a probability of individuals surviving and remaining within the stage, juveniles had a probability of maturing to become adults, and adults had a probability of reproducing and potentially recruiting individuals into the juvenile stage. Individuals that did not survive during a time-step were assumed to have either died or permanently emigrated from the population. I also modeled recruitment into the adult stage by immigration (see below).

Model structure

I used the model structure to predict future abundance of populations across the range of the gopher tortoise using a first-order Markovian process in which adult abundance at time *t* was a function of adult and juvenile abundance at time *t*-1 with vital rates stochastically drawn from parameter distributions:

$$N_t^a = N_{t-1}^a \times \varphi_{t-1}^a + N_{t-1}^j \times \varphi_{t-1}^j \times \tau_{t-1} + N_{t-1}^i, \quad (1)$$

where *N* is abundance, φ is the apparent annual survival rate, and τ is an annual transition rate from juvenile to adult (i.e., maturation) during each time step *t* (year); superscripts a, j, and i denote adults, juveniles, and immigrants, respectively.

Juvenile abundance at time *t* was a function of juvenile and hatchling abundance at time *t*-1 with vital rates similarly drawn from parameter distributions:

$$N_t^j = N_{t-1}^j \times \varphi_{t-1}^j \times (1 - \tau_{t-1}) + R_{t-1}, \quad (2)$$

where *N* is abundance, φ is survival, τ is the juvenile-adult transition rate, and R is recruitment (below) during each time step t (year).

For individuals to recruit into the juvenile stage, adult females must lay eggs that hatch into offspring and survive until the next survey period (i.e., time step). Therefore, to estimate annual recruitment by reproduction, we modeled the probability of females breeding (PB), the mean number of eggs laid per individual (fecundity; F), the probability of nests surviving predation (NS), the proportion of eggs that are viable and hatch (VE), the probability of eggs being female (PF) and the survival probability of hatchlings through the first year to the next survey period (φ^h) at time *t* (Noon and Sauer 1992). I modeled probabilities (*PB, NS, VE,* PF, φ^h) as beta-distributed random variables, and I modeled fecundity as a log-normal random variable. Together, I then modeled recruitment (R) at time *t* as a product of:

$$R_t = PB_t \times F_t \times NS_t \times VE_t \times PF \times \varphi_t^h, \quad (3)$$

where the superscript *h* denotes hatchling.

Demographic parameters

I sought to construct a baseline population model that approximated demographic conditions experienced by gopher tortoise populations in recent decades across the species' range. However, populations of gopher tortoises experience variation in abiotic characteristics across the species' range, and variation in abiotic characteristics influences demographic rates among populations. At southern latitudes, populations experience significantly warmer mean annual temperature, which may afford greater overall opportunity for thermoregulation, energy acquisition, and metabolism when compared to northern populations. As a result, southern populations of tortoises experience faster growth rates, younger ages of sexual maturity (hereafter, maturity age), and increased clutch size (Mushinsky et al. 1994, Ashton et al. 2007, Meshaka Jr. et al. 2019). Because my goal was to predict population growth and extinction risk of populations across the species' range and predictive population models are most useful when demographic parameters are modeled specific to populations of interest (Ralls et al. 2002), I extended the model to accommodate for geographic variation in demographic rates by estimating parameters specific to the geographic location of populations.

I reviewed the literature for demographic estimates from gopher tortoise populations in the wild (Appendix 1). For parameters thought to vary by abiotic features among sites, I fit linear regression models to estimate relationships between demographic rates and mean annual temperature (hereafter, MAT; degrees C) sourced from the 'WorldClim' database (Hijmans 2020). After testing whether the data met assumptions of parametric statistics, I evaluated whether regression models estimated statistically significant effects of independent variables on response variables with α = 0.05. I used observed statistically significant linear relationships between MAT and demographic rates among populations as a predictive tool to generate mean parameter estimates with error for populations in our predictive modeling framework, given georeferenced data describing MAT at sites. If parameters were not known to vary geographically, I modeled mean values as invariant among populations. In the following paragraphs, I describe how I modeled parameters describing recruitment, maturity age, survival, immigration, and initial population size, respectively; however, all stochastic parameters and the distributions used to model them are summarized in Table 1.

I modeled the proportion of breeding females (oviposition; PB) in a given year as 0.97; this estimate has recently been validated by two independent field studies (Jeffrey Goessling, Eckerd

College, personal communication; Elizabeth Hunter, personal communication). Because fecundity (F) varies widely among populations and is likely driven by a north-to-south latitudinal gradient in temperature (Ashton et al. 2007), I used linear regression to estimate the relationship between MAT and estimates of mean clutch size (F) from the literature and then used regression coefficients to simulate mean values of F for populations, given the geographic location and MAT of a population. I modeled the probability of nests that survive predation (NS) as 0.35 using an estimate from unmanipulated nests (Smith et al. 2013). I modeled the probability of eggs being viable and hatching (VE) as 0.85, an average from a review of field hatching rates (Landers et al. 1980, Rostal and Jones 2002). To account for males (and remove them) during projections, I assumed that sex ratios of eggs were even within populations and modeled the probability of eggs being female (PF) as 0.5. I modeled hatchling survival (φ^h) from nest emergence until the following survey period as 0.13 (0.04–0.34, 95% CI), given results from a meta-analysis of hatchling survival of gopher tortoises (Perez-Heydrich et al. 2012). I modeled mean values of PB, NS, VE, PF, and φ^h as invariant among populations; I modeled F as a function of MAT at local populations using regression coefficients from my analysis of literature values (Table 1). For each recruitment parameter, I modeled parameters using appropriate statistical distributions (below) and randomly estimated the parameter in each year using stochastic draws using estimates of variance associated with parameter estimates (Table 1).

Maturity age also varies along a latitudinal gradient among gopher tortoise populations (Mushinsky et al. 1994, Meshaka Jr. et al. 2019). I used linear regression to estimate the relationship between MAT and maturity age estimates of females from the literature (Table 1); I then used regression coefficients to simulate mean maturity ages for populations, given the population's geographic location and MAT. Given a predicted maturity age for a population, I then calculated the probability that a juvenile will transition to adulthood, τ, during a given year with:

$$\tau = \frac{1}{Maturity\ age - 1}. \quad (4)$$

This formula assumes that all individuals in the juvenile age class at a population have an equal probability, τ, of transitioning to the adult state (i.e., maturing), and that this probability is the inverse of the age of sexual maturity minus one, to account for one year spent as a hatchling.

Survival rates are difficult to measure for gopher tortoises because individuals are long-lived, challenging to recapture, may become unavailable for resurvey by emigrating away from study populations, or may die (e.g., Folt et al. 2021). When individuals disappear from a study population, mark-recapture analyses are often unable to estimate whether individuals died or emigrated away (Williams et al. 2002). To this end, most mark-recapture studies of gopher tortoise seeking to understand survival have estimated apparent annual survival (φ), which is the probability that individuals survived and stayed within a study area. Studies have found φ to vary between adults and juveniles, with adults having higher survival than juveniles (Tuberville et al. 2014, Howell et al. 2020, Folt et al. 2021). I reviewed the literature for apparent annual survival estimates for gopher tortoises (Appendix 1) and performed a linear regression analysis testing for effects of age and MAT on survival. This heuristic analysis confirmed that adults have greater survival than juveniles but failed to recover an effect of MAT on survival; rather, survival is likely most strongly influenced by habitat quality and management at sites (Howell et al. 2020, Folt et al. 2021, Hunter and Rostal 2021). I modeled adult survival (φ^a) as 0.96 and juvenile survival (φ^j) as 0.75, given demographic rates reported from relatively stable populations in Alabama (Folt et al. 2021). I modeled a density-dependent limit on population growth where for each time-step when density increased above 2 females/ha, I prevented recruitment into the adult age class. This was meant to simulate population conditions where juveniles may elect to disperse away from high-density conditions to other populations with lower density, while also enforcing a limit on maximum population size (i.e., carrying capacity). Field studies have estimated tortoise density to range from 0.02–1.50 individuals/ha among northern populations (Guyer et al. 2012) and from 4.2–24.9 individuals/ha in southern Florida. I selected a threshold of 2 females/ha (i.e., 4 tortoises/ha, assuming even sex ratios) as a limit for density dependence because there is a considerable uncertainty when estimating tortoise density and 2 females/ha was a conservative intermediate estimate of maximum density among populations across the species' range.

Gopher tortoises infrequently move long distances from established core home range areas; such movements can result in permanent emigration and immigration into other populations. I implicitly modeled losses to local populations due to emigration because the estimates of apparent annual survival (φ) account for mortality and permanent emigration away from local populations. Given ongoing emigration, local populations that are spatially proximate to other local populations might receive immigrants that bolster population size. While little quantitative information is available describing the frequency or success of immigration, one study found that 2% of adults emigrated from local populations each year (Ott-Eubanks et al. 2003). Given it is unlikely that all emigrants successfully immigrate into another population, I modeled the number of immigrants into local populations as a product of a randomly-drawn, beta distributed, time-varying annual immigration rate (γ; mean = 0.01) multiplied by the total number of adult tortoises in adjacent populations (i.e., landscape population size, N^m; see below) divided by the number of nearby local populations. I constrained γ during each time step such that its randomly-drawn value could never exceed $1 - \varphi^a$. Demographic parameters were modeled as random variables that accounted for both parametric uncertainty and temporal variability. We provide a full description of how the model treated uncertainty below, after describing simulation scenarios and other aspects of the model.

I sought to estimate population growth and extinction risk of tortoise populations across the species' range. To do so, I initialized the model with estimates of population size from populations on protected, conservation lands (e.g., national forests, state forests, state wildlife management areas), military installations, and some private lands across the species' range during the last ten years. Population estimates were collected by a diverse partnership of cooperating state agencies, private organizations, and academic institutions (see Acknowledgments) using burrow surveys burrow scope surveys, and lLine Transect Distance Sampling (LTDS) surveys. Population estimates do not represent an assessment of all local populations of tortoises that exist in southeastern North America, but rather represent information that was provided by partners through much of the species' range. Most population estimates came from assessments of local populations on lands managed for the conservation of biodiversity or natural resources.

I initialized starting population size using population estimates derived from data collected using burrow surveys, burrow scope surveys, and LTDS surveys. Burrow surveys involved a team of researchers searching a site to count the number of gopher tortoise burrows that were present and detected at a given site. Only burrows that were clearly identifiable as being constructed by a tortoise were counted. Because gopher tortoises often construct and/or use more than one burrow per individual, I used a published estimate of the relationship between the number of tortoises and burrows among six populations (0.4 tortoises/burrow; Guyer et al. 2012) to estimate the number of tortoises at sites from burrow count data. The burrow survey method assumes the tortoise-per-burrow estimate from Guyer et al. (2012) is generalizable to tortoise populations range-wide and that no burrows are missed during surveys; this method likely underestimates total population size, because small burrows are undetected (Gaya 2019). Burrow scope surveys used the same field survey methods as burrow surveys but included an additional step of using a burrow-scope camera to verify the presence of tortoises in burrows. Burrow scope surveys attempted to directly estimate abundance of local populations by counting individuals directly; this method assumes that all tortoise burrows were detected at sites and that only a single tortoise is present in a burrow. Burrow scope surveys also likely underestimate total population size because small burrows are difficult to detect during field surveys.

LTDS surveys are a population estimation method where a research team walks transects through habitat, observes tortoise burrows, searches the burrow for a tortoise with a burrow scope, records the spatial location of occupied tortoise burrows, and measures the perpendicular distance of each occupied burrow to the transect line. Invariably, burrows and individuals are imperfectly sampled, because detection probability of burrows is less than one. However, analysis of the LTDS survey data generates functions estimating the decay of the detection rate with increasing distance from the transect line, and this detection function can then be used to account for undetected burrows and therefore estimate the total number of occupied burrows in the search area (i.e., total population size). I note that because juvenile tortoises have small burrows that are difficult to observe, detection of juveniles during LTDS is lower than adults, and LTDS surveys may underrepresent smaller size classes in the population estimates.

Population estimates from surveys allowed us to parameterize initial population size during simulated projections of populations. However, many population estimates were measured at spatial scales that may not necessarily reflect the target unit for demographic projection models, the population, but rather express the number of individuals that exist across a larger spatial scale (e.g., a property boundary) that may functionally represent more than one local populations. Using spatial survey data associated with population estimates, I sought to operationally identify populations at two spatial scales: local populations and landscape populations. I defined local populations as geographic aggregations of individuals that interact significantly with one another in social contexts that make reproduction significantly greater between individuals within the aggregation than with individuals outside of the aggregation (*sensu* Smallwood 1999). I operationally delimited local populations by identifying aggregations of individuals or burrows where individuals were clustered together within a 600 m buffer to the exclusion of other adjacent individuals or burrows. Studies of gopher tortoise populations in Alabama (Conecuh National Forest; C. Guyer, unpublished data), Georgia (Ft. Stewart

Army Reserve; E. Hunter and D. Rostal, unpublished data), and Florida (Boyd Hill Nature Preserve; J. Goessling and G. Heinrich, unpublished data) have found that >80% of gopher tortoise movements within and among years were less than 500 m. I selected a 600 m distance to buffer populations to encompass typical movement distances and adjacent habitat around surveyed populations that might include tortoises. I assumed that unsuitable habitat for tortoises (i.e., interstates, freeways, and expressways (HPMS 2019); major rivers and lakes (Sciencebase.org); wetlands, and highly urbanized areas as determined by visual inspection with ESRI imagery)e.g., major rivers and lakes, wetlands, paved roads [interstates, freeways, and expressways], urban areas) were unsuitable for tortoise movement or survival and considered those strict barriers when delimiting local populations. Adjacent local populations connected to each other by suitable habitat through which dispersal might occur formed a landscape population. I operationally delimited landscape populations by identifying local populations connected by suitable habitat within a 2.5 km buffer around each local population or any single population that was isolated from other populations by greater than 2.5 km. I received some population estimates from properties that were delimited to have two or more local populations of tortoises; in these instances, I multiplied the population estimate (and confidence limits) by the area of each delimited local population and divided by the total survey area of the original survey. I assumed that population estimates being delimited into two or more local populations through this process would have even population densities and this process spread the population assessment evenly among local populations delimited by in the dataset.

The process of delimiting local populations and landscape populations resulted in a dataset of 626 local populations that formed 244 landscape populations; Florida had the greatest number of local (314) and landscape populations (152), followed by Georgia (151, 63, respectively), Mississippi (94, 7), Alabama (54, 14), Louisiana (7, 5), and South Carolina (6, 4). I used population estimates from local populations to parameterize initial population size of adults (N^a) and juveniles (N^j) during simulated population projections. I assumed a 1:1 sex ratio and a 3:1 adult:juvenile ratio in populations, given observations from stable local populations in Alabama (Folt et al. 2021), and used the ratios to isolate and separate the female population into juvenile and adult components.

Modeling threats

Climate warming – The world is rapidly changing in the 21st century, and numerous anthropogenic factors threaten the stability and persistence of natural ecosystems worldwide. I sought to model how predicted future changes to abiotic and biotic features in southeastern North America may threaten future population growth and viability of gopher tortoises. I met with scientists with expert knowledge in both gopher tortoise population biology and habitat management and identified a series of factors that experts considered to have high likelihood of influencing tortoise demographics in the future (hereafter, threats). Using the list of threats, I reviewed the literature to identify research describing quantitative effects of how threats (or similar mechanisms) influence specific demographic parameters in the conceptual model for tortoises. Here, I describe hypotheses for how four threats (climate warming, sea-level rise, urbanization, and climate-change effects on habitat management) may influence tortoise demographics, and how I used quantitative estimates of the threats from the literature to parameterize and simulate how threats may influence future population growth and viability of gopher tortoises.

Climate change is predicted to drive warming temperatures and seasonal shifts in precipitation across southeastern North America (Dalton and Jones 2010). Of these two effects, warming temperatures may have the greater impact on gopher tortoises, because tortoise demography is known to be sensitive to temperature gradients across the species' range. Specifically, maturity age and F vary along a north-south latitudinal gradient, where warmer, southern populations have faster growth rates, younger maturity ages, and increased fecundity relative to cooler, northern populations (Ashton et al.

2007, Meshaka Jr. et al. 2019). As climate warming increases temperatures in the region, individuals in populations may experience more favorable conditions for growth and reproduction across the species' range. Because no studies have linked tortoise growth or fecundity to interannual or interpopulation variation in precipitation, it seems less likely that climate-driven shifts in precipitation will influence tortoise demography. I modeled how climate warming may influence gopher tortoise demography by using the estimated linear relationships of MAT with maturity age and F (above) to predict how warming temperatures experienced by populations in the future will drive concurrent changes in demography. For each population, I extracted historic estimates of MAT using the 'WorldClim' database (Hijmans 2020) and then simulated step-wise climate-warming effects on MAT each year in the future where warming rates were parameterized by three treatments of climate warming: (1) a 1.0 °C increase in MAT over the next 80 years, (2) a 1.5 °C increase in MAT over the next 80 years, and (3) a 2.0 °C increase in MAT over the next 80 years (IPCC 2013). Each year in the future, I used simulated changes in MAT to calculated mean maturity age and F at sites. This analysis assumes that: (i) all local populations will respond homogeneously to warming temperatures, and (ii) there are no potential climatic ceilings that would limit growth and reproduction.

Habitat management – Through much of its range, gopher tortoises prefer upland habitat with open canopy, sparse midstory, and an understory plant community that provides diverse food sources (Aresco and Guyer 1999, Birkhead et al. 2005, McCoy et al. 2013, Bauder et al. 2014, Nussear and Tuberville 2014). Prescribed fire is the most common management technique to maintain high-quality, open habitat for gopher tortoises (Landers and Speake 1980, Diemer 1986, Yager et al. 2007, Ashton et al. 2008); however, when fire is not present in sufficient intervals or intensity to maintain open habitat on the landscape, apparent survival of gopher tortoises decreases (Hunter and Rostal 2021), potentially to levels that are insufficient for maintaining population viability (Folt et al. 2021). However, wildlife managers tasked with maintaining high-quality upland habitat for gopher tortoises and other fire-dependent upland plant and animal species (Guyer and Bailey 1993) may be challenged because regional climate warming may make habitat management with prescribed fire more difficult to accomplish. Managers require suitable fuel and weather conditions (e.g., relative humidity, temperature, wind speed; i.e., the 'burn window') to facilitate manageable fire behavior that will accomplish intended goals while limiting risk toward human communities. However, climate-change models predict the availability of burn window conditions to shift over future decades, with available conditions for fire management increasing in the winter but decreasing in the spring and summer (Kupfer et al. 2020); summed together, seasonal shifts in the burn window conditions will decrease overall opportunity for management with prescribed fire. If managers become limited in the use of prescribed fire, resulting decreases in habitat quality may drive decreases in gopher tortoise survival (Hunter and Rostal 2021). I modeled how habitat management influences gopher tortoise population growth by modeling habitat management of populations and linking the frequency of management to adult survival. I assumed that a baseline fire-return interval (FRI) of 1–4 years (mean = 2.5 years) maintains high-quality habitat for gopher tortoises (Guyette et al. 2012, Crawford et al. 2020) and then modeled the probability that a population is burned during a given year (burn probability; BP) as the inverse of the fire-return interval:

$$BP_t = \frac{1}{FRI}. \tag{5}$$

For example, an intended two-year FRI for a population would yield a BP of 0.5. Next, using historic baseline data describing average seasonal burn opportunity across southeastern North America (Kupfer et al. 2020), I modeled the number of available burn days (i.e., days within the burn window) in winter (January–February; W), spring (March–May; Sp), and summer (June–July; Su) as a product of the total days per season (59, 92, and 61 days, respectively) and the stochastically-drawn percentage of days historically available for burning (0.766, 0.800, and 0.645, respectively). I modeled four treatments for how the number of days available for prescribed fire may change in the future (Kupfer et al. 2020): (1) prescribed fire use will decrease consistent with climate shifts predicted by RCP4.5 ('decreased fire'), (2) prescribed fire use will decrease with climate predictions RCP8.5 ('very decreased fire'), (3) prescribed fire use will increase opposite of the effect predicted by RCP4.5 ('increased fire'), and (4) prescribed fire use will remain at current levels ('status quo'). For each treatment, I modeled effects of climate change on the percentage of available burn days over the next 80 years using average effects from across southeastern North America (Kupfer et al. 2020): 0.016 increase in winter, 0.040 decrease in spring, and 0.239 decrease in summer ('decreased fire' treatment); 0.030 increase in winter, 0.105 decrease in spring, and 0.436 decrease in summer ('very decreased fire' treatment); 0.016 decrease in winter, 0.040 increase in spring, and 0.239 increase in summer ('increased fire' treatment), and no effects on burn days ('status quo' treatment). The third and fourth scenarios could result if habitat managers can offset effects of climate change by benefiting from methodological advances in fire management or by using alternative methods rather than prescribed fire, such as mechanical or chemical treatments, to achieve similar management goals. We extracted all mean values and predicted effects from the text in Kupfer et al. (2020).

For the first three treatments, I used the predicted effects to model stepwise changes in the percentage of available burn days per season in each year. Assuming that changes in total burn opportunity result in changes in total burn frequency, I modeled BP in each year t as a product of the function of the inverse of FRI and predicted changes in the total number of burn days available due to climate change:

$$BP_t = \frac{1}{FRI} * \frac{W_t + Sp_t + Su_t}{W_1 + Sp_1 + Su_1}. \quad (6)$$

where subscript 1 is the first year of the projection and t is each year ranging from 1 to the last year in the projection. For the fourth treatment, I modeled no effects of climate on the number of available burn days per year; burn probability did not vary by fixed effects through time in an attempt to simulate unvarying management ability in the future. I used estimates of BP to simulate whether a population was burned in each year. Apparent annual survival probability of female gopher tortoises is highest in the first year after a site is burned, but declines by 0.027 each year without fire (Hunter and Rostal 2021). During each year of projections, I simulated adult survival as a stochastic effect of the number of years since last burn (YSB):

$$\varphi_t^a = 0.96 - 0.027 \times YSB. \quad (7)$$

Because Hunter and Rostal (2021) only estimated the effect of year-since-burn on survival of adults up to three years since burn, I did not extrapolate this effect beyond 3 years or to juveniles. This formulation assumes that: (i) changes in the number of days available to burn result in changes in burn frequency (i.e., management is limited by available burn days), the season that a burn is performed does not influence habitat quality (but see: Aresco and Guyer 1999, Yager et al. 2007), and (iii) effects of YSB on survival from Georgia (Hunter and Rostal 2021) is generalizable to all populations of gopher tortoises.

Urbanization – Human development of the landscape (i.e., urbanization) threatens terrestrial wildlife communities in the southeastern United States, including gopher tortoise populations that often rely on upland habitats that are popular sites for urban development or agriculture. While the local tortoise populations I modeled are largely on conservation lands intended for wildlife conservation, urbanization threatens to surround these lands, disrupt habitat connectivity, and decrease metapopulation dynamics that maintain connectivity and gene flow both among local populations and within landscape populations. Additionally, urbanization can disrupt habitat management by decreasing the ability of managers to use prescribed fire. I sought to model effects of urbanization pressure on tortoise populations by linking urbanization predictions from the SLEUTH urbanization model (Clarke 2000) to habitat management of local populations with prescribed fire and with baseline immigration rates (γ) of tortoises across landscape populations. First, I modeled an effect of urbanization on habitat management by making BP a function of each population's distance to the nearest urban area ($dNUA$). Specifically, I assumed that local populations immediately adjacent to urban areas (distance < 0.1 km) are unable to manage with prescribed fire and forced BP to 0, management is uninfluenced for populations far from urban areas (> 3.2 km; no effect on BP), and management of populations between 0.1–3.2 km from an urban area experience a negative effect on fire management with BP declining as a linear function of the population's proximity to the urban area (i.e., populations closer to urban areas experience less prescribed fire). For populations between 0.1–3.2 km of an urbanized area, I added an additional term to Equation 6 to estimate BP as a consequence of $dNUA$ at time t:

$$BP_t = \frac{1}{FRI} * \frac{W_t + Sp_t + Su_t}{W_1 + Sp_1 + Su_1} * \frac{dNUA_t}{3.2}. \qquad (8)$$

To model effects on urbanization on migration dynamics among local populations within landscape populations, I first estimated the total area (A; ha) and urbanized area (UA; ha) within landscape populations in year 2020 using the SLEUTH model. Assuming that tortoises cannot survive and/or move through urbanized areas but can survive and move in unurbanized areas, I estimated the initial proportion of suitable dispersal habitat (PDH_i) for tortoise dispersal in landscape populations at the start of population projections as:

$$PDH_i = \frac{A_i - UA_i}{A_i}. \qquad (9)$$

I next estimated future urbanization and its effect on dispersal habitat for tortoises using the SLEUTH model predictions for 40, 60, and 80 years in the future. I estimated predicted urbanized area in the future (UA_f; ha). Similar to Equation 9, I estimated the future proportion of suitable dispersal habitat (PDH_f) around populations in the future:

$$PDH_f = \frac{A_i - UA_f}{A_i}. \quad (10)$$

I calculated the predicted change in proportion of dispersal habitat (ΔPDH) due to future urbanization for landscape populations by taking the difference between PDH_f and PDH_i. For each year t ≥ 3 during population projections, I modeled the number of adult immigrants (N_t^i) into local populations in each year as a function of the number of individuals in the landscape population available for immigration to the local population during the previous year (N_{t-1}^{mp}), the total number of local populations in the landscape population (N^{lp}), γ_t, PDH_i, ΔPDH, and the time-step in the future:

$$N_t^i = \frac{N_{t-1}^{mp}}{N^{lp} - 1} * \gamma_t * \left[PDH_i + \Delta PDH * \frac{t}{total}\right], \quad (11)$$

where t is the year in the population projection, ranging from t_i = 1 to the total projection interval ($total$). I estimated N^{mp} at t = 1 by summing the starting population size of all local populations in the landscape population and subtracting the abundance of the focal population, because individuals from the focal population would be unavailable for immigration into their own population. I assumed that population growth of the landscape population term would change through time similarly to that of the local population being modeled in any instance; therefore, I modeled changes in N^{mp} through time as a function of changes in abundance of the local adult population size during the previous time step, $\frac{N_t^a}{N_{t-1}^a}$, during year 3 and beyond. I next estimated the distance of each local population to the nearest urban area currently and in the future using the SLEUTH model. I measured distance to urban area from the geometric center of local populations to the edge of the nearest neighbor urban area. I estimated predicted effects of urbanization on local and landscape populations by modeling three treatments from the SLEUTH urbanization model that corresponded to different probability thresholds of urbanization: (1) a low urbanization treatment where future urbanization was limited to cells with urbanization probability ≥0.95, (2) a moderate urbanization treatment with urbanization predicted by probability ≥0.50, and (3) a high urbanization treatment with urbanization probability ≥0.20. I assumed that: (i) immigration was limited to adults and that no juveniles successfully migrate among populations, and (ii) immigrants cannot survive or move through urbanized areas (e.g., due to road mortality) but survive perfectly while moving through unurbanized areas.

Sea-level rise – Warming temperatures across Earth are causing the polar ice caps to shrink, release freshwater into the oceans, and drive substantial increases in oceanic levels worldwide (hereafter, sea-level rise) (IPCC 2013). In southeastern North America, sea-level rise is predicted to influence low-lying coastal habitats by causing floods, inundation, and shifts in land-cover types (Marcy et al. 2011). Because gopher tortoises are a terrestrial species and not suited to wetland habitats, sea-level rise may negatively affect gopher tortoise populations in low-lying coastal areas, such as coastal sand-dune environments (Blonder et al. 2020). Projected sea-level rise scenarios provide a range of coastal inundation scenarios that vary in severity. I modeled effects of sea-level rise on tortoises using three scenarios of sea-level rise predicted by NOAA, the 'intermediate-high', 'high', and 'extreme' scenarios, which correspond to predictions from two of the most likely global emission scenarios, RCP6.0 and RCP8.5 (IPCC 2013, NOAA 2020). Local predictions for the two scenarios are available from USGS sea-level monitoring stations across the southeastern United States, providing estimates of sea-level rise for stations at decadal time steps in the future to year 2100. I modeled three treatments of sea-level rise using predictions from NOAA: (1) the 'intermediate-high' scenario derived from RCP6.0, which predicts ca. 1.83 m of sea-level rise over the next 80 years, (2) the 'high' scenario which predicts 2.55 m of sea-level rise over the next 80 years, and (3) the 'extreme' scenario derived from RCP8.5, which predicts 3.16 m of sea-level rise over the next 80 years (NOAA 2020). I modeled sea-level rise effects on populations in two ways. First, assuming that gopher tortoise populations cannot persist when oceanic levels encroach too close upon their habitat, I simulated decreasing elevation of tortoise populations due to sea-level rise. I extracted historic estimates of elevation above sea level (asl; in m) using the centroid geographic coordinates of each local population using the 'WorldClim' database (Hijmans 2020). Given the total predicted sea-level rise of each treatment over the next 80 years, I simulated incremental sea-level rise at each population in each year in the future and subtracted this incremental oceanic rise from the site's elevation through time. When the site elevation of populations decreased to less than 2 m asl, I considered the populations functionally extirpated and forced the population size vectors, N^j and N^a, to zero. Second, I assumed that habitat inundated by sea-level rise adjacent to local populations would decrease connectivity and dispersal dynamics of individuals among populations within landscape populations. I used spatial predictions from NOAA to estimate future inundation area due to sea-level rise for each landscape population, and then I modeled γ to decline as a function of decreasing habitat available for dispersal at the landscape scale. Assuming that tortoises cannot survive and/or move through inundated areas but can survive and move in inundated areas, I extended Equation (11) to subtract the proportion of area lost to sea-level rise (SLR) from the proportion of dispersal habitat (PDH_i) in each year:

$$N_t^i = \frac{N_{t-1}^{mp}}{N^{lp} - 1} * \gamma_t * \left[PDH_i + \Delta PDH * \frac{t}{total} - SLR * \frac{t}{total}\right], \tag{12}$$

The analysis of sea-level rise effects assumes that: (i) sea-level rise throughout southeastern North America will be homogeneous and characterized by NOAA predictions derived from data from Ft. Myers, Florida, (ii) populations less than 2 m asl are unable to persist, and (iii) populations are unable to migrate away from sites because coastal areas are often heavily developed and there is no guarantee that adjacent properties would be available for entire populations to migrate.

Population projection structure

I conceptualized and mathematically articulated different scenarios for how four factors (climate warming [3 treatments]; habitat management [4 treatments]; urbanization [3 treatments]; sea-level rise [3 treatments]) might influence future population growth of gopher tortoises. However, factors of global change are not independent; rather, most factors that I considered depend on other factors (e.g., sea-level rise is a consequence of climate warming). To understand how tortoise populations will respond to scenarios with multiple concurrent factors, I created a set of six scenarios with varying levels of threat magnitude and combination (Table 2). Specifically, I created three models with different levels of stressors (low stressors, medium stressor, and high stressors) that experienced habitat management consistent with contemporary target management goals. I then used the medium stressor values and built three additional models that varied in habitat management treatments, ranging from 'more management' conditions to worsening ('less management') and much worse ('much less management') conditions (Table 2). The three stressor models were meant to estimate the effects of uncertainty in unmanageable future stressors (climate warming, sea-level rise, urbanization), while the management models were meant to estimate the effects of uncertainty in actionable management practices (e.g., habitat management).

To encompass uncertainty in future states of risk factors and scenarios, I projected population growth for each local population under each of the six model scenarios using a stochastic projection uncertainty structure that accounted for scenario uncertainty, geographic variation among populations, parametric uncertainty, and temporal stochasticity (Figure 2). For each scenario, I parameterized certain stochastic variables specific to the scenario and then projected gopher tortoise populations across the species' range into the future. For each population, I specified mean demographic rates specific to the MAT of the population's geographic location (Table 1) and then simulated future population trajectories with 100 replicates each projected 80 years into the future. During simulations, I applied an uncertainty structure that accounted for both parametric uncertainty (among replicates) and temporal stochasticity (within replicates; McGowan et al. 2011). For each replicate, I drew mean values (and an associated error term) to model parametric uncertainty; I then modeled temporal stochasticity by drawing stochastically from the mean (given its error) during each time step within the replicate. I simulated parameters by drawing replicate-level means stochastically from either beta distributions (e.g., probabilities) with shape parameters calculated from mean and standard deviation estimates (Morris and Doak 2002), log-normal distributions (e.g., counts), or binomial distributions (e.g., probabilities simulating discrete events). I projected populations 80 years into the future because this interval overlapped with the maximum duration of future predictions of the climate, urbanization, and sea-level rise models that I used and the interval also encompassed ca. two generations of gopher tortoises (B. Folt, pers. obs.). I felt uncomfortable making predictions past 80 years into the future because of uncertainty among models and parameters.

Little to no data exist describing gopher tortoise immigration rates, γ, in wild populations. Given uncertainty associated with this parameter, I sought to include a sensitivity analysis to understand the effects of γ on our results. I crafted three additional scenarios: a 'no immigration' scenario with $\gamma = 0$, a 'high immigration' scenario with $\gamma = 0.02$, and a 'very high immigration' scenario with $\gamma = 0.4$. I simulated these scenarios with stressor and habitat management values from the 'medium stressors' scenario with a projection interval of 80 years, and I compared the resulting immigration scenarios to the 'medium stressors' scenario results that were simulated with $\gamma = 0.01$.

To understand redundancy, resiliency, and representation of the gopher tortoise in the future, I used the population projections to estimate future changes in tortoise populations under each of the six scenarios (Table 2). I assessed resiliency by measuring the predicted population rate of change in the total number of individuals, local populations, and landscape populations in the future relative to current conditions. I summarized population trends by estimating population growth rate (λ), a metric that describes change in population size as increasing ($\lambda > 1.00$), stable ($\lambda \sim 1.00$), or decreasing ($\lambda <$

1.00) over a projection interval; I measured population growth rate of total population size (N^{total}), the number of local populations (N^{p}), and the number of landscape populations (N^{m}) across the species' range during the projection interval. I report changes in population size (total, local, or landscape populations) with λ values or by expressing λ values as percent increases or decreases from initial current population size during the projection interval (e.g., a λ = 1.25 is a 25% increase; λ = 0.66 is a 34% reduction), and I report ranges of λ values among the six scenarios. I assessed the resiliency of future populations to changing environments by estimating extinction risk. Within populations, I evaluated extinction risk with a quasi-extinction probability (P_e), where I estimated P_e by the proportion of simulations resulting in < 3 females alive at the end of the simulation period. I chose < 3 females as a threshold to approximate functional extinction because populations with fewer than three females are extremely like to be inbred (Chesser et al. 1980, Frankham et al. 2011). For each population, I estimated persistence probability (P_p) as 1–P_e, and then I used P_p to categorize populations as 'extremely likely to persist' (P_p ≥ 0.95), 'very likely to persist' (0.80 ≤ P_p < 0.95), 'more likely than not to persist' (0.50 ≤ P_p < 0.80), and 'unlikely to persist' (i.e., extirpated; P_p < 0.50). I then took a random draw from a Bernoulli distribution with *p* = P_p for each population to simulate the likely number of populations predicted to persist at the end of the projection; I summarized this simulation with the median (95% CI) of 1000 replications. For each landscape population, I estimated resiliency by selecting the constituent focal population with the greatest persistence probability and used that value to categorize landscape population persistence and simulated landscape population survival by drawing from a Bernoulli distribution in the future. I evaluated how representation is predicted to change in the future by examining how population growth of total population size (number of individuals), number of populations, and number of landscape populations will vary by the five analysis units across the species' range. For each scenario, I summarized the results among all populations across the species' range, but also by analysis units (five units) and state (six states: Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina).

My demographic model for gopher tortoises included biotic, abiotic, and anthropogenic effects on demography. To understand the relative importance of how each hypothesized factor contributed to population persistence among the 626 populations modeled, I used model outputs from each scenario projected 80 years into the future and regressed P_p of populations by hypothesized fixed effects. Specifically, I built a generalized linear model where I evaluated how biotic (initial population size, number of populations per landscape population), abiotic (population area, elevation, latitude), and anthropogenic (sea-level rise, urbanization, management level) factors influenced population persistence; I fit the model with a binomial distribution to accommodate a response variable with values ranging between 0–1. To simplify the model, I treated management as a continuous variable with four values: more management (1), status quo (0), less management (-1), and much less management (-2). I evaluated statistical significance of mixed-effects model parameters using α = 0.05 and I reported the size of statistically significant effects using odds ratios.

I performed all analyses in the statistical program R (R Core Team 2018).

Results

Linear regression analysis of three demographic parameters reviewed in the literature (fecundity, maturity age, and apparent annual survival probability) found that fecundity and maturity age vary significantly by MAT across the species’ range (Figure 3). For each 1 °C increase in MAT, I found that maturity age decreased by 1.41 years (0.18–2.62, 95% CI), which was a statistically significant effect (P = 0.029). For each 1 °C increase in MAT, I found that fecundity increased by 0.48 eggs per clutch (0.24–0.72, 95% CI), which was statistically significant (P < 0.001). I used linear functions describing geographic variation in demographic rates to randomly simulated mean fecundity and age of maturity for each population during simulations, given the patterns of MAT at each population's location (Table 1).

I simulated population growth of an estimated 70,600 individual (female) gopher tortoises comprising 626 local populations and 244 landscape populations in the current conditions. Population projections under six scenarios of future change during 40, 60, and 80-year projection intervals predicted declines in the number of gopher tortoise individuals, local populations, and landscape populations of gopher tortoises (Table 3). Relative to current levels of total population size, predictions for total population size suggested declines by 2060 (λ = 0.65–0.67 among scenarios; i.e., 33–35% declines), 2080 (λ = 0.66–0.70 among scenarios; 30–34% declines), and 2100 (λ = 0.67–0.72 among scenarios; i.e., 28–33% declines). The six scenarios varied little in their effects on the total number of individuals, local populations, and landscape populations; but scenario effects become more magnified in each successive timestep. However, 95% confidence intervals (CI) for predictions of λ all overlapped with 1.00 in all scenarios and timesteps, indicating significant uncertainty in predictions for each scenario at each projection interval. Among the simulated populations, the number of local populations and landscape populations also were predicted to decline in each projection interval (Table 3). Declines in local populations and landscape populations were modest at the 40-year timestep (47–48% and 25–27% declines among scenarios, respectively) but were exacerbated at the 60-year (60–61% and 41–43% declines, respectively) and 80-year (68–70% and 53–57% declines, respectively) timesteps. Scenarios did not vary strongly in their effect on the predicted number of persisting local populations and landscape populations within each projection interval.

Categorization of populations by persistence probability revealed finer-scale variation of how scenarios varying in magnitude of stressors and management influenced persistence probability of populations (Table 4). Among the three projection intervals, the 'low stressors' scenario tended to predict higher percentages of Extremely Likely Extant populations and lower percentages of Unlikely

Extant (i.e., Extirpated) populations relative to the 'medium stressors' and 'high stressors' scenarios. Similarly, the 'more management' scenario tended to predict higher percentages of Extremely Likely Extant populations and lower percentages of Unlikely Extant (i.e., Extirpated) populations relative to the 'less management' and 'much less management' scenarios. Figure 5 illustrates persistence probabilities among populations and landscape populations predicted by the 'less management' scenario.

Changes in the number of individuals, local populations, and landscape populations varied by analysis unit and state (Appendix 2, Appendix 3). Among the five analysis units projected 80 years into the future, units 1, 3, and 5 were predicted to decline overall, with mean λ values ranging between 0.60–0.73, 0.47–0.49, and 0.52–0.58 among scenarios for each unit, respectively (i.e., 27–40%, 51–53%, and 42–48% declines, respectively); however, 95% CI of λ overlapped with 1.00 in all scenarios for each of the three units, indicating uncertainty in future abundance. Unit 4 was predicted to experience more modest declines in total abundance (λ = 0.86–0.98; i.e., 2–14% decrease), but 95% CI of λ also overlapped 1.00, indicating uncertainty in predicted future population growth. Alternatively, total abundance in Unit 2 was predicted to increase substantially (λ = 2.37–2.53; i.e., 137–153% increase); 95% CI of λ did not overlap 1.00, indicating a significant predicted increase in population size. Scenarios predicted substantial declines in the number of local populations among all units. Predicted reductions in populations were greatest in Unit 1 (λ = 0.22–0.23), Unit 2 (λ = 0.23–0.26), and Unit 5 (λ = 0.28–0.30), and slightly weaker (but still strong) in Unit 3 (λ = 0.37–0.39) and Unit 4 (λ = 0.39–0.41). The number of landscape populations was predicted to decline among all scenarios in each analysis unit, with the strongest loss of landscape populations in Unit 5 (λ = 0.36–0.41 among scenarios) and the weakest loss of landscape populations in Unit 3 (λ = 0.48–0.53 among scenarios).

Among the six states, total population size was predicted to decline in four states (Florida, Georgia, Mississippi, South Carolina) and increase in two (Alabama, Louisiana; Appendix 3; e.g., Figure 4). The number of local populations and landscape populations were predicted to decline among all scenarios for all states. In South Carolina, reductions in the number of individuals and populations were predicted to be particularly strong, where scenarios predicted substantial declines in individuals (λ = 0.03 among all scenarios; i.e., 97% declines), local populations (λ = 0.17 among all scenarios; i.e., 83% declines), and landscape populations (median λ = 0 among all scenarios; i.e., no remaining landscape populations). Similarly, Louisiana was predicted to lose all local populations and landscape populations except for one by 2100; however, growth of a single surviving population/landscape population caused the total population size to increase in the state during the projections. Similarly, Alabama was predicted to experience an 85–87% reduction in local populations (λ = 0.13–0.15 among scenarios), but predicted increases in the number of individuals in surviving populations caused predictions for the number of individuals in the state to increase substantially over the next 80 years. Mississippi was projected to lose 40–54% of total population size and 77–78% of local populations, but while maintaining 71% of its landscape populations. Predicted changes in the number of populations for Florida and Georgia were similar, with the number of local populations declining 66–68% and 61–62% among scenarios and landscape populations declining 52–55% and 52–57% among scenarios for each respective state (Appendix 3).

I found that model predictions were highly sensitive to input values for immigration rate, γ (Table 5). The population declines predicted by the 'medium stressors' scenario were exacerbated substantially when simulated with γ = 0; conversely, elevated values for γ produced population projections that substantially increased the total population size (overall λ > 1.00) and decreased declines in populations and landscape populations.

Regression analysis of how abiotic, biotic, and anthropogenic factors influenced persistence probability of local populations found support for significant effects of initial population size, number of populations per landscape population, area, elevation, latitude, sea-level rise, urbanization, and prescribed fire on persistence probability. With each 50-female increase in starting population size, populations were 1.029 (1.027–1.03; 95% CI) times as likely to persist, which was statistically significant ($P < 0.0001$). With each 1 local population increase in the landscape population, local populations were 0.987 (0.986–0.987; 95% CI) times as likely to persist (i.e., 1.013 times less likely), which was statistically significant ($P < 0.0001$). For each 500-ha increase in area, populations were 1.002 (1.001–1.003; 95% CI) times as likely to persist, which was statistically significant ($P = 0.044$). With each 10-m increase in elevation, populations were 0.901 (0.899–0.904; 95% CI) times as likely to persist (i.e., 1.109 times less likely), which was statistically significant ($P < 0.0001$). For each 0.5 degree increase in latitude, populations were 1.122 (1.119–1.125; 95% CI) times as likely to persist, which was statistically significant ($P < 0.0001$). With each 0.01 proportional loss in landscape area due to sea-level rise, local populations were 0.57 (1.67–1.82; 95% CI) times as likely to persist (i.e., 1.747 times less likely), which was statistically significant ($P < 0.0001$). With each 0.1 proportional loss in landscape area due to urbanization, local populations were 0.96 (0.955–0.965; 95% CI) times as likely to persist (i.e., 1.042 times less likely), which was statistically significant ($P < 0.0001$). With each categorical increase in fire management, local populations were 1.021 (1.014–1.029; 95% CI) times as likely to persist, which was statistically significant ($P < 0.0001$).

Discussion

I synthesized a large literature describing gopher tortoise life history and built a predictive population model that accounted for geographic variation in demography to estimate growth of populations across the species range. I then identified a series of stressors (climate warming, sea-level rise, urbanization, and habitat management) that have been hypothesized to have current and future negative effects on gopher tortoise populations; then, using estimates of stressor effects on tortoise demography and/or reasonable assumptions, I linked stressors to specific demographic rates and then used published model predictions of stressor prevalence in the future (Clarke 2000, IPCC 2013, Kupfer et al. 2020, NOAA 2020) to simulate how gopher tortoise populations will respond to plausible future conditions across the species range.

Using this integrative modeling framework, I simulated future population size, redundancy, and resiliency of gopher tortoises under six scenarios varying in the magnitude of threats at intervals of 40, 60, and 80 years in the future. Simulated growth of ca. 70,600 females from 626 local populations and 244 landscape populations predicted future declines in the number of individuals, local populations, and landscape populations among all scenarios and projection intervals. Scenarios did not vary strongly in their effect on λ of individuals, populations, and landscape populations; no single stressor scenario or management scenario was sufficient to prevent population declines, and 95% confidence intervals of predictions overlapped significantly among all scenarios, indicating statistical insignificance of scenario effects.

While scenarios did not have strong effects on overall trends in abundance and population redundancy, categorization of populations by persistence probabilities suggested that the ‘increased management’ and ‘low stressors’ scenarios performed better at increasing population persistence and reducing extirpation than other management and stressor scenarios. Increased habitat management promoted greater population persistence relative to decreased management scenarios because of positive effects of management on survival in local populations, which increases population growth and persistence probability of populations. While populations may experience reproductive benefits from warming temperatures in the future (i.e., positive effects with increased stressors), the ‘low stressors’ scenarios outperformed the elevated stressor scenarios because the negative effects of urbanization and sea-level rise on survival and immigration were stronger than the positive effects of warming on reproduction.

The regression analysis identified significant effects of initial abundance, number of populations per landscape population, area, elevation, urbanization, sea-level rise, and habitat management to influence persistence probabilities of local populations. For groups and agencies seeking alternatives to buffer tortoise populations from anthropogenic effects, these factors represent opportunities for management and/or conservation.

Previous demographic models for gopher tortoises have largely ignored including immigration parameters (e.g., Tuberville et al. 2009, Folt et al. 2021) and modeled tortoise demography as closed to immigration, perhaps due to the paucity of field estimates of immigration in wild populations. These models often predicted population declines, even though recent evidence was more consistent with population stability (Folt et al. 2021, Goessling et al. 2021). This discrepancy suggests a disconnect between demographic projections that are largely influenced by apparent survival projections and actual trends occurring in populations, a discrepancy that may be resolved by incorporating immigration during projection analyses. To this end, I incorporated an immigration parameter, γ, for local populations and found predictions were highly sensitive to variation in γ. This was supported by the fact that persistence probabilities were sensitive to threats that influenced immigration rates and two scenarios of 'no immigration' and 'high immigration' produced results that strongly deviated from results of the stressor and management scenarios. Together, these lines of evidence suggest that immigration is an important parameter in tortoise demography that may deserve future attention when studying tortoises in the field and building models of tortoise demography in the laboratory.

While the number of individuals, populations, and landscape populations were all expected to decline across each projection interval, overall projections suggest that extinction risk for the gopher tortoise is low in the future. Of the populations modeled here, mean predictions among scenarios for 80 years in the future suggested the presence of 47,202–50846 individuals (females) among 188–198 local populations within 106–114 landscape populations. The persistence of relatively large numbers of individuals and populations suggests resiliency of the species in the face of global change and also redundancy to buffer from future catastrophic events. The spatial distribution of populations predicted to persist in the future are distributed somewhat evenly among analysis units (e.g., Figure 5), which suggests the persistence of representation in the future as well. However, we note that the number of local populations in genetic analysis Unit 1 was the predicted decline by 27–40% among scenarios; this analysis unit includes the populations in Louisiana, Mississippi, and southwest Alabama that are currently protected federally as 'Threatened' under the ESA. The large declines in number of populations occurred, in part, because many local populations (N = 174) delimited in our surveys had very few individuals to start with in the current conditions. Assuming a 3:1 adult to juvenile ratio and an even sex ratio, local populations with less than 8 individuals were functionally extirpated at the start of projections, given our quasi-extinction probability (< 3 adult females). Thus, many local populations were doomed for extirpation from the start, because of insufficiently large population size in the current conditions. This also likely explains the negative effect of landscape population size on population persistence we observed in our regression analysis; a few extremely large landscape populations (e.g., six landscape populations had 13–50 local populations) were dominated by local populations with <8 individuals, thus driving down mean persistence probability in large landscape populations.

I sought to build a population modeling framework that accounts for important elements of population viability analyses, including clear objectives, detailed demographic data and knowledge of life history, temporal stochasticity, parametric uncertainty, density dependence, relevant extrinsic factors (i.e., threats), and sensitivity analysis, to name a few (Chaudhary and Oli 2020). However, like all models, the framework has limitations and opportunities for improvement. The model was sensitive to immigration, a parameterization that we derived largely from a single estimate of emigration (Ott-Eubanks et al. 2003). I modeled demography as an effect of predicted values of climate warming and fire management at broad spatial scales to support an impending listing decision for the species. Future models could evaluate regional variation in effects of warming and fire management for more realistic predictions of threat effects at more detailed spatial scales. The model also focused on simulating the fate of known populations and did not estimate the formation of new populations or project the abundance of existing populations not included in the dataset. Therefore, predictions for □ of local and landscape populations were constrained by an upper limit of 1 and therefore were unable to exceed this limit. My analysis provides an objective assessment of how stressors and management actions will influence future population growth, overall extinction risk of both populations and the species across landscape genetic group and by state, and how uncertainty in important input parameters (e.g., immigration) influences predictions.

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Table 1. Mean and standard error values used to estimate stochastic variables in our population projection model for gopher tortoises (*Gopherus polyphemus*) in conservation lands across the species' range. MAT = mean annual temperature (degrees C) of a population's locality; YSB = years since last burn of habitat using prescribed fire. See Appendix 1 for the full list of references used to compile parameter estimates for variables in the table.

Parameter	Distribution shape	Mean (variance)	Source
Probability of breeding	Beta	0.97 (0.01)	E. Hunter, pers. comm.
Fecundity	Log normal	-3.54 (2.42) + 0.48 (0.12) * MAT	Meshaka Jr. et al. (2019); this study
Nest survival	Beta	0.35 (0.10)	Smith et al. (2013)
Probability of viable eggs	Beta	0.85 (0.05)	Landers et al. (1980), Rostal and Jones (2002)
Probability of female	Beta	0.50 (0.04)	This study
Hatchling survival	Beta	0.13 (0.03)	Perez-Heydrich et al. (2012)
Juvenile survival	Beta	0.75 (0.06)	Appendix 1
Adult survival	Beta	0.96 (0.03)	Appendix 1
Maturity age	Log normal	43.52 (11.31) – 1.41 (0.53) * MAT	Appendix 1; this study
Juvenile abundance	Log normal	Varying by population	This study
Adult abundance	Log normal	Varying by population	This study
Immigration rate	Beta	0.01 (0.001)	Ott-Eubanks et al. (2003)
Percent of winter days for burning	Beta	0.77 (0.05)	Kupfer et al. (2020)

Percent of spring days for burning	Beta	0.80 (0.05)	
Percent of summer days for burning	Beta	0.65 (0.05)	
Change in winter days for burning	Beta	Varying by prediction scenario	
Change in spring days for burning	Beta	Varying by prediction scenario	
Change in summer days for burning	Beta	Varying by prediction scenario	
Burn probability	Beta	0.4 (0.015)	Guyette et al (2012), Crawford et al. (2020)
Fire effect on survival	Beta	0.96 – 0.027 (0.003) * YSB	Hunter and Rostal (2021)

Table 2. Six scenarios of future climate warming, sea-level rise, urbanization, and habitat management used to simulated population growth and extinction risk for gopher tortoises (*Gopherus polyphemus*) for 80 years into the future. Scenarios vary in the magnitude of threat influences on gopher tortoise demography; threat levels included three levels of climate warming (1.0, 1.5, and 2.0 degrees C increase), three levels of sea-level rise (intermediate-high [1.83 m], high [2.55 m], and extreme [3.16 m] scenarios), three levels of urbanization scenarios predicted by the SLEUTH model [Clarke 2000] at probability thresholds of 0.9 (conservative prediction), 0.5 (moderate prediction), and 0.1 (aggressive prediction), and four levels of changes in habitat management (no changes, less management predicted by RCP4.5 [Kupfer et al. 2020], much less management predicted by RCP8.5 [Kupfer et al. 2020], and improved management [the opposite of the effect predicted by RCP4.5 in Kupfer et al. 2020]).

Scenarios	Climate warming (deg C)	Sea-level rise (m)	Urbanization	Management
Low stressors	1.0	0.54 m	P = 0.95	Status quo
Medium stressors	1.5	1.83 m	P = 0.50	Status quo
High stressors	2.0	3.16 m	P = 0.20	Status quo
More management	1.5	1.83 m	P = 0.50	More
Less management	1.5	1.83 m	P = 0.50	Less
Much less management	1.5	1.83 m	P = 0.50	Much less

Table 3. Simulated population projections for female gopher tortoises under six scenarios of future change. Columns summarize the initial number (in 2020), future predicted number, and population growth rate (λ) for the total population size, number of populations, and number of landscape populations for six scenarios projected 40, 60, and 80 years into the future. See Table 2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of metapopulations		
	Initial	Future	λ	Initial	Future	λ	Initial	Future	λ
Year 2060									
Low stressors	70610	47468	0.67 (0.30–1.80)	626	332	0.53 (0.51–0.55)	244	179	0.73 (0.63–0.81)
Medium stressors	70614	47630	0.67 (0.30–1.91)	626	331	0.53 (0.51–0.54)	244	183	0.75 (0.61–0.80)
High stressors	70582	45998	0.65 (0.28–1.84)	626	329	0.53 (0.51–0.55)	244	177	0.73 (0.64–0.80)
More management	70611	46646	0.66 (0.29–1.84)	626	329	0.53 (0.51–0.55)	244	178	0.73 (0.61–0.80)
Less management	70610	46826	0.66 (0.29–1.79)	626	328	0.52 (0.50–0.54)	244	180	0.74 (0.62–0.80)
Much less management	70600	46495	0.66 (0.29–1.80)	626	323	0.52 (0.50–0.54)	244	178	0.73 (0.60–0.79)
Year 2080									
Low stressors	70609	49281	0.70 (0.36–1.77)	626	249	0.40 (0.38–0.41)	244	143	0.59 (0.44–0.73)
Medium stressors	70636	48924	0.69 (0.37–1.79)	626	250	0.40 (0.38–0.41)	244	142	0.58 (0.45–0.73)
High stressors	70592	46674	0.66 (0.34–1.70)	626	246	0.39 (0.37–0.41)	244	138	0.57 (0.43–0.70)
More management	70598	49246	0.70 (0.35–1.86)	626	250	0.40 (0.38–0.42)	244	145	0.59 (0.45–0.74)
Less management	70604	48754	0.69 (0.34–1.80)	626	247	0.39 (0.38–0.41)	244	138	0.57 (0.44–0.72)
Much less management	70569	48592	0.69 (0.35–1.69)	626	243	0.39 (0.37–0.42)	244	142	0.58 (0.42–0.72)

Year 2100									
Low stressors	70614	50846	0.72 (0.37–1.77)	626	198	0.32 (0.30–0.33)	244	114	0.47 (0.36–0.62)
Medium stressors	70594	48366	0.69 (0.36–1.74)	626	196	0.31 (0.29–0.33)	244	108	0.44 (0.35–0.59)
High stressors	70578	47378	0.67 (0.35–1.70)	626	194	0.31 (0.29–0.33)	244	109	0.45 (0.33–0.60)
More management	70584	49114	0.70 (0.36–1.73)	626	196	0.31 (0.30–0.33)	244	110	0.45 (0.33–0.62)
Less management	70596	47202	0.67 (0.37–1.75)	626	193	0.31 (0.29–0.33)	244	106	0.43 (0.34–0.61)
Much less management	70608	48520	0.69 (0.37–1.67)	626	188	0.30 (0.28–0.32)	244	106	0.43 (0.34–0.59)

Table 4. Predicted population persistence probabilities (P_p) categories for gopher tortoise populations in year 2100 under six future scenarios varying in the magnitude of future stressors. Persistence categories are Extremely Likely Extant (P_p > 95.0%), Very Likely Extant (P_p = 80.0–94.9%), More Likely Than Not Extant (P_p = 50.0–79.9%), and Unlikely Extant (P_p < 50.0%; i.e., extirpated). See Table 2 for descriptions of scenarios and their parameters.

Population persistence category	Scenario: Low stressors	Medium stressors	High stressors	More management	Less management	Much less management
Year 2060						
Extremely Likely Extant	104 (16.6%)	103 (16.5%)	101 (16.1%)	99 (15.8%)	102 (16.3%)	104 (16.6%)
Very Likely Extant	102 (16.3%)	97 (15.5%)	108 (17.3%)	108 (17.3%)	98 (15.7%)	91 (14.5%)
More Likely Than Not Extant	135 (21.6%)	145 (23.2%)	135 (21.6%)	134 (21.4%)	141 (22.5%)	141 (22.5%)
Unlikely Extant (i.e., Extirpated)	285 (45.5%)	281 (44.9%)	282 (45%)	285 (45.5%)	285 (45.5%)	290 (46.3%)
Year 2080						
Extremely Likely Extant	78 (12.5%)	74 (11.8%)	71 (11.3%)	79 (12.6%)	74 (11.8%)	76 (12.1%)
Very Likely Extant	35 (5.6%)	44 (7%)	41 (6.5%)	36 (5.8%)	41 (6.5%)	31 (5%)
More Likely Than Not Extant	122 (19.5%)	116 (18.5%)	117 (18.7%)	128 (20.4%)	103 (16.5%)	114 (18.2%)
Unlikely Extant (i.e., Extirpated)	391 (62.5%)	392 (62.6%)	397 (63.4%)	383 (61.2%)	408 (65.2%)	405 (64.7%)
Year 2100						
Extremely Likely Extant	76 (12.1%)	72 (11.5%)	70 (11.2%)	71 (11.3%)	70 (11.2%)	70 (11.2%)

Very Likely Extant	21 (3.4%)	20 (3.2%)	25 (4%)	24 (3.8%)	24 (3.8%)	24 (3.8%)
More Likely Than Not Extant	65 (10.4%)	62 (9.9%)	55 (8.8%)	58 (9.3%)	57 (9.1%)	54 (8.6%)
Unlikely Extant (i.e., Extirpated)	464 (74.1%)	472 (75.4%)	476 (76%)	473 (75.6%)	475 (75.9%)	478 (76.4%)

Table 5. Simulated population projections for gopher tortoises under scenarios varying in immigration rate (γ): no immigration ($\gamma =$ 0), intermediate immigration (γ = 0.01), high immigration (γ = 0.02), and very high immigration (γ = 0.04). Columns summarize the initial number (in 2020), future predicted number, and population growth rate (λ) for the total population size, number of populations, and number of metapopulations for four scenarios projected 80 years into the future. Each scenario models stressors and management actions using input values from the 'medium stressors' scenario from Table 2, and the 'intermediate immigration' scenario has the same input values the 'medium stressors' scenario from Table 2; see Table 2 for more information about input parameters.

Scenarios	Total population size			Number of local populations			Number of metapopulations		
	Initial	Future	λ	Initial	Future	λ	Initial	Future	λ
No immigration	70602	1566	0.02 (0.01–0.18)	626	81	0.13 (0.11–0.15)	244	46	0.19 (0.09–0.36)
Intermediate immigration	70594	48366	0.69 (0.36–1.74)	626	196	0.31 (0.29–0.33)	244	108	0.44 (0.35–0.59)
High immigration	70600	91805	1.30 (0.71–2.76)	626	247	0.39 (0.38–0.41)	244	124	0.51 (0.39–0.66)
Very high immigration	70600	151320	2.14 (1.18–4.44)	626	312	0.50 (0.48–0.52)	244	144	0.59 (0.48–0.68)

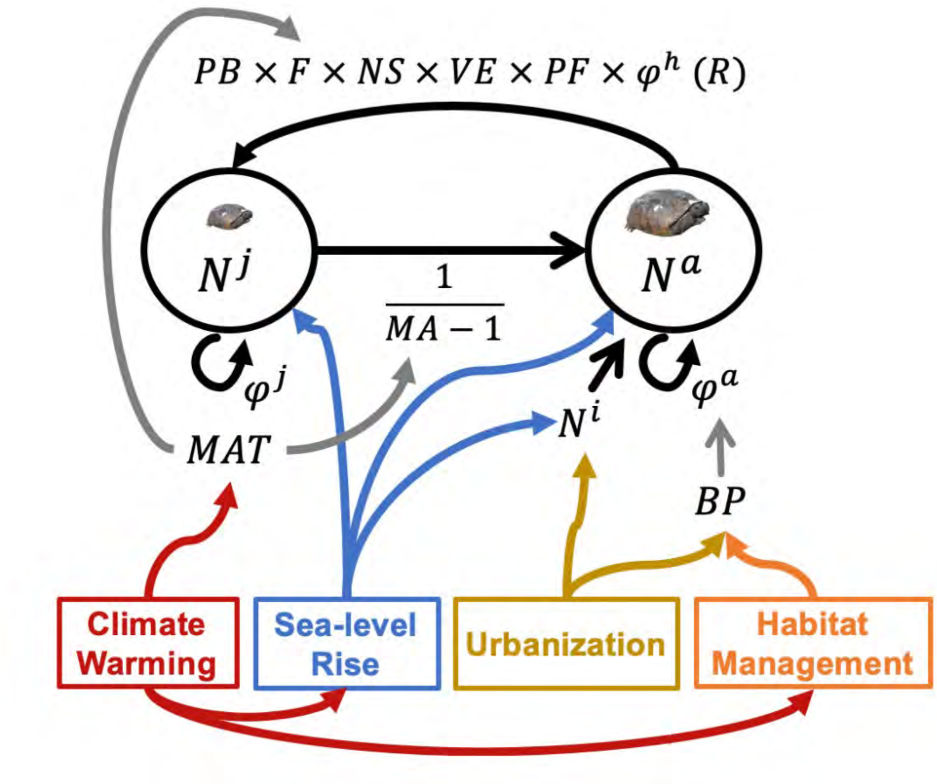


Figure 1. A conceptual model illustrating a stage-based, female-only population model (black text) used to simulate demography and project population size of the Gopher Tortoise (*Gopherus polyphemus*) into the future. Black arrows and circles indicate gopher tortoise demographic parameters (survival, growth, abundance); colored arrows and text indicate predicted threat effects on tortoise demography simulated through scenario analysis. See Table 1 for demographic variable definitions and baseline estimates; MAT = mean annual temperature (°C) and BP is burn probability with prescribed fire (see Methods). For each threat (colored box), I modeled three or four scenarios of future change in the threat magnitude (Table 2).

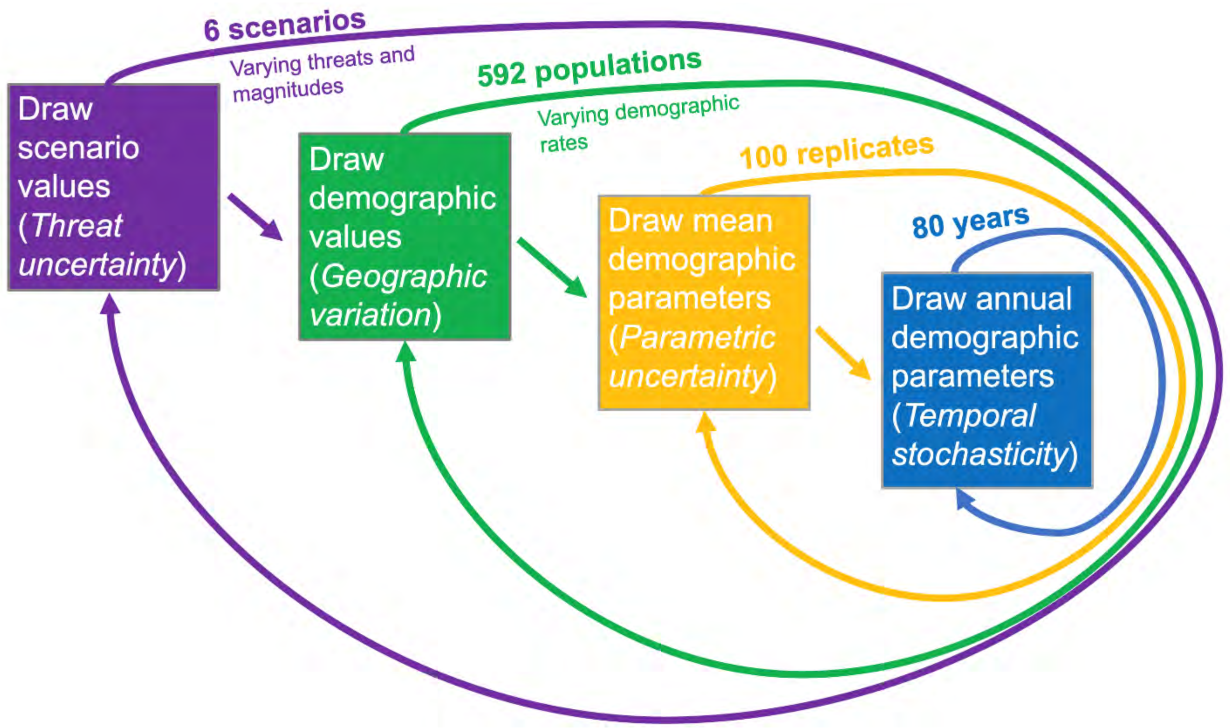


Figure 2. I used a four-loop uncertainty structure to simulate uncertainty in threats, geographic variation, parameter estimates, and temporal stochasticity of stochastic variables during population projections for gopher tortoises. For each scenario, I simulated each population using 100 replicates and projected each replicate into the future for 80 years.

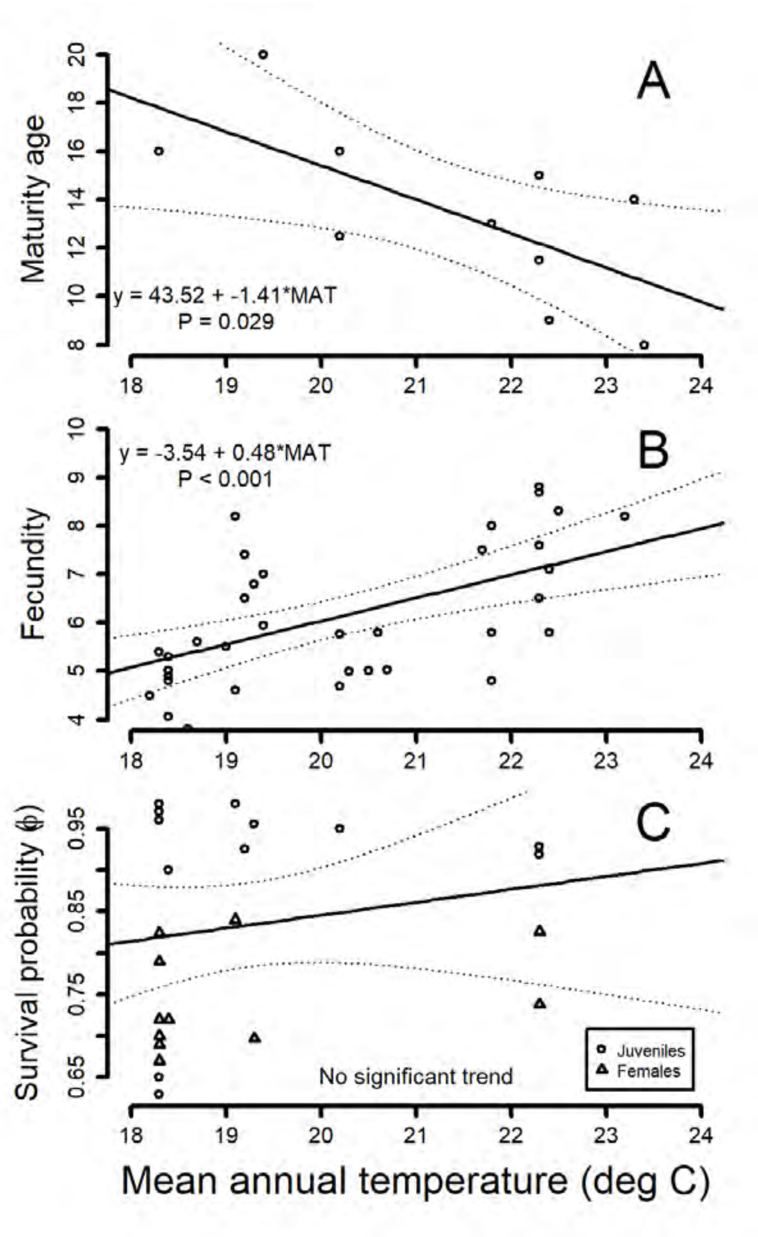


Figure 3. Effect of mean annual temperature (MAT; degrees C) on (A) maturity age (MA), (B), fecundity, and (C) annual apparent survival probability (φ) of gopher tortoise (*Gopherus polyphemus*) populations. Geographic variation in biotic conditions (e.g., MAT) predict significant variation in maturity age and fecundity ($P < 0.05$) but not in annual apparent survival probability (see inset text).

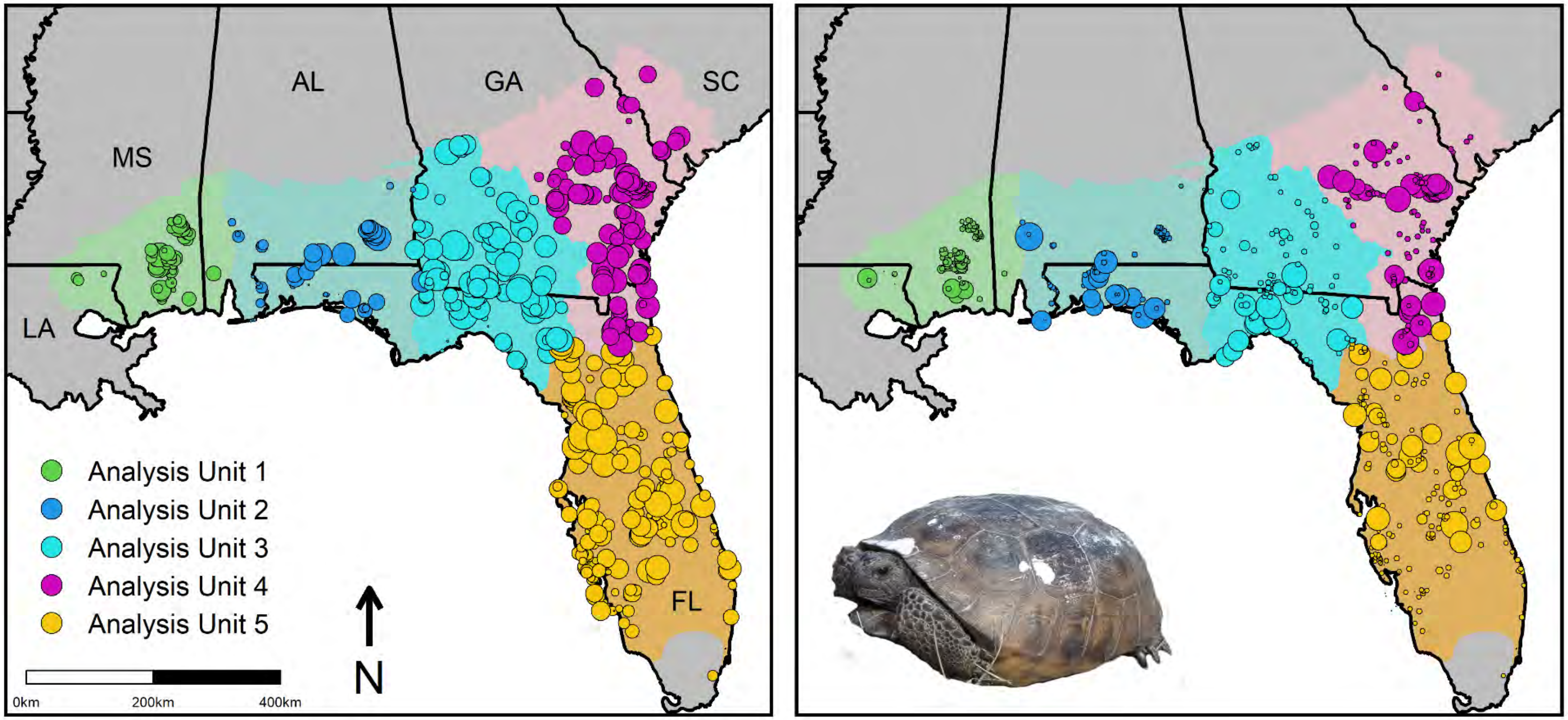


Figure 4. Current abundance (left) and predicted abundance 80 years in the future (right) of gopher tortoise (*Gopherus polyphemus*; right inset) populations in the southeastern United States that were modeled to predict future population growth and extinction risk for the species under scenarios of global change. Each circle represents a local population and circles are colored by analysis unit. Symbol size reflects a log-transformed scale of population size; the left panel shows population size estimated during a survey during 2010–2020; the right panel shows predicted population size under a future scenario of 'medium stressors with less management' (Table 2). Abundance of populations during

2010–2020 was estimated from analysis of data from burrow surveys or Line Transect Distance Sampling (LTDS) surveys at each the site within the last ten years.

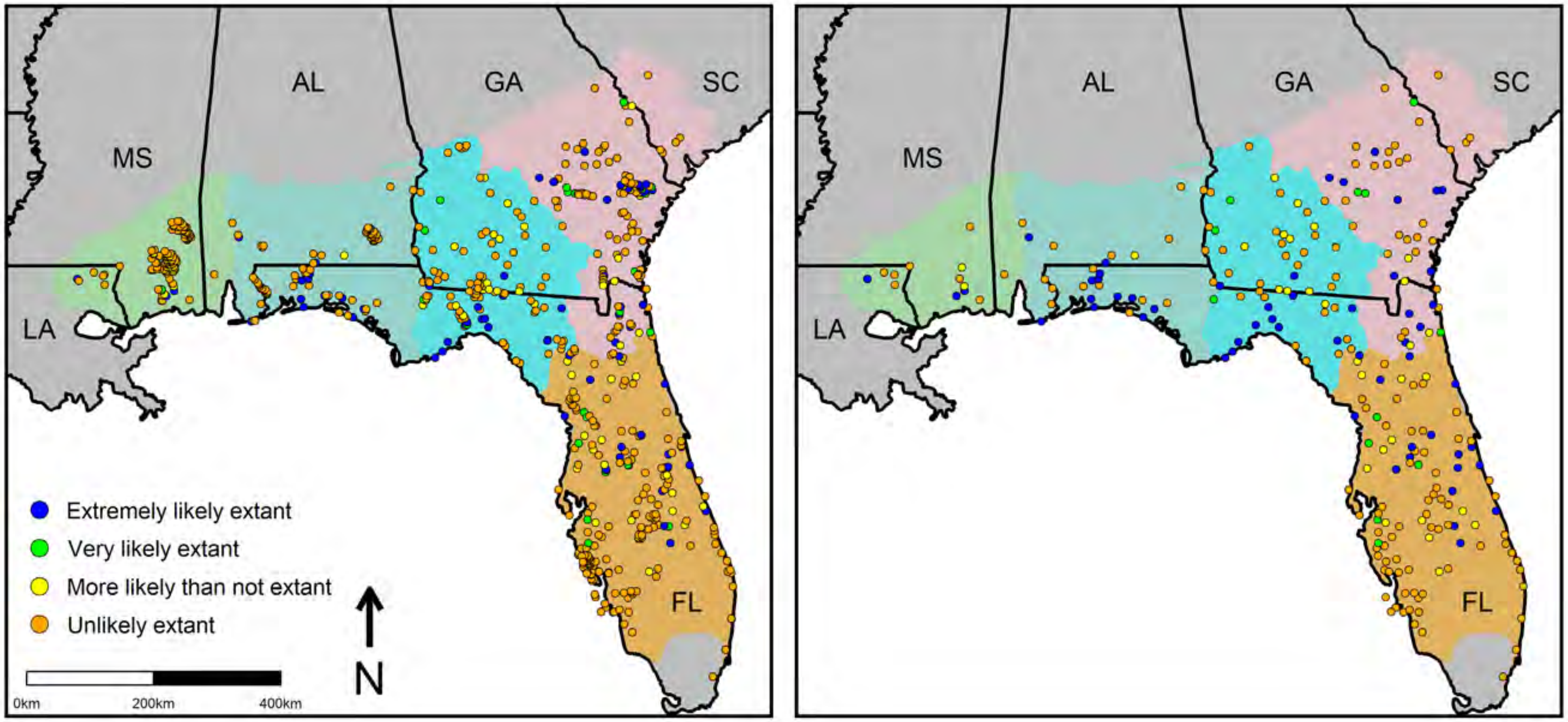


Figure 5. Persistence probabilities (P_p) of gopher tortoise (*Gopherus polyphemus*) local populations (left) and landscape populations (right) predicted by a future scenario of less habitat management with medium stressor (Table 2) projected 80 years into the future. Symbols are colored by persistence probability categories: Extremely Likely Extant (P_p > 95.0%), Very Likely Extant (P_p = 80.0–94.9%), More Likely Than Not Extant (P_p = 50.0–79.9%), and Unlikely Extant (P_p < 50.0%; i.e., extirpated). See Table 2 for descriptions of scenarios and their parameters.

Appendix 1. Demographic estimates for gopher tortoises (*Gopherus polyphemus*) identified during a literature review and used in the construction of a female-only population model. Parameters are: fecundity (F); nest survival (NS); probability of viable eggs (i.e., hatching success; VE); survival of hatchlings (φ^h), juveniles (φ^j), and adult females (φ^a); and maturity age for females (MA).

Parameter	Locality	Estimate	Reference
F	Okeeheelee County Park, FL	8.2	Ashton et al. 2007
F	Archbold Biological Station, FL	6.5	Ashton et al. 2007
F	Archbold Biological Station, FL	8.7	White et al. 2018
F	Archbold Biological Station, FL	8.1	White et al. 2018
F	South of Tampa, FL	7.6	Godley 1989
F	USF's Ecological Research Area, Tampa, FL	7.1	Mushinksy et al. 1994
F	Boyd Hill Nature Preserve, FL	8.3	Goessling and Heinrich, unpubl. data
F	North of Tampa, FL	4.8	Macdonald 1996
F	North of Tampa, FL	5.8	Small and Macdonald 2001
F	North of Tampa, FL	8.0	Small and Macdonald 2001
F	Cape Canaveral, FL	7.5	Demuth 2001
F	Gainesville, FL	5.8	Diemer-Berish et al. 2012
F	Gainesville, FL	4.7	Iverson 1980
F	Ordway Preserve, Gainesville, FL	5.8	Smith 1995
F	Jacksonville, FL	5.0	Butler and Hull 1996

F	Jacksonville, FL	5.0	Hallinan 1923
F	Branan Field Wildlife and Environmental Area, FL	5.0	Perez-Heydrich et al. 2012
F	Mobile County, AL	4.6	Marshall 1987
F	Ben's Creek WMA, LA	5.5	Smith et al. 1997
F	Silver Lake WMA, GA	7.0	Landers et al. 1980
F	The Wade Tract, GA	5.9	Radzio et al. 2017
F	Joseph W. Jones Ecological Research Center, GA	6.8	L. Smith, unpubl. Data
F	Marion County WMA, FL	5.6	Smith et al. 1997
F	Camp Shelby, MS	4.8	Epperson and Heise 2003
F	Camp Shelby, MS	5.3	J. Watkins (pers. comm.) in Butler and Hull 1996
F	Camp Shelby, MS	5.0	C. Jones and T. Mann (pers. comm.) in Butler and Hull 1996
F	Camp Shelby, MS	4.1	M. Hinderliter, unpubl. data
F	Camp Shelby, MS	4.9	J. Lee, unpubl. data
F	Fort Stewart, GA	6.5	Rostal and Jones 2002
F	St. Catherines Island, GA	8.2	Quin et al. 2016, p. 14
F	Reed Bingham State Park, GA	7.4	Quin et al. 2016, p. 14
F	Yuchi WMA, GA	6.7	Quin et al. 2016, p. 14
F	South Carolina	3.80	Wright 1982
F	George L. Smith State Park, GA	4.50	Rostal and Jones 2002
F	Alabama	4.29	Folt et al. submitted

NS	Joseph W. Jones Ecological Research Center, GA	0.35	Smith et al. 2013
VE	Archbold Biological Station, FL	0.78	White et al. 2018
VE	Ordway Preserve, Gainesville, FL	0.83	Smith 1995
VE	Jacksonville, FL	0.82	Butler and Hull 1996
VE	Branan Field Wildlife and Environmental Area, FL	0.90	Perez-Heydrich et al. 2012
VE	Silver Lake WMA, GA	0.86	Landers et al. 1980
VE	The Wade Tract, GA	0.73	Radzio et al. 2017
VE	St. Catherines Island, GA	0.90	Quin et al. 2016, p. 14
VE	Reed Bingham State Park, GA	0.93	Quin et al. 2016, p. 14
VE	Yuchi WMA, GA	0.93	Quin et al. 2016, p. 14
φ^h	Meta-analysis of three localities	0.13	Perez-Heydrich et al. 2012
φj	Archbold Biological Station, FL	0.83	Meshaka et al. 2019, p. 98
φj	Archbold Biological Station, FL	0.74	Howell et al. 2020
φj	Joseph W. Jones Ecological Research Center, GA	0.70	Tuberville et al. 2014
φj	St. Catherines Island, GA	0.84	Tuberville et al. 2008, p. 2694
φj	Conecuh National Forest, AL	0.82	Tuberville et al. 2014
φj	Conecuh National Forest, AL	0.67	Folt et al. 2021
φ^j	Conecuh National Forest, AL	0.69	Folt et al. 2021
φ^j	Conecuh National Forest, AL	0.79	Folt et al. 2021
φ^j	Conecuh National Forest, AL	0.70	Folt et al. 2021

φ^j	Conecuh National Forest, AL	0.72	Folt et al. 2021
φ^j	Conecuh National Forest, AL	0.72	Folt et al. 2021
φ^a	Archbold Biological Station, FL	0.92	Meshaka et al. 2019, p. 98
φ^a	Archbold Biological Station, FL	0.93	Howell et al. 2020
φ^a	Gainesville, FL	0.95	Ozgul et al. 2009
φ^a	Joseph W. Jones Ecological Research Center, GA	0.96	Tuberville et al. 2014
φ^a	St. Catherines Island, GA	0.98	Tuberville et al. 2008, p. 2694
φ^a	Conecuh National Forest, AL	0.98	Tuberville et al. 2014
φ^a	Conecuh National Forest, AL	0.97	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.63	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.96	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.96	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.65	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.90	Folt et al. 2021
MA	Silver Lake WMA, GA	20	Landers et al. 1982
MA	Conecuh National Forest, AL	16	Folt et al. 2021
MA	Gainesville, FL	16	Diemer and Moore 1994
MA	Gainesville, FL	12.5	Iverson 1980
MA	Tampa, FL	13	Linley 1986
MA	Tampa, FL	9	Mushinsky et al. 1994, p. 123

MA	Tampa, FL	15	Godley 1989
MA	Archbold Biological Station, FL	11.5	Meshaka et al. 2019, p. 98
MA	Jupiter, FL	8	Sano 2014
MA	Sanibel Island, FL	14	McLaughlin 1990

Appendix 2. Simulated population projections for gopher tortoises populations in each of the five genetic representation units (Gaillard et al. 2017). Six scenarios of predicted future change were projected 80 years into the future; results are summarized by the initial number, future predicted number, and population growth rate (λ) for the total population size, number of local populations, and number of metapopulations in each genetic unit. See Table 2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of metapopulations		
	Initial	Future	λ	Current	Future	λ	Initial	Future	λ
Unit 1									
Low stressors	1571	1151	0.73 (0.22–3.55)	102	23	0.23 (0.18–0.27)	13	6	0.46 (0.46–0.46)
Medium stressors	1573	1066	0.68 (0.22–3.50)	102	23	0.23 (0.18–0.27)	13	6	0.46 (0.46–0.54)
High stressors	1572	990	0.63 (0.22–3.86)	102	23	0.23 (0.18–0.26)	13	6	0.46 (0.46–0.54)
More management	1572	1066	0.68 (0.21–4.01)	102	23	0.23 (0.19–0.27)	13	6	0.46 (0.44–0.54)
Less management	1573	1026	0.65 (0.22–3.79)	102	22	0.22 (0.18–0.26)	13	6	0.46 (0.46–0.54)
Much less management	1572	947	0.60 (0.22–3.42)	102	22	0.22 (0.18–0.26)	13	6	0.46 (0.46–0.54)
Unit 2									
Low stressors	2896	7316	2.53 (1.49–4.08)	81	21	0.26 (0.21–0.30)	29	16	0.55 (0.48–0.66)
Medium stressors	2896	7022	2.42 (1.24–3.94)	81	19	0.23 (0.20–0.27)	29	15	0.52 (0.45–0.59)
High stressors	2894	6868	2.37 (1.50–4.04)	81	19	0.23 (0.20–0.28)	29	14	0.48 (0.45–0.59)
More management	2896	7086	2.45 (1.39–3.95)	81	20	0.25 (0.21–0.28)	29	15	0.52 (0.45–0.59)
Less management	2898	7007	2.42 (1.58–4.10)	81	20	0.25 (0.20–0.28)	29	15	0.52 (0.45–0.59)

Much less management	2898	7084	2.44 (1.44–3.92)	81	19	0.23 (0.20–0.27)	29	14	0.48 (0.45–0.52)
Unit 3									
Low stressors	19432	9468	0.49 (0.31–1.08)	110	42	0.38 (0.34–0.44)	55	29	0.52 (0.36–0.73)
Medium stressors	19428	9125	0.47 (0.31–1.04)	110	42	0.38 (0.34–0.44)	55	27	0.49 (0.32–0.68)
High stressors	19419	9406	0.48 (0.30–1.02)	110	42	0.38 (0.34–0.44)	55	28	0.50 (0.35–0.72)
More management	19426	9338	0.48 (0.30–1.11)	110	43	0.39 (0.35–0.45)	55	29	0.53 (0.38–0.76)
Less management	19430	9224	0.47 (0.31–1.06)	110	42	0.38 (0.33–0.43)	55	28	0.51 (0.35–0.75)
Much less management	19432	9332	0.48 (0.31–1.03)	110	41	0.37 (0.33–0.43)	55	27	0.48 (0.35–0.70)
Unit 4									
Low stressors	14032	13793	0.98 (0.55–2.20)	123	50	0.37 (0.33–0.43)	46	21	0.46 (0.35–0.65)
Medium stressors	14030	13368	0.95 (0.55–2.28)	123	50	0.39 (0.35–0.45)	46	22	0.48 (0.37–0.64)
High stressors	14040	12013	0.86 (0.42–1.98)	123	48	0.41 (0.37–0.46)	46	20	0.43 (0.35–0.62)
More management	14036	13325	0.95 (0.54–2.11)	123	51	0.40 (0.36–0.44)	46	22	0.48 (0.35–0.66)
Less management	14034	13109	0.93 (0.54–2.09)	123	49	0.41 (0.37–0.46)	46	22	0.48 (0.35–0.67)
Much less management	14039	13118	0.93 (0.56–2.11)	123	49	0.39 (0.35–0.43)	46	20	0.43 (0.36–0.63)
Unit 5									
Low stressors	32684	19120	0.58 (0.25–1.70)	210	62	0.30 (0.27–0.32)	103	41	0.40 (0.30–0.52)
Medium stressors	32666	17786	0.54 (0.24–1.65)	210	60	0.29 (0.26–0.31)	103	43	0.41 (0.27–0.53)

High stressors	32653	18102	0.55 (0.25–1.66)	210	60	0.29 (0.26–0.32)	103	39	0.38 (0.25–0.58)
More management	32655	18300	0.56 (0.24–1.64)	210	60	0.29 (0.26–0.31)	103	41	0.40 (0.26–0.57)
Less management	32662	16836	0.52 (0.23–1.71)	210	60	0.29 (0.25–0.32)	103	37	0.36 (0.27–0.54)
Much less management	32666	18038	0.55 (0.24–1.59)	210	58	0.28 (0.25–0.30)	103	40	0.38 (0.27–0.51)

Appendix 3. Simulated population projections for gopher tortoises in each of the six states within which the gopher tortoise occurs. Six scenarios of predicted future change were projected 80 years into the future; results are summarized by the initial number, future predicted number, and population growth rate (λ) for the total population size, number of local populations, and number of metapopulations in each state. See Table 2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of metapopulations		
	Initial	Future	λ	Initial	Future	λ	Initial	Future	λ
Alabama									
Low stressors	2318	3638	1.57 (0.98–2.49)	54	7	0.13 (0.09–0.19)	14	6	0.43 (0.29–0.43)
Medium stressors	2318	3709	1.60 (0.81–2.51)	54	7	0.13 (0.09–0.19)	14	5	0.36 (0.29–0.43)
High stressors	2316	3642	1.57 (1.13–2.70)	54	7	0.13 (0.09–0.19)	14	6	0.39 (0.29–0.43)
More management	2318	3752	1.62 (0.96–2.54)	54	8	0.15 (0.09–0.19)	14	6	0.43 (0.29–0.43)
Less management	2320	3633	1.57 (1.18–2.71)	54	7	0.13 (0.09–0.19)	14	5	0.36 (0.29–0.43)
Much less management	2320	3737	1.61 (1.02–2.53)	54	7	0.13 (0.07–0.17)	14	5	0.36 (0.29–0.43)
Florida									
Low stressors	44037	34536	0.78 (0.40–1.95)	314	108	0.34 (0.32–0.37)	152	74	0.48 (0.38–0.62)
Medium stressors	44022	32286	0.73 (0.39–1.87)	314	105	0.33 (0.31–0.36)	152	69	0.45 (0.36–0.59)
High stressors	44004	31798	0.72 (0.38–1.83)	314	103	0.33 (0.31–0.35)	152	70	0.46 (0.35–0.62)
More management	44009	33094	0.75 (0.39–1.90)	314	106	0.34 (0.31–0.36)	152	70	0.46 (0.34–0.63)

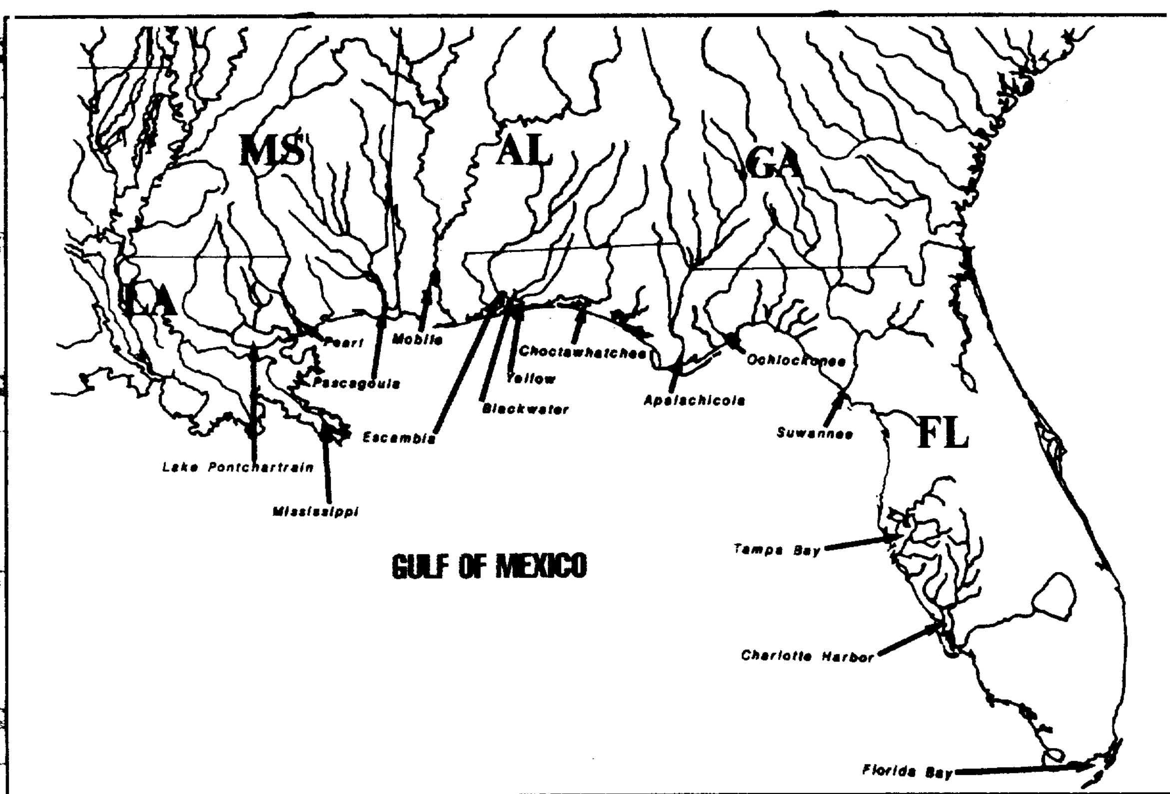
Less management	44020	31470	0.71 (0.38–1.91)	314	105	0.33 (0.31–0.36)	152	71	0.47 (0.36–0.61)
Much less management	44022	32924	0.75 (0.40–1.83)	314	102	0.32 (0.30–0.35)	152	68	0.45 (0.34–0.59)
Georgia									
Low stressors	22183	11510	0.52 (0.28–1.23)	151	59	0.39 (0.34–0.43)	63	27	0.43 (0.35–0.65)
Medium stressors	22176	11290	0.51 (0.27–1.32)	151	59	0.39 (0.35–0.43)	63	27	0.43 (0.32–0.63)
High stressors	22181	10934	0.49 (0.22–1.21)	151	58	0.38 (0.34–0.42)	63	30	0.48 (0.32–0.59)
More management	22180	11186	0.50 (0.27–1.21)	151	59	0.39 (0.35–0.44)	63	27	0.43 (0.33–0.63)
Less management	22178	11060	0.50 (0.27–1.22)	151	57	0.38 (0.33–0.42)	63	28	0.44 (0.33–0.63)
Much less management	22188	10897	0.49 (0.27–1.18)	151	57	0.38 (0.34–0.42)	63	27	0.43 (0.32–0.60)
Louisiana									
Low stressors	24	246	10.25 (8.00–14.29)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
Medium stressors	24	244	10.17 (7.88–13.79)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
High stressors	24	242	10.08 (7.71–14.21)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
More management	24	248	10.33 (7.63–14.83)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
Less management	24	244	10.17 (8.08–15.63)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.40)
Much less management	24	246	10.25 (8.21–15.42)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
Mississippi									
Low stressors	1514	902	0.60 (0.10–3.45)	94	22	0.23 (0.18–0.28)	7	5	0.71 (0.71–0.71)

Medium stressors	1516	820	0.54 (0.10–3.41)	94	22	0.23 (0.18–0.28)	7	5	0.71 (0.71–0.71)
High stressors	1515	746	0.49 (0.10–3.77)	94	21	0.22 (0.18–0.28)	7	5	0.71 (0.71–0.71)
More management	1515	816	0.54 (0.10–3.92)	94	22	0.23 (0.19–0.29)	7	5	0.71 (0.57–0.71)
Less management	1516	780	0.51 (0.10–3.69)	94	21	0.22 (0.18–0.28)	7	5	0.71 (0.71–0.71)
Much less management	1516	698	0.46 (0.10–3.30)	94	21	0.22 (0.17–0.27)	7	5	0.71 (0.71–0.71)
South Carolina									
Low stressors	538	16	0.03 (0.02–0.15)	6	1	0.17 (0–0.50)	4	0	0 (0–0.50)
Medium stressors	538	17	0.03 (0.02–0.14)	6	1	0.17 (0–0.50)	4	0	0 (0–1.00)
High stressors	538	16	0.03 (0.02–0.16)	6	1	0.17 (0–0.50)	4	0	0 (0–0.75)
More management	538	18	0.03 (0.02–0.17)	6	1	0.17 (0–0.50)	4	1	0.25 (0–0.75)
Less management	538	16	0.03 (0.02–0.18)	6	1	0.17 (0–0.50)	4	1	0.25 (0–1.00)
Much less management	538	17	0.03 (0.02–0.16)	6	1	0.17 (0–0.50)	4	0	0 (0–0.75)

Appendix C-2 Gulf Sturgeon Recovery/Management Plan

GULF STURGEON

RECOVERY/MANAGEMENT PLAN



GULF STURGEON
(*Acipenser oxyrinchus desotoi*)

RECOVERY/MANAGEMENT PLAN

Prepared by

The Gulf Sturgeon Recovery/Management Task Team

for

Southeast Region
U.S. Fish and Wildlife Service
Atlanta, Georgia

and

Gulf States Marine Fisheries Commission
Ocean Springs, Mississippi

and

National Marine Fisheries Service
Washington, D.C.

Approved: Noreen K. Clough Date: 9/22/95
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DISCLAIMER PAGE

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, sometimes prepared with the assistance of recovery teams, contractors, state agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. They represent the official position of the U.S. Fish and Wildlife Service and the National Marine Fisheries Service only after they have been signed by the Regional Director of the Fish and Wildlife Service and the Assistant Director for Fisheries of the National Marine Fisheries Service as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

LITERATURE CITATIONS

Literature citations should read as follows:

U.S. Fish and Wildlife Service and Gulf States Marine Fisheries Commission. 1995. Gulf Sturgeon Recovery Plan. Atlanta, Georgia. 170 pp.

Additional copies of this plan may be purchased from:

Fish and Wildlife Reference Service:

5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814
Telephone: 301/492-6403
or 1-800-582-3421

Fee for recovery plans vary, depending upon the number of pages.

ACKNOWLEDGEMENTS

The Gulf sturgeon would not have received federal protection without the dedication and persistence of a few individuals who raised our consciousness of the plight of this prehistoric species. Alan Huff completed the first life history of Gulf sturgeon and has since been influential in shaping recovery and restoration efforts. Dr. Archie Carr realized the magnificence of this subspecies, initiating sturgeon studies on the Apalachicola and Suwannee rivers. Each of his sons helped him through the years, the last being Stephen, who has continued the studies after Dr. Carr's death. Stephen's work has resulted in a long-term commitment to the subspecies. The Carrs were funded in their efforts by The Florida Phipps Foundation founded by Mr. John H. (Ben) Phipps. The Foundation continues to support Stephen Carr's work. Mr. Jim Barkuloo, while with the U.S. Fish and Wildlife Service (FWS), was instrumental in persuading the FWS to list the species. Dr. Michael Bentzien completed the tedious procedural work to list the subspecies and has continued to support the team's efforts in preparing the Recovery Plan. The Gulf States of Louisiana, Mississippi, Alabama, and Florida provided protection for the Gulf sturgeon before the subspecies was listed, by prohibiting take of "sturgeon." The states continue to provide protection through implementation of surveys and studies on the Gulf sturgeon so that management decisions can be based on scientific data.

Current Species Status: The current population levels of Gulf sturgeon in rivers other than the Suwannee and Apalachicola are unknown, but are thought to be reduced from historic levels. Historically, the subspecies occurred in most major rivers from the Mississippi River to the Suwannee River, and marine waters of the central and eastern Gulf of Mexico to Florida Bay.

Habitat Requirements and Limiting Factors: The Gulf sturgeon is an anadromous fish which migrates from salt water into large coastal rivers to spawn and spend the warm months. The majority of its life is spent in fresh water. Major population limiting factors are thought to include barriers (dams) to historical spawning habitats, loss of habitat, poor water quality, and overfishing.

Recovery Objectives: The short-term recovery objective is to prevent further reduction of existing wild populations of Gulf sturgeon. The long-term recovery objective is to establish population levels that would allow delisting of the Gulf sturgeon in discrete management units. Gulf sturgeon in discrete management units could be delisted by 2023, if the required criteria are met. Following delisting, a long-term fishery management objective is to establish self-sustaining populations that could withstand directed fishing pressure within discrete management units.

Recovery Criteria: The short-term recovery objective will be considered achieved for a management unit when the catch-per-unit-effort (CPUE) during monitoring is not declining from the baseline level over a 3 to 5-year period. This objective will apply to all management units within the range of the subspecies. Management units will be defined using an ecosystem approach based on river drainages, but may also incorporate genetic affinities among populations in different river drainages. Baselines will be determined by fishery independent CPUE levels.

The long-term recovery objective will be considered achieved for a management unit when the population is demonstrated to be self-sustaining and efforts are underway to restore lost or degraded habitat. A self-sustaining population is one in which the average rate of natural recruitment is at least equal to the average mortality rate in a 12-year period. While this objective will be sought for all management units, it is recognized that it may not be achievable for all management units. The long-term fishery management objective will be considered attained for a given management unit when a sustainable yield can be achieved while maintaining a stable population through natural recruitment. Note that the objective is not necessarily the opening of a management unit to fishing, but rather the development of a population that can sustain a fishery. Opening a population to fishing will be at the discretion of state(s) within whose jurisdiction(s) the management unit occurs. As with the long-term recovery objective, this objective may not be achievable for all management units, but will be sought for all units.

Priority 1 Recovery Tasks:

1. Develop and implement standardized population sampling and monitoring techniques (1.3.1).

2. Develop and implement regulatory framework to eliminate introductions of non-indigenous stock or other sturgeon species (2.5.3).

3. Reduce or eliminate incidental mortality (2.1.2).

4. Restore the benefits of natural riverine habitats (2.4.5).

5. Utilize existing authorities to protect habitat and where inadequate, recommend new laws and regulations (2.3.1).

Costs ($000's) of Priority 1 Tasks:

Year	Action 1	Action 2	Action 3	Action 4*	Action 5
FY 1	59	0	125	26	29
FY 2	73	25	125	48	29
FY 3	114	0	125	48	29
FY 4	108	0	75	31	29
FY 5	108	0	25	0	0

Cost of No. 1 Priority Actions: $1,231,000

* Actual restoration costs undetermined

Total Cost of Recovery: $8,413,000

Date of Recovery: Delisting should be initiated by 2023, for management units where recovery criteria have been met.

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PREFACE

The U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) jointly listed the Gulf sturgeon as threatened under the authority of the Endangered Species Act of 1973, as amended (ESA).

The FWS prepared a Report on the Conservation Status of the Gulf of Mexico Sturgeon *Acipenser oxyrhinchus desotoi* in 1988 as a precursor to the listing process. The Gulf States Marine Fisheries Commission (GSMFC) began an initiative in late 1990 to draft a fishery management plan for the Gulf sturgeon. The drafting team (ad hoc subcommittee of the GSMFC Technical Coordinating Committee, Anadromous Fish Subcommittee), on October 1, 1991, in response to the listing, took action to draft a management/recovery plan. This plan meets the requirements of a fisheries management plan as originally begun by the GSMFC, as well as the requirements associated with an Endangered Species Act recovery plan. The plan incorporates the format that has become standard in federal endangered and threatened species recovery plans in recent years. The FWS published a "Framework for the Management and Conservation of Paddlefish and Sturgeon Species in the United States" in March 1993. This document resulted from a workshop sponsored by the FWS that was attended by representatives of other federal agencies, the states, the private aquaculture community, and academia in January 1992. This recovery plan is consistent with the framework document, and in essence, steps down the recommendations and strategies contained therein.

The plan is intended to serve as a guide that delineates and schedules those actions believed necessary to restore the Gulf sturgeon as a viable self-sustaining element of its ecosystem. Some of the tasks described in the plan are ongoing by the FWS, GSMFC, NBS, and the states of Louisiana, Mississippi, Alabama, and Florida. The inclusion of these ongoing tasks represents an awareness of their importance, and offers support for their continuation. Because of this ongoing research on the subspecies, the plan incorporates personal communications and unpublished data.

LIST OF ABBREVIATIONS

ADCNR	Alabama Department of Conservation and Natural Resources
AGS	Alabama Geological Survey
ANSTF	Aquatic Nuisance Species Task Force
CCC	Caribbean Conservation Corporation
CES	Cooperative Extension Service
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COE	U.S. Army Corps of Engineers
CWA	Clean Water Act
CZM	Office of Coastal Zone Management
EIRP	Environmental Impact Research Program
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FDEP	Florida Department of Environmental Protection
FDNR	Florida Department of Natural Resources
FERC	Federal Energy Regulatory Commission
FGFC	Florida Game and Fresh Water Fish Commission
FRTES	Fisheries Resources Trace Elements Survey
FSBC	Florida State Board of Conservation
FWS	United States Fish and Wildlife Service
GCRL	Gulf Coast Research Laboratory
GSMFC	Gulf States Marine Fisheries Commission
GSRMA	Gulf States Resource Management Agencies (TX,LA,MS,AL,FL)
LDWF	Louisiana Department of Wildlife and Fisheries
MDWFP	Mississippi Department of Wildlife, Fisheries, and Parks
MMS	Minerals Management Service
NBS\BSC	National Biological Service, Southeastern Biological Science Center
NCSU	North Carolina Cooperative Research Unit, North Carolina State University
NGO	Nongovernmental organizations
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service (formerly SCS)
OCS	Outer Continental Shelf
SCS	Soil Conservation Service
TED	Turtle Excluder Device
USGS	United States Geological Survey
WES	Waterways Experiment Station
WSRFC	Warm Springs Regional Fisheries Center

LIST OF SYMBOLS

m	meter
mm	millimeter
cm	centimeter
kg	kilogram
km	kilometers
in	inches
ft	feet
mi	mile
lb	pound
hr	hour
°F	degrees Fahrenheit
°C	degrees Centigrade
ft/s	feet per second
m/s	meters per second
m^3/s	cubic meters per second
r	correlation coefficient
SD	standard deviation
TL	total length
FL	fork length
P	probability
hectare	not abbreviated
acre	not abbreviated

I. INTRODUCTION

NOMENCLATURE

The scientific name for Atlantic sturgeon is *Acipenser oxyrinchus* Mitchill. This species consists of two geographically disjunct subspecies: the Gulf sturgeon, *Acipenser oxyrinchus desotoi*, which inhabits the Gulf of Mexico watersheds, and the Atlantic coast subspecies, *Acipenser oxyrinchus oxyrinchus*.

Gilbert (1992) discovered that the species name of the Atlantic sturgeon has been "...misspelled for over one hundred years..." as *oxyrhynchus* rather than *oxyrinchus*. Consequently, based on the rules of zoological nomenclature, *oxyrinchus* is used throughout this plan.

Other colloquial names, in addition to Gulf sturgeon, are: Gulf of Mexico sturgeon, Atlantic sturgeon, common sturgeon and sea sturgeon.

TAXONOMY

Class: Osteichthyes
- Order: Acipenseriformes
  - Family: Acipenseridae
    - Genus: Acipenser
      - Species: oxyrinchus
        - Subspecies: desotoi

Type Specimens

The holotype was collected from the mouth of Singing River (West Pascagoula River) in Mississippi Sound off Gautier, Mississippi and is housed in the U.S. National Museum of Natural History, Washington, DC. The paratype was collected with the holotype and is deposited in the Chicago Natural History Museum (Vladykov 1955).

Current Taxonomic Treatment

The Gulf sturgeon is a member of the family Acipenseridae which inhabits the Atlantic, Gulf, Pacific and certain freshwaters of the United States (Ginsburg 1952). The family includes five members of the genus *Acipenser*, and three members of the genus *Scaphirhynchus*.

Other sturgeon likely to be found in the same waters with Gulf sturgeon include the pallid sturgeon, *Scaphirhynchus albus*, the shovelnose sturgeon, *S. platorynchus*, and Alabama sturgeon *S. suttkusi* (Rafinesque 1820; Forbes and Richardson 1908; Williams and Clemmer 1991). *Scaphirhynchus* are freshwater sturgeon that are native to the Mississippi and Mobile River systems. They formerly occurred in the upper Rio Grande River in New Mexico, but have not been recorded since 1874 (Lee et al., 1980). The fish are characterized by a flattened shovelshaped snout and are easily distinguished from Gulf sturgeon. *Acipenser oxyrinchus desotoi* is the only anadromous sturgeon occurring in the Gulf of Mexico.

Based on morphometrics, Wooley (1985) concluded that *A. o. desotoi* is a valid subspecies. Bowen and Avise (1990) analyzed the genetic structure of Atlantic and Gulf sturgeon using mitochondrial DNA (mtDNA) restriction fragment length polymorphism analysis, and postulated that relatively recent genetic contact had occurred between the two regions because of several shared mtDNA clones and clonal arrays. However, Ong et al. (manuscript submitted) used direct sequence analysis of the mtDNA control region and found three fixed nucleotide site differences between *A. oxyrinchus* from the Atlantic and Gulf coasts. They concluded that subspecific divisions are warranted for *A. oxyrinchus*, based on fixed genetic differences between the forms, their allopatric distributions, and their morphometric and life history differences. Ong et al. also postulated that their data, and those of Bowen and Avise (1990), indicate that the reproductive isolation between *A. o. desotoi* and *A. o. oxyrinchus* occurred because of climatic fluctuations in the Pleistocene in conjunction with related changes in the size of the Florida peninsula. Further, they noted that even if the two subspecies occasionally mix in ocean waters, the finding of fixed genetic differences between them suggests that homing fidelity is high in *A. oxyrinchus*.

STATUS

The U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) designated the Gulf sturgeon to be a threatened subspecies, pursuant to the Endangered Species Act of 1973, as amended (ESA). The listing became official on September 30, 1991. As part of the listing, a special rule was promulgated to allow taking of the subspecies for educational purposes, scientific purposes, the enhancement of propagation or survival of the subspecies, zoological exhibition, and other conservation purposes consistent with the ESA. The special rule will allow conservation and recovery activities for Gulf sturgeon to be accomplished without a federal permit, provided the activities are in compliance with applicable state laws (FWS 1991a).

DESCRIPTION

Gulf sturgeon are anadromous fish with a sub-cylindrical body imbedded with bony plates or scutes. The snout is greatly extended and bladelike with four fleshy barbels in front of the mouth, which is protractile on the lower surface of the head. The upper lobe of the tail is longer than the lower lobe (Figure 1). The subspecies is light brown to dark brown in color and pale underneath (Vladykov 1955; Vladykov and Greeley 1963).

Characteristics common to both subspecies, *A. o. oxyrinchus* and *A. o. desotoi* are: Scutes strongly developed in longitudinal rows; 7 to 13 (average 9.8) dorsal shields; 24 to 35 (average 28.7) lateral shields behind dorsal fin in pairs; elongated fulcrum at base of lower caudal lobe decidedly longer than base of anal fin; head elongate; snout longer than postorbital distance in individuals up to 95.0 cm (38.0 in), but shorter than postorbital distance in older specimens (Vladykov and Greeley 1963).

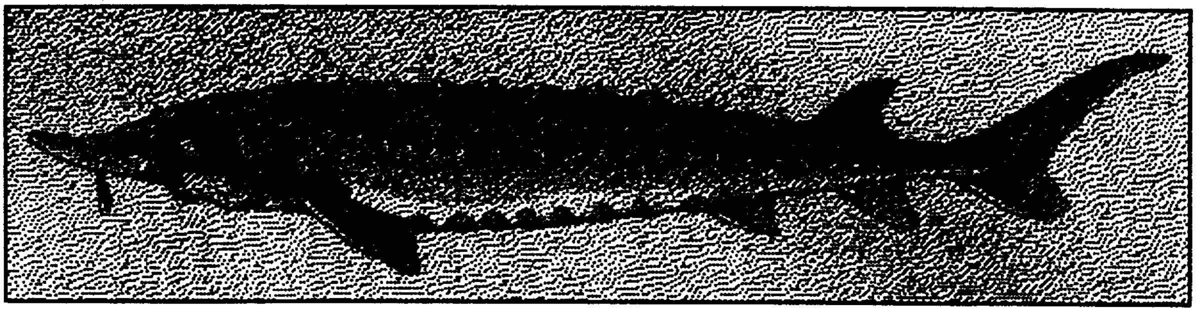

Figure 1: Gulf sturgeon *Acipenser oxyrinchus desotoi* (from Bigelow et al., 1963)

The most significant morphological characteristic to distinguish *A. o. oxyrinchus* from *A. o. desotoi* is the length of the spleen. Wooley (1985) found *A. o. desotoi* specimens had a mean spleen length versus fork length measurement of 12.3% (range 7.9 to 15.8%, SD 2.5, r = 0.212). *Acipenser o. oxyrinchus* specimens had a mean spleen length versus fork length (FL) measurement of 5.7% (range 2.8 to 8.3%, SD 1.8, r = 0.121) for a statistically significant difference ($P \leq 0.05$) and minimal overlap. He concluded that Gulf sturgeon and Atlantic sturgeon populations are allopatric and are sufficiently discrete to be considered distinct stocks for sturgeon population management.

POPULATION SIZE AND DISTRIBUTION

According to Wooley and Crateau (1985) Gulf sturgeon occurred in most major river systems from the Mississippi River to the Suwannee River, Florida and in marine waters of the Central and Eastern Gulf of Mexico south to Florida Bay (Figure 2). Comparison of historic information and current data indicates that Gulf sturgeon populations are reduced from historic levels (Barkuloo 1988). At present, Gulf sturgeon population estimates are unknown throughout its range; however, estimates have been completed for the Apalachicola and Suwannee rivers.

Extant Occurrences of Gulf Sturgeon

Offshore

A Gulf sturgeon was caught on hook and line in 1965 by Dianne Cox, a FWS employee. The 45.7-cm (18-in) Gulf sturgeon was caught in the Gulf of Mexico, 1.6 to 3.2 km (1 to 2 mi) east of Galveston Island in 6.1 m (20 ft) of water (Reynolds 1993).

The incidental catch of Gulf sturgeon in the industrial bottomfish (petfood) fishery in the north-central Gulf of Mexico from 1959 to 1963 was reported by Roithmayr (1965), based on the documentation of one juvenile specimen. The bottomfish fishery worked an area between Point au Fer, Louisiana and Perdido Bay, Florida from shore to 55 m (180 ft).

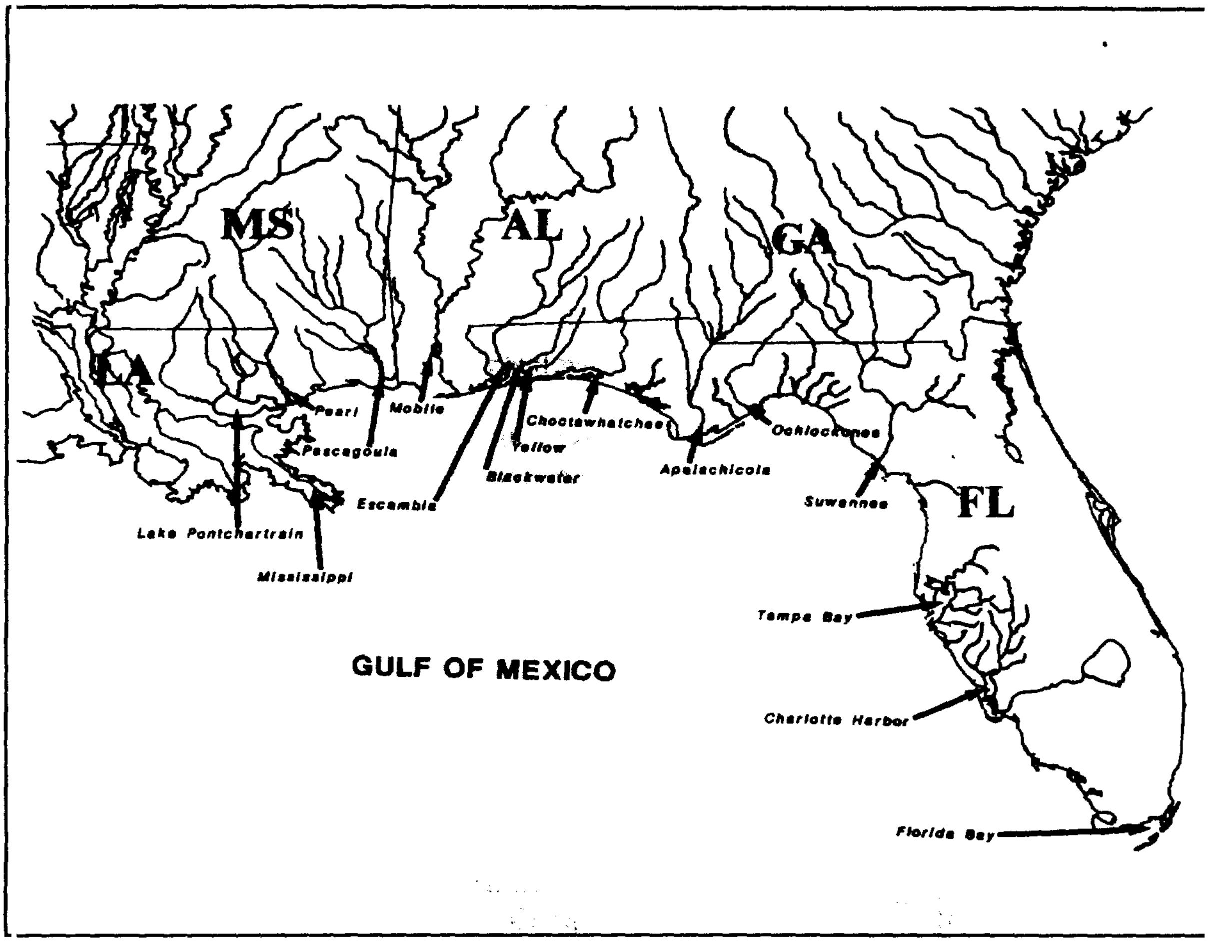

Figure 2: Range of the Gulf Sturgeon

Mermantau River Basin

Mermantau River: The Louisiana Department of Wildlife and Fisheries (1979) reported that an Atlantic sturgeon was caught by a Mr. Hugh Mhire in an otter trawl while shrimping in the Gulf off the mouth of the Mermentau River, Cameron Parish. This specimen was probably a Gulf sturgeon.

Mississippi River Basin

A photograph of a "sea" sturgeon captured at the mouth of the Mississippi River was shown in Fishes and Fishing in Louisiana (1965). Reynolds (1993) reported that a sturgeon measuring 282 cm (111.0 in) and weighing 228.2 kg (503.0 lb) was caught at the mouth of the Mississippi River at Cow Horn Reef in September of 1936.

Mississippi River: A Gulf sturgeon was caught by a commercial fisherman in the auxiliary outflow channel between river km 500.3 (river mi 311.0) of the Mississippi River and river km

16.09 (river mi 10.0) of the Red River on March 28, 1994 (G. Constant, personal communication). The Gulf sturgeon weighed 28.8 kg (63.5 lb) and was 151.2 cm (59.5 in) length and was caught in a 1.2 m (4.0 ft) hoop net.

Lake Pontchartrain Basin

Lake Pontchartrain/Lake Borgne/Rigolets: The Louisiana Department of Wildlife and Fisheries (LDWF) collected twelve Gulf sturgeon weighing 0.22 to 9 kg (0.5 to 19.8 lb) April through June of 1993 (H. Rogillio, personal communication). During a study from January 1990 to March 1993, LDWF collected and tagged 19 Gulf sturgeon weighing 0.25 to 14.5 kg (0.6 to 32.0 lb) from Lake Pontchartrain, Lake Borgne, and the Rigolets (Rogillio 1993). Commercial and sport fishermen incidentally caught 177 Gulf sturgeon measuring up to 220.0 cm (86.6 in) in length and weighing from 1.0 to 68.0 kg (2.2 to 149.9 lb) from Lake Pontchartrain from October 1991 to September 1992 (Rogillio 1993). Reynolds (1993) reported that sturgeon measuring up to 220.0 cm (86.6 in) in length and weighing up to 117.3 kg (258.0 lb) were incidentally caught by shrimp trawlers, netters and recreational anglers from 1989 to 1993 in Lake Pontchartrain. A specimen weighing 53.6 kg (118 lbs) was caught by a hook-and-line fisherman in 1986 (Sentry News 1986). Davis et al. (1970) reported that sturgeon were collected from Lake Ponchartrain during an anadromous fish survey from 1966 to 1969.

Tchefuncte River: Commercial gillnetters incidentally caught 15 Gulf sturgeon weighing from 1.0 to 18.0 kg (2.2 to 39.7 lb) between February and March 1991 in the mouth of the river (H. Rogillio, personal communication). Davis et al. (1970) reported that Gulf sturgeon were collected in trammel nets from the Tchefuncte River during an anadromous fish survey conducted from 1966 to 1969.

Tickfaw River: Davis et al. (1970) reported the collection of sturgeon in trammel nets from the Tickfaw River during an anadromous fish survey from 1966 to 1969.

Tangipahoa River: Davis et al. (1970) reported that sturgeon were collected in trammel nets from the Tangipahoa River during an anadromous fish survey from 1966 to 1969.

Amite River: Davis et al. (1970) reported catch of a sturgeon by a commercial fisherman from the Amite River. Identification of the fish was confirmed by the fisheries biologists with the Louisiana Wild Life (sic) and Fisheries Commission who were conducting an anadromous fish survey.

Pearl River: Esher and Bradshaw (1988) and Bradshaw (personal communication) gill netted a Gulf sturgeon in May 1988 in the lower Pearl River. Sixty-three Gulf sturgeon ranging from juvenile to subadult size were collected from river mile 20 of the Pearl River in 1985 (F. Petzold, personal communication). A 72.7 kg (160.3 lb) female Gulf sturgeon was caught just south of Jackson, Mississippi in 1984 by Miranda and Jackson (1987). The FWS donated a Gulf sturgeon caught by a commercial fisherman in the Pearl River at Monticello to the Mississippi Museum of Natural Science Fish Collection

(MMNS 20206) in 1982 (C. Knight, personal communication; W. McDearman, personal communication). The MDWFP measured and photographed a 119.0 kg (263.0 lb) Gulf sturgeon, 2.2 m (7.25 ft) in length taken by a commercial fisherman below the Ross Barnett Reservoir spillway in 1976 (W. McDearman, personal communication). McDearman and Stewart (personal communication) also note that in the Pearl River between Georgetown and Monticello, Mississippi, there is an area where 2 to 3 Gulf sturgeon are routinely reported by commercial fisherman every 4 to 5 years. In 1971 a Gulf sturgeon from the Pearl River was examined as part of a parasite study (N. Jordan, personal communication). Davis et al. (1970) reported the catch of Gulf sturgeon in hoop nets from the Pearl River at Highway 90 during an anadromous fish survey from 1966 to 1969. The Gulf sturgeon ranged in size from 15.2 cm (6.0 in) to 187.9 cm (74.0 in).

Middle Pearl River: Two Gulf sturgeon were collected in the Middle West Pearl River, St. Tammy Parish, Louisiana, one on March 1, 1995, and the other on March 2, 1995, by the U.S. Army Corps of Engineers, Waterways Experiment Station (WES). The Gulf sturgeon were collected in gill nets and the first sturgeon caught weighed 0.28 kg (0.62 lb) and measured 36.2 cm (14.3 in) in total length. The second Gulf sturgeon weighed 0.28 kg (0.62 lb) and measured 43.5 cm (17.1 in) in total length. Both fish were tagged with Peterson discs and released (M. Chan, personal communication).

Louisiana Department of Wildlife and Fisheries personnel collected 77 Gulf sturgeon from the west Middle Pearl River in 1994 (H. Rogillio, personal communication). The fish ranged in length from 45.7 to 165.1 cm (18 to 65 in). The majority of the fish (84 percent) ranged in length from 74.0 to 114.3 cm (29 to 45 in). The LDWF also collected 14 Gulf sturgeon weighing 1.5 to 14.5 kg (3.3 to 32 lb) in the Middle and west Middle Pearl River from June 1992 through June 1993 (H. Rogillio, personal communication). Two of those specimens were tagged with radio tags. The LDWF also collected 13 Gulf sturgeon weighing 0.27 to 4.3 kg (0.6 to 9.5 lb) in the Middle Pearl River (Drumhole) from April to May 1992 (Rogillio 1993). Commercial fishermen caught one Gulf sturgeon weighing 45.0 kg (99.2 lb) in the Middle Pearl River in February 1991.

Bogue Chitto: Three Gulf sturgeon were also captured by LDWF in the Bogue Chitto River below the Bogue Chitto sill in 1993. The Gulf sturgeon weighed from 2.9 to 4.5 kg (6.5 to 14.5 lb) (H. Rogillio, personal communication).

East Pearl River: Biologists with the FWS gill netted a Gulf sturgeon from the Mikes River, a tributary to the East Pearl River during a fishery survey in the spring of 1992. The fish was 0.7 m (2.3 ft) in length (P. Douglas, personal communication). Davis et al. (1970) reported that one sturgeon was collected in a trammel net from the East Pearl River on November 1, 1968 during an anadromous fish survey conducted from 1966 to 1969.

West Pearl River: Commercial fishermen caught five Gulf sturgeon weighing from 0.1 to 0.3 kg (0.22 to 0.66 lb) in the West Pearl River in October 1990 (H. Rogillio, personal communication).

Mississippi Sound

Bradshaw (personal communication) reported three tag returns from Gulf sturgeon that were incidentally caught by shrimpers working in Mississippi Sound during the fall of 1985. Bradshaw originally collected these Gulf sturgeon from river km 32 (river mi 20) on the Pearl River earlier in 1985. He also noted finding three dead Gulf sturgeon incidentally caught by gillnetters in the western part of the Sound and revived another Gulf sturgeon a gillnetter had caught "on" Horn Island in 1989. Five Gulf sturgeon from Mississippi Sound near Horn Island were examined as part of a parasite study (N. Jordan, personal communication). Of the five sturgeon, one was examined in each of the years 1973, 1976, and 1977, and two in 1982. One Gulf sturgeon [Gulf Coast Research Laboratory (GCRL) #1711] was incidentally caught in a shrimp trawl off the east end of Deer Island in Mississippi Sound in November 1966 in approximately 5.5 m (18 ft) of water. The Gulf sturgeon had a total length (TL) of 75.2 cm (29.6 in). Near this same location J.Y. Christmas (personal communication) reported catching one Gulf sturgeon (GCRL #28) with a TL of 55.2 cm (21.7 in) while sampling with a shrimp trawl in March 1960.

Biloxi Bay

One Gulf sturgeon was incidentally caught in a shrimp trawl in Biloxi Bay off Marsh Point on November 19, 1960 (GCRL #337). The fish was 55.5 cm (22.0 in) TL.

Pascagoula River Basin

Pascagoula Bay: Shepard (personal communication) caught two Gulf sturgeon at the mouth of Bayou LaMotte during the winters of 1991 and 1992 while gillnetting for the J.L. Scott Marine Education Center (GCRL). Reynolds (1993) reported commercial fishermen collecting Gulf sturgeon in and near the mouth of the Pascagoula River in the late 1980's and early 1990's. Shepard (personal communication) reports catching nine Gulf sturgeon from the mouth of the West Pascagoula River while gillnetting from 1983 to 1984. All but one of the sturgeon were caught at the mouth of Bayou LaMotte. The ninth fish was captured near the Sandalwood Canal. One Gulf sturgeon from the mouth of the Pascagoula River was examined in 1970 as part of as part of a parasite study conducted by GCRL (N. Jordan, personal communication).

Pascagoula River: Murphy and Skaines (1994) reported collection of seven Gulf sturgeon in the lower three miles of the Pascagoula River from April to June 1993. Two were radio tagged and released. The fish ranged in length from 46.4 to 111.8 cm (18.3 to 44.0 in) and from 0.8 to 10.4 kg (1.8 to 22.9 lb) in weight. Miranda and Jackson (1987), collected a 78.2 cm (30.8 in) Gulf sturgeon in June 1987 during 30 net-nights from the river. Three Gulf sturgeon were examined from the Pascagoula River as part of a parasite study conducted by GCRL. One was examined in 1978, the second in 1982 and the third in 1984 (N. Jordan, personal communication).

Chickasawhay River: Miranda and Jackson (1987) reported a catch of a 56.7 kg (125.0 lb) Gulf sturgeon in 1985 from the Chickasawhay River, which is a tributary of the Pascagoula River.

Leaf River: Murphy and Skaines (1994) reported that one of two fish radio-tagged from the lower Pascagoula River in May 1993 was located twice in September of that year. The last documented location of the fish was in the Leaf River three miles downstream from McLain, Mississippi approximately 123.8 km (77.0 mi) from its site of capture.

West Pascagoula River: Two Gulf sturgeon from the West Pascagoula River were examined in 1973 and 1979 as part of a parasite study conducted by GCRL (N. Jordan, personal communication). In December 16, 1964, a Gulf sturgeon (GCRL #4501) was collected by T.D. McIlwain in Big Lake off the West Pascagoula River. The sturgeon weighed 0.24 g (0.52 lb) and was 45.6 cm (18.0 in) TL. The water temperature was 13.9°C (57.0°F) with a salinity of 1.1 ppt.

Mobile River Basin

Mobile Bay: A live Gulf sturgeon was picked up on the shoreline of Bayou LaBatre by a fisherman on March 8, 1993 (F. Parauka, personal communication). The fish was 127 cm (50 in) long and weighed 12.5 kg (27.5 lb). The fish was held for observation at the Dauphin Island Sealab until a FWS biologist measured, weighed, radio-tagged, and collected genetic tissue samples and released it into Mobile Bay a day later. Efforts to locate the sturgeon again were unsuccessful. In July 1972 approximately one hundred Gulf sturgeon were observed at the mouth of the Blakeley River in eastern Mobile Bay feeding in shallow water (Vittor 1972). The sturgeon were approximately .91 m (3 ft) in length.

Mobile River: A Gulf sturgeon about 150 cm (59.1 in) long was sighted in the Mobile River near the head of Mobile Bay on October 3, 1992 by an Alabama Department of Conservation and Natural Resources (ADCNR) Marine Resources Division employee. There is a mounted specimen of a juvenile Gulf sturgeon at the Roussos Restaurant in Mobile, Alabama (J. Roussos, personal communication). The specimen is approximately 45.7 to 50.8 cm (18 to 20 in) TL and was collected in 1985 or 1986. The specimen was caught in a shrimp trawl in the Mobile River, presumably at the north end of Mobile Bay.

Tensaw River: The ADCNR reported that a commercial fisherman incidentally caught a 180 cm (70.9 in) Gulf sturgeon in the mouth of the Tensaw River in September 1991 (W. Tucker, personal communication). M. Mettee (personal communication) reported a 180 cm (70.9 in) Gulf sturgeon was incidentally netted and released in the Tensaw River in April 1986 by a commercial fisherman.

Blakeley River: Commercial gillnetters incidentally caught Gulf sturgeon in the Blakely River during the fall from 1989 to 1991.

Tombigbee River: A specimen caught in June 1987 upstream of Coffeeville on the Tombigbee River was verified by an Alabama Geological Survey (AGS) biologist as *Acipenser* (M. Mettee, personal communication). In 1977 a Gulf sturgeon from the Tombigbee River was examined as part of a parasite study (N. Jordan, personal communication). Incidental catches of Gulf sturgeon still occur annually from the Tombigbee River in the remaining riverine habitat below Coffeeville dam (J. Duffy, personal communication).

Alabama River: Incidental catches of Gulf sturgeon still occur annually from the Alabama River in the remaining riverine habitat below Claiborne dam (J. Duffy, personal communication).

Pensacola Bay Basin

Pensacola Bay: A 56.0 cm (22.0 in) TL Gulf sturgeon was collected in Pensacola Bay on January 20, 1978 (Collection No. 10319, Florida Department of Environmental Protection, FDNR).

Escambia River: Two Gulf sturgeon were collected, tagged and released in the Escambia River about 1.6 km (1.0 mi) downstream of highway 184 bridge in September 1994 by the FWS (F. Parauka, personal communication). The fish weighed 15.5 and 20.7 kg (34.0 and 45.5 lb). Incidental catches of Gulf sturgeon have been reported for the Escambia River (G. Bass, personal communication). Recreational anglers reported that prior to 1980 they would see as many as 10 Gulf sturgeon jumping in the river but now it is rare to see even one fish jump during a fishing trip (Reynolds 1993). Prior to a Florida law prohibiting sturgeon fishing in 1984, a limited commercial fishery existed on that river (National Marine Fisheries Service 1987).

Conecuh River: Annual sightings are reported from the Conecuh River in south central Alabama (J. Duffy, personal communication).

Blackwater River: Three Gulf sturgeon were collected in the Blackwater River during a Florida Game and Fresh Water Fish Commission (FGFC) striped bass netting project in March 1991. The fish weighed from 5.0 to 12.0 kg (11.0 to 26.5 lb) (FGFC, unpublished data).

Yellow River: Eighteen Gulf sturgeon were collected, tagged and released in the Yellow River below Boiling Lake in July 1993 by the FWS (F. Parauka, personal communication). The fish weighed from 5.8 to 63.6 kg (12.7 to 140.0 lb). Gulf sturgeon were collected in the Yellow River during a 1961 to 1962 survey by FGFC (1964). Commercial landings were occasionally reported prior to the 1984 fishing prohibition (J. Barkuloo, personal communication).

Choctawhatchee Bay Basin

Santa Rosa Sound: The U.S. Environmental Protection Agency (EPA) reported a 23 kg (50 lb) Gulf sturgeon washed up on the beach in Santa Rosa Sound near Navarre, Florida in 1988 (F. Parauka, personal communication).

Choctawhatchee Bay: Four Gulf sturgeon were collected by FDEP biologists on April 27, 1993 from Jolly Bay at the eastern end of Choctawhatchee Bay. The sturgeon ranged in length from 41.2 to 81.9 cm (16.22 to 32.2 in).

Choctawhatchee River: Fifty adult and subadult Gulf sturgeon were collected, tagged and released at the mouth of the Choctawhatchee River in April 1994 by the North Carolina Cooperative Research Unit, North Carolina State University (NCSU) and the FWS (Potak et al. 1995). Twenty-five of the fish were equipped with radio tags. The fish weighed from 2.5 to 72.7 kg (5.5 to 160.3 lb) and ranged in length from 73.8 to 192.0 cm (29.1 to 75.6 in). Twenty-seven Gulf sturgeon were captured, tagged, and released in the Choctawhatchee River between Howell Bluff and Rocky Landing in 1988, 1990, and 1991 by the FWS (FWS 1988, 1990, 1991b). The fish weighed from 4.5 to 52.3 kg (9.9 to 115.3 lb). In addition, a 0.13 kg (0.29 lb) specimen caught by an angler downstream from Caryville, Florida in 1991 was tagged and released by the FWS (FWS 1991b). Three Gulf sturgeon weighing from 17.0 to 26.0 kg (37.5 to 57.3 lb) were collected in the upper Choctawhatchee River below its confluence with Pea River at Geneva, Alabama in August 1991 by the FWS (FWS, unpublished data). Annual sightings are reported from the Choctawhatchee River in south central Alabama (J. Duffy, personal communication).

> **Pea River:** Three Gulf sturgeon 91.0 to 213.0 cm (35.8 to 83.9 in) in length were collected by the AGS during March 1992 about 1.0 to 3.0 km (0.62 to 1.86 mi) in the Pea River above its confluence with the Choctawhatchee River (M. Mettee, personal communication). Annual sightings are reported from the Pea River in south central Alabama (J. Duffy, personal communication).

Apalachicola, Chattahoochee, Flint River Basin

Apalachicola Bay: A 34.0 kg (74.8 lb) Gulf sturgeon was caught by a commercial fisherman in a shrimp trawl in Apalachicola Bay in November 1989 (F. Parauka, personal communication). The fish was taken to the Apalachicola National Estuarine Reserve for observation and was later tagged and released at the point of capture by the FWS. A 34.5 kg (76.0 lb) Gulf sturgeon was captured, tagged and released in Apalachicola Bay, south of Hwy 98 bridge in March 1988. Also, in March 1987, a 34.0 kg (74.6 lb) Gulf sturgeon was captured, tagged and released in Apalachicola Bay, north of Hwy 98 bridge (F. Parauka, personal communication). Incidental captures by commercial shrimpers and gill net fishermen in Apalachicola Bay were noted by Wooley and Crateau (1985) and reported by Swift et al. (1977).

Apalachicola River: The FWS Panama City, Florida Field Office has monitored the Apalachicola River Gulf sturgeon population since 1979. Three-hundred and fifty Gulf sturgeon were collected below Jim Woodruff Lock and Dam (JWLD), tagged and recaptured from May through September, 1981 through 1993. The number of fish staying below the dam in the summer was estimated using a modified Schnabel method. Fish smaller than 45.0 cm (17.7 in) TL were excluded because of sampling bias caused by net selectivity. Since 1984, the estimated annual number of fish ranged from 96 to 131 with a mean of 115 (FWS 1990, 1991b, 1992). A 145 cm (57.1 in) FL specimen was captured by FDEP (FSBC 640008) on October 28, 1970 in the river. The FGFC (1964) collected Gulf sturgeon during their anadromous fish survey conducted from 1954 to 1964.

A report of the U.S. Commission on Fish and Fisheries (1902) indicated the Apalachicola River provided the largest and most economically important commercial sturgeon fishery in Florida in 1901. Archie Carr (personal communication) noted that 32 families commercially fished for Gulf sturgeon in the mid-1940's. A commercial fishery continued until the late 1970's with only a few families. Sport fishing for Gulf sturgeon in the spring, and to a lesser extent in the fall, in some of the deeper holes in the Apalachicola River below the JWLD produced fish up to 73 kg (160.9 lb) and 2.3 m (7.5 ft) long (Tallahassee Democrat 1958, 1963, 1969).

Brothers River: Archie Carr (1978 and personal communication) began studying Gulf sturgeon in the Apalachicola River in 1975 and caught only eight sturgeon in 23 days of set-netting in Brothers Creek.

Flint River: Swift et al. (1977) noted a report of a 209 kg (460.8 lb) specimen from the Flint River near Albany, Georgia before 1950, prior to the completion of JWLD in 1957.

Ochlockonee River Basin

Ochlockonee River: Four Gulf sturgeon weighing from 2.0 to 4.0 kg (4.4 to 8.8 lb) were collected in the lower Ochlockonee River at the mouth of Womack Creek in June 1991 (FWS/Panama City and National Biological Survey/Southeastern Biological Service Center-Gainesville (NBS/SBSC-G), unpublished data). Gulf sturgeon were commercially fished in the vicinity of Hitchcock Lake in Wakulla County (Swift et al., 1977; Florida Outdoors 1959). The fish were shipped to the town of Apalachicola for processing and sale to the New York City area. Commercial landings comparable to the Apalachicola River fishery were noted in 1901 (U.S. Commission on Fish and Fisheries 1902). However, most commercial fishing for Gulf sturgeon in the river ended in the early 1970's (F. Parauka, personal communication).

Suwannee River Basin

Suwannee River: The Suwannee River appears to support the most viable Gulf sturgeon population among the coastal rivers of the Gulf of Mexico (Huff 1975). The Caribbean Conservation Corporation (CCC) has captured, marked, and released 1,670 spring migrating Gulf sturgeon at the river mouth since 1986. Based on the recapture of marked fish, the annual estimated population size ranged between 2,250 to 3,300 for Gulf sturgeon averaging about 18 kg (39.7 lb) (Carr and Rago, unpublished data). An ongoing complementary study by the NBS/BSC-G (unpublished data) has captured, marked, and released about 1,500 subadults, most of which were less than 15 kg (33.1 lb), throughout the river from March 1988 through March 1992. This river supported a limited commercial Gulf sturgeon fishery from 1899 (U.S. Commission on Fish and Fisheries 1902) until 1984 when the State of Florida prohibited harvest and possession.

Tampa Bay Basin

Tampa Bay: A commercial netter incidentally caught and released a Gulf sturgeon 56.4 cm (1.8 ft) in length, one mile west of Redington Beach near St. Petersburg in December 1992 (Reynolds 1993). Before this time, the most recent Gulf sturgeon catch reported from Tampa Bay was a 144 cm (56.7 in) FL female weighing 25.8 kg (56.9 lb), collected on December 11, 1987 near Pinellas Point (FDEP fish collection records, no collection number). Tampa Bay was the location of the first recorded significant sturgeon fishery on the Gulf of Mexico coast, lasting only three years (U.S. Commission on Fish and Fisheries 1902). The fishery began in 1886-1887 with a catch of 1,500 fish yielding 2,268 kg (5,000 lb) of roe. Two thousand fish and 2,858 kg (6,300 lb) of roe were marketed in 1887-1888. The fishery ended after the 1888-1889 season when only seven sturgeon were caught. Sturgeon catches have been reported sporadically since 1890.

Charlotte Harbor Basin

Charlotte Harbor: A 3.0 kg (6.6 lb) Gulf sturgeon was captured by a commercial mackerel net fisherman near the mouth of Charlotte Harbor on January 29, 1992 (R. Ruiz-Carus, personal communication). The sturgeon was caught on a sand bar near Boca Grande Pass, 2.4 to 3.0 m (7.9 to 9.8 ft) in depth. While specific information was given for this fish, the fishermen related that two or three sturgeon of the same size were released alive from the same net set near Boca Grande Pass. Two other specimens have been reported from Charlotte Harbor (University of Florida/Florida State Museum (UF/FSM) 35332; FSBC 18077), one of which is a 24.3 kg (53.6 lb) specimen now mounted at the Florida Marine Research Institute, FDEP, St. Petersburg, Florida.

BIOLOGICAL CHARACTERISTICS

Habitat

Gulf sturgeon are classified as anadromous, with immature and mature fish participating in freshwater migrations (Huff 1975; Carr 1983; Wooley and Crateau 1985; S. Carr, unpublished data; J. Clugston, unpublished data). Anecdotal information, gillnetting, and biotelemetry have shown that subadults and adults spend eight to nine months each year in rivers and three to four of the coolest months in estuaries or Gulf waters. It appears that Gulf sturgeon less than two years old remain in riverine habitats and estuarine areas throughout the year. Many Gulf sturgeon in the Suwannee River spend summer months near the mouths of springs and cool-water rivers (Foster 1993; S. Carr, unpublished data). The substrate of much of the Suwannee River is sand and limerock, especially in those areas near springs and spring runs.

Wooley and Crateau (1985) reported that Gulf sturgeon in the Apalachicola River utilized the area immediately downstream from JWLD from May through September. The area occupied consisted of the tailrace and spillway basin of JWLD and a large scour hole below the lock. During high flow periods in the late spring when water was passing through open water control gates at JWLD, Gulf sturgeon would congregate in the turbulent flow, often suspended just below the water surface. During the summer, Gulf sturgeon concentrated in the large scour hole below the lock and in the area of the dam spillway basin. This area represented the deepest available water within 25 km (15.5 mi) down-river of the JWLD. Mean total distance moved by Gulf sturgeon during this time was only 0.4 km (0.25 mi). In all cases Gulf sturgeon did not move more than 0.8 km (0.5 mi) from May through September. The area consisted of sand and gravel substrate, water depths ranged from 6.0 to 12.0 m (19.7 to 39.4 ft) with a mean depth of 8.4 m (27.6 ft) and velocities ranged from 60.0 to 90.0 cm/s (2.0 to 3.0 ft/s) with a mean velocity of 64.1 cm/s (2.1 ft/s). Because of the scarcity of historical biological data pertaining to the Gulf sturgeon in the Apalachicola River it is impossible to ascertain whether the area observed as a summer congregation area represents specific historic habitat. It may be the best alternative habitat type available to Gulf sturgeon whose migration upstream was blocked by the construction of JWLD in 1957.

The U.S. Army Corps of Engineers (COE) conducted surveys in this area in November 1991 and October 1992, to characterize flows associated with a strong cross current at the lock approach. In November 1991, velocities were measured at a depth 0.06 and 0.24 m (0.2 and 0.8 ft) of the water column, with velocities ranging from 0.19 to 0.67 m/s (0.61 to 2.19 ft/s) during normal powerhouse generation (two turbines on line with trash gate open). The follow-up survey in October 1992 included an additional measurement within the large scour hole below the lock at a depth within 0.6 m (2 ft) of the bottom. Velocities ranged from 0.08 to 0.92 m/s (0.25 to 3.01 ft/s) for normal powerhouse generation (with or without the trash gate open; with velocities at the bottom of the scour hole ranging from 0.11 to 0.37 m/s (0.36 to 1.2 ft/s) (COE 1993; COE 1994).

The Brothers River, a tributary entering the lower Apalachicola River at river km 19.3 (river mi 12.0) appears to be a staging area for Gulf sturgeon leaving the river (Odenkirk 1989). This was a favorite location for commercial Gulf sturgeon netting in past years (J. Fichera, personal communication). The Brothers River is a sluggish river with deep holes, swampy banks, and a sand and rock bottom. Wooley and Crateau (1985) characterized the habitat as having a mean depth of 11.0 m (36.1 ft), water depths ranged from 8.0 to 18.0 m (26.2 to 59.0 ft) and velocities ranged from 0.58 to 0.75 m/s (1.9 to 2.46 ft/s) with a mean velocity of .60 m/s (1.97 ft/s).

Swift et al. (1977) reported that local fishermen believed that Gulf sturgeon spawning occurred in June in the deeper holes and "lakes" along the rivers. Swift also reported that Gulf sturgeon were caught by sport fisherman from deep holes in the Apalachicola River below Jim Woodruff Dam during the spring and fall in the late 1950's to the late 1960's.

The WES reported the river conditions during collection of two Gulf sturgeon from the west Middle Pearl River on March 1, 1995. The conditions for at the surface and in 7.62 m (25 ft) of water were: temperature of 15.3°C (59.6°F) and 15.3°C (59.5°F); conductivity of 68 μmho's/cm; dissolved oxygen of 9.09 and 8.80 mg/l; pH of 6.64 and 6.57; and turbidity at the surface of 32 NTU (M. Chan, personal communication).

Bradshaw (personal communication) noted that 62 of 63 of the Gulf sturgeon collected from the East Pearl River at river km 32.2 (river mi 20) in 1985 were from one location, a deep, 12.2 m (40 ft) hole. He also reported that another Gulf sturgeon was captured at the same location in 1988.

Swift et al. (1977) noted that young Gulf sturgeon were reportedly captured in shrimp trawls in Apalachicola Bay. Muddy, soft bottom substrates, the dominant habitat of the Bay, comprise about 78% of the open water zone (Livingston 1984). Wooley and Crateau (1985) reported one Gulf sturgeon was captured 3.2 km (2.0 mi) from the mouth of Apalachicola River in the Bay in approximately 2 m (6.6 ft) depth over a mud substrate. Several Gulf sturgeon were collected from Gulf waters adjacent to Apalachicola Bay (Wooley and Crateau 1985). One Gulf sturgeon was caught 1.2 km (.75 mi) south of Cape St. George in 6 m (19.7 ft) of water and another Gulf sturgeon was captured 1.6 km (1.0 mi) south of Cape San Blas in 15 m (49.2 ft) of water. Limited stomach analyses from Suwannee and Apalachicola River Gulf sturgeon indicate that mud and sand bottoms and seagrass communities are probably important marine habitats for Gulf sturgeon (Mason and Clugston 1993).

Migration and Movement

The movements of Gulf sturgeon in the Apalachicola, Suwannee, Pearl, and Choctawhatchee rivers have been and are being monitored by ultrasonic and radio telemetry and by conventional fish sampling gear (Foster 1993; Carr 1983; Wooley and Crateau 1985; Odenkirk 1989; Rogillio 1993; Clugston et al., in press; Potak et al. 1995; S. Carr, unpublished data; Odenkirk et al., unpublished manuscript; F. Parauka, personal communication; H. Rogillio, personal communication). In general, subadult and adult Gulf sturgeon began to migrate into rivers from the Gulf of Mexico as river temperatures increased to about 16 to 23°C (60.8 to 75.0°F). They continued to immigrate through early May, but most arrive when temperatures reach 21°C. Gulf sturgeon have been collected as far upstream as river km 221 (river mi 137.3) in the Suwannee River. In the Suwannee River, most radio-tracked Gulf sturgeon appeared to settle into four 3.0 to 15.0 km (1.9 to 9.3 mi) long reaches of the river during the summer (Foster 1993). Upstream migration in the Apalachicola River is blocked at river km 171 (river mi 106.3) by the JWLD. Nearly all radio-tracked Gulf sturgeon remained in the dam tailrace during the summer (Wooley and Crateau 1985; Odenkirk 1989).

Wooley and Crateau (1985) reported that of 99 Gulf sturgeon tagged below JWLD, Apalachicola River, 6 were incidentally captured by shrimp trawlers during the fall season in Apalachicola Bay and the adjacent Gulf of Mexico. Bradshaw (personal communication) notes three Gulf sturgeon he collected and tagged in 1985 from the East Pearl River at river km 32.2 (river mi 20) that were incidentally caught by shrimpers in Mississippi Sound in the fall of that year. One Gulf sturgeon, a 53.0 cm (20.9 in) FL individual, was caught near the west tip of Cat Island, a distance of 64.6 km (40 mi) from the release point on the river.

Subadult and adult Gulf sturgeon in the Suwannee and Apalachicola Rivers generally began downstream migration in late September and October. Wooley and Crateau (1985) found that the Gulf sturgeon at the JWLD began their downstream migration in late fall when the temperature dropped to 23°C (73.4°F). Most return to the estuary or the Gulf of Mexico by mid-November to early December. In the Suwannee River, young Gulf sturgeon from about 0.3 to 2.5 kg (0.7 to 5.5 lb) remained at the river mouth during the winter and spring and were the only Gulf sturgeon captured during December, January and early February over a three year period from late 1987 to 1991 (Clugston et al. 1995). Based on mark-recapture data, these young fish did not appear to venture far into the Gulf of Mexico. Tagging (J. Clugston, unpublished data) and other life history studies (Huff 1975) found small Gulf sturgeon at river distributaries indicating that they were spawned in the Suwannee River.

Radio telemetry studies on the Choctawhatchee River conducted by NCSU in the summer of 1994, found that 25 tagged Gulf sturgeon did not distribute themselves uniformly throughout the river and did not occupy the deepest or coolest water available (Potak et al. 1995). Most fish were concentrated in relatively shallow straight stretches of the river. Of the 25 fish, 23 remained within two primary summer holding areas in the middle to lower river. They were found outside the main channel, where water velocities were less than the maximum available. Most of the fish were in water depths of 1.5 to 3.0 m (4.9 to 9.9 ft) and substrates were silt or clay.

Tagging and radio telemetry studies conducted by the LDWF during 1993 and 1994 showed subadult and adult Gulf sturgeon frequented or moved between specific areas from May through September. The most southern site is known as the Drum Hole on the west Middle Pearl River to the upper and lower Fridays Ditch on the west Middle Pearl River. Telemetry data showed movement of fish between Fridays Ditch to the West Pearl River at Powerline and Yellow Lake. Movement was also observed from Gulf sturgeon tagged from the Boque Chitto River below the sill at the canal and Lake Pontchartrain at Bayou Lacombe (H. Rogillio, personal communication).

Three sonic-tagged Gulf sturgeon were tracked into saline water and monitored in Apalachicola Bay for one to four hours in late October 1987. In November 1989, a Gulf sturgeon was monitored in Apalachicola Bay for 72 hours and tracked for 30.0 km (18.6 mi) (FWS 1988, 1989). Four Gulf sturgeon were similarly tracked in late October 1991 outside the Suwannee River and remained for about a week in water depths of 3.0 m (9.8 ft) and 5.0 km (3.1 mi) offshore in an area of mud bottom (Carr, unpublished data).

Gulf sturgeon tagging studies in the Apalachicola and Suwannee rivers demonstrate the high probability of recapture in the same river in which the fish were tagged. Between 1986 to 1992, approximately 3,750 Gulf sturgeon were tagged in the Suwannee River, and of nearly 700 recaptures, all but two were recovered in the Suwannee River. Those two recaptures occurred in the Apalachicola River and offshore near Tarpon Springs, Florida. From 1981 to 1993, a total of 350 Gulf sturgeon were tagged in the Apalachicola River. Of those, 160 were recaptured in the Apalachicola River, while six individuals were recaptured in the East Pass of the Suwannee River (S. Carr, unpublished data) and one was recaptured in the Ochlockonee River (F. Parauka, personal communication). Of those six individuals recaptured in the Suwannee River, three were recaptured the following year in the East Pass. Radio-tracking further suggests that individuals return to the same area of the river inhabited the previous summer (Foster 1993; Carr, unpublished data; FWS/Panama City, unpublished data).

Small Gulf sturgeon were noted to move southward along the western Florida coast to Florida Bay during the winters of 1957, 1959, and 1962 (D. Robins in personal communication to Wooley and Crateau 1985). Several sturgeon, estimated at 60 cm (23.6 in) FL, were also collected in fish traps in Government Cut, Miami, Florida during the winters of 1957, 1959, and 1962 (D. Robins, personal communication). Vladykov examined one of the specimens internally and determined it to be *A. o. desotoi*. These occurrences may have been in response to unusually low winter temperatures.

Stocks

Stabile et al. (unpublished manuscript) used RFLP analysis of mitochondrial DNA (mtDNA) of Gulf sturgeon collected from six geographically disjunct drainages along the Gulf of Mexico. The river systems included the Suwannee, Apalachicola, Ochlockonee, Blackwater, and Choctawhatchee rivers in Florida and the Pearl River in Louisiana/Mississippi. Their preliminary data analysis indicates that there are significant differences among Gulf sturgeon stocks. They found the most notable difference existed between the Choctawhatchee River samples and samples from other Gulf of Mexico rivers. In addition, the results indicated a break between the Apalachicola/Suwannee river populations and populations to the west of the Apalachicola River. Further, their data suggest that Gulf sturgeon display region-specific affinities and may exhibit river-specific fidelity.

Stabile et al. (unpublished manuscript) also indicated population-level polymorphisms using direct sequence analysis in sturgeon from the Gulf coast rivers. They found that Gulf sturgeon analyzed from the Pearl River exhibited haplotypes that were different from all other Gulf coast samples. Polymorphisms at other sites indicated possibly useful markers for discriminating sturgeon from the Choctawhatchee and Yellow rivers. No significant differences of mtDNA haplotypes were found among Gulf sturgeon from the eastern Gulf coast. However, these results are considered tentative because of the small sample size.

Food Habits

In the Suwannee River, stomachs of Gulf sturgeon 38 to 188 cm (15.0 to 74.0 in) FL caught in commercial gill nets 10.0 m (32.8 ft), 24.5 cm (9.4 in) stretch fished in the lower river in East Pass contained digested aquatic plant material interspersed with crab hard parts (probably blue crab, *Callinectes sapidus*). The relative abundance of crab parts was greater in stomachs of migrants entering the river in spring and usually absent from those exiting in fall (Huff 1975). Gammaridean amphipods were primarily found in smaller schooled Gulf sturgeon <82.0 cm (32.3 in) caught with trammel nets in shallow water 1.0 to 2.0 m (3.3 to 6.6 ft) in depth over a sand bank at the river's mouth (Alligator Pass). These prey species are associated with sandy substrates. Other food items included isopods (*Cyathura burbanki*), midge larvae, mud shrimp (Callianassidae), one eel (*Moringua* sp.), and unidentifiable animal or vegetable matter. Huff concluded that these small Gulf sturgeon occupied a different habitat than larger Gulf sturgeon harvested in the gill net fishery.

Mason and Clugston (1993) studied the food habits of Gulf sturgeon on the Suwannee River from 1988 to 1990. In the spring, immigrating subadult and adult Gulf sturgeon collected from the river mouth contained gammarid, haustoriid, and other amphipods, polychaete and oligochaete annelids, lancelets, and brachiopods. However, once in fresh water, these Gulf sturgeon did not eat as evidenced by the presence of only a greenish-tinged mucus in their guts during June through October. Stephen Carr (unpublished data) found in the Suwannee River that immigrating, sexually mature Gulf sturgeon were mainly empty of food; however, of food items present, brachiopods and mud shrimp dominated. By contrast, a 13.6 kg (30.0 lb) Gulf sturgeon was captured by bait trawlers on Red Bank Reef three miles from the mouth of the Suwannee River in spring 1986. Its stomach contained six species of lugworm, two species of clam, five species of crustacea, an echinoderm (sand dollar), an unidentifiable marine worm and two dozen lancelets (S. Carr, unpublished data). Mason and Clugston (1993) found that small Gulf sturgeon (0.5 to 4.0 kg) (1.1 to 8.8 lb) collected at the river mouth during the winter and early spring contained amphipod and isopod crustaceans, oligochaetes, polychaetes, and chironomid and ceratopogonid larvae. Although the guts of these young Gulf sturgeon contained small amounts of food as they migrated upstream to about river km 55 (river mi 34), they too contained only a detrital mass and were essentially empty in the freshwater reaches during the summer and fall. It remains unclear why most subadult and adult Gulf sturgeon feed for three to four months in a marine environment and enter fresh water where they do not feed for the following eight or nine months.

Growth

Huff (1975) used cross sections of pectoral fin rays to estimate the age of 631 Gulf sturgeon collected from the Suwannee River. Because back calculation using fin ray sections was not possible, mean fork lengths for fish ages 1 through 17 were calculated (Figure 3). Mean fork length at age 1 was approximately 35.0 cm (13.8 in) and increased to approximately 145.0 cm (57.1 in) at age 17.

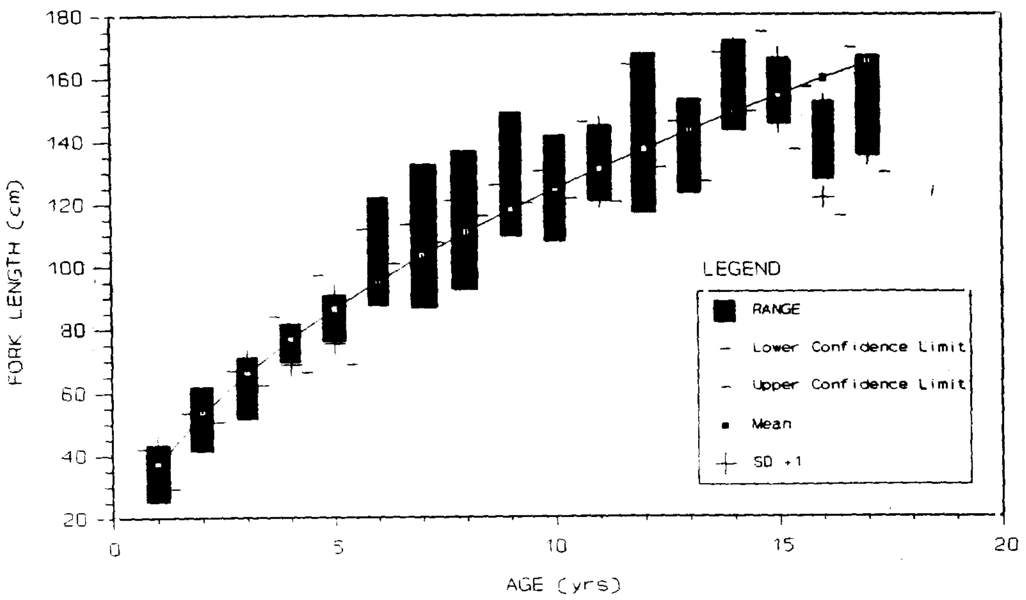

Figure 3: Length-range diagram and regression line,
Gulf sturgeon age groups 1 to 17, from 1972 to 1973 (Huff 1975)

Cross sections of pectoral fin rays were also used to estimate the age of 76 Gulf sturgeon collected from the Apalachicola River, Florida from 1982 to 1990 (Jenkins, unpublished manuscript). Fish ranged from 2 to 28 years old with lengths and weights ranging from 47.0 to 227.0 cm (18.5 to 89.4 in) and 0.2 to 90.7 kg (0.4 to 200.0 lb). Fin rays from four fish exhibited possible spawning belts. Average growth was 24.0 cm (9.4 in) per year for fish two to five years old, and 8.0 cm (3.1 in) per year to the age of eight. Fish marked and later recaptured exhibited similar large growth variations which may be the result of sexual dimorphism. The time of annulus formation was in the late summer and fall, which is a period of weight loss according to mark-recapture studies.

Carr (1983) found that on the average, marked Gulf sturgeon from the Suwannee River gained 30% of body weight in one year. He also noted that little or no growth was seen when recapture occurred during the same season and a little weight was lost by some. Wooley and Crateau (1985) noted that Gulf sturgeon 80.0 to 114.0 cm (31.5 to 44.9 in) FL tagged in early summer in the Apalachicola River below JWLD and subsequently recaptured in the same area in July and September exhibited weight losses of 4% to 15% or 0.5 to 2.3 kg (1.1 to 5.1 lb). Gulf sturgeon from 75.5 to 101.0 cm (29.7 to 39.8 in) FL tagged in September and recaptured the following year between May and September, after spending the winter period feeding in Apalachicola Bay and/or the Gulf of Mexico, showed weight gains of 35% to 137% or 4.3 to 10.2 kg (9.5 to 22.5 lb). These growth rates are considered normal for young Gulf sturgeon.

The recapture of 229 marked fish provided an opportunity to calculate seasonal growth rates of Gulf sturgeon in the Suwannee River (Clugston et al. 1995). It appears that Gulf sturgeon gain weight only during the winter and spring while in marine or estuarine waters and lose weight during the eight to nine month period while in fresh water. In general, Gulf sturgeon weighing between 7.0 kg (15.4 lb) and 27.0 kg (59.5 lb) grew about 11.0 cm (4.3 in) and gained 2.0 to 3.0 kg (4.4 to 6.6 lb) per year. In nearly all cases, however, fish that were marked and recaptured during the same summer lost weight. Those recaptures that spanned the three or four months that most fish were in the Gulf of Mexico increased in weight. Likewise, the young fish collected at the mouth of the river during the winter and spring and recaptured during the same period increased in weight. Lengths and weights were monitored for two Gulf sturgeon hatched and reared for 17 months under laboratory conditions (Mason et al., 1992). In the first year these fish grew to 71.9 cm (28.3 in) and 63.4 cm (25.0 in) in total length and to weights of 1.9 kg (4.2 lb) and 1.4 kg (3.1 lb). After 17 months they grew to 84.6 cm (33.3 in) and 78.7 cm (31.0 in) and to 3.1 kg (6.7 lb) and 2.7 kg (6.0 lb). These two fish received special treatment, and their growth in the laboratory may not represent growth of wild fish. Nevertheless, the data represent the first measured growth of young Gulf sturgeon and provide insight into the species' growth potential.

Reproduction

Timing, location and habitat requirements for Gulf sturgeon spawning are not well documented. Most subadult and adult Gulf sturgeon ascend coastal rivers from the Gulf of Mexico from mid-February through April when some adults are sexually mature and in ripe condition. Studies conducted on the Apalachicola River resulted in the only known collection of wild Gulf sturgeon larvae. Two larvae were collected at river km 168 (river mi 104.2); one on May 11, 1977 (Wooley et al., 1982) and one on May 1, 1987 (Foster et al., 1988). At the time of the 1977 collection, the surface water temperature was 23.9°C (75.0°F), water depth 4.2 m (13.78 ft), flow 365.0 m^3/s (12,888.0 ft^3/s), and velocity of .67 m/s (2.2 ft/s). During the 1987 collection the surface water temperature was 21.6°C (70.9°F), water depth 4.2 m (13.8 ft), flow 437.0 m^3/s (15430.0 ft^3/s), velocity not measured. The larva collected in 1977 was estimated to be 1 to 2 days old while the other larva was estimated to be a few hours old. A third larva was collected on April 3, 1987 at river km 18.7 (river mi 11.6) at a water temperature of 16.1°C (61.0°F), water depth 7.9 m (25.9 ft), flow not measured, and velocity .96 m/s (3.2 ft/s). The larva was estimated to be about 1 to 1.5 days old (FWS 1988).

Huff (1975) spent considerable time using anchored plankton nets to collect Gulf sturgeon eggs and larvae in the Suwannee River but was unsuccessful. However, two Gulf sturgeon eggs were collected in the river on April 22, 1993 (Marchant and Shutters, unpublished manuscript). The eggs were collected in water depths of 5.5 m and 7.3 m (18.0 ft and 24.0 ft) and water temperature 18.3°C (65.0°F) at river km 215 (river mi 134.2), just downstream of the confluence of the Alapaha River. Additional eggs were collected during late March and April 1994 at river km 201 to 221 (river mi 124.9 to 137.3) when water temperatures ranged from 18.8°C to 20.1°C (65.8°F to 68.2°F)(Smith and Clugston, unpublished manuscript). From 1988 through 1992, Gulf sturgeon investigations were conducted throughout the Suwannee River using plankton nets, small-mesh trap nets, trawls and gill nets, and electrofishing equipment. The smallest Gulf sturgeon collected was a 30.6 cm (12.0 in) specimen weighing 85.0 g (0.2 lb) at river km 215.0 (river mi 133.6) on December 3, 1991 (Clugston et al. 1995).

Stephen Carr and F. Tatman (unpublished data) found that 15 ultrasonic-tagged gravid females were associated with springs between river kms 32.0 and 145.0 (river mi 19.9 and 90.1) in the Suwannee River. The bottom habitats surrounding the springs consist mainly of rock. Their consistent association with these springs has led to Carr's speculation that spawning occurs in these areas.

Remnant reproductive populations may still occur in many small and large rivers draining into the Gulf where Gulf sturgeon have historically ranged. Infrequent anecdotal reports and incidental captures of small Gulf sturgeon indicate that reproduction is occurring in tributary rivers. Small Gulf sturgeon are closely associated with the river basin where they were spawned (river-specific affinity). This has been demonstrated in the Suwannee River and Apalachicola River/Bay distributaries, by the occurrence of similar size Gulf sturgeon in similar depths, and on similar substrate. Any analogous occurrence of small Gulf sturgeon suggests that a reproducing population remains nearby.

Spawning Age

Huff (1975) found that sexually mature females ranged in age from 8 to 17 years and sexually mature males from 7 to 21 years in the Suwannee River. The youngest ripe female specimen and the oldest immature female were age 12. The youngest ripe male specimen was 9 years old and the oldest immature male was age 10. Jenkins (unpublished manuscript) estimated a ripe male captured from the Suwannee River in 1990 to be six to seven years old.

Fecundity

Chapman et al. (1993) reported that three mature Gulf sturgeon had 458,080, 274,680, and 475,000 eggs and were estimated to have an average fecundity of 20,652 eggs/kg (9,366 eggs/lb). Smith et al. (1980) estimated that Atlantic sturgeon weighing 50.0 and 100.0 kg (110.2 and 220.5 lb) would yield over 400,000 and 1,000,000 eggs, respectively.

Gulf sturgeon eggs are demersal and adhesive (Vladykov 1963; Huff 1975; Parauka et al., 1991; Chapman et al., 1993). The eggs are globular and vary in color from gray to brown to black. Smith et al. (1980) reported that Atlantic sturgeon eggs ranged in size from 2.5 to 3.0 mm (0.10 to 0.12 in) in diameter. Parauka et al., (1991) found that eggs from Gulf sturgeon averaged 2.10 and 2.20 mm (0.08 to 0.09 in) in diameter.

Reproduction in Hatcheries

Hormone-induced ovulation and spawning of Gulf sturgeon was accomplished in 1989 at a portable hatchery located on the Suwannee River and at the Welaka National Fish Hatchery in

Florida (Parauka et al., 1991). The project was a joint effort involving the FWS, CCC, and University of California, Davis. The initial spawning produced 5,000 fry for fishery research. In 1990, 1991, and 1992, the University of Florida, the FWS, and CCC again successfully induced spawning and produced about 60,000 fry for fish culture programs. Hatching time for the artificially spawned Gulf sturgeon eggs ranged from 85.5 hr at 18.4°C (65.1°F) to 54.4 hr at about 23.0°C (73.4°F) (Figure 4) (Parauka et al., 1991). Also, at temperatures ranging from 15.6 to 17.2°C (60.1 to 63.0°F) and 19.5 to 21.0°C (67.1 to 69.8°F), eggs hatched in 95 and 65 to 70 hr, respectively (FWS 1991b). Chapman et al. (1993) reported that artificially spawned Gulf sturgeon eggs incubated at 20°C (68°F) hatched in 3.5 days. Hatching time for Atlantic sturgeon eggs has been reported to be 94 hr at 20.0°C (68.0°F) (Dean 1893), 121 to 140 hr at 16.0 to 19.0°C (60.8 to 66.2°F) (Smith et al., 1980) and 168 hr at 17.8°C (64.0°F) (Vladykov and Greeley 1963). One-hour-old Gulf sturgeon larvae, hatched under artificial conditions on the Suwannee River in 1989, ranged in length from 0.66 to 0.71 cm (0.26 to 0.28 in) with a mean length of 0.69 cm (0.27 in) (Parauka et al., 1991). Hatching success ranged from 5 to 10%.

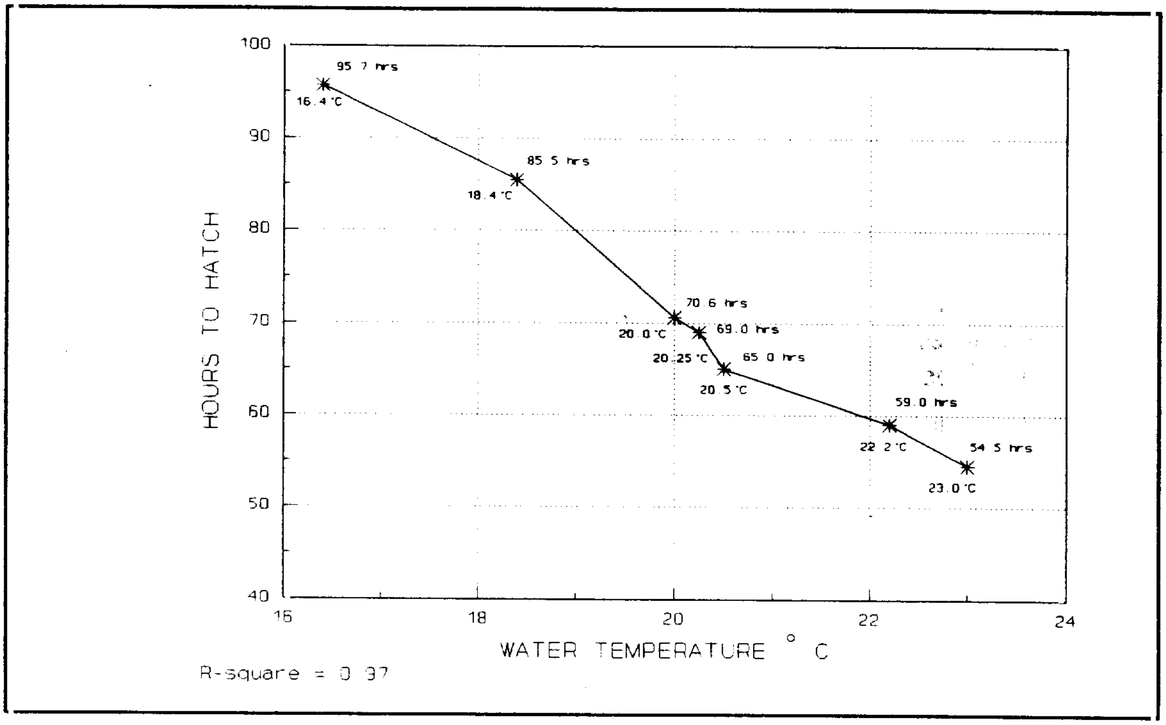

Figure 4: Gulf sturgeon egg incubation periods
at different mean water temperature (F. Parauka et al., 1991; FWS 1991b).

Predator/Prey Relationships

Van Den Avyle (1984) noted there was little written regarding competitors and predators of sturgeon. He pointed out that many fish species live in the same waters as sturgeon and that there is the possibility for competition with other bottom dwelling species. In fresh water, benthic feeders could compete with young sturgeon or feed directly on eggs and larvae. Competition with Gulf sturgeon for food or space in the marine environment is unknown. Scott and Crossman (1973) speculated that the sturgeon's "size and protective plates protect it from most predaceous fishes and its habitat and secretiveness from other predators."

Parasites and Disease

Fish lice *Argulus stizostethi*, an ectoparasitic copepod, have occasionally been observed on the opercula and gill filaments and in the gut of Gulf sturgeon collected in fresh and estuarine water. The numbers noted were not significant (Mason and Clugston 1993; F. Parauka, personal communication). Endoparasites, such as nematodes, trematodes, and leeches were noted in the guts of Gulf sturgeon (Mason and Clugston 1993). Five species of helminth parasites and one parasitic arthropod have been identified in Atlantic sturgeon from the St. Johns River, New Brunswick (Appey and Dadswell 1978). No detrimental effects from these parasites were noted in these studies.

The shovelnose sturgeon serves as host for glochidia of three mussel species. Rates of glochidial infestation on fish gills are typically low, but thought not to be detrimental to the host (R.S. Butler, personal communication). Huff (1975) reported tumor-like growths on several Gulf sturgeon ovaries from the Suwannee River. Macroscopic tumors were found from 7.5% of gill-netted females in Fall 1972, 3.5% of females in Spring 1973, and 4.6% of females in Fall 1973. Examination of this material revealed two types of growth (Harshbarger 1975). One was a perifollicular pseudocyst (surrounding follicles) filled with proteinaceous fluid often containing viable oocytes. The other type was a parafollicular serous cyst (a true separate fluid-filled cyst) containing denser proteinaceous fluid. Both types are considered subclinical, having little or no effect on adjacent organs, general ovarian development, fecundity, or spawning behavior. Microscopic slides (RTLA nos. 979 and 980) containing this material were accessioned by the Registry of Tumors in Lower Animals, Smithsonian Institution (Huff 1975). Moser and Ross (1993) reported the capture of six Atlantic sturgeon from the Brunswick River, North Carolina from June to September 1991 and in April 1992. Three of the specimen were in poor condition with abnormalities characterized by deformed mouths, lesions of the ventral buccal region and/or lesions around the eye. Oral, buccal, and ventral lesions or ulterations are common signs of poor water quality. Veterinarians examined another sturgeon from the Brunswick River that died without external evidence of disease and found the liver and heart tissues to be in poor condition.

FACTORS CONTRIBUTING TO THE DECLINE AND IMPEDIMENTS TO RECOVERY

Many members of the family Acipenseridae, including Gulf sturgeon, virtually disappeared throughout their ranges at the turn of the 20th century. Their decline was likely caused by over-exploitation and exacerbated by damming of rivers and other forms of habitat destruction and water quality deterioration, among other factors (Birstein 1993; Huff 1975; Barkuloo 1988; McDowall 1988; Smith and Clugston, unpublished manuscript).

Exploitation

The Gulf sturgeon was heavily fished because of the high value of its eggs used to produce caviar and its flesh for smoking (Carr 1983; J. Barkuloo, personal communication). Sturgeon also provided isinglass, a semi-transparent gelatin prepared from the swim bladder and used in jellies, wine and beer clarification, special cements, and glues. Directed commercial fishing contributed to the depletion of sturgeon populations. Aperiodic commercial landing statistics are available from 1887 to 1985 for Gulf sturgeon (Huff 1975; Futch 1984; Barkuloo 1988). Commercial landings data for the Suwannee River are available for 1981 to 1984 (Tatman, unpublished data). These records show that the only consistent fisheries for Gulf sturgeon occurred in west Florida. There was a directed fishery in Alabama, while there is no record of a directed commercial fishery in Mississippi, only incidental catches. Davis et al., (1970) notes a minor commercial fishery for Gulf sturgeon in the Lake Pontchartrain and its tributaries during the late 1960's.

Recreational and subsistence fishing may have contributed to population declines. A "snatch-hook" recreational fishery was popular on the Apalachicola River, Florida, during the late 1950's to 1960's (Burgess 1963; Swift et al., 1977) and continued until 1984 when the State of Florida enacted protective measures.

Incidental Catch

Incidental catch of Gulf sturgeon in other fisheries has been documented (Wooley and Crateau 1985; D. Mowbray, personal communication; H. Rogillio, personal communication). Incidental captures by commercial shrimpers and gill net fishermen in Apalachicola Bay were noted by Wooley and Crateau (1985) and reported by Swift et al. (1977). Such catches have also occurred in Mobile Bay, Tampa Bay, and Charlotte Harbor (J. Roussos, personal communication; FDEP, unpublished data). The FWS caught a small Gulf sturgeon in St. Andrew Bay while gill-net collecting for seatrout for contaminant analysis in 1986 (M. Brim, personal communication). Gulf sturgeon are occasionally caught in Gulf coast rivers on set-hooks targeting catfish (J. Duffy, personal communication). Captures of young Gulf sturgeon have been reported in blue crab traps in the Suwannee River estuary (F. Tatman, personal communication). The incidental catch of Gulf sturgeon in the industrial bottomfish (petfood) fishery in the north-central Gulf of Mexico from 1959 to 1963 was reported by Roithmayr (1965). The bottomfish fishery worked an area between Point au Fer, Louisiana and Perdido Bay, Florida from shore to water depths of about 55 m (180 ft). Hastings (1983) and Moser and Ross (1993) report capture and disruption of spawning migrations of shortnose and Atlantic sturgeon in commercial gill nets targeted for shad in the Cape Fear River, North Carolina.

The LDWF records indicate 177 Gulf sturgeon were incidentally captured and reported by commercial fishermen in southeastern Louisiana during 1992 (H. Rogillio, personal communication). Forty-four of these Gulf sturgeon were delivered to the LDWF field office or held until LDWF employees could secure them. Specimens were generally held in captivity for 1 to 7 days by the fishermen. These sturgeon were then measured, weighed, tagged and released by departmental personnel. Seventy-six Gulf sturgeon were captured in trawls, 10 in wing nets, and 91 in gill nets. A mortality of less than 1% was noted. This percentage is based on 177 Gulf sturgeon incidentally captured by commercial fishermen and 51 Gulf sturgeon captured by LDWF personnel during a Gulf sturgeon status survey.

Bradshaw (personal communication) reported three tag returns from Gulf sturgeon he collected in early 1985 which were incidentally caught by shrimpers in Mississippi Sound during the fall of that year. He also noted finding three dead Gulf sturgeon incidentally caught by gillnetters in the western part of the Sound and revived another Gulf sturgeon a gillnetter had caught "on" Horn Island in 1989.

Entrainment of *Acipenser guldenstadti* and *A. stellatus* larvae during dredging operations has been assessed by Veshchev (1982) in the lower Volga River, Russia. He concluded that hydraulic dredging operations caused significant mortality of sturgeon larvae in the Caspian basin.

Hastings (1983) reported anecdotal accounts of adult sturgeon being expelled from dredge spoil pipes while conducting a study on shortnose sturgeon on the Atlantic coast. Whether the "adult sturgeon" was an Atlantic or shortnose sturgeon was not indicated in the report.

Habitat Reduction and Degradation

Gulf sturgeon have evolved within Gulf coast drainages that exhibit seasonal patterns of high and low flows, temperature regimes, sedimentation, and other physical factors. Provision of these essential life requirements are part of and dependent on a fully functioning ecosystem.

Dams have limited sturgeon access to migration routes and historic spawning areas (Boschung 1976; Murawski and Pacheco 1977; Wooley and Crateau 1985; McDowall 1988) (Table 1). While sturgeon are able to pass some water control structures, low-head dams, or sills during high water, these structures can create barriers that preclude normal migration. An example of complete migration restriction occurred in the St. Andrew Bay system, Bay County, Florida. A newspaper account from 1895 reports sturgeon were caught at the head of North Bay in upper St. Andrew Bay (Womack 1991). The account notes that an average of three sturgeon a day were caught and 90.7 kg (200 lb) of fish had been smoked and on sale for $0.10 per lb. The FGFC collected four Gulf sturgeon 173.0 to 201.5 cm (68.1 to 79.3 in) in length from Bear Creek, a tributary to Econfina Creek which drains into North Bay, in May of 1961. A dam was placed across North Bay in 1962 preventing anadromous fish migration, and no reports of Gulf sturgeon from above the dam have been reported since that time. Not only was migration to the creeks cutoff, but approximately 2024 hectares (5,000 acres) of estuarine habitat was converted into a fresh water lake.

Another example of complete restriction to Gulf sturgeon migration is the JWLD on the Apalachicola River. Swift et al. (1977) noted a report of a Gulf sturgeon from the Flint River near Albany, Georgia prior to 1950. Huff (1975) noted Gulf sturgeon migrated 322 km

Table 1: Examples of reduction in available river habitat due to dam, water control structure, or sill construction.

River/Watershed	Total River Length	Location of Impediment	Percent Habitat Remaining
St. Andrew Bay Drainage Bear Creek, Lower Econfina Creek, upper North Bay (now known as Deer Point Lake)	11 km (6.8 mi)	Deer Point Dam County Rd 2321	0%
Apalachicola, Chattahoochee, Flint River Basin (to the fall line)	790 km (491 mi)	JWLD river km 172 (river mi 107)	22%
Mobile Bay Drainage Basin Alabama River	1691 km (1051 mi)	Claiborne Dam river km 130 (river mi 81)	8%
Tombigbee River	988 km (614 mi)	Coffeeville Dam river km 121 (river mi 75)	12%
Pearl River	772 km (480 mi)	Ross Barnett Dam (RBD) river km 486 (river mi 302)	63%
During low water conditions		Pools Bluff Sill river km 78.3 (river mi 48.7)	10%
Bogue Chitto River (during low water conditions)	217 km (135 mi)	Boque Chitto Sill river km 6.4 (river mi 4)	3%
Amite River	274 km (170 mi)	control weir river km 40.7 (river mi 25.3)	15%

(200 mi) upstream in the Apalachicola-Chattahoochee-Flint river system before the dam construction in 1957. There are numerous anecdotal reports of Gulf sturgeon in the Flint and Chattahoochee rivers prior to construction of JWLD (Swift et al. 1977). In spite of many tagging studies conducted on the Apalachicola River, no tags have been returned as a result of Gulf sturgeon moving upstream of JWLD, nor does evidence exist that the Gulf sturgeon passes though the lock system (A. Carr, personal communication; U.S. Fish and Wildlife Service, personal communication). The COE (1978) acknowledged that the dam on the Apalachicola River adversely affect Gulf sturgeon by impeding upstream migration.

An example of barriers that limit movement is found in the Pearl River basin above the Pools Bluff and Bogue Chitto Sills. Gulf sturgeon have been reported to be incidentally collected above the Pools Bluff Sill as far north as the Ross Barnett Reservoir spillway as late as 1984 (J. Stewart, personal communication; R. Jones, personal communication; W. McDearman, personal communication; R. Bowker, personal communication). Based on gauge data (COE, personal communication), the duration of water depths allowing passage of Gulf sturgeon over the sills is limited at the Bogue Chitto Sill and less restrictive at the Pools Bluff Sill (Table 2). It appears Gulf sturgeon movement above the sills is also possible through cutoffs that have developed since the construction of the Pearl River navigation canal (H. Poitevint, personal communication). However, Gulf sturgeon migration is entirely prevented above Jackson, Mississippi by the Ross Barnett Dam at river km 515 (river mi 320). Jones (personal communication) reports that Gulf sturgeon were historically found above this area. He notes the capture of a 154.2 kg (340 lb) female Gulf sturgeon 2.3 m (7.5 ft) from the river 32 km (20 mi) north of Jackson in 1942.

Navigation activities including dam construction, dredging, dredged material, and other maintenance actions could adversely affect Gulf sturgeon habitats depending on the location and timing of the activity. Elimination of deep holes and alterations of rock substrates result in loss of habitat for the Gulf sturgeon in the Apalachicola River (Carr 1983; Wooley and Crateau 1985). At Rock Bluff, river km 148.8 (river mi 92.5), this deep, rocky area frequently used by Gulf sturgeon was filled with dredged spoil material drifting downstream from a within bank disposal site at river km 150 (river mi 93) during routine maintenance dredging. This caused Gulf sturgeon to cease use of this area as a regular habitat (Carr 1983, J. Barkuloo, personal communication). The within bank disposal site is no longer used. Essential habitats of young-of-the-year Gulf sturgeon are unknown, so the impacts of dredging on early life stage habitats of Gulf sturgeon are difficult to assess.

Table 2: Duration Data on Lower Pearl River Sills (COE, personal communication).

Depth Over Sill (m)	Percent Equaled or Exceeded	
	Pools Bluff Sill[1]	Bogue Chitto Sill[2]
.3 m (1.0 ft)	100	90
.61 m (2.0 ft)	70	25
.9 m (3.0 ft)	48	10
1.2 m (4.0 ft)	35	-
1.5 m (5.0 ft)	28	-
1.8 m (6.0 ft)	24	-
2.1 m (7.0 ft)	18	-

[1]Duration based on gauge data for Pearl River at Bogulusa, Louisiana
[2]Duration based on gauge data for Bogue Chitto River at Sun, Louisiana

The entrenchment of the Apalachicola River's streambed due to the trapping of sediments in Lake Seminole, has been attributed to the construction of JWLD (COE 1986). The effects entrenchment occurred in the upper third of the river from the base of the dam to the vicinity of Blountstown, Florida. The streambed elevation lowering was also exacerbated by deepening rock sills, cutting out river bends, and repeated dredging to maintain the channel. This has resulted in elimination of some habitats that had been available to Gulf sturgeon during the summer months prior to the construction of JWLD and navigation channels. For example, as a result of streambed degradation, access to spring-fed tributary creeks has been reduced during low water periods. A cooperative effort by the COE and FGFC removed sedimentation and debris from a midstream spring below the JWLD, navigation km 170.6 (navigation mi 106.0) in January 1994. In addition, the COE obtained environmental clearances and unertook habitat restoration action by the removal of sediments at the mouth of Blue Spring Run, navigation 157.7 (river mi 98.0) in May, 1994.

Cool water habitats are thought to be important to Gulf sturgeon during the summer. Cool-water habitats in streams can be significantly reduced or even eliminated by decreased groundwater levels (Lynn Torak, personal communication). Springs emanating from the streambed originate in the groundwater-flow system and are regulated by relative differences in stream stage, spring-discharge elevation, and groundwater level. Decreased groundwater levels in the vicinity of streams, caused by pumping or climatic variation, can reduce springflow that provides cool-water habitats for the Gulf sturgeon during summer months. Pumping or climate-induced groundwater-level declines can reduce the groundwater component of streamflow (baseflow) in addition to and in the absence of springs. For example, a study in the Albany, Georgia area by Torak et al. (1993) indicates that about 74% of water pumped from the Upper Floridan aquifer in November 1985, approximately 79 million gallons a day, would have discharged to the Flint River under predevelopment conditions. The Flint River is generally unregulated and has a major spring-fed flow component that, in comparison with the Chattahoochee River, contributes the larger share of flow to the Apalachicola River during low-flow periods. The Chattahoochee River is a regulated stream that derives its flow predominantly from surface runoff. Consequently, the Chattahoochee River contributes the major portion of flow to the Apalachicola River during mean- to high-water events. Base-flow of the Flint River has been reduced since the early 1970s, mainly from groundwater and surface water irrigation withdrawals (Leitman et al. 1993). The analysis by Leitman et al. (1993) indicates that the Flint River's percent contribution to the Apalachicola River decreases, instead of increasing as would be expected as the flow in the Apalachicola River decreases. Several springs and spring runs along the upper Apalachicola and Flint Rivers have already exhibited greatly reduced flow or have ceased flowing during periods of drought. If these cool water habitats are important and are reduced in size or eliminated at critical periods of summer, Gulf sturgeon could be subjected to increased environmental stress.

Contaminants may also contribute to population declines. Experiments have shown that DDT and its derivatives and toxaphene are toxic to fish in minute quantities (Johnson and Finley 1980; White et al. 1983). Twelve Gulf sturgeon were collected from the Apalachicola, Suwannee, Choctawhatchee rivers, Ochlockonee Bay and the Gulf of Mexico near Cape San Blas, Florida, at various times between 1985 to 1991. This specimens were analyzed for pesticides and heavy metals (Bateman and Brim 1994). The Gulf sturgeon ranged in size from 1.8 to 49.0 kg (4.0 to 108.0 lb). Concentrations of arsenic, mercury, DDT metabolites, toxaphene, polycyclic aromatic hydrocarbons, and aliphatic hydrocarbons high enough to warrant concern were detected in individual fish. Specific sources of contamination were not identified. Suwannee River Gulf sturgeon had higher concentrations of arsenic in liver samples than Apalachicola River fish. However, Apalachicola River Gulf sturgeon had higher liver mercury concentrations. Organochlorine pesticides were also highest in fish from the Apalachicola River.

Organochlorines enter the environment as pesticides or industrial waste products. Use of most of these compounds has been prohibited because of effects on nontarget species and suspected carcinogenicity in humans and wildlife. Effects include reproductive failure, reduced survival of young, or physiological alterations which can affect the ability of the fish to withstand stress (White et al. 1983). Levels of DDT and derivative compounds in the samples were found at low concentrations in all Gulf sturgeon tissues, however, DDD and/or DDE was detected in 84% of the samples (Bateman and Brim 1994). In addition, amounts detected in reproductive tissue, while relatively low (range non-detect to 4.02 ppm), could affect Gulf sturgeon reproduction because DDT compounds are known to be estrogenic (Fox 1992). Like DDT, toxaphene is persistent in the environment and biomagnifies through the food chain. Toxaphene was the most heavily used insecticide after prohibition of DDT in the 1970s. Toxaphene was detected in four fish, all from the Apalachicola River. The level of toxaphene in the roe of one specimen was 14.00 ppm wet weight and exceeded the Food and Drug Administration (FDA) action level of 5.00 ppm for fish for human consumption. The highest level in muscle tissue (0.48 ppm) fell below the FDA action level for human consumption (Bateman and Brim 1994). Toxaphene is more toxic to fishes than DDT compounds (Johnson and Finley 1980) and has been shown to impair reproduction, reduce growth in adults and juveniles, and alter collagen formation in fry, resulting in "broken back syndrome" (Mayer and Mehrle 1977).

Polycyclic aromatic hydrocarbons (PAH), primarily from petroleum products, are known to be carcinogenic, cocarcinogenic and tumorigenic. Concentrations found in the ovarian tissue sample (total PAH 410 ppb; Apalachicola River) and eggs (total PAH 409 and 815 ppb; Suwannee River) could adversely affect development and survival of some percentage of eggs, larval, and juvenile fish (Bateman and Brim 1994). Aliphatic hydrocarbons are components of oils, fuels, and other petroleum products. Two or more aliphatic compounds were detected in all tissue samples of the Gulf sturgeon. Hall and Coon (1988) stated that it is likely that any animal with demonstrated petroleum hydrocarbon residues in the tissues has suffered effects of the pollutant (Bateman and Brim 1994).

Arsenic is used in herbicides, insecticides, and fungicides and can be toxic to fish in certain metabolic forms. The metal was detected in 92% of the Gulf sturgeon samples, however the metabolic form was not identified. The arsenic concentrations detected in all of the muscle tissue samples were greater than the FDA action limit of 0.50 ppm for swine muscle tissue (Bateman and Brim 1994).

Mercury, predominantly found as methylmercury in fish fillets, is highly toxic and was detected in 87% of the Gulf sturgeon samples. The mercury concentrations in muscle tissue were well below the Florida limited consumption advisory (0.50 ppm) and the FDA consumptive use action level (1.00 ppm) but, almost all tissue samples exceeded the predator protection limit of 0.10 ppm recommended by Eisler (1987) for the protection of fish-eating birds. However, the mercury levels of the Gulf sturgeon in the study were well below those reported by Armstrong (1979) for other fish species, to cause either chronic inability to catch food, rolling from side to side or acute toxicity.

Cadmium, a known teratogen, carcinogen, and probable mutagen was detected in 42% of the Gulf sturgeon samples. The concentrations were in the low to normal range for muscle and liver tissue when compared to fish species in the Fisheries Resources Trace Elements Survey (FRTES) of the NMFS (Bateman and Brim 1994). Low levels of lead were detected in 8%.

Culture and Accidental or Intentional Introductions

Where viable wild populations exist or sturgeon possibly can be reintroduced, the potential harm from incidental or accidental introduction of non-endemic species is a threat to the genetic integrity and biodiversity of entire ecosystems. The likelihood of these introductions increases dramatically where imports and culture of exotic species is allowed or facilitated, and even where laws or regulations exist which prohibit release of non-endemic species. Accidental releases from culture facilities and intentional releases by aquarists tiring of their hobby is a frequent occurrence. Schwartz (1972, 1981) identifies bibliographic citations of hybrid combinations between species of sturgeons (Acipenseridae). Therefore, an introduction, for example, of white sturgeon from the Pacific coast into Gulf river systems could potentially do great harm to Gulf sturgeon stocks.

An introduction has already occurred in Alabama. A white sturgeon, 50.1 cm (1.6 ft) TL, was caught by a commercial fisherman on a trotline in Lake Weiss, about 2.4 km (1.5 mi) south of Cedar Bluff, Alabama in 1989 (M. Pierson, personal communication). Lake Weiss is part of the upper Coosa River system flowing through Georgia and Alabama. In 1992 a white sturgeon, 96.0 cm (3.15 ft) TL, was caught by a fisherman in the Coosa River east of Birmingham (Sun Herald 1992). This sturgeon was caught about 100 km (62.1 mi) downstream from the 1989 capture. The white sturgeon is thought to have been accidentally released from a private fish hatchery located adjacent to the Coosa River in Georgia. The State of Georgia confiscated the white sturgeon from the hatchery in 1990.

A controversial fishery management problem revolves around the issue of hatchery stocks' adversely affect wild stocks. Hatchery technology has been employed for salmon in the Pacific Northwest for well over thirty years, but salmon stocks in many river systems have recently experienced significant declines. Biologists and many opponents of the hatchery programs attribute these declines on loss of genetic diversity caused by hatchery programs. Proponents of hatcheries argue that the basis of the problem is failure to protect habitat, manage water resources, control harvest, and prevent environmental contamination, among other factors.

These problems and failures may continue to contribute to reductions in stocks of Gulf sturgeon. The problems are readily evident and appropriate actions should be taken to correct them before or in conjuction with introduction of hatchery stock.

Other

Finally, life history characteristics of Gulf sturgeon may complicate and protract recovery efforts. Gulf sturgeon cannot establish a breeding population rapidly because of the long period they require to achieve sexual maturity. Further, Gulf sturgeon appear to be river-specific spawners, although immature Gulf sturgeon occasionally exhibit plasticity in movement or occurrence among Gulf basin rivers. Therefore natural repopulation may be non-existent or very low by Gulf sturgeon migrating from other rivers.

Fishery Management Jurisdiction, Laws, and Policies

The take of Gulf sturgeon is prohibited in the state waters of Louisiana, Mississippi, Alabama, and Florida. Section 6(a) of the ESA provides for extended cooperation with states for the purpose of conserving threatened and endangered species. The Departments of the Interior and Commerce may enter into cooperative agreements with a state, provided the state has an established program for the conservation of a listed species. The agreements authorize the states to implement the authorities and actions of the ESA relative to listed species recovery. Specifically, the states are authorized (1) to conduct investigations to determine the status and requirements for survival of resident species of fish and wildlife (this may include candidate species for listing), and (2) to establish programs, including acquisition of land or aquatic habitat or interests for the conservation of fish and wildlife. Federal funding is also provided to states under the agreements to implement the approved programs. All four of the above mentioned states have entered into Section 6 agreements with the FWS. More detailed descriptions of pertinent agencies, laws, and regulations are provided in Appendix A.

CONSERVATION ACCOMPLISHMENTS

Caribbean Conservation Corporation/Phipps Florida Foundation

1. Initiated tagging of Gulf sturgeon in 1975, using monel tags, in the Apalachicola and Suwannee Rivers which resulted in evidence of home-river fidelity, yearly growth rates, in-river weight loss, and an estimate of population size.

2. Initiated telemetry studies of Gulf sturgeon in 1976, providing evidence of the importance of the Floridian Aquifer to Gulf sturgeon ecology and in-river site fixity.

3. Initiated consultations which resulted in prohibition of take of Gulf sturgeon in the State of Florida.

Gulf States Marine Fisheries Commission

1. Initiated a Gulf sturgeon interjurisdictional fishery management plan in 1990 which evolved into the Gulf Sturgeon Recovery Plan.

National Biological Service, Southeastern Biological Science Center, (BSC-G formerly U.S. Fish and Wildlife Service), Gainesville, Florida

1. Since 1987 conducted comprehensive population and life history studies of Gulf sturgeon in the middle and lower Suwannee River, Florida, in cooperation with the CCC.

2. Facilitated survival and abundance estimates for Gulf sturgeon in the Suwannee River by FWS Resource Analysis Branch using CCC long-term data.

4. Developing relational database on physical, chemical, and biological characteristics of the Suwannee River for use with geographic information system (GIS) software.

5. Evaluating habitat characteristics in areas Gulf sturgeon are known to occupy during the summer months.

6. Conducted studies on movement of hatchery reared Gulf sturgeon released into the Suwannee River.

7. Conducted feasibility study for offshore sonic tracking of Gulf sturgeon.

8. Initiated field sampling in Tampa Bay and the Waccasassa, Steinhatchee, and Ochlockonee rivers to determine presence of Gulf sturgeon and evaluate existing habitat.

9. Provided an analysis of food habits of subadult and adult Gulf sturgeon in the Suwannee River.

10. Provided an assessment of the water quality of the Suwannee River and impacts of natural and human-induced disturbances on the food resources of the Gulf sturgeon.

11. Instituted and maintained a voucher specimen reference collection of Gulf sturgeon foods and provided expert assistance in identification of food organisms.

12. Devised and tested methods for culture of key foods used to rear Gulf sturgeon; amphipod crustaceans, brandling worm, West-African nightcrawler, blackworm, and tubificid oligochaetes.

13. Participated in first artificial spawning of the Gulf sturgeon at a temporary streamside facility in 1989-1991 and in 1992-1993 at the NBS\BSC.

14. Provided the first documented growth of Gulf sturgeon fed natural foods in a laboratory from fry stage to 17 months.

15. Conducted food preference study on cultured juvenile Gulf sturgeon comparing survivorship and growth between live and commercially prepared foods.

16. Identified critical thermal maximum and preferred temperature for cultured juvenile Gulf sturgeon.

17. Conducted investigations into plasma osmotic and metabolic responses to a wide range of experimental salinities.

18. Evaluating the retention rate of passive integrated transponders (PIT tags) and coded wire tags in cultured Gulf sturgeon.

State of Alabama

Alabama Department of Conservation and Natural Resources

1. Established a regulation in 1972 prohibiting all take of sturgeon within the jurisdiction of the State of Alabama.

2. Conducted literature search and field survey in 1991 and 1992 to determine historic and current status of Gulf sturgeon and possible reasons for apparent decline.

3. Conducted sampling of juvenile Gulf sturgeon on the Alabama River from 1990-1992.

4. Conducted feasibility work in 1992 regarding the use of ADCNR's Claude Peteet Mariculture Center in Gulf Shores, Alabama, as a Gulf sturgeon hatchery for the Mobile system.

Alabama Geological Survey

1. Conducted Gulf sturgeon sampling in the Alabama, Mobile, Conecuh, and Choctawhatchee river systems.

State of Florida

Florida Department of Environmental Protection (formerly Florida Department of Natural Resources

1. Conducted an anadromous fish survey, including Gulf sturgeon, in 1970-1971.

2. Completed the first life history study of Gulf sturgeon in the Suwannee River, Florida from 1972-1973.

3. Conducted a status review of Gulf sturgeon in Florida waters in 1984, and recommended prohibition of all take of the species within the jurisdiction of the State of Florida.

Florida Game and Fresh Water Fish Commission

1. Completed F10-R Anadromous Fish Study from 1964-1967.

2. In 1987 listed the Atlantic sturgeon as a Species of Special Concern in: Official list of endangered and potentially endangered fauna and flora in Florida. Florida Game and Fresh Water Fish Commission. 19 pp.

3. In conjuction with the COE, Mobile District, removed sedimentation and debris from a midstream spring below the JWLD on the Apalachicola River, navigation km 170.6 (navigation mi 106.0), to restore important thermal refuge habitat for the Gulf sturgeon and other anadromous species in January 1994.

Florida Marine Fisheries Commission

1. Established a regulation in 1984 prohibiting all take of sturgeon within the jurisdiction of the State of Florida.

University of Florida

1. Artificial propagation of Gulf sturgeon 1991-1995.

State of Mississippi

Gulf Coast Research Laboratory

1. Distributed Gulf sturgeon posters at boat ramps and other appropriate locations during 1992 in order to acquire information and reports on Gulf sturgeon sightings.

Mississippi Department of Wildlife, Fisheries, and Parks

1. Established a regulation in 1974 prohibiting all take of sturgeon within the jurisdiction of the State of Mississippi.

2. Listed the sturgeon as an endangered species in 1974.

3. Conducted Gulf sturgeon investigation and documentation in the Pascagoula River during 1993.

Mississippi State University

1. Documented Gulf sturgeon presence in the lower Pearl River in 1985 and 1988.

2. Documented incidental catches of Gulf sturgeon in Mississippi in 1989.

3. Investigated and documented Gulf sturgeon in the Pascagoula River in 1993.

State of Louisiana

Louisiana Department of Wildlife and Fisheries

1. Initiated a survey in 1990 to assess the status of Gulf sturgeon in Louisiana waters.

2. Initiated a radio-tracking project in 1992 on Gulf sturgeon in the Pearl River drainage and continuing into 1994.

3. Established a computerized data base in 1991 on all pallid and Gulf sturgeon sightings and captures in Louisiana and continues to be updated as needed.

4. Conducted Gulf sturgeon tagging using T-bar and monel tags beginning in 1992 and ongoing in 1994.

5. Collected blood and tissue samples for genetic analysis beginning in 1991 and ongoing in 1994.

6. Established a regulation in 1990 prohibiting all take of sturgeon within the jurisdiction of the State of Louisiana.

State of Texas

Texas Parks and Wildlife Department

1. Conducted sampling for sturgeon in the Rio Grande in 1992 - 1993.

2. Documented historic distribution of sturgeon in Texas.

U.S. Army Corps of Engineers, Mobile District, Mobile, Alabama

1. Restored access into Battle Bend Cutoff on the Apalachicola River, approximate river km 46.3 (river mi 28.8) in 1987.

2. Conducted flow/velocity studies below the JWLD to document velocities in Gulf sturgeon habitat areas during low flow conditions during November 1991 and October 1992, as

part of a Biological Assessment associated with the Jim Woodruff Powerhouse Major Rehabilitation Evaluation Report.

3. In conjuction with the FGFC, removed sedimentation and debris from a midstream spring below the JWLD on the Apalachicola River, navigation km 170.6 (navigation mi 106.0), to restore important thermal refuge habitat for the Gulf sturgeon and other anadromous species in January 1994.

4. Obtained environmental clearances and undertook action to restore habitat for the Gulf sturgeon and other anadromous species by removal of sediments at the mouth of Blue Spring Run, Apalachicola River, navigation km 157.7 (river mi 98.0) in March 1994, under the Department of the Army/National Oceanic and Atmospheric Administration Cooperative Agreement to Create and Restore Fish Habitat.

5. Initiated Anadromous Fish Hatchery Reconnaissance Study in 1987.

6. During January 1994, the COE proposed that the Waterways Experiment Station (WES) consider in the FY 1995 Environmental Impact Research Program (EIRP) a proposal to document issues affecting the protection of sturgeon related to O&M activities in North American rivers. This proposal was submitted because of similar concerns expressed by other COE divisions and districts that operation and maintenance (O&M) projects may impact sturgeon populations. It is also proposed to quantify responses of sturgeon to broad ranges of relevant physical conditions so that risk from O&M activities can be predicted. Districts will be surveyed for specific issues on sturgeon and the scope of problems will be defined. The District has been informed from COE headquarters that funds are available for WES to initiate efforts in FY 1995.

U.S. Army Corps of Engineers, Vicksburg District, Vicksburg, Mississippi

1. Funded a study conducted by WES on Gulf sturgeon in the Pearl River during 1994 and 1995.

U.S. Fish and Wildlife Service

Fisheries Resources Office, Panama City Field Office, Florida

1. First documented in-river habitat usage of Gulf sturgeon in 1977.

2. First documented Gulf sturgeon spawning in the Apalachicola River, Florida in 1977.

3. Investigated methods of externally marking Gulf sturgeon beginning in 1981.

4. Documented the movement of Gulf sturgeon in the Apalachicola River using radio and sonic telemetry devices beginning in 1982.

5. Estimated the Gulf sturgeon population size in the Apalachicola River below JWLD beginning in 1983.

6. Reviewed and validated the morphometric characteristics used in the taxanomic separation of Gulf and Atlantic sturgeon in 1985.

7. Developed field techniques and equipment which aided in the handling of Gulf sturgeon in 1985.

8. Investigated the age structure of Gulf sturgeon in the Apalachicola River by utilizing cross-sections from pectoral fin rays beginning in 1986.

9. Initiated artificial propagation of Gulf sturgeon in 1989.

10. Collected samples for and funded genetic studies on Gulf sturgeon throughout their range beginning in 1990.

11. Collected samples for and funded contaminant tissue analyses of Gulf sturgeon from the Apalachicola and Suwannee rivers, Florida beginning in 1990.

12. Initiated a program through news releases and information posters to document Gulf sturgeon sightings (past and present) from Tampa Bay, Florida to the Mississippi River in 1992.

13. Funded development of a dual radio-sonic telemetry tag in 1992.

14. Compiled and maintained a directory/data base of sturgeon and paddlefish researchers beginning in 1992.

17. Produced a report entitled Gulf Sturgeon Sightings, Historic and Recent - a Summary of Public Responses in 1993.

18. Conducted field investigations to develop a population model for the Gulf sturgeon and to delineate riverine habitat requirements in 1993 and 1994, in cooperation with the NBS, North Carolina Cooperative Fish and Wildlife Research Unit.

Ecological Services, Panama City, Florida

1. Funded preparation of an information report on the Gulf sturgeon, entitled: Gulf of Mexico Sturgeon, *Acipenser oxyrhynchus* (Vladykov), Information. 1980. Unpublished. 15 pp. J.L. Hollowell.

2. Completed a document entitled: Report on the Conservation Status of the Gulf of Mexico Sturgeon *Acipenser oxyrhynchus desotoi* in 1988.

3. **Prepared report entitled, Reconnaissance Report on the Feasibility of Constructing an Anadromous Fish Hatchery Apalachicola River, Florida for the COE, Mobile District in 1989.**

4. **Initiated the proposal to list the Gulf sturgeon under the ESA.**

5. Coordinated development of Gulf Sturgeon Management/Recovery Plan from 1992 to 1995.

Ecological Services, Jacksonville, Florida

1. Prepared the listing package to list the Gulf sturgeon as a threatened species under the ESA (listed September 30, 1991 in conjuction with the Department of Commerce-NOAA).

Ecological Services, Jackson, Mississippi

1. Produced a Mobile River Basin Aquatic Ecosystem Recovery Plan in 1995.

Warm Springs Regional Fisheries Center, Georgia

1. Developed Gulf sturgeon artificial feeding program in 1989.

Welaka National Fish Hatchery, Florida

1. Hormone induced spawning of Gulf sturgeon beginning in 1989.

2. Developed Gulf sturgeon artificial feeding program in 1989.

Gulf Coast Fisheries Coordination Office, Ocean Springs, Mississippi

1. Participated as a technical advisor in development of the Gulf sturgeon Management/Recovery Plan from 1992 to 1995

Memorandum of Understanding (MOU) on Implementation of the Endangered Species Act.

Fourteen federal agencies including the COE, NMFS, FWS, NPS, DOD, MMS, CG and EPA signed the MOU in September of 1994. The purpose of the MOU was to establish a general framework for cooperation and participation among the agencies in accordance with responsibilities under the ESA. The agencies are to work together along with appropriate involvement of the public, states, Indian Tribal governments, and local governments, to achieve the common goal of conserving species listed as threatened or endangered under the ESA by protecting and managing their populations and the ecosystems upon which those populations depend. The cooperating federal agencies involved in recovery of the Gulf sturgeon will now be able to work closer together under the umbrella of this MOU.

II. RECOVERY AND FISHERY MANAGEMENT

OBJECTIVES AND CRITERIA

Objectives constitute those results that are desired to be attained through implementation of the Recovery Plan. Criteria are those factors that define how attaining the objective will be pursued, and what will constitute sucess.

1. Short-term Objective: The short-term recovery objective is to prevent further reduction of existing wild populations of Gulf sturgeon within the range of the subspecies. This objective will apply to all management units within the range of the subspecies. Ongoing recovery actions will continue and additional actions will be initiated as needed.

   Criteria:

   A. Management units will be defined using an ecosystem approach based on river drainages. This approach may also incorporate genetic affinities among populations in different river drainages.

   B. A baseline population index for each management unit will be determined by fishery independent catch-per-unit-effort (CPUE) levels.

   C. Change from the baseline level will be determined by fishery independent CPUE over a three to five year period. This time frame will be sufficient to detect a problem and to provide trend information. The data will be assessed annually.

   D. The short-term objective will be considered achieved for a management unit when the CPUE is not declining (within statistically valid limits) from the baseline level.

2. Long-term Objective A: The long-term recovery objective is to establish population levels that would allow delisting of the Gulf sturgeon by management units. Management units could be delisted by 2023 if the required criteria are met. While this objective will be sought for all management units, it is recognized that it may not be achievable for all management units.

   Criteria:

   A. The timeframe for delisting is based on known life history characteristics including longevity, late maturation, and spawning periodicity.

   B. A self-sustaining population is one in which the average rate of natural recruitment is at least equal to the average mortality rate over a 12-year period (which is the approximate age at maturity for a female Gulf sturgeon).

C. This objective will be considered achieved for a management unit when the population is demonstrated to be self-sustaining and efforts are underway to restore lost or degraded habitat.

3. Long-term Objective B: This is a long-term fishery management objective to establish, following delisting, a self-sustaining population that could withstand directed fishing pressure within management units. Note that the objective is not necessarily the opening of a management unit to fishing, but rather, the development of a population that can sustain a fishery. Opening a population to fishing will be at the discretion of state(s) within whose jurisdiction(s) the management unit occurs. As with Long-term Objective A, this objective may not be achievable for all management units, but will be sought for all units.

Criteria:

A. All criteria for delisting must be met.

B. This objective will be considered attained for a given management unit when a sustainable yield can be achieved while maintaining a stable population through natural recruitment.

C. Particular emphasis will be placed on the management unit that encompasses the Suwannee River, Florida, which historically supported the most recent stable fishery for the subspecies.

These objectives and criteria are preliminary. After better identification of population status and evaluation of the adequacy of the habitat to support self-sustaining populations, these objectives and criteria may be revised. The criteria stated above will be more quantitatively defined through identification of management units and through population assessments in those individual management units.

OUTLINE FOR RECOVERY ACTIONS ADDRESSING THREATS

Recovery Outline Narrative

1.0 Determine essential ecosystems, identify essential habitats, assess population status, and refine life history investigations in management unit rivers.

As an initial step to enhance the long-term recovery of populations of Gulf sturgeon, collection of basic biological information is essential. Without a clear understanding of life history requirements, recovery efforts are severely hampered. Presently, lack of information in the marine environment and sparse information in the riverine environment make it difficult to adequately census populations or to implement appropriate recovery actions. Studies to provide this information should be conducted as soon as possible.

1.1 Identify essential habitats important to each life stage in river basin and contiguous estuarine and neritic waters.

Investigations are needed to locate and describe the micro- and macrohabitat characteristics critical for recovery and maintenance of the Gulf sturgeon. Radio and ultrasonic tracking studies of juveniles and adults will help determine movements and habitat utilization over time. Emphasis should be placed on tracking Gulf sturgeon in the estuarine and marine environment where it is believed that most feeding and growth occurs, and where the least information is available. Spawning areas and larval and post-larval movements and distribution within rivers must be determined. When a sufficient number of animals has been monitored and distributions identified, habitat characterization studies can be used to better define essential habitat requirements. Significant ecosystems for the recovery of the Gulf sturgeon will be identified once essential habitats are defined in riverine, estuarine, and marine environments

1.1.1 Conduct and refine field investigations to locate important spawning, feeding, and developmental habitats.

Gulf sturgeon have been successfully tracked with radio and ultrasonic transmitters in riverine systems. These studies have been limited to a very few locations, and usually for a short time spans. Multi-year tracking studies in the estuarine and marine environment have never been accomplished. Knowledge of spawning areas, developmental habitat requirements and feeding requirements are essential to the recovery of Gulf sturgeon in all river basins across the range of the species. Tracking studies appear to be the best way to initially locate important habitat. Technological advances in telemetry should facilitate long-term tracking studies to provide the needed information. The FWS and NBS should expand their efforts to identify and inventory essential habitats of Gulf sturgeon. The Gulf states resource management agencies should continue or initiate studies to identify essential habitats in their respective states. The CCC should continue their multi-year monitoring program on the Suwannee River. New field work by other researchers such as universities and non-government organizations (NGOs) should incorporate this research need into their plans. The NMFS should work with FWS and NBS to identify marine habitats used by adult Gulf sturgeon during winter migration. The MMS should seek funding to obtain this information because of the potential for impacts to the Gulf sturgeon from outer continental shelf oil and gas operations and other non-energy mineral mining activities.

1.1.2 Characterize riverine, estuarine, and neritic areas that provide essential habitat.

When areas of utilization have been delineated (Task 1.1.1), characterization of these habitats should be conducted. Characteristics of the areas regarding particular life history requirements of Gulf sturgeon at various life stages must be determined. Among the parameters that may be important include substrate, depth, instream flow, current, pH, temperature, turbidity, and food availability. The Gulf states resource management agencies, FWS, NMFS, NBS, CCC, NGOs, and universities should refine their studies or surveys to provide these data.

1.2 Conduct life history studies on the biological and ecological requirements of little known or inadequately sampled life stages.

Because of the difficulty in collecting eggs, larvae, and adequate numbers of Gulf sturgeon less than a year old, essentially nothing is known about requirements of these life stages in the wild. Year-class strength is established during these stages, and water temperature, salinity, flow, turbidity, and other factors affect survival rates. As outlined in Task 1.1, intensive field investigations must be initiated to locate and characterize habitats used by early life stages. Likewise laboratory studies on wild and cultured Gulf sturgeon must be conducted to evaluate habitat requirements and tolerances. The University of Florida, NBS, and FWS should expand ongoing investigations into the biology and ecology of Gulf sturgeon. Non-fatal sampling techniques to examine stomach contents need to be determined. Diet studies of fish captured in estuaries should be expanded. Diet of Gulf sturgeon captured offshore (neritic environments) should also be evaluated, not only to assess food preferences, but also to determine habitat use.

It is known that subadult and adult Gulf sturgeon spend winters feeding in estuarine and marine waters. Little is known about specific areas and habitat requirements. Ultrasonic techniques should be improved and studies conducted to document marine habitats frequented by Gulf sturgeon. Identified habitats must be described by depth, water quality, substrate, and food availability. The FWS and NBS should continue ongoing marine habitat investigations of Gulf sturgeon. The NMFS should initiate marine habitat investigations of Gulf sturgeon.

1.3 Survey, monitor, and model populations.

Intensive field investigations have concentrated on Gulf sturgeon life history in the Suwannee and Apalachicola rivers in Florida. Additionally, long-term monitoring of Gulf sturgeon in these systems has resulted in reliable population estimates with which population models are being developed. Outside these systems, few studies have been conducted on the Gulf sturgeon. Information such as distribution, relative abundance, age structure and other biological information should be compiled to identify baseline population status and identify index monitoring sites to evaluate success of recovery and management programs.

1.3.1 Develop and implement standardized population sampling and monitoring techniques.

The assessment of Gulf sturgeon populations Gulfwide are essential to develop and evaluate recovery and management efforts. Standardized programs to address size, age and sex composition, and stock size must be developed so that the condition of each stock can be evaluated over time and compared with those in other river systems. Government agencies, NGOs, and universities investigating Gulf sturgeon should participate in a coordinated effort to develop standardized sampling and monitoring techniques and conduct appropriate programs. Standard operating procedures will facilitate application of statistical data set comparisons between various Gulf coast river systems. In addition, fishery management/recovery decisions could be more accurately formulated with uniform data collection and reporting procedures. The FWS should take the lead in coordinating, preparing and distributing a standardized sampling and monitoring protocol document. The Gulf states resource management agencies should evaluate the status of populations of Gulf sturgeon in their streams and coastal waters. The FWS and NBS in conjunction with other researchers should verify current aging techniques for Gulf sturgeon.

1.3.2 Develop population models.

Modeling is needed to better assess fishery restoration and management options. Capture-recapture models can estimate survival, abundance and recruitment of Gulf sturgeon. Population models should be developed to forecast the future condition of Gulf sturgeon populations and provide estimates on potential rates of recovery. Appropriate models will also help identify future research needs. The FWS and NBS should continue to take the lead in formulating peer accepted population models for the Gulf sturgeon.

1.4 Continue experimental culture of Gulf sturgeon.

Successful artificial propagation of Gulf sturgeon was first accomplished in 1989. Additional work is still needed to refine culture techniques, develop handling and holding procedures for fry and broodstock, maintaining genetic diversity of broodstock, research nutritional requirements and initiate fish health management. In addition, research is needed to document the optimum chemical and physical parameters necessary for maintaining growth and survival of Gulf sturgeon under artificial and natural conditions.

1.4.1 Continue culture of Gulf sturgeon.

State, federal, and NGOs should continue to develop culture techniques for Gulf sturgeon in accordance with the Gulf Sturgeon Hatchery Guidelines, Hatchery Manual for White Sturgeon protocols addressed in the Gulf Sturgeon Recovery Plan, and state and federal laws and regulations. Efforts should be directed towards filling data gaps (i.e. hormone dosages and types, incubation temperatures, egg de-adhesion methods, broodstock reproductive staging, elimination of stress related to capture, handling, and holding, among other factors).

1.4.2 Identify the physical, chemical and biological parameters necessary to maintain growth, health and survival of Gulf sturgeon reared under artificial conditions.

Studies are needed to determine the optimum water quality conditions necessary to maintain growth and survival of fry and fingerlings. In addition, nutritional requirements and artificial feeding methods need to be identified. Research is required to document carrying capacity for various fish rearing facilities, and hauling densities of fry and fingerlings. The FWS, researchers, and universities should continue to implement additional studies to address this need. Also, the FWS should take the lead in providing updated information on artificial propagation of Gulf sturgeon.

1.4.3 Identify and test internal and external markers or techniques useful for differentiation of wild and hatchery-produced Gulf sturgeon.

The identification of non-genetic internal and external markers to differentiate between wild and hatchery-produced Gulf sturgeon is important in the development and regulation of hatchery programs. Unique markers (i.e. PIT tags, coded wire tags, and chemical marking) could allow investigators, law enforcement officers, and others to distinguish hatchery-reared fish from wild stocks. In addition, these markers or techniques may be used in selective enhancement programs and provide a means to evaluate introductions. The FWS and other researchers should continue to investigate and develop useful internal and external markers or techniques.

1.5 Identify genetic characteristics of wild and hatchery-reared Gulf sturgeon.

Research is needed to determine whether or not significant genetic differences exist among Gulf sturgeon from throughout the range of the subspecies. Determining whether genetic differences exist among populations is essential to ensure successful recovery and management of the subspecies. Genetically distinct management units may be identified and could affect reintroduction and/or population augmentation.

1.5.1 Conduct a Gulfwide genetic assessment to determine geographically distinct management units.

Determination of the genetic structure for Gulf sturgeon is essential in formulating future management decisions for the subspecies. It is important that sound restoration efforts of Gulf sturgeon address the genetic structure of the subspecies in order to identify and maintain genetic integrity and diversity. Mitochondrial DNA analysis of Gulf sturgeon should be continued with emphasis placed on obtaining Gulf sturgeon tissues and/or blood from the following river systems:

1. Pascagoula River, Mississippi.
2. Mobile and Alabama rivers, Alabama.
3. Ochlocknee River, Florida.
4. Escambia River, Florida.

A genetic tissue bank should be established and curated where state or federal agencies deposit tissue or blood for genetic analysis. The Gulf states resource management agencies, universities, NGOs, NBS, FWS, and other Gulf sturgeon researchers should establish tissue collection protocol and insure that tissue samples are collected whenever possible.

1.5.2 Assess the potential to develop genetic markers to differentiate wild and hatchery-produced Gulf sturgeon.

The development of genetic markers for differentiating between wild and hatchery produced Gulf sturgeon may be important in the development and regulation of hatchery programs. A unique genetic marker could allow investigators, law enforcement officers, and others to distinguish hatchery reared fish from wild stocks. In addition, hatchery stocks possessing a different genetic mark from wild fish may be used in selective enhancement programs and provide a means to evaluate their introductions. The FWS and NMFS should continue to investigate the potential of viable genetic markers.

2.0 Protect individuals, populations, and their habitats.

In efforts to recover listed species, protection is the most obvious initial step. By virtue of their endangered or threatened status, species may not be able to sustain continuing losses of individuals, and steps should be taken immediately to eliminate any known preventable take. Initial measures to protect individuals, populations, and their habitats can be strengthened or reduced as new information is collected.

2.1 Reduce or eliminate unauthorized take.

Under the ESA, take means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." "Harm" in the definition of "take" in the ESA means an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. "Harm" in the definition means an act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. In the case of the Gulf sturgeon, the immediate concern is with lethal or injurious take by non-directed fisheries. Directed fisheries for listed species are prohibited by virtue of the listing. However, a number of fisheries targeting other species use fishing gear that take Gulf sturgeon.

2.1.1 Increase effectiveness and enforcement of state and federal take prohibitions.

Directed take of the Gulf sturgeon is prohibited under the ESA and laws or regulations of Louisiana, Mississippi, Alabama, and Florida. All states within the geographic distribution of the Gulf sturgeon have cooperative agreements with the FWS that require enforcement of federal endangered species laws. Both federal and state officials are empowered to enforce prohibitions on the take of Gulf sturgeon. Appropriate steps should be taken to support and enhance enforcement activities related to restoration and protection of Gulf sturgeon. The Gulf states resource management agencies should evaluate their enforcement programs and if needed, implement appropriate enhancements or actions. The FWS and NMFS should insure that during ESA section 7 consultations, incidental take is stipulated to provide full protection of the species.

On July 1, 1975, the Atlantic sturgeon (*Acipenser oxyrinchus*, including the Gulf sturgeon) was included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The effect of this listing is that CITES permits are required before international shipment may occur.

2.1.2 Reduce or eliminate incidental mortality.

Incidental catch and mortality of Gulf sturgeon is a difficult or cryptic problem to address because it requires a knowledge of effort and catch composition in a variety of different fisheries. Gear types used in many fisheries are capable of capturing Gulf sturgeon, and it is essential that the magnitude of the problem in each fishery is known before effective steps can be taken to reduce or eliminate mortality. A limited observer program may be needed to evaluate the amount/extent of incidental take or mortality in some fisheries and navigation-related and other activities. When problem fisheries or other activities have been identified, gear or equipment modifications, seasonal restrictions, limited gear or equipment deployment times, and other measures may be employed to reduce mortality of Gulf sturgeon and allow the affected fisheries or other activities to continue to operate.

If incidental take is found to be related to any fishery, the NMFS and the Gulf states should promulgate adequate regulations that protect the Gulf sturgeon from such incidental take. The NMFS should also evaluate Turtle Excluder Devices (TEDs) in commercial shrimp nets to determine if they are effective in allowing Gulf sturgeon to escape from trawls. If they are not effective, funding should be sought to investigate the appropriate gear technology. The NMFS should also fund an observer program, enforcement of regulations, and other necessary actions which reduce or eliminate incidental take of Gulf sturgeon during fishing operations.

In addition, the NMFS and FWS in cooperation with the responsible federal agency should develop methodologies that would cause Gulf sturgeon to avoid areas during navigation-related (includes O&M) activities, Clean Water Act (CWA) Sections 10 and 404, or other construction activities. The NMFS and FWS should assure that the objective of ESA section 7 consultation is to reduce or eliminate incidental take during such activities. As an example, section 7 consultation for a dredging project may result in the COE permitting the activity to occur only during seasons when Gulf sturgeon are not present in the action area.

2.2 Identify and eliminate known or potentially harmful chemical contaminants, and water quantity and water quality problems which could impede recovery of Gulf sturgeon.

Chemical contaminants, water quantity, and water quality factors may have contributed to the decline or are limiting the recovery of Gulf sturgeon. These factors include pesticides (organochlorines), metals (lead, mercury, etc.), industrial byproducts, temperature, pH, suspended solids, dissolved oxygen, water depth, and water velocity. Review of existing data and information is necessary to refine or identify the chemical and water quality and quantity requirements of Gulf sturgeon.

An information search for each management unit or coastal habitat area regarding potential types of chemical contaminant loading, including chemicals from point sources, agriculture, silviculture, industrial activities and urbanization, should be conducted. Existing chemical contaminant field evaluation reports (water, sediment or biota studies) should be examined and the information utilized to make decisions related to field sampling and chemical analysis. Field sampling of water, sediments, and sentinel and/or surrogate species should be conducted, as necessary, to fill critical information gaps. State agencies in Louisiana, Mississippi, Alabama, and Florida, with assistance from the Environmental Protection Agency (EPA) and FWS should collect existing information and provide an assessment report with recommendations. The FWS should provide coordination between the federal and state agencies as needed, compile state reports, and identify a consensus priority listing of chemical contaminant sources that may have impacts on Gulf sturgeon in the river systems. The EPA "Priority Pollutants" for each management unit or habitat area should be assessed by chemical analyses for Gulf sturgeon and other benthic species. The FWS and EPA, using the compiled contaminant data, should prepare the list and conduct necessary analyses.

2.2.1 Identify potentially harmful chemical contaminants and water quality and quantity changes associated with surface water restrictions.

A comprehensive inventory of river basins with existing surface water restrictions is needed to document physical and biological impacts that may negatively affect recovery and management of Gulf sturgeon. The GSMFC, FWS, and COE should coordinate preparation of this inventory with GSMFC taking the lead for final product completion.

2.2.2 Identify and eliminate potentially harmful point and non-point sources of chemical contaminants.

Significant point sources and high-impact non-point source areas of contaminant introductions should be identified. Appropriate actions to reduce or eliminate the contaminants should be taken. With the results of 2.2.1, EPA and state agencies in Louisiana, Mississippi, Alabama, and Florida should take actions to enforce existing regulations or promulgate new ones.

2.2.3 Assess selected contaminant levels in Gulf sturgeon from management units.

Gulf sturgeon tissue analyses should be conducted to evaluate selected chemical contaminants. Appropriate actions should be taken to reduce or eliminate contaminant sources. The EPA should take the lead in efforts to reduce or eliminate identified contaminant sources through their regulatory authorities. The EPA could also assist state agencies in Louisiana, Mississippi, Alabama, and Florida in enforcement of state regulations. During the Triennial Review of state water criteria, EPA should ensure that the states have incorporated adequate water quality standards to protect the Gulf sturgeon and its benthic habitat.

Routine, standardized inspections should be conducted on all incidental catches of Gulf sturgeon (alive or dead) for the presence of gross lesions, tumors or other abnormalities to focus evaluation on chemical contaminants.

Histopathological examinations of liver tissue for cases of incidental Gulf sturgeon mortalities should be conducted to detect the presence of cellular abnormalities or carcinogenic cells.

Chemical analyses of selected tissues should be conducted from incidental mortalities of Gulf sturgeon. The FWS should take the lead in developing protocol to collect samples, conduct training if necessary, process samples for analyses, and prepare summaries of results. Wherever possible, Gulf state resource management agencies should conduct similar analyses.

Appropriate surrogate species should be utilized to better define bio-accumulation of contaminants in particular river basins. An extrapolation formula for estimating potential chemical contaminant impacts to Gulf sturgeon should be developed. The FWS and EPA should lead the efforts to identify appropriate surrogate species, conduct bio-accumulation studies, and develop an extrapolation formula. Appropriate peer review should be conducted during formula development.

2.2.4 Identify and eliminate known and potential impacts to water quantity and quality associated with existing and proposed developments, agricultural uses, and water diversions in management units.

Domestic and industrial effluent, rural and urban run-off, and inter- and intra-water diversions affect the clarity, pH, biological oxygen demand, nutrient and contaminant composition, temperature, sediment loads, and seasonal quantity of river waters. A comprehensive inventory of known or potential problem areas associated with these factors is needed. Once identified, actions to reduce or eliminate problems and promote wise land use should be taken. With the results of 2.2.1, EPA and Gulf states resource management agencies should take actions to enforce existing regulations or promulgate new ones.

Water quality and sediment factors resulting from point and nonpoint sources may negatively affect Gulf sturgeon habitat. Examples include total dissolved solids, suspended solids, turbidity, siltation, pH, temperature, and changes in sediment types. Studies to assess the effect of river water and sediment quality should be conducted to determine the habitat suitability for Gulf sturgeon.

2.2.5 Assess the relationship between groundwater pumping and reduction of groundwater flows into management units, and quantify loss of riverine habitat related to reduced groundwater in-flows.

Groundwater diversions which affect flows into management unit rivers should be identified. The loss of riverine groundwater flows attributed to diversions should be quantified and its effect on Gulf sturgeon evaluated. The U. S. Geological Survey (USGS) should take the lead in implementing appropriate studies including modelling. The Tri-State Study for the Alabama-Tallapoosa-Coosa and Apalachicola-Chattahoochee-Flint river basins funded by the COE and Alabama, Georgia, and Florida should incorporate an effort to provide a preliminary assessment of the effects of groundwater pumping into the groundwater scope of work plan.

2.2.6 Conduct studies to determine the effects of known chemical contaminants in water from management unit rivers on Gulf sturgeon or a surrogate species.

After identification of priority contaminants, physiological and behavioral responses of Gulf sturgeon life stages to long-term exposures to such chemicals should be determined. In particular, newly fertilized eggs, Gulf sturgeon larvae, and juvenile Gulf sturgeon should be tested. The EPA should work with the FWS to conduct bioassays of water from the management unit rivers to determine effects on Gulf sturgeon.

2.3 Develop a regulatory and/or incentive framework to ensure that essential habitats, streamflow, and groundwater in-flows are protected.

Where existing laws and regulations are inadequate to meet recovery objectives, appropriate state and federal agencies should propose new incentives, laws, and/or regulations.

2.3.1 Utilize existing authorities to protect habitat and, where inadequate, recommend new incentives, laws, and regulations.

The ESA provides for the protection and recovery of the Gulf sturgeon and its habitats. Likewise individual Gulf states have regulations and laws for that purpose. Adequate funding levels must be provided to enforce existing protection measures and laws. Federal and state natural resource law enforcement programs are understaffed and underbudgeted to adequately enforce laws protecting the Gulf sturgeon and its habitats. Even with adequate funding, existing authorities may be inadequate to fully protect the Gulf sturgeon and its habitats. Adoption of new incentives, laws or regulations may be necessary to ensure the recovery of the species. Protection measures should be based on the biological requirements of the subspecies and not political boundaries. The FWS should ensure protection of the Gulf sturgeon through the ESA section 7 consultation process with other federal agencies including the COE (federal projects, Section 10/404 permits), MMS (OCS oil and gas lease sales), EPA (National Pollutant Discharge Elimination System permits, Triennial Review).

2.3.2 Identify, protect and/or acquire appropriate land or aquatic habitats on an ecosystem approach.

Habitat components of the Gulf sturgeon which provide essential life requirements should be considered as part of and dependent on a fully functioning ecosystem . These ecosystems should be protected and/or acquired. The Gulf states resource management agencies, FWS, and NMFS should seek appropriate avenues of funding and take action to acquire, manage, and protect identified significant habitats or their ecosystems as appropriate.

For example, spawning habitats should receive maximum protection from disturbance. In order to protect specific habitats, the ecosystem where it occurs also requires protection. Thus, protection of spawning habitats of the Apalachicola River would include the upper 20 km (12.4 mi) of the river and its surrounding basin components. Another example includes the maintenance of habitats such as the springs that occur in the Suwannee River. To protect these springs, it is essential to maintain other ecosystem components including upstream water quality, groundwater flows and quality, and adjacent floodplains.

2.4 Restore, enhance, and provide access to essential habitats.

Gulf sturgeon have evolved within Gulf coast drainages exhibiting seasonal patterns of high and low flows, temperature regimes, sedimentation, and other physical factors which historically may have been much different than those which exist today. The restoration and enhancement of some river and stream habitats, particularly benthic habitat, within the historical range of the Gulf sturgeon may be necessary before its recovery is successful. Within some drainages, man's alterations (mainstem dams, low-head diversions) may be preventing Gulf sturgeon from gaining access to important habitats essential to some aspect of its life history. If such structures are identified as impeding migration or preventing access to critical habitats, action should be taken to restore the natural hydrography or provide a viable bypass route around the structure.

2.4.1 Identify dam and lock sites that offer the greatest feasibility for successful restoration of and to essential habitats (i. e., up-river spawning areas).

Mainstem and low-head diversion dams that are known to be impeding potentially viable Gulf sturgeon populations from reaching historically essential habitats need to be identified. The extent of important habitat types upstream from such structures (e.g., potential spawning sites and summer refugia) should be evaluated.

The GSMFC should take the lead in identifying these sites throughout the Gulf states and preparing summary and recommendations. Federal and non-federal permitted dams should be identified. The COE, FERC, and entities such as the Pearl River Valley Water Supply District should investigate ways of mitigating impacts of federal and private water resource projects or permitted activities on Gulf sturgeon populations.

2.4.2 Evaluate, design, and provide means for Gulf sturgeon to bypass migration restrictions within essential habitats.

The structures preventing upstream migrations to essential habitats should be modified or removed to allow for Gulf sturgeon passage. Specific modifications will depend on the type of obstruction, river hydrology and the importance of the habitat to the recovery of the species in that particular ecosystem. Studies regarding Gulf sturgeon behavior may be required to assist in development and design of fish passages. Modifications which provide for both up- and downstream travel by large and small fish need be considered.

First, an assessment of existing modifications should be conducted. The assessment should consider the effectiveness of the modification for use by other migratory species such as shad and striped bass. Designs should be solicited from engineering and environmental consultants. Passage structures which show promise must be evaluated to document the relative degree of usage by Gulf sturgeon. The NMFS, COE, NBS, FWS, and Federal Energy Regulatory Commission (FERC) should investigate the use of potential passage structures and initiate action or studies to assess the structure's effectiveness for Gulf sturgeon passage.

2.4.3 Operate and/or modify dams to restore the benefits of historical flow patterns and processes of sedimentation.

The operating schedules of the dams need to be evaluated to determine if water releases are benefiting the life history requirements of the Gulf sturgeon. The operations of existing structures found to be detrimental to the life cycle of Gulf sturgeon should be evaluated to determine if modifications to approximate historical flow and sedimentation patterns are possible. The COE and FERC in coordination with the GSMFC, Gulf states resource management agencies, FWS, and NMFS should identify potential modifications to and/or operations of dams and initiate action or studies to assess the feasibility for implementation.

2.4.4 Identify potential modifications to specific navigation projects to minimize impacts which alter riverine habitats or modify thermal or substrate characteristics of those habitats.

Navigation projects that have altered or modified the thermal characteristics or natural substrates of rivers should be evaluated to determine if modifications to approximate historical conditions are possible. The COE should assist the FWS in its efforts to define and protect Gulf sturgeon spawning and other essential habitats in federal project areas. The COE should study, seek funding, implement or take appropriate remedial actions to rectify navigation projects where feasible.

2.4.5 Restore the benefits of natural riverine habitats.

Dams and channel modifications have reduced habitat diversity within the range of the Gulf sturgeon. Diversity of riverine habitat (e.g., main channel, side channel, backwater and braided channel) promotes a corresponding faunal diversity. The Gulf sturgeon evolved in natural riverine settings where such diversity was prevalent. Gulf sturgeon survival could be expected to be compromised if the benefits of riverine habitat diversity are not restored. The FWS should work with the COE to identify ways to restore and protect natural river habitat diversity.

2.4.6 Seek optimum consistency between the purposes of federal and state authorized reservoirs, flood control projects, navigation projects, hydropower projects, and federal and state mandated restorations of fish populations.

Many water projects, such as hydropower and flood control dams and navigation activities, are authorized by state and federal governments for their respective purposes. Also, there are many state and federal programs authorized to restore declining fish populations. Examples include species listed under the ESA, anadromous fisheries addressed under the Anadromous Fish Conservation Act, and coastal fisheries addressed under the Interjurisdictional Fisheries Act and the Magnuson Fisheries Conservation and Management Act.

All government authorized and proposed projects and mandates should be reviewed in order to evaluate the potential to achieve recovery of Gulf sturgeon. The GSMFC should facilitate a multi-agency effort to identify project mandates and prepare a summary and recommendation report in partnership with the appropriate state and federal agencies. Recommendations should be forwarded to each of the States of Louisiana, Mississippi, Alabama, and Florida's State legislature and congressional delegation.

2.5 Maintain genetic integrity and diversity of wild and hatchery-reared stocks.

Major conservation issues that must be addressed by this recovery program relative to health of stocks, genetic conservation of stocks and displacement of stocks. A major concern in any stock restoration and enhancement program is the potential impact of introduced fish on existing wild stocks. This impact can affect wild stocks by a variety of mechanisms:

1. Disease and parasite transfer.
2. Behavioral and ecological interference.
3. Genetic consequences of interbreeding, reduction in gene flow, introduction of strains susceptible to disease.

Problems resulting from failure to protect habitat, to control fishing pressure, to ensure correct management of water resources, to control environmental contamination, and to effectively manage other parameters have contributed to reductions in stocks of Gulf sturgeon. These problems are readily evident and appropriate actions can be taken to correct them. At this point, the potential adverse effects of initiating a stocking program are unknown. The potential effects of initiating any stocking program should be evaluated. An experimental hatchery and strictly limited release program to the wild is prudent until such time as stocking has been thoroughly evaluated.

2.5.1 Evaluate the need to stock hatchery-produced Gulf sturgeon considering habitat suitability and current population status.

An assessment of whether stocking hatchery-produced fish will benefit the overall recovery of the Gulf sturgeon is paramount to the future development of Gulf sturgeon hatchery programs. An evaluation of whether the rivers to be stocked have suitable habitat to support the stocked fish, natural reproduction, and any progeny should be conducted. The recovery of the subspecies cannot be based on a "put and take" Gulf sturgeon fishery. Government agencies, NGOs, and universities investigating Gulf sturgeon should conduct an evaluation of each river system that is under consideration for stocking on the ability of the system, at its current status, to support the stocked fish and assure that natural reproduction can occur. Only ongoing improvements to the river systems should be included in the analyses. Each of the Gulf states resources management agencies should evaluate the river systems in their states. The FWS should take the lead in coordinating the assessment and preparing a summary finding report. No stocking should be conducted without approval by appropriate state agencies.

If it is determined that there is a need for stocking, the stocking should be secondary to other recovery efforts that identify essential habitats and emphasize habitat restoration. The COE should continue to work with the FWS in efforts to construct a permanent hatchery on the Apalachicola River to help in the restoration and maintenance of the Apalachicola River Gulf sturgeon population if it is determined that stocking is necessary for recovery of the subspecies.

2.5.2 Develop policy and guidelines for hatchery and culture operations related to stocking.

Raising hatchery produced fish to a size large enough to overcome lack of suitable habitat increases survival. Also, at larger sizes, these fish can be tagged and recovered, enabling assessment of the efficacy or success of the stocking effort. Peer review and evaluation of a particular stocking effort should be included in any proposal to release hatchery-reared Gulf sturgeon. Gulf states resource management agencies, GSMFC, FWS, NMFS, NGOs, universities, and other involved researchers should prepare a hatchery and culture operations plan relating to stocking policy/guidelines. The FWS should take the lead in coordinating, seeking peer review, and completing the document.

2.5.3 Develop and implement a regulatory framework to eliminate accidental and intentional introductions of non-indigenous stock or other sturgeon species.

Release of hatchery-reared fish without a program of monitoring does not fulfill government's role as a steward of renewable natural resources. Monitoring and systematic assessment of stocks will assist in determining the impact of accidental and intentional releases of non-indigenous stock or other sturgeon species. This recovery plan recognizes that it is irresponsible to intentionally release fish without review or concurrence from the recovery team or coordinator, and therefore undocumented intentional releases should not occur. In the case of federal agencies who undertake actions that may affect a listed species (stock introductions), consultation with FWS and/or NMFS is required under section 7 of the ESA.

At a minimum, the recommendations of the Aquatic Nuisance Species Task Force (ANSTF) which was established under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 should be conducted. The task force developed recommendations regarding direct introductions and indirect, accidental release from public and private sector facilities. All State agencies within the subspecies' range and GSMFC, FWS, NBS, NMFS, NGOs, universities, and other involved researchers should prepare a consensus policy regarding introduction of non-indigenous sturgeon stocks into the range of Gulf sturgeon in accordance with the options or actions identified by the ANSTF to reduce risks and adverse consequences associated with introductions. States should implement necessary actions for promulgating regulations consistent with the policy.

3.0 Coordinate and facilitate exchange of information on Gulf sturgeon conservation and recovery activities.

Any research and/or management activities on fish species which transcend jurisdictional boundaries must be coordinated. Management and recovery actions must be consistent across the range of the subspecies in order to be effective. Gulf sturgeon recovery efforts will be enhanced by the coordination of activities and exchange of information regarding the biology and management of all sturgeon species.

3.1 Coordinate research and recovery actions.

Coordination activities involving state and federal resource management agencies, NGOs, and universities with an interest in the Gulf sturgeon should be conducted at least every two years. Such coordination will provide for studies and management plans which will reduce duplication of effort, enhance cooperation, and optimize agency manpower and funding. The FWS and GSMFC should take the lead in conducting the coordination activities.

3.2 Develop an effective communication program or network for obtaining and disseminating information on recovery actions and research results.

All recovery participants including state and federal agencies, NGOs, and universities working on Gulf sturgeon are strongly urged to publish research findings in technical publications. Unpublished reports (gray literature), bibliographies, and available data on Gulf sturgeon should be compiled and published or otherwise made available to all participants. Acquiring, disseminating, and maintaining information regarding Gulf sturgeon recovery activities should be centralized. The FWS should take the lead in collecting and centralizing information regarding Gulf sturgeon recovery activities.

In order to ensure effective communication among the various entities involved in Gulf sturgeon research, recovery and management, a newsletter should be developed and disseminated on a regular basis. This newsletter would provide all interested parties with the most up-to-date information regarding progress toward achieving the goals of the Recovery Plan. The FWS should take the lead in preparing, printing, and disseminating the newsletter and coordinating with other existing sturgeon newsletters.

3.3 Develop a non-scientific constituency and public information program directed toward enhancing recovery actions.

In order for Gulf sturgeon recovery actions to be successful, the general public must be aware of such actions and understand the need for them. An information and education program must be developed to inform the public of the causes of the decline of Gulf sturgeon, to increase the public's awareness, understanding, and involvement in Gulf sturgeon recovery efforts and to promote wise use of land in watersheds. Educational materials such as brochures, newspaper and magazine articles, publications, posters, and slide and television presentations, among others, must be produced and disseminated to target audiences, such as commercial and recreational fishermen, boaters, and civic organizations. The Gulf states resource management agencies, FWS, NBS, and NMFS should seek funding for the development of educational material for dissemination to the public. The FWS or GSMFC should take the lead in coordinating this effort providing a centralized location for storage of information if necessary.

4.0 Implement recovery program.

Existing budgets of involved agencies and other parties are not capable of fully funding the Gulf sturgeon recovery plan. Competition for funding under the ESA is intense, partly due to the low level of appropriations to the program and the increasing number of listed species. In order to assure that actions which would result in recovery of the Gulf sturgeon are implemented, funding for activities must be secured and a designated lead recovery office must be identified. Involvement of NGOs, and universities should be solicited.

4.1 Designate and fund a Gulf sturgeon recovery lead office.

Funding to support a FWS recovery lead office must be identified to coordinate a multi-agency, multi-disciplinary recovery implementation committee. The lead office should document all research, recovery, and management information and plans. Work would be combined with other FWS duties. The lead office should be in a location which facilitates coordination with all Gulf sturgeon activities. The lead office should be funded until the Gulf sturgeon is considered recovered according to the Recovery Plan.

4.2 Seek funding for Gulf sturgeon recovery activities.

The recovery lead office, with support from involved agencies, NGOs, universities, and the public should seek to bring high visibility to the need for funding of Gulf sturgeon recovery activities. Funding strategies to acquire Congressional appropriations and other funding sources should be developed. The recovery lead office should facilitate this effort and coordinate a unified funding package for Gulf sturgeon recovery activities in the southeast.

4.3 Implement projects or actions which will achieve recovery plan objectives.

Based on the recovery plan, a series of specific projects will be identified which could bring about improvements in the habitat or stock condition of Gulf sturgeon in specific river systems throughout the range of the species. Projects should be submitted to the appropriate agencies or funding sources for consideration. The Gulf states resource management agencies should be given first opportunity to implement the identified projects, through joint efforts with FWS, NBS, NMFS, universities, NGOs, or other interested researchers.

4.4 Develop and implement a program to monitor population levels and habitat conditions of known populations in the management units as well as newly discovered, introduced, or expanding populations.

The status of the subspecies and its ecosystems should be monitored to assess any progress toward recovery while recovery actions are ongoing and following completion of actions. A standardized assessment program should be designed by a multi-agency group coordinated by the recovery lead office and the GSMFC. The Gulf states resource management agencies, federal agencies, universities, NGOs, and other researchers should conduct an annual assessment of the management unit population levels in their area of responsibility or as appropriate. The recovery lead office should maintain, collate, and review the assessments preferably on an annual basis but at least every two years. This information should be summarized for distribution and used in the Congressionally required biennial species status reports.

5.0 Monitor recovery program.

A recovery plan benefits a species only if it is implemented. The plan and its implementation must be strong enough to provide adequate guidance to species managers but be flexible enough so that it may be changed or revised to recover the species. In addition, the FWS and NMFS are required by Congress to track the status of all listed species and the implementation of recovery plans, financial expenditures for each species or clusters of species, and status of recovered species.

5.1 Assess overall success of the recovery program and recommend action.

The recovery program must be evaluated periodically to determine if it is making progress in achieving recovery objectives and to recommend future actions. These actions could include changes in recovery objectives, continuing or increasing protection, implementing new measures, revising recovery plans and recommending delisting. The recovery program should be preferably evaluated annually but at least biennially. The recovery lead office should be responsible for collection of the required information and preparation of the Congressional reports. As part of this effort, the lead office should prepare standardized reporting forms so that the affected parties can easily provide the necessary information. Reporting requirements should continue for five years after the delisting of the Gulf sturgeon.

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III. IMPLEMENTATION SCHEDULE

The Implementation Schedule indicates task priorities, task numbers, task descriptions, duration of tasks, potential or participating parties, and lastly, estimated costs (Table 3). These tasks, when accomplished, will bring about the recovery objectives for the Gulf sturgeon as discussed in Part II of this plan.

Parties with authority, responsibility, or expressed interest to implement a specific recovery task are identified in the Implementation Schedule. When more than one party has been identified, the proposed lead party is indicated by an asterisk (*). The listing of a party in the Implementation Schedule does not imply a requirement or that prior approval has been given by that party to participate or expend funds. However, parties willing to participate will benefit by being able to show in their own budget submittals that their funding request is for a recovery task which has been identified in an approved recovery plan and is therefore part of the overall coordinated effort to recover the Gulf sturgeon. Also, Section 7(a)(1) of the ESA directs all federal agencies to utilize their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of threatened and endangered species.

Following are definitions to column headings and keys to abbreviations and acronyms used in the Implementation Schedule:

Task Number & Task: Recovery tasks as numbered in the recovery outline. Refer to the Narrative for task descriptions.

Priority Number: All priority 1 tasks are listed first, followed by priority 2 and priority 3 tasks.

Priority 1 - All actions that must be taken to prevent extinction or to prevent the subspecies from declining irreversibly in the foreseeable future.

Priority 2 - All actions that must be taken to prevent a significant decline in subspecies population/habitat quality, or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to provide for full recovery (or reclassification) of the species.

Task Duration: Years to complete the corresponding task. Study designs can incorporate more than one task, which can reduce the time needed for task completion.

Underway - Task already being implemented.

Continuing - Task necessary until recovery.

Responsible or Participating Party: Federal or state government agencies or universities (party) with the responsibility and/or capability to fund or carry out the corresponding recovery task.

FWS Region - FWS Regions (only states in the Gulf sturgeons's range are listed)
- 2 - Albuquerque (Texas)
- 4 - Atlanta (LA, MS, AL, FL)

FWS Program - Division or program of the FWS
- FF- Fisheries
- FRO- Fisheries Resources Office
- ES- Ecological Services
- LE- Law Enforcement
- WNFH- Welaka National Fish Hatchery
- WSRFC- Warm Springs Regional Fisheries Center
- GCFCO- Gulf Coast Fisheries Coordination Office

Other Federal Agencies
- COE - U.S. Army Corps of Engineers
- EPA - U.S. Environmental Protection Agency
- MMS - Minerals Management Service
- NMFS - National Marine Fisheries Service
- FERC - Federal Energy Regulatory Coummission
- NBS - National Biological Service/Southestern Biological Science Center Gainesville, FL
- NRCS - Natural Resources Conservation Service

State Agencies
- GSRMA - Gulf States Resource Management Agencies
  - Louisiana Department of Wildlife and Fisheries
  - Mississippi Department of Wildlife, Fisheries, and Parks
  - Alabama Department of Conservation and Natural Resources
  - Florida Department of Environmental Protection
  - Texas Parks and Wildlife Department
- CES - Cooperative Extension Service (all GSRMA)

Other Parties
- GSMFC - Gulf States Marine Fisheries Commission
- CCC - Caribbean Conservation Corporation
- UF - University of Florida

Cost Estimates: Estimated fiscal year cost, in thousands of dollars, to complete the corresponding task. The costs associated with a task or party represent the estimated dollar amount to complete the task and are not necessarily the fiscal responsibility of the associated party.

Study designs can incorporate more than one task, which when combined can reduce the cost from when tasks are conducted separately. Cost for implementing "continuing" recovery tasks are in excess of what is displayed for the five years in the schedule.

Comments: Additional information if appropriate.

TABLE 3. IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

Priority	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY			ESTIMATED FISCAL YEAR COSTS ($000)										COMMENTS
				FWS		OTHER	FY 1		FY 2		FY 3		FY 4		FY 5		
				Region	Program		FWS	Other	FWS	Other	FWS	Other	FWS	Other	FWS	Other	
1	1.3.1	Develop and implement standardized population sampling and monitoring techniques	underway	4	FF* FRO-PC	NBS* GSRMA COE	1 6	30 20 2	1 20	30 20 2	7 40	30 32 5	1 40	30 32 5	1 40	30 32 5	Tasks 1.1.1, 1.3.1, 2.5.1, and 1.5.1 can be conducted concurrently
1	2.5.3	Develop and implement a regulatory framework to eliminate acidental and intentional introductions of non-indigenous stock or other sturgeon species	1	4	FF FRO-PC* ES-PC GCFCO	NBS* GSRMA GSMFC UF			5 8 2 2	2 4 1 1							Some of this effort will be dependent on the outcome of 2.5.1
1	2.1.2	Reduce or eliminate incidental mortality	underway continuing	4	FRO-PC* ES	GSMFC* GSRMA NMFS	15	15 20 75	15	15 20 75	15	15 20 75		75		25	Majority of funding for fish excluder devices & sampling protocols
1	2.4.5	Restore the benefits of natural riverine habitats	underway continuing	4	ES FRO-PC GCFCO	NBS COE GSRMA	2 2 2	2 10 8	10 2 2	2 20 12	10 2 2	2 20 12	20 5 3	3			Wk funded under existing programs. Actual restoration costs undetermined.
1	2.3.1	Utilize existing authorities to protect habitat and where inadequate, recommend new incentives, laws, and regulations	underway continuing	4	ES* GCFCO	EPA* COE GSRMA GSMFC	5 3	5 5 8 3	5 3	5 5 8 3	5 3	5 5 8 3	5 3	5 5 8 3			Section 7 consultation conducted with existing program funds
2	2.1.1	Increase effectiveness and enforcement of state and federal take prohibitions	continuing	4	LE FF* ES*	NMFS* GSRMA*	75	75 180	75	75 180	75	75 180	75	75 180	75	75 180	Sec 7 consultation will be conducted under existing programs. Add. monitoring or law personnel may be necessary
2	1.1.1	Conduct and refine field investigations to locate important spawning, feeding, and developmental habitats	underway continuing	4	FF FRO-PC* GCFCO	NBS* GSRMA COE CCC UF	1 5 1	20 60 5 10 1	1 58 1	20 60 5 10 1	1 70 2	20 80 5 10 2	1 70 2	20 80 5 12 2	1 70 5	20 80 5 12 5	Tasks 1.1.1, 1.3.1, 2.5.1, and 1.5.1 can be conducted concurrently

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY: FWS Region	RESPONSIBLE PARTY: FWS Program	RESPONSIBLE PARTY: OTHER	FY 1 FWS	FY 1 Other	FY 2 FWS	FY 2 Other	FY 3 FWS	FY 3 Other	FY 4 FWS	FY 4 Other	FY 5 FWS	FY 5 Other	COMMENTS
2	1.1.2	Characterize riverine, estuarine, and neritic areas that provide essential habitat	underway continuing	4	FRO-PC*	NBS* CCC GSRMA COE	5	15 2 28 5	20	15 2 28 5	70	15 3 40 5	70	15 3 40 5	10	15 3 40 5	Tasks 1.1.1 and 1.1.2 can be conducted concurrently
2	1.2	Conduct life history studies on the biological and ecological requirements of little known or inadequately sampled life stages	underway continuing	4	FRO-PC*	NBS* CCC GSRMA	5	25 2 28	20	25 2 28	20	25 3 40	40	25 3 40	40	25 3 40	Tasks 1.1.1 and 1.1.2, and 1.2 can be conducted concurrently
2	2.2.1	Identify potentially harmful chemical contaminants and water quality and quantity changes associated with surface water restrictions	3	4	ES-PC*	EPA GSRMA	25	10 40	15	10 100	75						Cost and time to complete year 2 efforts will be dependent on information collection in year 1.
2	2.2.2	Identify and eliminate potentially harmful point and non-point sources of chemical contaminants	4	4	ES-PC	EPA* GSRMA NRCS			20	10 28	25	15 40	25		25		
2	2.4.6	Seek optimum consistency between the purposes of federal and state authorized reservoirs, flood control, navigation, and hydropower projects and federal and state mandated restorations of fish populations	continuing	4	ES GCFCO	GSMFC* FERC COE NMFS				10		5		5		5	Most agency related wk., funded under existing programs

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY: FWS Region	FWS Program	OTHER	ESTIMATED FISCAL YEAR COSTS ($000): FY 1 FWS	FY 1 Other	FY 2 FWS	FY 2 Other	FY 3 FWS	FY 3 Other	FY 4 FWS	FY 4 Other	FY 5 FWS	FY 5 Other	COMMENTS
2	2.4.1	Identify dam and lock sites that offer the greatest feasibility for successful restoration of and to essential habitats	1	4	ES-PC FRO-PC	GSMFC* COE GSRMA			5 2	15 10 20							
2	2.4.4	Identify potential modifications to specific navigation projects to minimize impacts which alter riverine habitats or modify thermal or substrate characteristics of those habitats.	underway continuing	4	ES FRO-PC GCFCO	FERC* COE* NMFS GSRMA GSMFC	5 5 5	10 10 2 8 5	5 5 5	10 10 2 8 5	2 2 2	5 5 2 4 2					Some funding under existing programs. Proj. mod. costs undetermined and may require Congress. auther. & non-federal sponsor
2	4.3	Implement projects or actions which will achieve recovery plan objectives	underway continuing	4	FF FRO-PC	GSRMA* NGOs											Individual project funding ID elsewhere in schedule
2	4.2	Seek funding for Gulf sturgeon recovery activities	underway continuing	4	ES* GCFCO	NBS GSMFC GSRMA											Funded under existing programs
2	2.2.4	Identify and eliminate known and potential impacts to water quantity and quality associated with existing and proposed developments, agricultural uses, and water diversions in management units	continuing	4	ES	NBS EPA* GSRMA NRCS	2	2 2 8	10	5 20 8	75	5 20 8	75	5 20	75	20	Amount of effort will be determined by outcome of task 2.2.1
2	2.2.5	Assess the relationship between groundwater pumping and reduction of groundwater flows into management units, and quantify loss of riverine habitat related to reduced groundwater in-flows	2	4	ES	USGS* GADNR						252		125			Mostly funded under the Tri-state Comp Study- AL,GA,FL

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY			ESTIMATED FISCAL YEAR COSTS ($000)										COMMENTS
				FWS		OTHER	FY 1		FY 2		FY 3		FY 4		FY 5		
				Region	Program		FWS	Other	FWS	Other	FWS	Other	FWS	Other	FWS	Other	
3	2.5.1	Evaluate the need to stock hatchery-produced Gulf sturgeon considering habitat suitablity and current population status	underway	4	FF FRO-PC ES-PC GCFCO	NBS GSRMA	1 1 1 1	5 8	1 3 1 1	10 8	1 5 2 1	10 4	1 10 2 1	10 4	1 10 2 1	10 13	Tasks 1.1.1, 1.3.1, 2.5.1, and 1.5.1 can be conducted concurrently
3	1.5.1	Conduct a Gulfwide genetic assessment to determine geographically distinct management units	underway	4	FF* FRO-PC GCFCO	NBS GSRMA NGOs	15 8 2	1 3 1	15 48 1	1 100 1							Majority of samples and analyses completed 1995. Will continue to completion.
3	2.2.3	Assess selected contaminant levels in Gulf sturgeon from management units	underway continuing	4	FF* ES*	EPA* GSRMA	15		30	10 20	30	10 20	10	5 20			Study on adult fish across FL panhandle completed 1994. Study on juvenile fish, Suwannee River completed 1995.
3	1.3.2	Develop population models	underway continuing	4	FF FRO-PC	NBS NMFS GSRMA NGOs	5 15	15 2 8 2	5 5	15 2 8 2	20						
3	4.1	Designate and fund a Gulf sturgeon recovery lead office	continuing	4	ES* FF		7 3		7 3		7 3		7 3		7 3	7 3	Majority of funding provided under other recovery actions
3	1.4.1	Continue culture of Gulf sturgeon	underway	4	WNFH WSRFC* FRO-PC	NBS LDWF ADNCR UF	3 2 1	2 3 3 5	23 25 10	2 3 3 5	23 25 10	2 5 5 5	23 25 10	2 5 5 10	23 25 10	2 5 5 10	

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY			ESTIMATED FISCAL YEAR COSTS ($000)										COMMENTS
				FWS		OTHER	FY 1		FY 2		FY 3		FY 4		FY 5		
				Region	Program		FWS	Other	FWS	Other	FWS	Other	FWS	Other	FWS	Other	
3	2.2.6	Conduct studies to determine the effects of known chemical contaminants in water from management units on Gulf sturgeon or a surrogate species	4	4	ES-PC* WNFH WSRFC	EPA NBS			75 5	10 5	75 5	10 5	75		75		WNFH & NBS may provide specimens for the studies
3	2.4.3	Operate and/or modify dams to restore the benefits of historical flow patterns and processes of sedimentation	underway continuing	4	ES FRO-PC GCFCO	FERC* COE* NMFS GSMFC											Some funding under existing programs. Project mod. costs underterm. May require Congress. authority & non-federal sponsor.
3	2.3.2	Identify, protect, and/or acquire appropriate land or aquatic habitats on an ecosystem approach	underway continuing	4	FF FRO-PC ES-PC* GCFCO RW	NBS NMFS GSRMA NGOs											ID conducted with other studies. Land acquis. & water rights costs undeterminable.
3	2.4.2	Evaluate, design, and provide means for Gulf sturgeon to bypass migration restrictions to essential habitats	continuing	4	ES FF	FERC* COE* NMFS				10 10		25 25		25 25		25 25	FWS & NMFS funded under exist. progs. Studies conducted or infrastructure funded by COE & FERC. May req. Congress. auth. & non-fed sponsor.
3	3.1	Coordinate research and recovery actions	continuing	4	ES* FF GCFCO	NBS GSMFC*	5	5	10 5 5	2 15	5	5	10 5 5	2 15	5	5	Funding for interval workshops
3	2.5.2	Develop policy and guidelines for hatchery and culture operations related to stocking	2	4	FF FRO-PC* ES-PC GCFCO	NBS* GSRMA GSMFC UF			5 5 2 2	2 4 1 1					5 10 5 5	2 4 2 15	Conducting this effort will be dependent on the outcome of 2.5.1
3	3.2	Develop an effective communication program or network to obtain and disseminate information on recovery actions and research results	continuing	4	ES*	GSMFC CES			5	5 2	5	5 2	5	5 2	5	5 2	Funding for producing and distributing quarterly newsletters

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY			ESTIMATED FISCAL YEAR COSTS ($000)										COMMENTS
				FWS		OTHER	FY 1		FY 2		FY 3		FY 4		FY 5		
				Region	Program		FWS	Other	FWS	Other	FWS	Other	FWS	Other	FWS	Other	
3	3.3	Develop a non-scientific constituency and public information program directed toward enhancing recovery actions	underway continuing	4	FF* ES* GCFCO CES	GSMFC* NMFS GSRMA			5 5 8	10 5	5 5 8	10 5	5 5 8	5	2 2 8	5	
3	1.5.2	Assess the potential to develop genetic markers to differentiate wild and hatchery-produced Gulf sturgeon	ongoing	4	FF* ES	NMFS UF			25 25	10 10	25 25	10 10					Funding this task dependent on task 1.4.3 decision
3	1.4.2	Identify physical, chemical and biological parameters necessary to maintain growth, health, and survival of fish reared under artificial conditions	underway continuing	4	WNFH WSRFC*	NBS UF LDWF ADNCR	5 5	10 5 3 3	5 20	10 5 3 3	10 20	10 8 5 5	10 20	10 8 5 5	10 20	10 10 5 5	Continuation of this effort dependent on the outcome of 2.6.1.
3	1.4.3	ID and test non-genetic internal and external markers or techniques to differentiate wild and hatchery-produced Gulf sturgeon	2	4	FF FRO-PC*	NBS CCC GSRMA			25 5	5 2 4	25 5	5 2 4					Funding this task dependent on task 1.4.3 decision
3	4.4	Develop and implement a program to monitor levels and habitat conditions of known populations in the management units as well as newly discovered, introduced, or expanding populations	continuing	4	ES* FRO-PC	NBS CCC GSRMA	1 5	5 5 20	5 5	5 5 20	1 5	5 5 20	5 5	5 5 20	1 5	5 5 20	
3	5.1	Assess overall success of the recovery program and recommend action	continuing	4	ES*		2		2		2		2		2		

APPENDIX A

FISHERY MANAGEMENT JURISDICTIONS, LAWS AND POLICIES AFFECTING THE GULF STURGEON

APPENDIX A

FISHERY MANAGEMENT JURISDICTIONS, LAWS AND POLICIES AFFECTING THE STOCKS:

Gulf sturgeon may utilize both fresh water and marine habitats at different times of the year. Excursions into the territorial waters (Exclusive Economic Zone) of the United States may occur. This factor in its biology, together with its range, subject the subspecies to the regulatory jurisdictions of the federal government as well as the States of Alabama, Louisiana, Mississippi and Florida. Numerous state and federal legislative and regulatory actions may affect the stocks. The following is a partial list of some of the more important agencies and regulations that affect the Gulf sturgeon and its habitat. State agencies should be consulted for specific and current state laws and regulations.

Federal Management Institutions. Although some recreational and subsistence harvests of Gulf sturgeon have occurred at times, the primary fishery for the sturgeon has been commercial. Because Gulf sturgeon fisheries have occurred primarily in state waters, federal agencies historically have not directly managed the stocks; though, the federal government has maintained commercial fishery landing records on the subspecies for about the past 100 years. Nonetheless, a variety of federal agencies, through their administration of laws, regulations and policies, may influence Gulf sturgeon stocks.

Regional Fishery Management Councils. With the passage of the Magnuson Fishery Conservation and Management Act (MFCMA), the federal government assumed responsibility for fishery management within the Exclusive Economic Zone (EEZ). The EEZ is contiguous to the territorial sea, with an inner boundary at the outer boundary of each coastal state. The outer boundary continues out 200 miles. Management of the EEZ is to be based on fishery management plans developed by regional fishery management councils. Each council prepares plans, with respect to each fishery requiring management, within its geographical area of authority and amends such plans as necessary. Plans are implemented as federal regulation through the Department of Commerce (DOC).

Among the guidelines, under which the councils must operate, are standards which state that, to the extent practicable, an individual stock of fish shall be managed as a unit throughout its range and that management shall, where practicable, promote efficiency, minimize costs and avoid unnecessary duplication (MFCMA Section 301a).

The Gulf of Mexico Fishery Management Council has not developed, nor is it considering, a management plan for the Gulf sturgeon. Furthermore, no significant fishery for the subspecies exists in the EEZ of the U.S. Gulf of Mexico.

Department of Commerce, National Oceanic and Atmospheric Administration (NOAA).

National Marine Fisheries Service. The Secretary of Commerce, acting through the NMFS, has the ultimate authority to approve or disapprove all fishery management plans prepared by regional fishery management councils. Where a council fails to develop a plan, or to correct an unacceptable plan, the Secretary may do so. The NMFS also collects data and statistics on fisheries and fishermen, performs research, and conducts management authorized by international treaties. The NMFS has the authority to enforce the Magnuson Act and the Lacey Act and is the federal trustee for living and nonliving natural resources in coastal and marine areas under United States jurisdiction pursuant to the Endangered Species Act, Section 107(f) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund"), Section 311(f)(5) of the Clean Water Act (CWA), Executive Order 12580 of January 23, 1987, and Subpart G of the National Oil and Hazardous Substances Pollution Contingency Plan.

The NMFS exercises no management jurisdiction of the Gulf sturgeon, other than permitting scientific or incidental take under the Endangered Species Act and enforcement. The NMFS conducts some research and data collection programs and comments on all projects that affect marine fishery habitat under the Fish and Wildlife Coordination Act and Section 10 of the Rivers and Harbors Act.

The NMFS has entered into a Cooperative Agrrement with the Department of the Army to Restore and Create Fish Habitat. Under this agreement, the NMFS and the COE coordinate efforts to identify federal projects that could be modified to enhance fish habitat.

Office of Ocean and Coastal Resource Management (OCRM). The OCRM asserts its authority through the National Marine Sanctuaries Program pursuant to Title III of the Marine Protection, Research, and Sanctuaries Act (MPRSA). The OCRM Estuarine Sanctuary Program has designated Looe Key in Monroe County, Rookery Bay in Collier County, the Apalachicola River and Bay in Franklin County, Florida, and Weeks Bay in Baldwin County, Alabama, as estuarine sanctuaries.

The OCRM may influence fishery management for Gulf sturgeon indirectly through administration of the Coastal Zone Management Program and by setting standards and approving funding for state coastal zone management programs. Some states in the Gulf utilize a portion of these monies in their habitat protection and enhancement programs including reef maintenance and enhancement.

Department of the Interior (DOI).

National Park Service (NPS). The NPS under the DOI may regulate fishing activities within national park boundaries. Such regulations may affect Gulf sturgeon within specific parks. The NPS has authority to protect fishes and fish habitat primarily through the establishment of coastal and nearshore national parks and national monuments. Everglades National Park in Florida and the Mississippi District of Gulf Islands National Seashore are two examples of national park areas where Gulf sturgeon may occur.

U.S. Fish and Wildlife Service. The authority of the FWS to affect the management of the Gulf sturgeon is based primarily on the Endangered Species Act and the Fish and Wildlife Coordination Act. The FWS is the lead agency in developing the recovery plan for the subspecies under the Endangered Species Act. Under the Fish and Wildlife Coordination Act, the FWS, in conjunction with the NMFS, reviews and comments on proposals to alter habitat. Dam construction, drainage projects, channel alteration, wetlands filling and marine construction are projects that can potentially affect the Gulf sturgeon. Further, the FWS may seek mitigation of fishery resource impairment due to federal water-related development. The FWS has the responsibility to focus efforts on nationally significant fishery resources. The FWS also facilitates restoration by rebuilding certain major, economically valuable, anadromous, endangered, threatened, and interjurisdictional (managed by two or more states) fishery resources to full, self-sustainable productivity. Because the Gulf sturgeon is a threatened and an anadromous species, the FWS has conducted studies on various aspects of the subspecies' biology.

Gulf sturgeon occur in the aquatic portions (riverine, estuarine, marine) of national wildlife refuges (NWR) such as Pine Island NWR, Island Bay NWR, Passage Key NWR, Pinellas NWR, Chassahowitzka NWR,Cedar Keys NWR, Lower Suwannee NWR, St. Marks NWR, St. Vincent NWR, Florida, Bon Secour NWR, Alabama, Bogue Chitto NWR, Louisiana and Mississippi, and Delta NWR, Breton Island NWR, Bayou Sauvage NWR, Lacassine NWR, Louisiana. Fish and wildlife populations and their harvest within refuges are usually managed by the respective state which the refuge is located. Special use permits are required for commercial fishing on national wildlife refuges.

<u>National Biological Service.</u> The National Biological Service (NBS) is the Department of Interior's newest bureau. The NBS was created November 11, 1993, by consolidating the biological research, inventory, monitoring, and information transfer programs of seven Interior bureaus: FWS, NPS, MMS, USGS, Bureau of Land Management, Bureau of Reclaimation, and Office of Surface Mining. The Southeastern Biological Service Center (Center), Gainesville, Florida, of NBS was formerly a research center for FWS. The Center has conducted research on Gulf sturgeon since 1987 and will continue work in this area as requested by FWS and other agencies.

<u>Environmental Protection Agency.</u> The EPA, through its administration of the Clean Water Act, National Pollutant Discharge Elimination System (NPDES), may provide protection to Gulf sturgeon habitat. Applications for permits to discharge pollutants may be disapproved or conditioned to protect fresh and estuarine aquatic resources.

U.S. Department of the Army, Corps of Engineers. Gulf sturgeon habitat may be influenced by the COE's regulatory responsibilities pursuant to the Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. Under these laws, the COE may authorize proposals to dredge, fill and construct in navigable waters (Section 10) or to discharge dredged or fill material into wetland areas and waters of the United States (Section 404). Such proposals could affect Gulf sturgeon habitat. The COE is also responsible for planning, construction and maintenance of dams, navigation channels and other projects that may affect Gulf sturgeon habitat.

Treaties and Other International Agreements. There are no treaties or other international agreements that affect the Gulf sturgeon. No foreign fishing applications for Gulf sturgeon harvest have been submitted to the United States government.

Federal Laws, Regulations and Policies. The following Federal laws, regulations and policies may directly and indirectly influence the habitat, populations and ultimately the management of the Gulf sturgeon.

Anadromous Fish Conservation Act (AFCA). The AFCA authorizes the Secretary of the Interior to initiate cooperative programs with the states to conserve, develop and enhance the nation's anadromous fisheries. The Act authorizes construction, installation, maintenance and operation of structures to improve or facilitate feeding, spawning and free migration of anadromous fish.

Coastal Zone Management Act and Estuarine Areas Act. Congress passed policy on values of estuaries and coastal areas through these Acts. Comprehensive planning programs to be carried out at the state level, were established to enhance, protect, and utilize coastal resources. Federal activities must comply with the individual state programs. Habitat may be protected by planning and regulating development damage to sensitive coastal habitats.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). This act is also referred to as the "Superfund". It can provide funding for "clean-up" of important habitat areas affected by oil spills or other distinct pollution discharge events.

Endangered Species Act (ESA). The ESA provides for the protection of habitat necessary for the continued existence of species listed as threatened or endangered. Section 7 of the ESA requires consultation with the FWS or NMFS by a federal agency if an action authorized, funded or carried out by such agency may affect a listed species or its critical habitat (a legal, area-specific designation). Section 7 also prohibits any federal action that would jeopardize the continued existence of a listed species or its critical habitat. Section 9 of the ESA prohibits any person or entity from "taking" a listed species without a proper permit from the FWS or NMFS. Under the ESA, taking may include harassment or habitat degradation if such would interfere with feeding, reproduction or other essential life functions. The ESA also requires preparation of a recovery plan for each listed species outlining actions needed to allow the particular species to reach a population level at which it may be delisted.

Federal Power Act (FPA). The FPA regulates the construction and operation of hydroelectric power plants through a system of licenses and permits issued by the federal Energy Regulatory Commission (FERC) (formerly Federal Power Commission). The FWS, NMFS, state agencies and others may review proposed licenses and make recommendations with respect to the needs of instream flow for fish and wildlife downstream of dams as well as the impacts that reservoir establishment may have on fish and wildlife upstream of the dams. The Act also provides for construction of fish passage facilities during dam or diversion construction. Dams are likely major factors affecting anadromous fish populations in some Gulf streams.

Federal Water Pollution Control Act (FWPCA). Also called the "Clean Water Act", the FWPCA provides for the protection of water quality at the federal level. The law also provides for assessment of injury, destruction, or loss of natural resources caused by discharge of pollutants.

Of major significance is Section 404 of the Clean Water Act (CWA), which prohibits the discharge of dredged or fill material into navigable waters without a permit. Navigable waters are defined under the CWA to include all waters of the United States, including the territorial seas and wetlands adjacent to such waters. The permit program is administered by the COE. The Environmental Protection Agency (EPA) may approve delegation of Section 404 permit authority for certain waters (not including traditional navigable waters) to a state agency; however, it retains the authority to prohibit or deny a proposed discharge under Section 404(c) of the CWA. Recent attempts to revise Section 404 or change the legal definition of wetlands may affect the utility of the CWA in wetlands protection. Although of limited applicability to anadromous fish restoration, Section 404 may be important in protecting certain types of coastal habitats or in protecting water quality in certain streams. It may also be a consideration in approval of certain types of restoration projects.

The FWPCA also authorized programs to remove or limit the entry of various types of pollutants into the nation's waters. A point source permit system was established by the EPA and is now being administered at the state level in most states. This system, referred to as the National Pollutant Discharge Elimination System (NPDES), sets specific limits on discharge of various types of pollutants from point source outfalls. A non-point source control program focuses primarily on the reduction of agricultural siltation and chemical pollution resulting from rain runoff into the nation's streams. This control effort currently relies on the use of land management practices to reduce surface runoff through programs administered primarily by the Department of Agriculture.

Both chemical contamination and siltation may be major factors limiting populations of anadromous Gulf fish species. Efforts to achieve anadromous fish restoration in key river drainages should be aimed at assuring compliance with established point and non-point source reduction programs in these basins.

Federal Water Project Recreation Act. This Act requires that consideration be given to fish and wildlife enhancement in federal water projects.

Fish and Wildlife Act of 1956. This act provides assistance to states in the form of law enforcement training and cooperative law enforcement agreements. It also allows for disposal of property abandoned or forfeited in conjunction with convictions. Some equipment may be transferred to states. The act prohibits airborne hunting and fishing activities.

Fish and Wildlife Coordination Act (FWCA). The Fish and Wildlife Coordination Act (FWCA) is the primary law providing for consideration of fish and wildlife habitat values in conjunction with federal water development activities. Under this law the Secretaries of Interior and Commerce may investigate, report and advise on the effects federal water development projects may have on fish and wildlife habitat. Such reports and recommendations, which require concurrence of the state(s) involved, must accompany the construction agency's request for congressional authorization, although, the construction agency is not bound by the recommendations. Construction agencies may transfer funds to the FWS or NMFS to investigate and report on specific projects.

The FWCA also applies to water-related activities proposed by other organizations or individuals if those activities require a federal permit or license. The FWS and NMFS may review the proposed permit action and recommend to the permitting agencies to avoid or mitigate any potential adverse effects on fish and wildlife habitat.

Fish Restoration and Management Projects Act of 1950. Under this act, the DOI is authorized to provide funds to state fish and game agencies for fish restoration and management projects. Funds for protection of threatened fish communities that are located within state waters could be made available under the act.

Food and Agriculture Act of 1962. This Act established a Resource Conservation and Development Program for regionally-sponsored flood control and drainage projects that receive financial and technical assistance from the Soil Conservation Service. Though not as active a program as it once was, activities under this program may have relevance, both positive and negative, to anadromous fish habitat protection, restoration or enhancement.

Lacey Act of 1981, as amended. The Lacey Act prohibits import, export and interstate transport of illegally-taken fish and wildlife. As such, the Act provides for federal prosecution for violations of state fish and wildlife laws. The potential for federal convictions under this Act, with its more stringent penalties, has probably reduced interstate transport of illegally-possessed Gulf sturgeon.

Magnuson Fishery Conservation and Management Act. This Act provides for the conservation of habitats throughout the ranges of anadromous species within the Exclusive Economic Zone (EEZ). It mandates the preparation of fishery management plans for important fishery resources and sets national standards to be met by such plans. Each plan attempts to define, establish and maintain the optimum yield for a given fishery.

Marine Plastic Research and Control Act of 1987 and MARPOL Annex V. MARPOL Annex V is a product of the International Convention for the Prevention of Pollution from Ships, 1973/78. Regulations under this Act prohibit ocean discharge of plastics from ships; restrict discharge of other types of floating ship's garbage (packaging and dunnage) for up to 25 nautical miles from any land; restrict discharge of victual and other recomposable waste up to 12 nautical miles from land; and require ports and terminals to provide garbage reception facilities. The MPRCA of 1987 and 33 CFR, Part 151, Subpart A, implement MARPOL V in the United States.

Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA), Titles I and III and the Shore Protection Act of 1988 (SPA). The MPRSA protects fish habitat through establishment and maintenance of marine sanctuaries. This Act and the SPA regulate ocean transportation and dumping of dredged materials, sewage sludge and other materials. Criteria for issuing permits include considering the effects dumping has on the marine environment, ecological systems and fisheries resources. Permits are issued by the Corps of Engineers.

National Environmental Policy Act (NEPA). The NEPA requires an environmental review process of all federal actions. This includes preparation of an environmental impact statement for major federal actions that may affect the quality of the human environment. Less rigorous environmental assessments are reviewed for most other actions while some actions are categorically excluded from formal review. These reviews provide an opportunity for the agency and the public to comment, on projects that may impact fish and wildlife habitat.

Oil Pollution Act. This Act provides a degree of protection to coastal fisheries habitat by regulating discharge of oil from United States registry ships. Under the Act, tankers cannot discharge oil within 50 nautical miles of land, and other ships must discharge as far as practicable from land.

Outer Continental Shelf (OCS) Lands Act Amendments of 1979. These Amendments provide for assessments of the effects oil and gas exploration, development and production have on biological resources. The law also provides a channel for comments on federal approval of leasing OCS areas for exploration and development. Oil and gas leasing activities could be of concern for coastal anadromous fish habitat and offshore winter habitat of the Gulf sturgeon.

River and Harbor Act of 1899. Section 10 of the River and Harbor Act requires a permit from the U.S. Army Corps of Engineers (COE) to place structures in navigable waters of the United States or modify a navigable stream by excavation or filling activities.

Water Resources Development Acts (WRDA). These legislative actions authorize the COE to study and/or construct individual water resource projects. Prior to 1974 such acts were known as the "Flood Control Act of (year)", the "River and Harbor Act of (year)" or commonly called the "Omnibus Bill." Beginning in 1974 these laws have been referred to as the "WRDA of (year)". Numerous projects may be authorized under these Acts in any given year. Under the FWCA, "Wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs . . ." and the FWS, NMFS and state fish and wildlife agencies may review, comment and make recommendations to the COE regarding these projects' impacts on fish and wildlife resources. These comments may address the avoidance, mitigation or compensation for habitat damages.

Of particular relevance to anadromous fish habitat restoration or enhancement is the WRDA of 1986. This Act authorized the COE to study and construct environmental enhancement projects in conjunction with existing federal water projects.

STATE MANAGEMENT INSTITUTIONS, LAWS, REGULATIONS AND POLICIES.

State management institutions, laws and regulations for the Gulf sturgeon are relatively consistent among the four Gulf States within the species' range. Each state delegates substantial authority to its administrative agencies for establishing management regulations. Brief narrative descriptions are presented below for each state institution. Important state laws, regulations and policies are also summarized. **To the greatest extent possible, these requirements are current to the date of publication.**

FLORIDA

Administrative Organization.

Florida Marine Fisheries Commission
2540 Executive Center Circle West, Suite 106
Tallahassee, FL 32301
Telephone: (904) 487-0554

The Florida Marine Fisheries Commission, a seven-member board appointed by the governor and confirmed by the senate, was created by the Florida legislature in 1983. This commission was delegated rule-making authority over marine life in the following areas of concern: gear specification; prohibited gear; bag limits; size limits; species that may not be sold; protected species; closed areas; seasons; quality control codes with the exception of specific exemptions for shellfish; and special considerations relating to oyster and clam relaying. All rules passed by the commission require approval by the governor and cabinet. The commission does not have authority over endangered species, license fees, penalty provisions or over regulation of fishing gear in residential saltwater canals.

Florida Department of Environmental Protection (FDEP)
Division of Marine Resources
3900 Commonwealth Boulevard
Tallahassee, Florida 32303
Telephone: (904) 488-6058

This agency is charged with the administration, supervision, development and conservation of marine natural resources in Florida. The Florida Department of Natural Resources was the predecessor marine resources agency until its merger with the Florida Department of Environmental Regulation July 1, 1993. The agency is headed by the Governor and Cabinet. The governor and cabinet serve as the seven-member board that approves or disapproves all rules and regulations promulgated by the FDEP. The administrative head of the FDEP is the Department Secretary. Within the FDEP the Division of Marine Resources, through Section 370.02(2), Florida Statutes, is empowered to conduct research directed toward management of marine and anadromous fisheries in the interest of all people of Florida. The Division of Law Enforcement is responsible for enforcement of all marine resource related laws and all rules and regulations of the department. The Division of Marine Resources has the responsibility of overseeing the management and research efforts on the Gulf sturgeon including issuance of collecting permits for the subspecies.

Florida Game and Fresh Water Fish Commission.
Division of Wildlife
620 South Merdian Street
Tallahassee, Florida 32399
Contact: Mr. Don A. Wood, Endangered Species Coordinator
Telephone: (904) 488-3831

This agency is charged with the administration, supervision, development and conservation of wildlife and fresh water aquatic life in Florida. The FGFC is a constitutionally autonomous agency and is overseen by a governor appointed five-member board. The administrative head of the FGFC is the executive director. Within the FGFC the Division of Wildlife Resources, in accordance with the Florida Endangered and Threatened Species Act of 1977, Section 372.072, Florida Statutes, and the Wildlife Code of the State of Florida, Title 39, Florida Administrative Code, Article IV, Sec. 9, Florida Constitution, is responsible for research and management of listed fresh water and upland species. These efforts include the administrative designation of all wildlife species (including marine and estuarine species), issuance of collection permits, and various types of research of listed upland and fresh water aquatic wildlife species. The Gulf sturgeon was listed as a species of special concern by the FGFC in 1987.

Florida has habitat protection and permitting programs and a federally-approved Coastal Zone Management (CZM) program.

Legislative Authorization. Chapter 370 of the Florida Statutes Annotated contains law regulating coastal fisheries. The legislature passes statutes for the management of fisheries resources as well as specific laws which are applicable within individual counties.

Reciprocal Agreement and Limited Entry Provisions. Not applicable, since any take of Gulf sturgeon is illegal in Florida.

Commercial Landings Data Reporting Requirements. Not applicable since all take of Gulf sturgeon is illegal in Florida.

Penalties for Violations. Penalties for violations of Florida statutes and regulations are prescribed in Section 370.021, Florida Statutes. Upon the arrest and conviction for violation of any of the regulations or laws, the license holder shall show just cause why his saltwater license should not be suspended or revoked.

Annual License Fees. Not applicable, since all take of Gulf sturgeon is illegal in Florida.

Laws and Regulations. It is illegal to take *Acipenser oxyrinchus* by any means statewide according to Rule No. 46-15.01 (1984) of the Florida Marine Fisheries Commission. (Most federal and state agencies have used the specific name *A. oxyrinchus* instead of the subspecific name *A. o. desotoi*.

ALABAMA

Administrative Organization.

Alabama Department of Conservation and Natural Resources (ADCNR)
Alabama Marine Resources Division (AMRD)
P.O. Box 189
Dauphin Island, Alabama 36528
Telephone: (205) 861-2882

Management authority of fishery resources in Alabama is held by the Commissioner of the Department of Conservation and Natural Resources. The Commissioner may promulgate rules or regulations designed for the protection, propagation and conservation of all seafood. He may prescribe the manner of taking, times when fishing may occur and designate areas where fish may or may not be caught; however, all regulations are to be directed toward the best interest of the seafood industry.[5]

Most regulations are promulgated through the Administrative Procedures Act approved by the Alabama Legislature in 1983; however, bag limits and seasons are not subject to this Act. The Administrative Procedures Act outlines a series of events that must precede the enactment of any regulations other than those of an emergency nature. Among this series of events are (a) the advertisement of the intent of the regulation, (b) a public hearing for the regulation, (c) a 35-day waiting period following the pubic hearing to address comments from the hearing and (d) a final review of the regulation by a joint house and senate review committee.

Alabama also has the Alabama Conservation Advisory Board (ACAB) that is endowed with the responsibility to provide advice on policies of the ADCNR. The board consists of the governor, the ADCNR commissioner and ten board members.

The AMRD has responsibility for enforcing state laws and regulations, for conducting marine biological research and for serving as the administrative arm of the commissioner with respect to marine resources. The division recommends regulations to the commissioner.

Alabama has a habitat protection and permitting program and a federally approved CZM program.

Legislative Authorization. Chapters 2 and 12 of Title 9, Code of Alabama, contain statutes that concern marine fisheries.

Reciprocal Agreement and Limited Entry Provisions. Not applicable since all take of Gulf sturgeon is illegal in Alabama.

Commercial Landings Data Reporting Requirements. Not applicable since all take of Gulf sturgeon is illegal in Alabama.

Penalties for Violations. Take of Gulf sturgeon is illegal in Alabama, any take is considered a Class C misdemeanor and punishable by fines up to $500.00 and three months in jail.

Annual License Fees. Not applicable since all take of Gulf sturgeon is illegal in Alabama.

Laws and Regulations. It is currently illegal to take Gulf sturgeon in freshwater or coastal waters in Alabama. Alabama has no official State list of threatened and endangered species. *Acipenser oxyrinchus* is considered a threatened species by the Symposium on Endangered and Threatened Plants and Animals of Alabama (Boshung 1976).

MISSISSIPPI

Administrative Organization.

Mississippi Department of Wildlife, Fisheries and Parks (MDWFP)
Bureau of Marine Resources (BMR)
2620 Beach Boulevard
Biloxi, Mississippi 39531
Telephone: (601) 385-5860

The MDWFP administers coastal fisheries and habitat protection programs through the BMR. Authority to promulgate regulations and policies is vested in the Mississippi Commission on Wildlife, Fisheries and Parks, the controlling body of the MDWFP. The commission consists of five members appointed by the governor. The commission has full power to "manage, control, supervise and direct any matters pertaining to all saltwater aquatic life not otherwise delegated to another agency" (Mississippi Code Annotated 49-15-11).

Mississippi has a habitat protection and permitting program and a federally approved CZM program.

Legislative Authority. Chapter 49-15 of the Mississippi Code of 1972 (Annotated) contains provisions for the management of marine fisheries resources.

Reciprocal Agreement and Limited Entry Provisions. Not applicable since it is illegal to take Gulf sturgeon anywhere in the State of Mississippi.

Commercial Landings Data Reporting Requirements. Not applicable since it is illegal to take Gulf sturgeon anywhere in the State of Mississippi.

Penalties for Violations. Any person, firm or corporation violating any of the provisions of Chapter 49-15 or any ordinance duly adopted by the commission, unless otherwise specifically provided for herein, shall, on conviction, be fined not less than $100, nor more than $500, for the first offense, unless the first offense is committed during a closed season, in which case the fine shall be not less than $500, nor more than $1,000; and not less than $500, nor more than $1,000, for the second offense when such offense is committed within a period of 3 years from the first offense; and not less than $2,000 nor more than $4,000, or imprisonment in the county jail for a period not exceeding 30 days for any third or subsequent offense when such offense is committed within a period of 3 years from the first offense and also upon conviction of such third or subsequent offense, it shall be the duty of the court to revoke the license of the convicted party and of the boat or vessel used in such offense, and no further license shall be issued to such person or for said boat to engage in catching or taking of any seafoods from the waters of the State of Mississippi for a period of 1 year following such conviction. Further, upon conviction of such third or subsequent offense committed within a period of 3 years from the first offense, it shall also be the duty of the court to order the forfeiture of any equipment or nets used in such offense. Provided, however, that equipment as used in this section shall not mean boats or vessels. Any person convicted and sentenced under this section shall not be considered for suspension or other reduction of sentence. Except as provided under subsection 5 of Section 49-15-45, any fines collected under this section shall be paid to the Mississippi Commission on Wildlife, Fisheries and Parks to be paid into the Seafood Fund.

Annual License Fees. Not applicable since it is illegal to take Gulf sturgeon anywhere in the State of Mississippi.

Laws and Regulations. *Acipenser oxyrinchus* was listed as an endangered species by the Mississippi Game and Fish Commission and the Rare and Endangered Species Committee (1975) and is protected by law. The subspecies is also listed as endangered by the Mississippi Natural Heritage Program, 1977, and as a Special Animal Species by the Mississippi Parks Commission, Bureau of Outdoor Recreation, Jackson, MS.

LOUISIANA

Administrative Organization.

Louisiana Department of Wildlife and Fisheries (LDWF)
P.O. Box 98000
Baton Rouge, Louisiana 70898
Telephone: (504) 765-3617

The LDWF is one of 21 major administrative units of the Louisiana government. A seven-member board, the Louisiana Wildlife and Fisheries Commission (LWFC) is appointed by the Governor. Six of the members serve overlapping terms of six years, and one serves a term concurrent with the Governor. The commission is a policy-making and budgetary-control board with no administrative functions. The legislature has sole authority to establish management programs and policies; however, the legislature has delegated certain authority and responsibility to the LDWF. The Secretary of the LDWF is the executive head and chief administrative officer of the department and is responsible for the administration, control and operation of the functions, programs and affairs of the department. The secretary is appointed by the Governor with consent of the Senate.

Within the administrative system, an Assistant Secretary is in charge of the Office of Fisheries. In this office a Marine Fisheries Division and an Inland Fisheries Division may have management jurisdiction over the Gulf sturgeon. The Enforcement Division, in the Office of the Secretary, is responsible for enforcing all fishery statutes and regulations.

The LDWF's Natural Heritage Program is responsible for administering the laws, rules, and regulations regarding threatened and endangered species (R.S. 56:1830). In addition, under a full authorities Section 6 agreement with the FWS, the take of threatened and endangered species may be authorized by permits issued by the Department.

Louisiana has habitat protection and permitting programs and a federally approved CZM program.

Legislative Authorization. Title 56 Louisiana Revised Statutes contains rules and regulations that govern marine fisheries in the state.

Reciprocal Agreement and Limited Entry Provisions. Not applicable, since take of Gulf sturgeon is illegal in Louisiana.

Commercial Landings Data Reporting Requirements. Not applicable, since take of Gulf sturgeon is illegal in Louisiana.

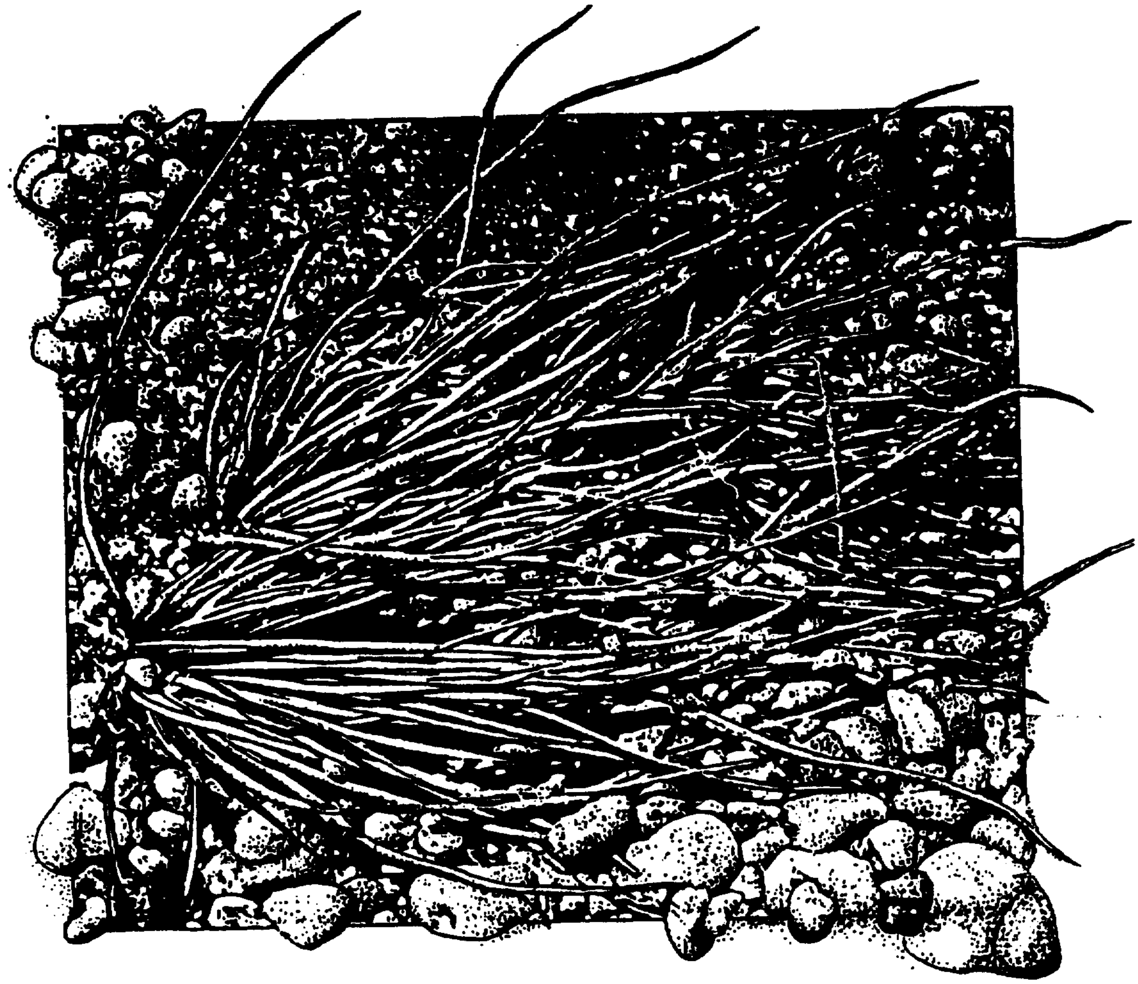
Penalties for Violations. The fine for each illegally caught fish is $2,500.00

Annual License Fees. Not applicable, since take of Gulf sturgeon is illegal in Louisiana.

Laws and Regulations. Louisiana law currently prohibits take of all sturgeon anywhere in the state. The Louisiana Division of Natural Heritage is responsible for listing of endangered and threatened species.

Appendix C-3: Louisiana Quillwort Recovery Plan

Recovery Plan For The Louisiana Quillwort (*Isoetes louisianensis*) Thieret



U.S. Fish and Wildlife Service
Southeast Region
Atlanta, Georgia

LOUISIANA QUILLWORT

Isoetes louisianensis Thieret

RECOVERY PLAN

Prepared by

Julia Larke
Louisiana Natural Heritage Program
Louisiana Department of Wildlife & Fisheries

for

U.S. Fish and Wildlife Service
Jackson, Mississippi

and

U.S. Fish and Wildlife Service
Southeast Regional Office
Atlanta, Georgia

Approved: Noreen K. Clough
Noreen K. Clough, Regional Director,
Southeast Region, U.S. Fish and Wildlife Service

Date: September 30, 1996

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the species. Plans are prepared by the U.S. Fish and Wildlife Service, sometimes with the assistance of recovery teams, contractors, State agencies, and others. Objectives will only be attained and funds expended contingent upon appropriations, priorities, and other budgetary constraints. Recovery plans do not necessarily represent the views nor the official positions or approvals of any individuals or agencies, other than the U.S. Fish and Wildlife Service, involved in the plan formulation. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

By approving this document, the Regional Director certifies that the information used in its development represents the best scientific and commercial data available at the time it was written. Copies of all documents reviewed in development of the plan are available in the administrative record, located at the Jackson, Mississippi, Field Office.

Acknowledgment:

The cover illustration was originally done by Julia Larke of the Louisiana Natural Heritage Program. It was enhanced by Ms. Larke and Terri Jacobson of the U.S. Fish and Wildlife Service.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1996. Recovery Plan for Louisiana quillwort (*Isoetes louisianensis* Thieret). Atlanta, Georgia. 26 pp.

Additional copies may be purchased from:

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814

Telephone: 301-492-6403 or
1-800-582-3421

Fees for recovery plans vary, depending upon the number of pages.

EXECUTIVE SUMMARY

Current Status: *Isoetes louisianensis* is listed as endangered without critical habitat. It is currently known to occur in St. Tammany and Washington Parishes in southeastern Louisiana and in Jackson and Perry Counties in southern Mississippi. In Louisiana, all known sites are on private land; in Mississippi, all known sites occur on National Forest land.

Habitat Requirements and Limiting Factors: Louisiana quillwort occurs in the East Gulf Coastal Plain physiographic province in Pleistocene Prairie Terraces and Pleistocene High Terraces in southeastern Louisiana and in Pleistocene High Terraces in southern Mississippi. It appears to be restricted to sandy soils and gravel bars in or near shallow blackwater streams and overflow channels in riparian woodland/bayhead forests of pine flatwoods and upland longleaf pine. *Isoetes louisianensis* is extremely vulnerable because of its small population size and habitat loss from actions which affect the hydrology or stability of the streams it inhabits.

Recovery Objective: Delisting.

Recovery Criteria: This species will be considered for delisting when 10 reproductively viable and geographically distinct populations from different drainage systems are protected from foreseeable threats. A reproductively viable population is one which is reproducing and stable or increasing in size as shown by monitoring for at least a 10-year period.

Actions Needed:

1. Protect known populations by protecting their habitat.
2. Conduct life history research.
3. Monitor population trends and developing threats.
4. Search for additional populations in southeastern Louisiana, southern Mississippi, and south Alabama.
5. Preserve genetic stock.
6. Inform the public about the conservation needs of the species.

Estimated Cost of Recovery: It is not possible to estimate costs beyond the first few years. Cost estimates of recovery tasks over the next 3 years total $74,000.

Date of Recovery: Since the species' recovery depends upon the outcome of several recovery tasks, it is not possible to determine a date at this time.

TABLE OF CONTENTS

I. INTRODUCTION

A. Background

Isoetes louisianensis Thieret, Louisiana quillwort, is a member of the Isoetaceae, a family of primitive seedless plants related to ferns. The family consists of a single genus, *Isoetes*, with approximately 150 species occurring nearly worldwide in aquatic and moist terrestrial habitats. Twenty-five species occur in North America (Brunton *et al*. 1994, Taylor *et al*. 1993) and one of the rarest is *I. louisianensis*. Within the East Gulf Coastal Plain physiographic province this species occurs in the Pleistocene Prairie Terraces and High Terraces in southeastern Louisiana and in the Pleistocene High Terraces in southern Mississippi. Louisiana quillwort is apparently restricted to sandy soils and gravel bars in or near shallow blackwater creeks and overflow channels in narrow riparian woodland/bayhead forest communities in pine flatwoods and upland longleaf pine.

In southeastern Louisiana, it is currently known from eight sites in St. Tammany and Washington Parishes; in southern Mississippi, it is known from a single site in Jackson County, and from three sites in Perry County. Louisiana quillwort is extremely vulnerable because of its small population size and restricted range. On October 28, 1992, the U.S. Fish and Wildlife Service (1992) officially listed *Isoetes louisianensis* Thieret (Louisiana quillwort) as an endangered species under the Endangered Species Act of 1973, as amended.

B. Taxonomy and Description

Isoetes louisianensis Thieret was discovered by Garrie Landry in April 1972 at Thigpen Creek in Washington Parish, Louisiana, and later described (Landry and Thieret 1973). Type specimens are held at the Gray Herbarium (GH) and the University of Michigan (MICH). *Isoetes louisianensis* is a small, semi-aquatic, facultative evergreen plant with spirally-arranged leaves (sporophylls) arising from a globose, two-lobed corm. The pliant, hollow leaves are transversely septate and measure 2 to 3 millimeters (mm) (0.12 inch) wide, and up to 40 centimeters (cm) (16.0 inches) long. Spore-containing structures (sporangia) are embedded in the pale, broadened bases of the leaves. Kral (1983) has suggested that aquatic quillwort leaves may vary in length depending upon water depth.

Key morphological features that differentiate *Isoetes* taxa are megaspore ornamentation, texture, and size, and length of the velum (a membranous flap of tissue covering the sporangium) (Hickey 1986, Taylor *et al.* 1993). Megaspores are white and reticulate-cristate in texture with relatively thick proximal ridges; they measure 500 to 625 micrometers (μm) (approximately 0.02 inch) in diameter. Surface texture of the girdle (a narrow band along the distal side of the equatorial ridge encircling the megaspore) is obscure and not distinguishable from the overall texture of the spore. Microspores are light brown in mass and densely spinulose; they measure 25 to 35 μm (approximately 0.001 inch) in diameter. The velum in *I. louisianensis* covers less than one-half of the adaxial wall of the sporangium and the sporangial wall is brown-streaked. Biosystematic studies by Neil Luebke and Carl Taylor at the Milwaukee Public Museum indicate that this species is a tetraploid (2n=44) (Taylor *et al.* 1993).

Sporogenesis appears to be weather dependent and occurs from late spring through fall as evidenced by collections and field observations of *Isoetes louisianensis* (Larke #3193, #3456 LSU, USL; Leonard, Mississippi Natural Heritage Program, pers. comm. 1996; Sorrie, Sand Pines, North Carolina, pers. comm. 1996). Apparently, if conditions are warm and wet enough, sporangia develop and spores mature. From observations, megasporophylls appear to be located on the outer edges of the spirally arranged leaves and it seems that megasporangia mature and disperse spores just prior to microsporangia. It is possible that leaf development follows a continual pattern of megasporophylls alternating with microsporophylls, and specimens might be found that show mature microsporangia on the outer leaves and mature megasporangia in the inner leaves. An earlier suggestion that an alternating cycle of sporogenesis occurs, with microspores maturing in the fall and megaspores in the late winter or early spring (Landry and Thieret 1973) may have come from observations of specimens that were collected after megasporophylls had matured and dropped off the plant.

Landry and Thieret (1973) described *Isoetes louisianensis* as closely resembling the diploid species *I. engelmannii* A. Braun var. *caroliniana* A. A. Eaton (= *I. caroliniana* (A.A. Eaton) Luebke). However, they noted that the brown-spotted sporangial walls of *I. louisianensis* easily separated the two species. Boom (1980, 1982) considered *Isoetes louisianensis* a hybrid of *Isoetes engelmannii* A. Braun x *I. melanopoda* Gay & Durieu.

Luebke and Taylor (1986) questioned the hybrid specific status for *Isoetes louisianensis* proposed by Boom and submitted that it was a legitimate species. *Isoetes* hybrids typically are sterile because spores are often malformed and variable in size, shape and texture; their studies revealed that *I. louisianensis* spores readily germinated in culture and were uniform in size and texture. Boom concurred with Luebke and Taylor's determination (U.S. Fish and Wildlife Service 1992).

Taylor *et al.* (1993) recognized *Isoetes louisianensis* as a full species in their treatment of the genus *Isoetes* for the *Flora of North America*. *Isoetes louisianensis* is an allotetraploid (2n=44) of probable hybrid origin and the reticulate texture of the megaspore suggests *I. engelmannii* as a possible parent. Both *I. engelmannii* and *I. melanopoda* occur northward in the Mississippi River watershed and opportunities for contact via waterfowl exist because of the proximity of the Mississippi River flyway (Boom 1980, 1982). Further DNA and enzyme electrophoretic studies are needed to determine parentage.

The recently described *Isoetes hyemalis* (Brunton *et al.* 1994) is the only other tetraploid taxon in southeastern United States; it occurs in shallow creeks and sloughs primarily in the Coastal Plain in Virginia, North Carolina, South Carolina, Georgia, and Alabama. It also shares many features with possible diploid progenitors *I. engelmannii* and *I. caroliniana*. *Isoetes hyemalis* is very similar to *I. louisianensis* but it has a clear velum (not brown-streaked), and its megaspores are less reticulate and have a distinctly spiny equatorial band.

C. <u>Distribution</u>

Louisiana quillwort is currently known from two parishes in southeastern Louisiana and two counties in southern Mississippi in the Gulf Coastal Plain physiographic province (Figure 1). A report of this species from Worth County, Georgia was in error (U.S. Fish and Wildlife Service 1992). In this recovery plan, a population is characterized as one that is reproductively viable and geographically distinct. Populations occurring in different drainage systems, where gene flow appears to be limited, are considered geographically distinct. Because it is difficult to identify gene flow patterns in aquatic species, it may be more

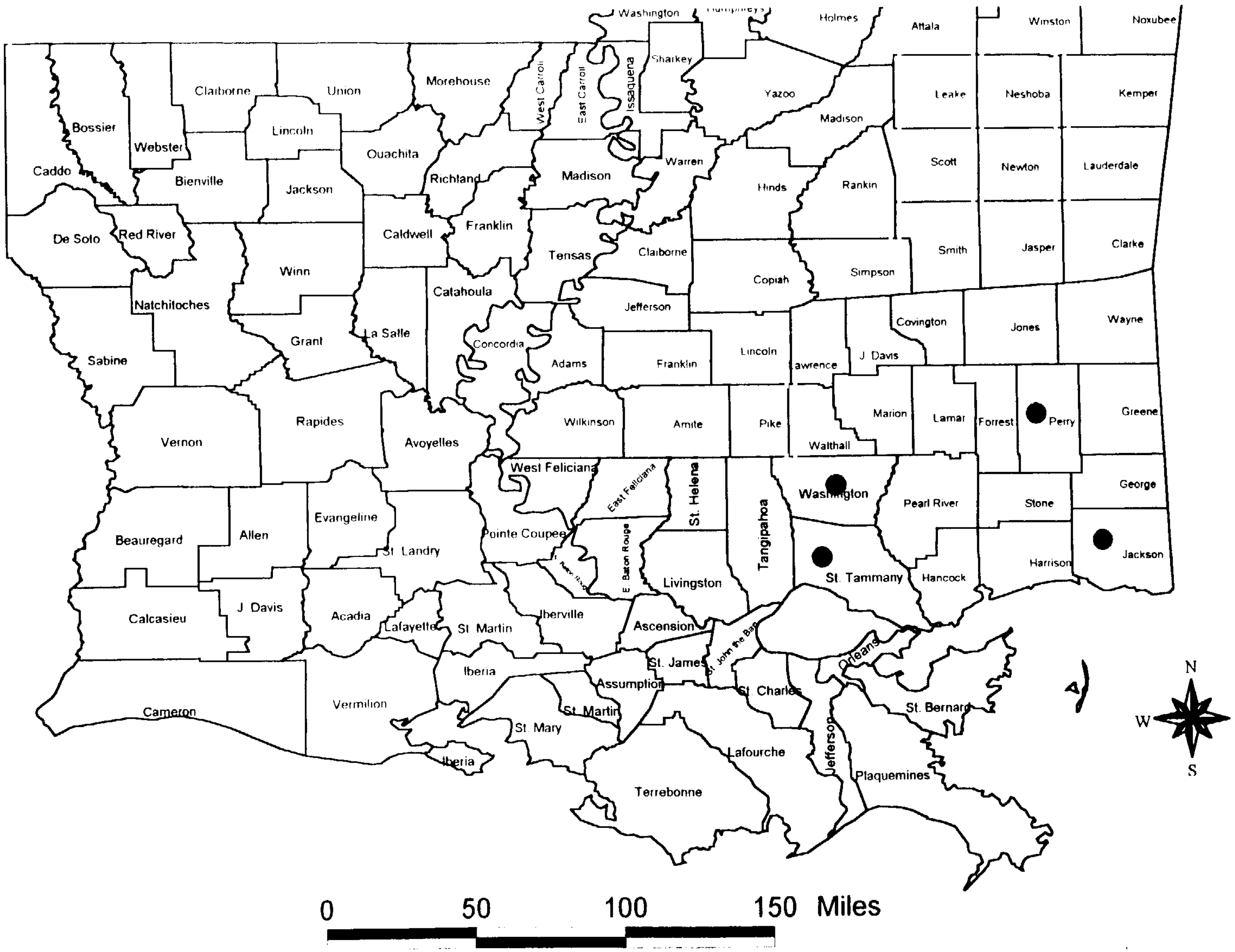


Figure 1. Current distribution of Louisiana quillwort

precise to use the term subpopulation when referring to populations in drainages of major watersheds. For Louisiana quillwort, population size in the spatial sense is linear, because plants follow the stream course, and spacing of individuals and subpopulations within the population tends to occur in patches or colonies. Ecological constraints, such as stream dynamics, moisture availability, and soil conditions limit population size and range for Louisiana quillwort.

Populations are located at the following sites in Louisiana:

Washington Parish:
The Bogue Chitto River watershed:
(1) Louisiana quillwort occurs in upper Mill Creek and the lower portions of Thigpen and Clearwater Creeks. Plants from the three sites constitute a single population. Over 2,600 plants are located along a 1.25 kilometer (km) (0.75 mile) section of Thigpen Creek; 335 plants occur in a 1.0 km (0.6 mile) section of Mill Creek; and, 20 plants occur along a 0.5 km (0.3 mile) section of Clearwater Creek. 2) Four plants occur at a site on Miller Creek.

St. Tammany Parish:
Tchefuncta River watershed:
The Bogue Falaya River drainage: (1) Over 1,500 plants are located along a 1.0 km (0.6 mile) section of a tributary to the Bogue Falaya. (2) Approximately 50 plants occur near the headwaters of a small drainage of LaTice Branch Creek.

The Little Bogue Falaya River drainage: Over 350 plants are located at the Little Bogue Falaya River southeast of Barkers Corner.

The Abita River drainage: (1) Approximately 400 plants occur along a 0.5 km (0.3 mile) section of Abita Creek, and 18 plants occur at a site on Coon Creek, a small tributary of Abita Creek. These two sites are considered a single population. (2) Two plants are located at Ten-Mile Creek.

Bayou Chinchuba drainage: Bayou Chinchuba drains directly into Lake Pontchartrain. This population of over 350 plants is atypical because it occurs in a seasonally-flooded small depression in wet-loblolly pine flatwoods instead of near a streamside. (Tad Zebryk *in litt.* 1995).

In 1996, Louisiana quillwort was discovered in Mississippi by Bruce Sorrie in Jackson County and Steve Leonard in Perry County. Populations occur at the following sites:

Jackson County:

DeSoto National Forest, Red Creek Wildlife Management Area, Tchoutacabouffa River watershed:
Approximately 50 plants occur in overflow channels near the streamhead of a branch of Bayou Billie.

Perry County:

DeSoto National Forest, Camp Shelby National Guard Training Site, Pascagoula River watershed:
(1) Approximately 2,500 plants are located in five colonies along a 1.6 km (ca 1.0 mile) stretch near the headwaters of Pearces Creek. (2) 1,500 plants occur in scour channels aggregated mainly along a 0.3 km (0.2 mile) section of a small tributary to Joes Creek. (3) 20 plants occur near an intermittent stream draining into Whiskey Creek.

D. Habitat

The following discussion focuses primarily on descriptions of quillwort habitat in Louisiana. Mississippi populations were recently discovered and are not fully described in this document. Observations on the habitat of Mississippi sites were contributed by Steve Leonard, Natural Heritage Inventory Botanist, Camp Shelby National Guard Training Site, DeSoto National Forest (*in litt.* 1996).

In southeast Louisiana, geomorphology, soils, hydrology, and vegetation combine to form an environment that supports one of the rarest quillworts in North America. The habitat has been well described by McInnis (1991a) and Hartfield (1991). Louisiana quillwort is apparently restricted to areas in or near shallow, blackwater streams in riparian woodland and bayhead forests of pine flatwoods and upland pine forests. These creeks originate in the dissected hills of the Pleistocene High Terraces and flow out into extensive flatwoods and bayhead forests of the Prairie Terrace formation. In these areas, *Isoetes louisianensis* grows singly, or in large patches of several hundred plants.

Plants grow in stable sand and gravel bars and moist overflow channels with silty sand substrate, and on low, sloping banks near and below water levels. They occur in a relatively firm substrate of fine sandy loam, and sometimes coarser sands and small to medium-sized gravel. One site at a seasonally flooded small depression is atypical because it is not a streamside habitat. This population may maintain itself because of an abandoned artesian well nearby, or because it is fed by subsurface seepage from the larger wetland surrounding the site. The surrounding flatwoods show evidence of flooding and immature *Isoetes* plants could easily have washed into the safe site of the moist depression (Zebryk *in litt.* 1995).

Sandy blackwater streams in southeast Louisiana are typically a clear, tannin-colored brown. They are shallow and range from only a few centimeters deep in riffle areas to 0.75 meters (m) (2.5 ft) deep, with occasional deeper pools (McInnis 1991a). Stream widths vary from 0.6 to 4.6 m (2 to 15 ft), narrowing in shallow areas, widening in deeper areas, and occasionally splitting or braiding temporarily between mossy hummocks, exposed tree roots, or cypress knees. Debris from flooding has been observed as high as 2.2 m(approximately 7 ft) and more commonly about 1.0 m (over 3 ft). Floodplain widths vary, from under 10 m to over 150 m(30 to over 500 ft).

Plants are regularly inundated following rains and may remain submerged for extended periods during flooding. Corms rooted in sandy soil are often overlain with coarser gravel, in some cases to nearly 4 cm (1.5 inches) in depth. Two *Isoetes* species (*I. georgiana* and *I. hyemalis)*, that grow in similar habitat in southeastern United States, often are anchored in soils by a subterranean or surfical network of tree rootlets which allow the plants to withstand intense scouring by flood waters (Brunton *in litt.* 1995). Similar anchoring has been observed in *I. louisianensis* populations in Louisiana.

Quillwort populations in Louisiana appear to be facultatively evergreen. During summer dry periods, plants within the same population were observed to remain evergreen if growing in water, and to wither and die back if growing in areas such as overflow channels that became dry if located at a distance from the main channel. In Mississippi, all of the known Louisiana quillwort populations occur at sites that dry out during the summer (Leonard *in litt.* 1995). Brunton (*in litt.* 1995) notes that *I. georgiana* and *I. hyemalis* are found at sites that dry out completely by early summer and stay dry until early winter.

Soils from five of the six quillwort sites in St. Tammany Parish are mapped as Myatt fine sandy loam, frequently flooded (Natural Resources Conservation Service 1990). Myatt soils are found on broad flats or stream terraces in depressional areas or narrow drainageways; soil is level with a slope of less than 1 percent and is poorly drained with very slow water run-off. Brief flooding is said to occur mainly in the winter and spring, although flooding can occur anytime during the year. The site near Bayou Chinchuba is mapped as Abita silt loam, a soil type located in slightly raised positions on stream terraces. The adjacent stream is mapped as Myatt sandy loam. Although the soil survey for Washington Parish has not yet been published, the general soil map shows the quillwort sites occurring in the Myatt-Stough-Cahaba association (Natural Resources Conservation Service 1971).

Soils at the Perry County, Mississippi quillwort sites are mapped as Bibb silt loam and Trebloc silt loam in the Perry County Interim Soil Survey (Natural Resources Conservation Service, undated) (Leonard pers. comm. 1996). The soil type at the Jackson County site is not known at this time.

Vegetation along blackwater creeks is a riparian woodland/bayhead forest community with filtered light from a mostly closed canopy. The canopy is composed of *Nyssa biflora* (swamp blackgum), *Magnolia virginiana* (sweetbay magnolia), *Taxodium distichum* (bald cypress), *Acer rubrum* (red maple), *Quercus laurifolia* (laurel oak), and *Pinus taeda* (loblolly) and occasionally, *Pinus glabra* (spruce pine). Understory species include *Cyrilla racemiflora* (black titi), *Leucothoe axillaris* (fetterbush), *Itea virginica* (virginia willow), *Viburnum dentatum* (arrowwood), *Rhododendron viscosum* (summer azalea), *Vaccinium elliottii* (Elliott's blueberry), *Ligustrum sinense* (chinese privet), and various species of *Ilex* (holly). In areas where the floodplain widens, bayhead forests may be present with a similar species composition as the riparian zones (McInnis 1991a). Louisiana quillwort has been found growing in association with aquatics *Oronticum aquaticum* (golden club), *Potamogeton pusillus* (pondweed), and *Sparganium americanum* (bur-weed), and other species such as *Viola primulifolia* (violet), *Micranthemum umbrosum, Scirpus divaricatus* (bulrush), *Justicia lanceolata* (water-willow), *Hypoxis leptocarpa* (stargrass), *Woodwardia areolata* (netted chainfern), *Lycopus virginicus* (bugleweed), *Pallavicinia lyellii* (a liverwort), and *Mnium affine* (a moss).

E. Reproductive Biology

Species of *Isoetes* appear to have evolved either by ecological isolation and genetic divergence, or by interspecific hybridization and chromosome doubling as divergent species migrated into the same aquatic habitats (Taylor *et al.* 1993). Early researchers, such as, Pfeiffer (1922) and Reed (1965), and later Boom (1980, 1982), characterized the genus and recognized that a proliferation of interspecific hybrids existed. A polyploid series has been identified in aquatic *Isoetes*, implying that some species in the series may have evolved abruptly through hybridization and allopolyploidy (Taylor *et al.* 1985). Of the 25 described species of quillwort in North America, 10 are polyploid submerged or emergent aquatics (Brunton *et al.* 1994, Taylor *et al.* 1993). Evidence for such hybridization has been obtained from distribution patterns, spore morphology, chromosome numbers, *in vitro* hybridizations, and enzyme electrophoresis (Hickey *et al.* 1989, Taylor *et al.* 1985).

When Louisiana quillwort was first discovered, Thieret (1980) collected live plants with surrounding soil and cultivated them in a greenhouse at the University of Southwestern Louisiana. Plants were still thriving after 6 months. Thieret noted that "numerous young quillwort plants appeared in the soil of the pots. Many of these, while still only about 1 cm long and still attached to the megaspore, floated to the surface of the water." He postulated that this phenomenon could be evidence, in natural conditions, for downstream dispersal of young plants. Brunton (*in litt.* 1995) observed this condition in young plants of *Isoetes hyemalis* in Alabama and agrees with Thieret's premise.

Taylor and Luebke (1986) experimented with spore germination and growing sporelings of aquatic species of *Isoetes*. They speculate (pers. comm. 1996) that the spiny surface ornamentation of microspores (and to a lesser degree, megaspores) may lend itself to trapping, as spores become caught in the bases of the parent or nearby plants, or become embedded in soil nearby. In this manner, spores maintain close proximity to the colony despite sometimes swift water currents. Taylor and Luebke also suggest that an optimal grain size of the sandy loam substrate may favor capture of spores in the soil near the bases of sporophyte plants. After fertilization of the gametophyte, young sporophytes can emerge close to the parent sporophyte in a manner observed by Thieret (1980) and Taylor and Luebke (1986) and take root nearby or be dispersed downstream. This process may explain the often dense growth patterns in quillwort populations.

F. Reasons for Listing and Threats

Isoetes louisianensis is one of the rarest quillworts in the United States and is extremely vulnerable because of its small population size and restricted range. The current state of knowledge would suggest that suitable small-stream habitat is rare in Louisiana and Mississippi. However, the recent discovery of this species in Mississippi may indicate greater occurrence in the southern third of the state. It is not inconceivable that Louisiana quillwort will be found in southern Alabama as botanists search for stream habitat similar to that of Mississippi (Leonard *in litt.* 1996).

Habitat loss through land use practices that significantly transform riparian forest communities and alter stream quality and dynamics, poses the most serious threat to populations of Louisiana quillwort. This species is adapted to a dynamic stream environment and is negatively affected by adverse anthropogenic changes. Anthropogenic constraints change natural drainage patterns and stream dynamics, potentially damaging quillwort habitat and possibly inhibiting formation of new habitat. Dredging, ditching, channelization, road construction, and off-road vehicles (ORV) can alter natural processes and result in habitat loss. In addition, the effects of timber removal, mining, feral hogs, beaver dams, and plant collection are discussed in this section.

Timber removal increases surface runoff and contributes to stream erosion and sediment siltation. Removal of canopy alters light and temperature regimes on the forest floor; soils become drier and weedy vegetation tends to invade. Logging adjacent to creeks creates debris and detritus which can obstruct water flow and change stream dynamics. While streamside management zones (SMZs) are theoretically protective buffers to the streams themselves, observations of logging practices in Mississippi show that logging sometimes occurs to the stream edge, that slash is frequently left in the drainage, and that quillwort habitat is crossed by skidders and trucks during timber harvest. These generally rough logging trails and roads are then used by hunters and others until saplings regenerate and block vehicular access (Leonard *in litt.* 1996).

Sand and gravel mining poses a significant threat, as evidenced by portions of Clearwater Creek in Washington Parish, Louisiana, that have been completely cleared, channelized, and re-routed. Degradation of water quality from siltation, prolific algal growth, and sediment pollution from overflow of adjacent gravel pits was observed at the creek site (McInnis 1991a). Mining operations in or adjacent to creeks and rivers can have a detrimental effect upon aquatic resources. A recent study by Brown and Curole (1995) discussed impacts of gravel mining in Louisiana on mussel assemblages. In their study, it was noted that most damage occurred upstream from mining activity resulting in channel degradation, bank erosion, and the formation of broader, shallow braided streams.

Feral hogs pose a potential threat to quillwort habitat in DeSoto National Forest in Mississippi. Rooting has been observed at one of the Camp Shelby sites. Wildlife managers on the national forest are aware of this problem and they are considering appropriate measures for controlling the hogs (Leonard pers. comm. 1996).

Beaver dams occur in drainages supporting quillwort habitat in Louisiana and in Mississippi. Beaver activity could easily inundate a population by impounding a stream and downstream plants could also be affected by changes in water flow.

Plant collectors could present a danger to quillwort populations if they are over zealous in their collecting of a species with such a small population size and extent. University students, environmental managers, members of botanical clubs, and others interested in making a field trip to observe this species need to remain aware of the rarity of Louisiana quillwort and treat its environment in an ecologically sound manner.

McInnis (1991a) and Larke (1996) searched, without success, numerous small-stream, riparian woodlands that appeared to have similar physiognomy and vegetation to known quillwort sites. The following conditions were observed at sites in Louisiana not supporting quillwort: (1) silty substrate with little coarse sand or gravel; (2) instable substrate;(3) steep banks; (4) absence of sand and gravel bars; (5) differing stream dynamics with either too much energy preventing establishment of vegetation on gravel bars, or with too little energy resulting in swampy conditions; (6) excessive dryness during periods of low precipitation; and, (7) alteration due to activities such as channelization and ORV use.

Observations in Mississippi reveal that quillworts at drier sites are subject to desiccation and often cannot be seen during late June, July, and August. Therefore, it may not be possible to conclude that a particular stream does not have quillworts if one is searching during the hotter and drier summer months (Leonard *in litt.* 1996). It is also necessary to consider broader climate trends when surveying for quillwort (*e.g.*, searches for quillwort during wet years might prove more successful than searches in drought years). More field observations are needed to fully understand the optimum environmental conditions for Louisiana quillwort populations.

Because development pressure within the known range is severe, populations may be unknowingly extirpated. Although the known range of Louisiana quillwort has recently broadened from two parishes in southeastern Louisiana to include two counties in southern Mississippi, any negative environmental impacts to quillwort habitat are important because of the small global range of this species. Research (Gilpin and Soule 1986) has shown that the possibility of local extinction is greater for species in variable dynamic environments and that more individuals are needed to maintain a minimum viable population (McInnis 1991a).

G. <u>Conservation Measures</u>

In 1992, Cavenham Timber Company established a portion of Thigpen Creek supporting quillwort as a protected Nature Area. The area is well-marked by signs indicating no trespassing and no wheeled or track vehicles. Timbering in the area is prohibited. Weyerhauser Timber Company purchased Cavenham Timber land in southeast Louisiana in 1996, and they are maintaining the protected Nature Area.

The Natural Areas Registry Program, a joint endeavor between The Nature Conservancy (TNC) and the Louisiana Department of Wildlife and Fisheries (LDWF), proposed the Thigpen Creek Natural Area in the early 1990's. A registry is a non-legal binding agreement to promote habitat conservation in significant natural areas. The landowner agrees to follow TNC/LDWF management recommendations designed to promote conservation of the biological diversity at the site. On Thigpen Creek, one of the private landowners with quillwort on their property has registered their land. Five others have registered as part of a buffer zone adjacent to the proposed Natural Area. Additional landowners in the area may reconsider their original decision not to register now that the local timber company has led the way in choosing to protect their quillwort colonies. Preliminary contacts have been made to landowners of quillwort sites in St. Tammany Parish to elicit their help in protection of this species.

All of the known Louisiana quillwort populations in Mississippi occur on DeSoto National Forest land. Three of them occur on lands leased from the U.S. Forest Service by the Mississippi Military Department for Camp Shelby, U.S. Army Reserve and National Guard Training Site in Perry County. The fourth population occurs at the Red Creek Management Area in Jackson County. Federal agencies are required to ensure that actions they authorize, fund, or carry out do not jeopardize the continued survival of the species. Military operations in wetlands are limited, and tracked vehicle use is restricted to designated wetland crossings. All new construction plans for projects that might impact wetlands and thus quillwort habitat include field inspection and habitat assessment. Attention is also given to upland construction where runoff and sedimentation might adversely impact known colonies (Leonard *in litt.* 1996).

Surveys for new populations have been conducted in Louisiana by the Louisiana Natural Heritage Program. Other surveys are ongoing or planned for Mississippi and Alabama. Additional research and field studies currently being conducted with *Isoetes* species, and specifically biosystematic research with *Isoetes louisianensis* by Taylor and Luebke at the Milwaukee Public Museum, are rapidly increasing our understanding of the life history and ecology of these obscure plants. An ecological study of Louisiana quillwort habitat at Camp Shelby, Mississippi has recently been initiated by University of Southern Mississippi biologists (Leonard *in litt.* 1996). Results of these studies will allow biologists and land managers to make more informed decisions in conserving and protecting Louisiana quillwort populations and their habitat.

A sixth grade class in Sanford, Connecticut, undertook a class project of developing a plan to recover the Louisiana quillwort after learning of the species' status from the Fish and Wildlife Service's public notification process on draft recovery plans. The students wrote articles, made speeches and posters, and heightened the public's awareness of the Louisiana quillwort's plight. They also developed their own list of actions to be implemented to improve the status of the species, many of which corresponded with those in the Fish and Wildlife Service's recovery plan. Similar activities should be encouraged as educational experiences for students. These efforts help to inform the public on the recovery process and conservation needs of endangered species.

II. RECOVERY

A. <u>Recovery Objective</u>

The objective of this plan is the conservation of Louisiana quillwort habitat to ensure that populations are self-sustaining components of their ecosystem. Delisting is a primary goal of this plan. Louisiana quillwort will be considered for delisting when 10 viable and geographically distinct populations from distinctly separate drainages are protected. A viable population is one which is reproducing and stable or increasing in size as shown by monitoring for at least a 10-year period.

Recovery criteria may be revised based upon the availability of new information, including information gathered from identified recovery tasks.

B. <u>Narrative Outline</u>

1. <u>Protect existing populations and their habitat from further impacts</u>. Based upon survey work to date, populations have been located in 12 drainages, eight in Louisiana and four in Mississippi. Over half of the known sites occur in St. Tammany Parish, Louisiana in areas undergoing intensive development. In Mississippi, currently known sites occur on national forest land. Continued survival of this species depends upon protection of the hydrology, soils, and plant communities in drainages where Louisiana quillwort is known to occur.

   1.1 <u>Ensure protection of populations on Federal land</u>. The Endangered Species Act (ESA) provides for the protection of endangered plants on Federal lands through Section 7 and Section 9. Federal agencies must ensure that activities they implement, fund, or permit are not likely to jeopardize the continued existence of a listed species. Federal agencies are also instructed to implement programs for the conservation of listed species. Section 9 prohibits the malicious damage or destruction of endangered plants on Federal lands and prohibits their removal, without a permit. The Fish and Wildlife Service will work with the Forest Service to ensure the protections of populations on their lands.

1.2 Protect populations on private land. All populations in Louisiana occur on private land. Survival of the species in Louisiana depends upon achieving protection for known sites.

1.2.1 Pursue land acquisition. Land acquisition for Natural Area reserves by organizations such as The Nature Conservancy, the Louisiana Department of Wildlife and Fisheries, or local area land trusts provide a high level of protection. The newly proposed Little Bogue Falaya Natural Area is a relatively small tract along a stretch of the creek containing Louisiana quillwort. It is currently being considered by The Nature Conservancy as a possible preserve site. However, current trends in preserve acquisition are to acquire large tracts of land with many rare species, and small area preserves such as the Little Bogue Falaya, with a single rare species, do not have as high priority for purchase.

1.2.2 Utilize conservation agreements and easements where appropriate. In Washington Parish, the Weyerhauser Timber Company Nature Area at Thigpen Creek provides protection for a section of creek supporting Louisiana quillwort. Conservation agreements and easements such as those of the Natural Areas Registry Program at Thigpen Creek Natural Area in Washington Parish also provide species protection. Preliminary contacts have been made by letter to landowners at quillwort sites in St. Tammany Parish.

1.2.3 Utilize indirect protection through Louisiana Natural and Scenic Rivers Act where applicable. State agencies provide indirect protection through their permitting processes. The Louisiana Natural and Scenic Rivers Act established the Louisiana Department of Wildlife and Fisheries Scenic River System in the 1970's. Four rivers within the range of Louisiana quillwort are protected as part of the Scenic Rivers program: Pushepatapa Creek in Washington Parish; Bogue Chitto River in Washington and St. Tammany Parishes; the Bogue Falaya in St. Tammany Parish; and the Tchefuncta River and its tributaries in Washington, Tangipahoa, and St. Tammany Parishes. Tributaries of these scenic rivers are afforded protection if it is shown that activities on the tributary will negatively impact the river downstream. Indirect protection of quillwort habitat occurs because the following activities are prohibited on Scenic Rivers: channelization, channel re-alignment, clearing and snagging, impoundments of any type and commercial clear-cutting of timber within 50 to 100 m (165 to 330 ft.) of the low watermark. Activities that need permits are: bridge, pipeline, and powerline crossings; waste water discharges; and land development adjacent to the stream.

1.3 Enforce State laws protecting environmental quality. The Louisiana Department of Environmental Quality (DEQ) is responsible for permitting discharge into the State's streams and rivers. Sand and gravel mining operations near Louisiana quillwort habitat affect the hydrology, water quality, and substrate stability (Hartfield 1991). DEQ personnel can provide protection for the habitat by establishing rigorous permit requirements.

1.4 Enforce Federal law protecting Louisiana quillwort on private land. Habitat protection opportunities, through the ESA, are limited for listed plants on private lands. Federal agencies are required to ensure that any action they carry-out, fund, or authorize does not jeopardize the continued survival of a listed species. Compliance with Section 404 of the Clean Water Act and Section 7 of the Endangered Species Act, U.S. Army Corps of Engineers and Natural

Resources Conservation Service wetland determinations can provide indirect protection of endangered or threatened species. Federal permit requirements for receiving federal funds to develop private property, or develop wetland sites, offers some protection for quillwort habitat.

1.5 Establish management guidelines for the protection of Louisiana quillwort and its habitat. Water quality and natural hydrologic regimes of stream systems providing habitat for Louisiana quillwort must be safeguarded in order to maintain viable populations. The following timber company management guidelines for minimizing streamside habitat loss, as developed by McInnis (1991b), may serve as a basis for the development of management plans for this species:

Streamside zone protection - A streamside buffer of 50 m (165 ft) in which timber harvest is restricted is suggested. However Brunton (*in litt.* 1995) recommends a larger buffer of 2 to 3 tree lengths (approximately 100 m or 330 ft) to achieve protection from edge effects. Protection of a riparian zone will ensure that habitat conditions are not altered, such as changes in ambient light, increase in sediment load from run-off, or alteration of stream flow from debris deposition.

Timber management in areas other than streamside zones - To minimize erosion and maintain stream quality and watershed values, timber harvesting should involve selective cutting. Harvesting should be conducted during dry periods to prevent soil compaction and rutting, especially in wetland areas dominated by sweetbay, swamp blackgum, and bald cypress. Mechanical site preparation methods such as drum-chopping or disking should not be used. Timber removal should be conducted in a manner that favors maintenance of indigenous ground cover and minimizes soil disruption. Prescribed burning is considered compatible with management of an area for quillwort, especially in surrounding uplands. Herbicide application should be prohibited.

Sand and gravel mining - Surface mining for sand and gravel should be prohibited near known quillwort habitat and should be carefully monitored in watersheds. Mining in the area of Clearwater Creek has significantly degraded stream quality through sediment deposition. Dams around gravel pits erode and frequently break through during periods of heavy rainfall. Such an event would critically degrade the microhabitat of Louisiana quillwort and could pose a significant threat to a population.

Beaver dams - Beaver activity has been noted near sites near Thigpen Creek in Louisiana and near Pearces Creek in Mississippi. It should be closely monitored in both Louisiana (and Mississippi) to prevent permanent inundation of quillwort habitat.

Additional quidelines need to be designed to protect habitat from off-road vehicle use, flood control measures, road construction, and feral hogs.

2. Conduct biosystematic research on the species. Fertile live specimens of *Isoetes louisianensis* have been cultivated for biosystematic research by Taylor and Luebke. Specimens were collected from widely separated sites: 1) the northernmost site in the Bogue Chitto River drainage in Washington Parish; 2) from mid-range in the Abita River and Little Bogue Falaya River drainages in central St. Tammany Parish; and, 3) from the southernmost site near Bayou Chinchuba in south St. Tammany Parish. Taylor and Luebke plan to report results upon completion of their studies.

3. Monitor populations to learn more about the habitat, life history, and to determine positive and negative trends. All known sites should be checked at least yearly over a period of not less that 10 years. Population numbers and vitality should be recorded, as well as observations on specific habitat characteristics. Negative environmental impacts such as bank erosion, sand sedimentation, trash dumping, or increased competition from removal of canopy trees should also be noted. Monitoring of the population's status and habitat will aid in determining optimal habitat conditions.

4. Search for additional populations. Further systematic survey is needed. Many potential sites on private property in Louisiana have not been surveyed. It is highly probable that additional populations exist in the region near the known occurrences of this species. Surveys in Louisiana should also focus on Prairie Terraces west of the Mississippi in southwest Louisiana flatwoods in Allen, Beauregard, Calcasieu, and Jefferson Davis Parishes.

   Potential quillwort habitat exists in the Pleistocene Prairie Terraces that extend from near Picayune, Mississippi in a narrow band along the Gulf Coast to Alabama. Although Rosso (1987) looked for *Isoetes louisianensis* without success in Forrest, Lamar, Lauderdale, Marion, Pearl River, Stone and Walthall counties, the recent discoveries of Louisiana quillwort in the Pleistocene High Terraces in Perry County and Jackson County have broadened the potential search range. Further surveys in Mississippi and Alabama are recommended.

5. Preserve genetic material. The collection, storage, and maintenance of genetically representative material from the wild is necessary to guard against destruction of populations. This material could also be used for education, research, and reestablishment, if needed. The Center for Plant Conservation can provide guidance in implementing this task.

6. Inform the public on conservation needs of Louisiana quillwort. Public education increases awareness of the rarity of this species and the importance of maintaining its habitat. As more is learned about the habitat and life history of Louisiana quillwort, Federal and State permitting agencies will be better able to protect quillwort habitat. Informing Corps of Engineers and Natural Resources Conservation Service wetland biologists, as well as those with State agencies and with private consulting firms, is needed to improve species recognition and understanding of quillwort habitat requirements. Any streamside *Isoetes* in southeastern Louisiana or southern Mississippi should be assumed rare. Management guidelines

developed under Task 1.5 will provide valuable assistance to landowners and others in the protection of this species' habitat.

Programs such as the Forest Stewardship Program, a national program coordinated in Louisiana by the Louisiana Department of Agriculture and Forestry, Office of Forestry, in cooperation with a number of State and Federal agencies, including the Louisiana Department of Wildlife and Fisheries Forestry Section, provide forest management plans to private landowners throughout the State. School programs, nature center programs, and public television can provide ways for the public to become aware of the rarity of Louisiana quillwort and importance of safeguarding its aquatic habitat. Such efforts will benefit other endangered species and the protection of natural environments.

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III. IMPLEMENTATION SCHEDULE

The following Implementation Schedule outlines recovery actions and their estimated costs for the first 3 years of the recovery program. It is a guide for meeting the objective discussed in Part II of this plan. This Schedule indicates task priorities, task numbers, task descriptions, duration of tasks, the responsible agencies, and lastly, estimated costs.

Priorities in column 1 of the following Implementation Schedule are assigned as follows:

1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

3 - All other actions necessary to meet the recovery objective.

Keys to acronyms used in Implementation Schedule:

ALNHP - Alabama Natural Heritage Program
COE - U.S. Army Corps of Engineers
CPC - Center for Plant Conservation
DEQ - Department of Environmental Quality
HC - Habitat Conservation, U.S. Fish and Wildlife Service
LANHP - Louisiana Natural Heritage Program, Louisiana Department of Wildlife and Fisheries
LDAF - Louisiana Department of Agriculture and Forestry
LDWF - Louisiana Department of Wildlife & Fisheries
MSNHP - Mississippi Natural Heritage Program, Mississippi Department of Wildlife, Fisheries, & Parks
NRCS - U.S. Department of Agriculture, Natural Resources Conservation Service
TE - Endangered Species Division, U.S. Fish and Wildlife Service
TNC - The Nature Conservancy
USFS - U.S. Forest Service
USFWS - U.S. Fish and Wildlife Service

IMPLEMENTATION SCHEDULE										
				RESPONSIBLE PARTY			COST ESTIMATES ($K)			
				USFWS						
PRIORITY NUMBER	TASK NUMBER	TASK DESCRIPTION	TASK DURATION	Region	Division	Other	FY 1	FY 2	FY 3	COMMENTS/NOTES
1	1.1	Protect populations on Federal lands.	Ongoing	4	TE	USFS				
1	1.2-1.2.3	Protect populations on private lands.	Ongoing	4	TE	TNC/LDWF LANHP	3.0	3.0	3.0	Estimates do not include cost of land acquisition.
1	1.3	Enforce State laws protecting environmental quality.	Ongoing	4	TE	DEQ, LDWF, LANHP	---	---	---	
1	1.4	Enforce Federal law protecting Louisiana quillwort on private land.	Ongoing	4	TE, HC	NRCS, COE	---	---	---	
1	1.5	Develop management guidelines.	1 year	4	TE	LANHP, USFS, TNC/LDWF	3.5	---	---	
2	2	Conduct biosystematic research on the species.	2 years	4	TE	LANHP & Others	10.0	8.0	---	
2	3	Monitor populations to learn more about the life history; monitor trends.	Ongoing	4	TE	LANHP, USFS	5.0	5.0	5.0	
2	4	Search for additional populations.	2 years	4	TE	ALNHP, LANHP, MSNHP, COE, USFS, NRCS	6.0	6.0	---	
3	5	Preserve genetic stock.	Ongoing	4	TE	CPC, Others	3.0	3.0	3.0	
3	6	Public information efforts.	Ongoing	4	TE	LANHP, USFS, LDWF, TNC, LDAF	2.5	2.5	2.5	

IV. APPENDIX

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The following agencies, organizations, and individuals were mailed copies of this recovery plan. This does not imply that they provided comments or endorsed the contents of this plan.

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Appendix C-4: Red-cockaded Woodpecker Recovery Plan

Recovery Plan for the

Red-cockaded Woodpecker (*Picoides borealis*)

Second Revision

Original Approved: August 24, 1979
First Revision Approved: April 11, 1985

U.S. Fish and Wildlife Service
Southeast Region
Atlanta, GA

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Regional Director, Southeast Region
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____
Craig Manson, Assistant Secretary of the Interior for Fish, Wildlife and Parks

Date: 1/27/03

1-27-03

DISCLAIMER

This Recovery Plan Revision outlines the actions that, to the best of current understanding, are necessary to recover red-cockaded woodpeckers. It does not represent the view or official position of any individuals or agencies involved in the development of the plan, other than the U.S. Fish and Wildlife Service. It represents official policy of the U.S. Fish and Wildlife Service only after the regional director has signed it as approved. This revision is subject to further modification as dictated by new findings, changes in species status, and completion of recovery tasks. Implementation of this plan is the responsibility of federal and state management agencies in the areas where the species occurs. Implementation is done through incorporation of management guidelines identified within this Recovery Plan Revision into agency decision documents. Decision documents, as defined by the National Environmental Policy Act (NEPA), are subject to the NEPA process for public review and alternatives selection.

LITERATURE CITATION SHOULD READ AS FOLLOWS:

U.S. Fish and Wildlife Service. 2003. Recovery plan for the red-cockaded woodpecker (*Picoides borealis*): second revision. U.S. Fish and Wildlife Service, Atlanta, GA. 296 pp.

ADDITIONAL COPIES MAY BE PURCHASED FROM:

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
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Fees for documents vary depending on postage and number of pages.

STANDARD ABBREVIATIONS

The following standard abbreviations for units of measurement are found throughout this document:

cm = centimeters	in = inches	m^2 = square meters
m = meters	ft = feet	ft^2 = square feet
km = kilometers	mi = miles	dbh = diameter at breast height
ha = hectares	ac = acres	
g = grams	oz = ounces	

ACKNOWLEDGMENTS

The process of revising the 1985 red-cockaded woodpecker recovery plan began in August 1995, when potential recovery team members were identified. In January 1996, 15 potential members were asked to participate on the team; all accepted. The first team meeting was held in March 1996; two additional meetings, each one week long, were held in April and December 1997. Between March 1996 and March 2000, team members individually spent hundreds of hours working on the revision, including participation in team meetings, writing, and reviewing. The U.S. Fish and Wildlife Service is very appreciative of the time and hard work put forth by team members during this process. Combined, the team has approximately 257 years of red-cockaded woodpecker experience in the private, state, and federal sectors. Their professional experiences with red-cockaded woodpeckers have included research, population and habitat management, and regulatory and policy responsibilities. They have unselfishly contributed their knowledge, time, and expertise to the many challenges of the recovery plan revision process. The U.S. Fish and Wildlife Service thanks each of them for their contributions and is grateful to have worked with such a team.

By April 1999, much of the Introduction had been drafted. However, several major tasks remained to be accomplished. These tasks included writing Recovery, Listing, Executive Summary, and other sections; compiling and editing the contributions of 15 other authors; and creating tables, Literature Cited, and Index. In April 1999, the U.S. Fish and Wildlife Service hired Ms. Susan Daniels as a wildlife biologist and recovery team member to take the lead on completing these tasks. The recovery team and U.S. Fish and Wildlife Service are proud to extend special thanks to "one of our own" for her continuous hard work during the past four years on this challenging project. Sue has done an outstanding job of assembling and completing this revision.

Ultimately, recovery of the red-cockaded woodpecker is and will be dependent upon the on-the-ground hard work of biologists, foresters, technicians, researchers, and land managers working on the private, state, and federal properties where the birds survive. During the past seven years, many of these individuals have been asked to supply information including population and habitat data, maps, and management costs. The U.S. Fish and Wildlife Service and the recovery team are particularly grateful to these many individuals for their timely and reliable responses to our requests. They have supplied a tremendous amount of information for this document.

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EXECUTIVE SUMMARY

CURRENT STATUS

The red-cockaded woodpecker (*Picoides borealis*) is a federally listed endangered species endemic to open, mature and old growth pine ecosystems in the southeastern United States. Currently, there are an estimated 14,068 red-cockaded woodpeckers living in 5,627 known active clusters across eleven states. This is less than 3 percent of estimated abundance at the time of European settlement. Red-cockaded woodpeckers were given federal protection with the passage of the Endangered Species Act in 1973. Despite this protection, all monitored populations (with one exception) declined in size throughout the 1970's and into the 1980's. In the 1990's, in response to intensive management based on a new understanding of population dynamics and new management tools, most populations were stabilized and many showed increases. Other populations remain in decline, and most have small population sizes. Our major challenge now is to bring about the widespread increases in population sizes necessary for recovery.

BASIC ECOLOGY AND POPULATION DYNAMICS

Red-cockaded woodpeckers are a cooperatively breeding species, living in family groups that typically consist of a breeding pair with or without one or two male helpers. Females may become helpers, but do so at a much lower rate than males. The ecological basis of cooperative breeding in this species is unusually high variation in habitat quality, due to the presence or absence of a critical resource. This critical resource is the cavities that red-cockaded woodpeckers excavate in live pines, a task that commonly takes several years to complete.

Red-cockaded woodpeckers exploit the ability of live pines to produce large amounts of resin, by causing the cavity tree to exude resin through wounds, known as resin wells, that the birds keep open. This resin creates an effective barrier against climbing snakes. Longleaf pine is a preferred tree species for cavity excavation because it produces more resin, and for a longer period of time, than other southern pines.

Group living has profound influence over population dynamics. In non-cooperatively breeding birds, breeders that die are replaced primarily by the young of the previous year. Thus, variation in reproduction and mortality can have strong, immediate impacts on the size of the breeding population. However, in red-cockaded woodpeckers and other cooperative breeders, a large pool of helpers is available to replace breeders. As a result, the size of the breeding population is not strongly affected by how many young are produced each year, or even on how many breeders may die. Because of this, we use the number of potential breeding groups rather than number of individuals as our measure of population size. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young.

Because of the cooperative breeding system, red-cockaded woodpecker populations are unusually resistant to environmental and demographic variation, but highly sensitive to the spatial arrangement of habitat. The buffering effect of helpers against annual variation operates only when helpers can readily occupy breeding vacancies as they arise. Helpers do not disperse very far and typically occupy vacancies on their natal territory or a neighboring one. If groups are isolated in space, dispersal of helpers to neighboring territories is disrupted and the buffering effect of the helper class is lost. When this happens, populations become much less likely to persist through time. Also, the cooperative breeding system does not allow rapid natural growth of populations. Colonization of unoccupied habitat is an exceedingly slow process under natural conditions, because cavities take long periods of time to excavate and birds do not occupy habitat without cavities. As forests age and old pines become abundant, rates of natural cavity excavation and colonization may increase.

Understanding these three components of the population dynamics of red-cockaded woodpeckers provides us the foundation for recovery efforts: (1) population size and trend are determined by the number of potential breeding groups rather than annual variation in reproduction and survival; (2) the buffering capacity of the helper class must be maintained, by maintaining close aggregations of territories; and (3) colonization of unoccupied habitat will be very slow without management assistance.

Habitat Requirements and Limiting Factors

Red-cockaded woodpeckers require open pine woodlands and savannahs with large old pines for nesting and roosting habitat (clusters). Large old pines are required as cavity trees because the cavities are excavated completely within inactive heartwood, so that the cavity interior remains free from resin that can entrap the birds. Also, old pines are preferred as cavity trees, because of the higher incidence of the heartwood decay that greatly facilitates cavity excavation. Cavity trees must be in open stands with little or no hardwood midstory and few or no overstory hardwoods. Hardwood encroachment resulting from fire suppression is a well-known cause of cluster abandonment. Red-cockaded woodpeckers also require abundant foraging habitat. Suitable foraging habitat consists of mature pines with an open canopy, low densities of small pines, little or no hardwood or pine midstory, few or no overstory hardwoods, and abundant native bunchgrass and forb groundcovers.

Limiting factors are those that directly affect the number of potential breeding groups, because this is the primary determinant of population size and trend. Several factors currently impact the persistence of breeding groups. Foremost among these are the factors that limit suitable nesting habitat, namely fire suppression and lack of cavity trees. Fire suppression has resulted in loss of potential breeding groups throughout the range of red-cockaded woodpeckers, because the birds cannot tolerate the hardwood encroachment that results from lack of fire. This limitation is addressed through the use of prescribed burning. Lack of cavity trees, and potential cavity trees, limits the number of breeding groups in most populations. This limitation is addressed in the short-term through cavity management tools such as artificial cavities and restrictor plates, and over the long-term by growing large old trees in abundance.

Another factor directly limiting the number of potential breeding groups is habitat fragmentation and consequent isolation of groups, which results in disrupted dispersal of helpers and failure to replace breeders. This limitation is best addressed through the appropriate placement of clusters of artificial cavities, and implementation of silvicultural practices that minimize fragmentation.

There are several other threats to the existence and recovery of the species, not limiting most populations currently, but which will become more important as the current limitations are addressed. Chief among these are (1) degradation of foraging habitat through fire suppression and loss of mature trees, and (2) loss of valuable genetic resources because of small size and isolation of populations. As currently limiting factors such as lack of cavities are relieved, the continued growth and natural stability of red-cockaded woodpecker populations will depend on provision of abundant, good quality foraging habitat and careful conservation of genetic resources.

POPULATION AND SPECIES VIABILITY

Four types of threats to species and population viability have been identified: genetic stochasticity (consisting of both inbreeding and genetic drift), demographic stochasticity, environmental stochasticity, and catastrophes. We now have some knowledge of population sizes of red-cockaded woodpeckers necessary to withstand these extinction threats, primarily from research performed with a spatially explicit, individually based simulation model of population dynamics developed specifically for this species.

Red-cockaded woodpeckers exhibit inbreeding depression and inbreeding avoidance behaviors. Inbreeding is expected to affect population viability in populations of less than 40 potential breeding groups, and may be a significant factor affecting viability in isolated populations of 40 to 100 potential breeding groups as well. Immigration rates of 2 or more migrants per year can effectively reduce inbreeding in populations of any size, including very small ones.

Effects of demographic stochasticity on population viability vary with the spatial arrangement of groups. Populations as small as 25 potential breeding groups can be surprisingly resistant to random demographic events, if those groups are highly aggregated in space. Populations as large as 100 potential breeding groups can be impacted by demographic stochasticity, if groups are not aggregated and dispersal of helpers is disrupted. Demographic stochasticity is not expected to affect populations larger than 100 potential breeding groups. Similarly, effects of environmental stochasticity vary with the spatial arrangement of groups. Based on preliminary results of the model and estimates of environmental stochasticity derived from the North Carolina

Sandhills, 250 potential breeding groups will likely withstand effects of environmental stochasticity regardless of their spatial arrangement.

Loss of genetic variation through the process of genetic drift is an inevitable consequence of finite population size. New genetic variation arises through the process of mutation. In large populations, mutation can offset loss through drift and genetic variation is maintained. Just how large a population must be to maintain variation is a difficult question. Currently, researchers recognize that in general, only populations with actual sizes in the thousands, rather than hundreds, can maintain long-term viability and evolutionary potential in the absence of immigration. However, if populations are connected by immigration rates on the order of 1 to 10 migrants per generation (0.5 to 2.5 migrants per year), the genetic variation maintained by these populations is equal to that of one population as large as the sum of the connected populations. Thus, sufficient connectivity among populations can maintain genetic variation and long-term viability for the species.

RECOVERY GOAL

The ultimate recovery goal is species viability. This goal is represented by delisting. Once delisting criteria are met, the size, number, and distribution of populations will be sufficient to counteract threats of demographic, environmental, genetic, and catastrophic stochastic events, thereby maintaining long-term viability for the species as defined by current understanding of these processes. Regions and habitat types currently occupied by the species will be represented to the best of our ability, given habitat limitations.

RECOVERY CRITERIA

Recovery criteria have been formulated using eleven recovery units delineated according to ecoregions. Populations required for recovery are distributed among recovery units to ensure the representation of broad geographic and genetic variation in the species. Viable populations within each recovery unit, to the extent allowed by habitat limitations, are essential to the recovery of the species as a whole.

Population sizes identified in recovery criteria are measured in number of potential breeding groups. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young. A traditional measure of population size has been number of active clusters. Potential breeding groups is used in recovery criteria in addition to active clusters, because number of active clusters can include varying proportions of solitary males and captured clusters. (A captured cluster is one that does not support its own group, but is kept active by a member or members of a neighboring group.) Increases in proportions of captured clusters and solitary males are early indicators of population decline. Estimates of all three parameters—number of active clusters, proportion of solitary males, and proportion of captured clusters—are required to derive estimates of potential breeding groups.

To facilitate use of potential breeding groups as a measure of population size, we have provided a range of numbers of active clusters considered the likely equivalents of the required number of potential breeding groups. Estimated number of active clusters is likely to be at least 1.1 times the number of potential breeding groups, but it is unlikely to be more than 1.4 times this number. Thus, an estimated 400 to 500 active clusters will be necessary to contain 350 potential breeding groups, depending on the proportions of solitary males and captured clusters and also on the estimated error of the sampling scheme. It is expected that all recovery populations will have sampling in place that is adequate to judge potential breeding groups. If this is not the case, only the highest number of active clusters in the range given can be substituted to meet the required population size.

Delisting

Delisting shall occur when each of the following criteria is met. Rationale for each criterion is given immediately following this list. See Tables 1, 2, and 3 for population designation. All properties identified as part or all of a recovery population (Tables 1, 2, and 3) should be managed for maximum size that the habitat designated for red-cockaded woodpeckers will allow. (Maximum size is generally based on 200 ac [81 ha] per group).

Criterion 1. There are 10 populations of red-cockaded woodpeckers that each contain at least 350 potential breeding groups (400 to 500 active clusters), and 1 population that contains at least 1000 potential breeding groups (1100 to 1400 active clusters), from among 13 designated primary core populations, and each of these 11 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size. The 13 designated primary core populations, and the recovery units in which they are located, are listed in Table 1.

Criterion 2. There are 9 populations of red-cockaded woodpeckers that each contain at least 250 potential breeding groups (275 to 350 active clusters), from among 10 designated secondary core populations, and each of these 9 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size. The 10 designated secondary core populations, and the recovery units in which they are located, are listed in Table 2.

Criterion 3. There are at least 250 potential breeding groups (275 to 350 active clusters) distributed among designated essential support populations in the South/Central Florida Recovery Unit, and six of these populations (including at least two of the following: Avon Park, Big Cypress, and Ocala) exhibit a minimum population size of 40 potential breeding groups that is independent of continuing artificial cavity installation.

Designated essential support populations in the South/Central Florida Recovery Unit are listed in Table 3.

Criterion 4. The following populations are stable or increasing and each contain at least 100 potential breeding groups (110 to 140 active clusters): (1) Northeast North Carolina/Southeast Virginia Essential Support Population of the Mid-Atlantic Coastal Plain Recovery Unit, (2) Talladega/Shoal Creek Essential Support Population of the Cumberlands/Ridge and Valley Recovery Unit, and (3) North Carolina Sandhills West Essential Support Population of the Sandhills Recovery Unit; and these populations are not dependent on continuing artificial cavity installation to remain at or above this population size. These populations are also listed in Table 3.

Criterion 5. For each of the populations meeting the above size criteria, responsible management agencies shall provide (1) a habitat management plan that is adequate to sustain the population and emphasizes frequent prescribed burning, and (2) a plan for continued population monitoring.

Rationale for Delisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift. One primary core population has the potential to harbor 1000 potential breeding groups within the near future; this criterion is included because such a large population may well be resistant to loss of genetic variation through drift. Eleven of 13 primary core populations are required for delisting because it is recognized that at any given time, one or two may be suffering hurricane impacts. Thirteen primary core populations are designated because of available habitat and because this number, together with 10 secondary core populations (below), may serve to facilitate natural dispersal among populations and maximize retention of genetic variability. Primary and secondary core populations provide for the conservation of the species within each major physiographic unit in which it currently exists, with the exception of South/Central Florida. This recovery unit is represented by several, smaller, essential support populations (below). Populations that depend on continuing artificial cavity installation to maintain stable or increasing trends are barred from meeting delisting criteria because this management technique is considered appropriate for short-term management only.

Criterion 2. A population size of 250 potential breeding groups is the minimum size considered robust to environmental stochasticity, and is well above the size necessary to withstand inbreeding and demographic stochasticity. Nine of 10 designated secondary core populations are required for delisting to allow for hurricane impacts.

Criterion 3. This unique habitat type is represented to the extent that available habitat allows. Unique genetic resources are conserved as much as reasonably possible.

Because of small size, some of these populations will remain vulnerable to extinction threats and may eventually be lost. The likelihood of extirpation of small populations is minimized by enhancing the spatial arrangement of territories so that they are highly aggregated.

Criterion 4. These unique or important habitats, and genetic resources contained within this population, will be represented at the time of delisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. Continued habitat management and population monitoring are necessary to ensure that the species does not again fall to threatened or endangered status.

Downlisting

Downlisting shall occur when each of the following criteria is met. Rationale for each criterion is presented immediately following this list.

Criterion 1. The Central Florida Panhandle Primary Core Population in the East Gulf Coastal Plain Recovery Unit is stable or increasing and contains at least 350 potential breeding groups (400 to 500 active clusters).

Criterion 2. There is at least one stable or increasing population containing at least 250 potential breeding groups (275 to 350 active clusters) in each of the following recovery units: Sandhills, Mid-Atlantic Coastal Plain, South Atlantic Coastal Plain, West Gulf Coastal Plain, Upper West Gulf Coastal Plain, and Upper East Gulf Coastal Plain.

Criterion 3. There is at least one stable or increasing population containing at least 100 potential breeding groups (110 to 140 active clusters) in each of the following recovery units: Mid-Atlantic Coastal Plain, Sandhills, South Atlantic Coastal Plain, and East Gulf Coastal Plain.

Criterion 4. There is at least one stable or increasing population containing at least 70 potential breeding groups (75 to 100 active clusters) in each of four recovery units, Cumberlands/Ridge and Valley, Ouachita Mountains, Piedmont, and Sandhills. In addition, the Northeast North Carolina/Southeast Virginia Essential Support Population is stable or increasing and contains at least 70 potential breeding groups (75 to 100 active clusters).

Criterion 5. There are at least four populations each containing at least 40 potential breeding groups (45 to 60 active clusters) on state and/or federal lands in the South/Central Florida Recovery Unit.

Criterion 6. There are habitat management plans in place in each of the above populations identifying management actions sufficient to increase the populations to recovery levels, with special emphasis on frequent prescribed burning during the growing season.

Rationale for Downlisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift.

Criterion 2. This population size, 250 potential breeding groups, is sufficient to withstand extinction threats from environmental uncertainty, demographic uncertainty, and inbreeding depression. These 6 populations, in combination with the single population identified in criterion (1), will represent each major recovery unit.

Criterion 3. A second population in these coastal recovery units will decrease the species' vulnerability to hurricanes. The West Gulf Coastal Plain is excluded because there are no candidate populations there. The lower size, 100 potential breeding groups, is considered sufficient to withstand threats from demographic uncertainty and inbreeding depression, and is much more quickly attained than 250 potential breeding groups thought necessary to withstand environmental stochasticity.

Criterion 4. These special habitats will be represented at the time of downlisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. This unique region will be represented at the time of downlisting. Forty potential breeding groups is at the lower end of estimates of sizes necessary to withstand inbreeding depression and are considered robust to demographic stochasticity if territories are highly aggregated in space.

Criterion 6. These habitat management plans are necessary to ensure progress toward delisting.

ACTIONS NEEDED

The primary actions needed to accomplish the ultimate (delisting) and interim (downlisting) recovery goals are (1) application of frequent fire to both clusters and foraging habitat, (2) protection and development of large, mature pines throughout the landscape, (3) protection of existing cavities and judicious provisioning of artificial cavities, (4) provision of sufficient recruitment clusters in locations chosen to enhance the spatial arrangement of groups, and (5) restoration of sufficient habitat quality and quantity to support the large populations necessary for recovery.

Date of Recovery

We estimate that, with full implementation of this recovery plan, red-cockaded woodpeckers will be downlisted by the year 2050 and delisted by 2075.

TABLE 1. Designated primary core populations (13) by recovery unit. Location (state) and individual properties comprising recovery populations are also listed. At delisting, the Central Florida Panhandle will contain 1000 or more potential breeding groups, and at least 11 of the remaining 12 primary core populations will contain 350 or more potential breeding groups. See 7 for more information, including definitions of recovery roles and recovery units. See map insert also.

Recovery Unit **Population**	**Property Full Name**	**State**
East Gulf Coastal Plain		
(1) Central Florida Panhandle	Apalachicola Ranger District, Apalachicola National Forest	FL
	Ochlockonee River State Park	FL
	St. Marks National Wildlife Refuge	FL
	Tate's Hell State Forest	FL
	Wakulla Ranger District, Apalachicola National Forest	FL
(2) Chickasawhay	Chickasawhay Ranger District, DeSoto National Forest	MS
(3) Eglin	Eglin Air Force Base	FL
Mid-Atlantic Coastal Plain		
(4) Coastal North Carolina	Croatan National Forest	NC
	Holly Shelter Game Lands	NC
	Marine Corps Base Camp Lejeune	NC
(5) Francis Marion	Francis Marion National Forest	SC
Sandhills		
(6) Fort Benning	Fort Benning	GA
(7) North Carolina Sandhills East	Calloway Tract	NC
	Carver's Creek Tract	NC
	Fort Bragg	NC
	McCain Tract	NC
	Weymouth Woods State Nature Preserve	NC
South Atlantic Coastal Plain		
(8) Fort Stewart	Fort Stewart	GA
(9) Osceola/Okefenokee	Osceola National Forest	FL
	Okefenokee National Wildlife Refuge	GA
Upper East Gulf Coastal Plain		
(10) Bienville	Bienville National Forest	MS
Upper West Gulf Coastal Plain		
(11) Sam Houston	Sam Houston National Forest	TX
West Gulf Coastal Plain		
(12) Angelina/Sabine	Angelina National Forest	TX
	Sabine National Forest	TX
(13) Vernon/Fort Polk	Fort Polk	LA
	Vernon Unit, Calcasieu Ranger District, Kisatchie National Forest	LA

TABLE 2. Designated secondary core populations (10) by recovery unit. Location (state) and individual properties comprising recovery populations are also listed. At delisting, at least 9 of these populations will contain 250 or more potential breeding groups. See 7 for more information, including definitions of recovery roles and recovery units. See map insert also.

Recovery Unit / Population	Property Full Name	State
East Gulf Coastal Plain		
(1) Conecuh/Blackwater	Blackwater River State Forest	FL
	Conecuh National Forest	FL
(2) DeSoto	DeSoto Ranger District, DeSoto National Forest	MS
(3) Homochitto	Homochitto National Forest	MS
Ouachita Mountains		
(4) Ouachita	Ouachita National Forest	AR
Piedmont		
(5) Oconee/Piedmont	Oconee National Forest	GA
	Piedmont National Wildlife Refuge	GA
Sandhills		
(6) South Carolina Sandhills	Carolina Sandhills National Wildlife Refuge	SC
	Sand Hills State Forest	SC
South Atlantic Coastal Plain		
(7) Savannah River	Savannah River Site	SC
Upper East Gulf Coastal Plain		
(8) Oakmulgee	Oakmulgee Ranger District, Talladega National Forest	AL
West Gulf Coastal Plain		
(9) Catahoula	Catahoula Ranger District, Kisatchie National Forest	LA
	Winn Ranger District (portion), Kisatchie National Forest	LA
(10) Davy Crockett	Davy Crockett National Forest	TX

TABLE 3. Designated essential support populations (16) by recovery unit. Location (state) and individual properties comprising recovery populations are also listed. At delisting, North Carolina Sandhills West, Northeast North Carolina/Southeast Virginia, and Talladega/Shoal Creek will each contain 100 or more potential breeding groups, and 6 populations (including at least 2 of the following: Avon Park, Big Cypress, and Ocala) in South/Central Florida will each contain 40 or more potential breeding groups. See 7 for more information, including definitions of recovery roles and recovery units. See map insert also.

Recovery Unit / **Population**	**Property Full Name**	**State**
Cumberlands/Ridge and Valley		
(1) Talladega/Shoal Creek	Shoal Creek Ranger District, Talladega National Forest	AL
	Talladega Ranger District, Talladega National Forest	AL
Mid-Atlantic Coastal Plain		
(2) Northeast North Carolina/ Southeast Virginia	Alligator River National Wildlife Refuge	NC
	Dare County Bombing Range	NC
	Palmetto-Peartree Preserve	NC
	Pocosin Lakes National Wildlife Refuge	NC
	Piney Grove Preserve	VA
Sandhills		
(3) North Carolina Sandhills West	Camp Mackall	NC
	Sandhills Game Lands	NC
South/Central Florida		
(4) Avon Park	Avon Park Air Force Range	FL
	Kicco Wildlife Management Area	FL
(5) Babcock/Webb	Babcock/Webb Wildlife Management Area	FL
(6) Big Cypress	Big Cypress National Preserve	FL
(7) Camp Blanding	Camp Blanding Training Site	FL
(8) Corbett/Dupuis	J. W. Corbett/Dupuis Wildlife Management Area	FL
(9) Goethe	Goethe State Forest	FL
(10) Hal Scott Preserve	Hal Scott Preserve	FL
(11) Ocala	Ocala National Forest	FL
(12) Picayune Strand	Picayune Strand State Forest	FL
(13) St. Sebastian River	St. Sebastian River State Buffer Preserve	FL
(14) Three Lakes	Three Lakes Wildlife Management Area	FL
(15) Withlacoochee – Citrus Tract	Withlacoochee State Forest - Citrus Tract	FL
(16) Withlacoochee – Croom Tract	Withlacoochee State Forest - Croom Tract	FL

PART I. INTRODUCTION

1. LISTING

A. REASONS FOR LISTING

The red-cockaded woodpecker was listed as endangered in 1970 (35 Federal Register 16047) and received federal protection with the passage of the Endangered Species Act in 1973. Once a common bird distributed continuously across the southeastern United States, by the time of listing the species had declined to fewer than 10,000 individuals in widely scattered, isolated, and declining populations (Jackson 1971, Ligon *et al.* 1986).

This precipitous decline was caused by an almost complete loss of habitat. Fire-maintained old growth pine savannahs and woodlands that once dominated the southeast, on which the woodpeckers depend, no longer exist except in a few small patches. Longleaf pine (*Pinus palustris*) ecosystems, of primary importance to red-cockaded woodpeckers, are now among the most endangered systems on earth (Simberloff 1993, Ware *et al.* 1993). Shortleaf (*P. echinata*), loblolly (*P. taeda*), and slash pine (*P. elliottii*) ecosystems, important to red-cockaded woodpeckers outside the range of longleaf, also have suffered severe declines (Smith and Martin 1995).

Loss of the original pine ecosystems was primarily due to intense logging for lumber and agriculture. Logging was especially intense at the turn of the century (Frost 1993, Martin and Boyce 1993, Conner *et al.* 2001). Two additional factors resulting in the loss of original pine systems in the 1800's and earlier were exploitation for pine resins and grazing by free-ranging hogs (*Sus scrofa*; Wahlenburg 1946, Frost 1993). Later, in the 1900's, fire suppression and detrimental silvicultural practices had major impacts on primary ecosystem remnants, second-growth forests, and consequently on the status of red-cockaded woodpeckers (Frost 1993, Ware *et al.* 1993, Ligon *et al.* 1986, 1991, Landers *et al.* 1995, Conner *et al.* 2001). Longleaf pine suffered a widespread failure to reproduce following initial cutting, at first because of hogs and later because of fire suppression (Wahlenburg 1946, Ware *et al.* 1993). These factors are discussed in more detail below.

Loss of the Original Ecosystems

Southern pine savannahs and open woodlands once dominated the southeastern United States, and may have totaled over 80 million ha (200 million ac) at the time of European colonization (Conner *et al.* 2001). Longleaf pine communities characterized the Atlantic and Gulf coastal regions, and covered an estimated 24 to 37 million ha (60 to 92 million ac; Wahlenburg 1946, Frost 1993, Ware *et al.* 1993, Landers *et al.* 1995). Roughly one quarter of the longleaf communities also supported other pines such as loblolly, shortleaf, slash, and pond pine (*P. serotina*) in various proportions depending on soil conditions, especially in transitional zones between the coastal plains and other physiographic regions (Frost 1993, Landers *et al.* 1995).

Today, longleaf forests have declined to less than 1.2 million ha (3 million ac; Landers *et al.* 1995), of which roughly 3 percent remains in relatively natural condition (Frost 1993). Little old growth remains, and virtually no longleaf forest has escaped changes in the natural fire regime (Simberloff 1993, Walker 1999). Shortleaf pine was prevalent outside the range of longleaf, especially on dry slopes and ridges in the Interior Highlands and Oklahoma, and has declined considerably (Landers 1991, Smith and Martin 1995). In the precolonial forests, loblolly pine was present as a minor component of riparian hardwood ecosystems or in association with shortleaf pine in some upland interior forests (White 1984, Landers 1991, Christensen 2000).

Southern pine forests today are very different from precolonial communities not only in extent, but also in species composition, age, and structure (Ware *et al.* 1993, Noel *et al.* 1998). Original pine forests were old, open, and contained a structure of two layers: canopy and diverse herbaceous groundcover. These forests were dominated by longleaf pine in the coastal plain, longleaf and shortleaf pines in the Piedmont and interior highlands, and slash pine (*P. elliottii* var. *densa*) in south Florida. Forests dominated by loblolly pine were restricted to a portion of southern Arkansas and perhaps eastern Virginia and extreme northeastern North Carolina (White 1984, Christensen 2000). In contrast, much of today's forest is young, dense, and dominated by loblolly pine, with a substantial hardwood component and little or no herbaceous groundcover (Ware *et al.* 1993, Noel *et al.* 1998).

Original longleaf communities in the Atlantic and Gulf coastal plains were first heavily impacted by exploitation for naval stores and then virtually eliminated by widespread logging and the subsequent reproductive failure of longleaf pine (Frost 1993, Ware *et al.* 1993). Naval stores industries harvested pine resin for the production of tar, pitch, and turpentine—commodities in high demand during colonial times. Pine woodlands were logged for lumber and conversion to agricultural fields. Impacts to easily accessible areas began with the arrival of Europeans, but technological developments of the 1800's, such as the copper still, steam power, and especially railroads, dramatically increased the rate and area of loss (Frost 1993). In the late 1800's logging operations moved to the previously inaccessible interior forests of longleaf, shortleaf, and loblolly pines. For over a decade these operations removed a reported 3 to 4 billion board feet per year (Frost 1993); an estimated 13 billion board feet of longleaf was extracted in 1907 alone (Wahlenburg 1946, Landers *et al.* 1995). This especially intense period of logging from 1870 to 1930 resulted in the loss of nearly all of the remaining old growth forest in the southeast (Frost 1993, Martin and Boyce 1993, Conner *et al.* 2001).

A common logging practice before the late 1800's was to leave a fair number of residual trees, including small trees, some of those infected with red heart fungus (*Phellinus pini*), and some that had been boxed for resin production (Wahlenburg 1946, Conner *et al.* 2001). Cavity trees of red-cockaded woodpeckers probably were left in much higher proportion than their numbers, due to the likelihood of red heart infection and the abundant resin coating. These residual pines enabled the red-cockaded woodpeckers to survive the original devastation (Phillips and Hall 2000). Loss of residual trees in the twentieth century has been a major factor in the decline of woodpecker populations (Costa and Escano 1989, Conner *et al.* 2001; see 2D).

Fire Suppression

Precolonial fire frequencies in the southeast have been estimated at 1 to 3 years for the Atlantic and lower Gulf coastal plains (Stout and Marion 1993, Ware *et al.* 1993, Frost 1998), 4 to 6 years for the Piedmont and upper Gulf coastal plain, and 7 to 25 years for the southern Appalachians and interior highlands (Masters *et al.* 1995, Frost 1998). Fire frequency increases with size of fire compartments, and natural firebreaks in the southeastern coastal plains were rare (Ware *et al.* 1993, Frost 1998). Historically, fires were ignited by Native Americans and by lightning. Lightning was the primary ignition source shaping the evolution of these fire-maintained ecosystems, but Native Americans may have played a substantial role in maintaining them (Delcourt *et al.* 1993, Frost 1993). Such maintenance vanished, of course, as Native Americans were severely impacted by the diseases and aggression of incoming Europeans. Natural fire frequency also declined as fires were reduced in area because of roads, plowed fields, and other human-made firebreaks (Frost 1993, Ware *et al.* 1993).

Europeans brought their perceptions of fire with them as they colonized North America. In Europe, fire was an integral part of traditional swidden agriculture (i.e., shifting cultivation) and was celebrated by peasants as a source of renewal (Pyne 1998). In contrast, urban intellectuals and authorities viewed fire as a destructive force. This view was rooted in a social context: controlling the use of fire could facilitate control of the populace by discouraging the nomadic system (Pyne 1998). Such socially constructed perceptions of fire impacted natural fire regimes in all of Europe's colonies (Pyne 1998).

In North America, after European settlement and prior to the mid 1800's, farmers burned the woodlands regularly to improve forage for free-ranging livestock. Burning the open woods decreased with the fencing of livestock in the mid to late 1800's (Frost 1993), although many people continued to use fire in agricultural fields well into the 1900's (Martin and Boyce 1993). In the twentieth century, the rise of mechanical and chemical agriculture has replaced fire-based agricultural methods.

Active fire suppression began to be institutionalized in the southeastern United States between 1910 and 1930 (Frost 1993, Ware *et al.* 1993). Several factors influenced its rise. First was the existing bias against fire brought to this continent by European intellectuals (Pyne 1998). Then, in the late 1800's, fire suppression grew in response to the extreme intensity of fires burning the logged-over slash across the entire eastern United States. Fires in pine resin orchards were similarly intense and had been suppressed for some time to protect resin production (Frost 1993). Many ecologists denounced fire as detrimental to southern pines rather than an integral or useful component of the natural system. Suppression of fire increased with the rise of pine plantations, a land use that began in the 1930's and 40's and continues to increase today (Martin and Boyce 1993, Stout and Marion 1993, Ware *et al.* 1993).

Fire suppression has severe and numerous impacts on southern pine ecosystems, including changes in tree species composition and forest structure. Longleaf pine cannot reproduce without access to the mineral soil, and will be replaced under fire suppression by other species of pines and hardwoods. The structure of the forest changes from two layers, a canopy and a diverse groundcover, to a multi-layered midstory and canopy with little or no groundcover. With increasing hardwood midstory, arthropod communities change in species abundance, species composition, and distribution on the substrate (Collins 1998, Provencher *et al.* 2001a). Red-cockaded woodpeckers are directly and adversely affected by each of these changes (see 2D and 2E).

Reproduction of longleaf pine has been severely restricted since the precolonial era, first because of the impacts of free-ranging hogs and more recently because of the absence of fire (Wahlenburg 1946, Frost 1993, Ware *et al.* 1993). A short period of reproduction took place after hogs were fenced and before fires were suppressed. Most second-growth longleaf in existence today is 70 to 100 years in age and reproduced naturally during this short period of opportunity (Kelly and Bechtold 1990, Frost 1993, Landers *et al.* 1995). Reproduction of longleaf in the twentieth century has been, and still is, constrained by hardwood midstory developed as a result of fire suppression (Landers *et al.* 1995, Frost 1993, Peet and Allard 1993).

Detrimental Silvicultural Practices

Several silvicultural practices have been detrimental to red-cockaded woodpeckers, including short rotations, clearcutting, and conversion to sub-optimal pine species. Cutting of second-growth longleaf pines began during World War II and continues today. Removal of second-growth longleaf has exceeded growth by over 40 percent, and much of the remaining longleaf is aging without replacement (Landers *et al.* 1995).

The years following World War II also saw the rise of plantation forestry. Plantations of dense slash or loblolly pines covered over 4.9 million ha (12 million ac) by the mid 1960's and over 6.1 million ha (15 million ac) at present (Ware *et al.* 1993). Plantations typically have been under rotations of 35 to 70 years for sawtimber production and 20 to 40 years for pulp production (Conner *et al.* 2001), and industry has continued to shift from logs and poles to pulp (Landers *et al.* 1995). With technological developments such as chainsaws, the practice of leaving 'cull' pines that were infected with red heart fungus or boxed for resin production declined. These two practices—short rotations and the removal of all trees—had substantial negative impacts on the woodpecker populations that remained after the initial logging (Conner *et al.* 2001).

B. CURRENT THREATS

Despite protection under the Endangered Species Act in 1973, populations of red-cockaded woodpeckers continued to decline throughout the 1970's and into the 1980's in all parts of the species' range (Baker 1983, Ligon *et al.* 1986, 1991, Ortego and Lay 1988, Conner and Rudolph 1989, Costa and Escano 1989, James 1991, 1995, Haig *et al.* 1993, Kelly *et al.* 1994). Only one population was reported to be increasing during this time (Hooper *et al.* 1991a). In the 1990's, most populations were stabilized and many have shown increases (R. Costa, pers. comm.). Stabilizing the declines was the result of a new understanding of population dynamics (see 2B) and the use of powerful management tools such as artificial cavities, translocation, and prescribed burning (see 3B and 3F). Our challenge now is to bring about the widespread increases in population sizes necessary to recover the species.

Primary threats to species viability for red-cockaded woodpeckers all have the same basic cause: lack of suitable habitat. Red-cockaded woodpeckers require open mature pine woodlands and savannahs maintained by frequent fire, and there is very little of this habitat remaining (Lennartz *et al.* 1983, Frost 1993, Simberloff 1993, Ware *et al.* 1993). On public and private lands, both the quantity and quality of red-cockaded woodpecker habitat are impacted by past and current fire suppression and detrimental silvicultural practices (Ligon *et al.* 1986, 1991, Baker 1995, Cely and Ferral 1995, Masters *et al.* 1995, Conner *et al.* 2001). Serious threats stemming from this lack of suitable habitat include (1) insufficient numbers of cavities and continuing net loss of cavity trees (Costa and Escano 1989, James 1995, Hardesty *et al.* 1995); (2) habitat fragmentation and its effects on genetic variation, dispersal, and demography (Conner and Rudolph 1991b); (3) lack of foraging habitat of adequate quality (Walters *et al.* 2000, 2002a, James *et al.* 2001); and (4) fundamental risks of extinction inherent to critically small populations from random demographic, environmental, genetic, and catastrophic events (Shaffer 1981, 1987).

Fire suppression and exclusion is still a profound threat to red-cockaded woodpecker populations (see 2D, 2G). Hardwood encroachment due to fire suppression has been a leading cause of loss of woodpecker groups on both public and private lands and continues to be a major threat throughout the species' range (Van Balen and Doerr 1978, Hovis and Labisky 1985, Conner and Rudolph 1989, 1991a, Costa and Escano 1989, Loeb *et al.* 1992, Baker 1995, Cely and Ferral 1995, Escano 1995, Masters *et al.* 1995). Moreover, most assessments of the impacts of fire suppression on woodpecker groups have been restricted to effects of hardwood midstory on nesting and roosting habitat. Recent research indicates that exclusion of fire from foraging habitat has negative impacts as well (James *et al.* 1997, 2001, Hardesty *et al.* 1997, Doster and James 1998, Walters *et al.* 2000, 2002a). Even if nesting and roosting habitat is frequently burned, lack of fire in the foraging habitat can reduce group size and productivity (James *et al.* 1997, 2001, Hardesty *et al.* 1997, Walters *et al.* 2000, 2002a). Thus, negative effects of fire suppression are more pervasive than previously thought.

Widespread and frequent application of early-mid growing season fire throughout lands managed for red-cockaded woodpeckers is essential to the recovery of the species (Conner and Rudolph 1989, 1991a, Baker 1995, James 1995). Regrettably, there are several major difficulties affecting the increased use of fire across the southeast. These difficulties include lack of funding for both public land management agencies and private landowners; prohibitive smoke regulations; increasing density of human populations and associated development; proliferation of firebreaks such as roads, fields, and power lines; and perhaps most importantly, the prejudice against fire held by many private citizens and some public land managers. As this prejudice, built by decades of intensive anti-fire publicity, shifts toward acceptance of the natural role of fire and its benefits for resource management and catastrophic fire prevention, smoke regulations and funding constraints may change. Extreme caution is needed, however, in moving from restoration to maintenance burns. Should restoration burns of fuel-heavy forests cause loss of human life or property, public perception will be slow to change.

Logging is a potential threat to woodpecker populations on private lands (Cely and Ferral 1995), as harvests of mature pines continues at a high rate. One recent study estimated the current rate of pine cutting on private lands in parts of South Carolina and Georgia at 4.0 percent per year, a rate much higher than those estimated by similar methods for temperate or tropical rainforest (Pinder *et al.* 1999). Trees being cut were in older, natural stands established during the 1930's and 1940's. Other researchers have predicted that as these second-growth forests mature, there may well be another episode of substantial forest harvest (Ware *et al.* 1993, Landers *et al.* 1995). Moreover, the total area of both private and public lands that support longleaf pine is still sharply declining, from an estimated 1.53 million ha (3.77 million ac) in 1985 (Kelly and Bechtold 1990) to 1.19 million ha (2.95 million ac) in 1995 (Outcalt and Sheffield 1996). Privately owned lands have sustained the greatest losses. Private lands continue to support significant amounts of longleaf, although much of it occurs in parcels of less than 20.2 ha (50 ac; Outcalt and Sheffield 1996). One of the most common ways longleaf pine cover is lost is by replacement of other pine species after logging (Outcalt and Sheffield 1996). Widespread conversion of longleaf to plantations of other pine species began in the 1940's and this process still continues today. Plantations of off-site pine species (species that were not the original cover type) now cover over 6.1 million ha (15 million ac) in the southeast (Stout and Marion 1993, Ware *et al.* 1993).

Silvicultural practices on public lands have improved in recent years. Agency responses to legislated protection of red-cockaded woodpeckers include longer rotation times (USFS 1995), increases in the area under protection (USFS 1995), and elimination of intentional conversion of native pines to off-site species. Enlightened management plans emphasize prescribed burning, pine thinning to open dense second-growth stands, and retention of scattered relict old growth pines (USFS 1995). For many public lands, timber removal is now an important management tool rather than an overriding objective (USFS 1995). Overall, current timber production and conversion to off-site pines on public lands are less of a threat than earlier this century, although effects of past practices are still nearly overwhelming.

As described above (this section and 1A), fire suppression and past timber harvests have resulted in an almost complete loss of habitat for red-cockaded woodpeckers. Species recovery is only possible through habitat restoration (see 2D, 2E, 3F, 3G; James 1995, Smith and Martin 1995). However, restoration of habitat may itself jeopardize red-cockaded woodpeckers, if approached without suitable caution. Clearcutting of off-site pine species to restore longleaf and shortleaf pines can potentially disrupt woodpecker populations (Ferral 1998, F. C. James, pers. comm.). Restoration of native pines is best achieved through conversion of habitat patches rather than large clearcuts, especially if woodpeckers are using off-site pines for foraging or dispersal (Ferral 1998, see 3G).

One of the primary threats to red-cockaded woodpeckers, stemming from past habitat loss, is a severe bottleneck in the number of pines available as cavity trees (Costa and Escano 1989, Rudolph *et al.* 1990b, Conner *et al.* 1991a, Walters *et al.* 1992a). Red-cockaded woodpeckers require older pines for cavity excavation for two reasons: (1) only older pines have sufficient heartwood to house a cavity at preferred cavity heights (Jackson and Jackson 1986, Clark 1993, Conner *et al.* 1994) and (2) older pines are more likely to be infected with red heart fungus (Wahlenburg 1946, Conner *et al.* 1994), which substantially reduces the time required for cavity excavation (Conner and Rudolph 1995a, see 2D). Red-cockaded woodpeckers survived the 20th century (although at drastically reduced numbers) because timber harvest practices of the 19th and early 20th century left some relict pines standing. Harvest methods used during the mid 20th century did not follow this practice, and many relict pines were cut during this period. Still, most cavity trees in existence today are survivors of the original removal of the primary forest (Jackson *et al.* 1979, Rudolph and Conner 1991). These pines are older than the surrounding forest and suffer high rates of mortality due to increased effects of wind, lightning, southern pine beetles (*Dendroctonus frontalis*) and other pests, and natural senescence (Jackson *et al.* 1978, Conner *et al.* 1991a, Conner and Rudolph 1995b, Rudolph and Conner 1995, Watson *et al.* 1995). Because the surrounding forest is much younger in age, few potential cavity trees are available as replacements. As second-growth forests are allowed to age, more potential cavity trees will become available. In the meantime, a net loss of cavity trees threatens current populations (Costa and Escano 1989). Crisis intervention through intensive cavity management (artificial cavities and restrictors; see 3B) is helping to offset cavity loss but the threat will remain until mature and old growth trees are restored.

A second major impact of habitat loss on the viability of red-cockaded woodpeckers is the resultant fragmented distribution. Fragmentation and isolation have occurred both among groups within a population and among populations, with serious consequences for red-cockaded woodpeckers. Red-cockaded woodpeckers are particularly sensitive to effects of isolation because of the limited dispersal characteristic of cooperative breeders (Walters *et al.* 1988a, Daniels and Walters 2000a; see 2B). Fragmentation among populations increases the vulnerability of those populations to adverse genetic, demographic, and environmental events (Walters *et al.* 1988a, Conner and Rudolph 1991b, Hooper and Lennartz 1995; see below and 2C), because the dispersal that can help offset such threats is easily disrupted. Fragmentation and isolation of groups within a population can substantially increase that population's risk of extinction (Crowder *et al.* 1998, Letcher *et al.* 1998, Walters *et al.* 2002b). Populations of red-cockaded woodpeckers are surprisingly persistent if the spatial arrangement of groups within the population is tightly clumped. If groups are isolated and dispersal behavior disrupted, risk of population extinction increases (Crowder *et al.* 1998, Letcher *et al.* 1998, Walters *et al*. 2002b, see 2C).

Managers have some limited tools to combat effects of fragmentation (e.g., strategic location of recruitment clusters, retention of forest cover, and translocation). More importantly, as populations recover, isolation effects will not be as intensely acute as they are at present, because larger populations have greater resistance to impacts from environmental and demographic threats, greater retention of genetic variation, and thus greater probability of persistence. However, effects of fragmentation are likely to remain serious threats to population viability throughout the period of recovery.

A third threat to red-cockaded woodpeckers from past habitat loss is lack of suitable foraging habitat. As described above, recent research indicates that optimal foraging habitat is maintained by fire and contains an old growth or mature pine component (Conner *et al.* 1991b, Hardesty *et al.* 1997, James *et al.* 1997, 2001, Walters *et al.* 2000, 2002a). Restoration of foraging habitat will likely increase red-cockaded woodpecker densities (Walters *et al.* 2000, 2002a, James *et al.* 2001; see 2E), which in turn will positively influence demography and dispersal. However, the threat to woodpecker populations from low-quality or insufficient foraging habitat is not as immediate as threats from habitat fragmentation and lack of suitable nesting habitat. Fragmentation and lack of nesting habitat are presently limiting populations and are responsible for recent declines (Walters 1991). Foraging habitat, on the other hand, affects population densities; it may be a secondary factor currently limiting populations and will likely become a primary limiting factor once abundant nesting habitat is provided (Walters *et al.* 2000, 2002a). Foraging habitat is therefore an important concern for long-term viability.

One last identified threat to species viability that stems from habitat loss is the set of risks inherent to critically small populations. These are similar to fragmentation effects, but rather than occurring through isolation, these threats are related to population size. Small populations may be extirpated because of random environmental, demographic, genetic, and catastrophic events (Shaffer 1981, 1987; see 2C). Random environmental events affect an entire population; for example, an exceptionally severe winter that causes high adult mortality. Random demographic events act on individuals within populations; for example, a death due to predation, or a brood consisting of all males. Random genetic events are losses or gains in frequency of any given gene, simply due to chance inheritance. Lastly, catastrophic events, which can affect large as well as small populations, are similar to environmental events but larger in scale. Any of these processes alone or in concert can cause the extirpation of a small population. Such processes will continue to remain threats until population sizes are sufficient to withstand them (Shaffer 1981, 1987, Crowder *et al.* 1998, Letcher *et al.* 1998, Walters et al. 2002b; see 2C). Catastrophes will continue to threaten even the largest populations in perpetuity, although the species as a whole will not be in danger once enough large populations are established (e.g., Hooper and McAdie 1995).

Other factors unrelated to habitat loss may threaten red-cockaded woodpeckers, but their importance has not yet been determined. Foremost among unevaluated threats are the risks from pesticides and other environmental contaminants. Suburban groups of woodpeckers may be at especially high risk of adverse effects from toxins. Similarly, impacts of exotic species have not yet been assessed. Exotic species such as melaleuca (*Melaleuca quinquenervia*) and red imported fire ants (*Solenopsis invicta*) may be negatively affecting woodpeckers in some parts of their range.

Unlike many endangered and threatened species, red-cockaded woodpeckers are well studied (see Jackson 1995). Biologists are developing a good understanding of what constitutes optimal habitat for this species. Further information from experimental research is certainly needed to understand the best ways to restore ecosystems and habitat for red-cockaded woodpeckers, but a detailed picture of excellent red-cockaded woodpecker habitat is now emerging. In addition, managers are now equipped with effective tools to stabilize existing populations until sufficient quantity and quality of habitat for self-sustaining populations can be provided (Walters 1991). However, such habitat restoration and interim crisis management requires ample funding and a strong political will (Conner *et al.* 2001). Any weakness in determination or political will, with accompanying changes in law and policy, would constitute an extremely serious threat to the species.

2. GENERAL BIOLOGY AND ECOLOGY

A. TAXONOMY AND SPECIES DESCRIPTION

Red-cockaded woodpeckers are currently recognized as *Picoides borealis.* The species is endemic to the southeastern United States but other members of the genus are found throughout the Americas. Red-cockaded woodpeckers were first described for science as *Picus borealis*, “le pic boreal”, by the French businessman and amateur naturalist Vieillot (1807). In 1810, unaware of Vieillot’s description, Alexander Wilson described the species as *Picus querulus* because of its distinctive vocalizations (Wilson 1810).

Wilson gave the species the English common name we use today, red-cockaded woodpecker, in reference to the several red feathers of males, located between the black crown and cheek patch, that are briefly displayed when the male is excited. In Wilson’s time, “cockade” was a common term for a ribbon or other ornament worn on a hat as a badge. The cockade is a poor field mark because it is rarely seen in the field, but does identify the sexes of adult birds in the hand.

Red-cockaded woodpeckers are relatively small. Adults measure 20 to 23 cm (8 to 9 in) and weigh roughly 40 to 55 g (1.5 to 1.75 oz; Jackson 1994, Conner *et al.* 2001). They are larger than downy woodpeckers (*Picoides pubescens*), similar in size to yellow-bellied sapsuckers (*Sphyrapicus varius*), and smaller than other southeastern woodpeckers. Size of red-cockaded woodpeckers varies geographically, with larger birds to the north (Mengel and Jackson 1977). Because of this, Wetmore (1941) considered the birds of peninsular Florida to be a subspecies (*P. b. hylonomus*) which was later recognized by the American Ornithologists' Union (1957). Mengel and Jackson (1977), however, examined a larger series of specimens and considered the variation in the species to be smoothly clinal with no justification for distinguishing the birds in south Florida from those elsewhere.

Red-cockaded woodpeckers are black and white with a ladder back and large white cheek patches. These cheek patches distinguish red-cockaded woodpeckers from all others in their range. Red-cockaded woodpeckers are black above with black and white barring on their backs and wings. Their breasts and bellies are white to grayish white with distinctive black spots along the sides of breast changing to bars on the flanks. Central tail feathers are black and outer tail feathers are white with black barring. Adults have black crowns, a narrow white line above the black eye, a heavy black stripe separating the white cheek from a white throat, and white to grayish or buffy nasal tufts. Bills are black, and legs are gray to black.

Sexes of adult red-cockaded woodpeckers are extremely similar in plumage and generally indistinguishable in the field. In contrast, sexes of juveniles can be distinguished in the field until the first fall molt, because juvenile females have black crowns whereas juvenile males have red crown patches. Sexes of nestlings in the hand often can be distinguished by eight days of age: capital feather tracks, observed through the transparent skin before feather emergence, appear grayish black in females and reddish in males (Jackson 1982).

Juveniles may be distinguished from adults in the field by duller plumage, white flecks often present just above the bill on the forehead, and by diffuse black shading in the white cheek patch. In the hand, red-cockaded woodpeckers can be aged by the relative length and shape of the vestigial tenth primary until this primary is molted in the fall. This primary of juveniles is longer and more rounded than that of adults (Jackson 1979a). Second-year red-cockaded woodpeckers often can be identified because juveniles do not molt their secondaries during their first fall molt, whereas older birds do. As a result, the secondaries of juveniles during the second calendar year appear more worn and brown in contrast to newer black primaries (Jackson 1994).

B. SOCIOBIOLOGY AND COOPERATIVE BREEDING

The Breeding System

Red-cockaded woodpeckers live in groups that share, and jointly defend, all-purpose territories throughout the year. Group living is a characteristic of their cooperative breeding system. Red-cockaded woodpeckers are one of only a handful of bird species found in the United States that exhibit this unusual system. In cooperative breeding systems, some mature adults forego reproduction and instead assist in raising the offspring of others (Emlen 1991). The cooperative breeding system of red-cockaded woodpeckers is well studied, and several recent reviews are available (Walters 1990, 1991, Jackson 1994). In this species, most helpers are males that remain and assist the breeders, who typically are their parents or other close kin, on their natal territory (Ligon 1970, Lennartz and Harlow 1979, Lennartz *et al.* 1987, Walters *et al.* 1988a). A few females become helpers on their natal territories, and a few individuals of each sex disperse to become helpers of unrelated breeders in other groups (Lennartz *et al.* 1987, Walters *et al.* 1988a, DeLotelle and Epting 1992). Helpers are strictly non-breeders (Haig *et al.* 1994b), but participate in incubation, feeding and brooding of nestlings and feeding of fledglings, as well as territory defense, nest defense, and cavity excavation. Groups may contain as many as four helpers, but most groups consist of only a breeding pair with no helpers, or a breeding pair plus one helper. Groups containing more than two helpers are uncommon.

Red-cockaded woodpecker groups are highly cohesive. Each individual has its own roost cavity, but typically group members congregate immediately after emerging from their cavities at dawn, and then move together through their large territories until they return to their cavities at dusk. Much like a primate troop, they visit only a portion of their territory or home range each day, and travel different routes on different days.

Group formation is best understood in terms of alternative life-history tactics practiced by young birds (Walters 1991). Young birds may either disperse in their first year to search for a breeding vacancy, or they may remain on the natal territory and become a helper. The proportion of each sex adopting each strategy varies among populations (Lennartz *et al.* 1987, Walters *et al.* 1988a, DeLotelle and Epting 1992), but dispersal is always the dominant strategy for females whereas both strategies are common among males. A dispersing individual, if it survives, may become a breeder at age one, but many fail to locate a breeding vacancy and exist as a floater at age one, or in a few cases as a helper in a new group (Walters *et al.* 1988a, 1992a). Some dispersing males locate a territory but no mate, and hence are solitary males at age one. Solitary males and floaters, like helpers (see below), may become breeders at subsequent ages.

It is those individuals who choose to remain at home as helpers rather than disperse that are primarily responsible for group formation. Individuals may remain helpers for up to eight years, but most become breeders within a few years (Walters *et al.* 1988a, 1992a). Helpers may become breeders by inheriting breeding status on their natal territory or by dispersing to a nearby territory to fill a breeding vacancy. When helpers move, it is usually to an adjacent territory, and they rarely disperse across more than two territories.

In contrast, individuals of both sexes dispersing in their first year sometimes move long distances, more than 100 km in a few cases (Walters *et al.* 1988b, Conner *et al.* 1997c, Ferral *et al.* 1997). Still, typical dispersal distances of even first-year birds are much lower than in other avian species. The median dispersal distance of females is only two territories from the natal site, and about 90 percent settle 1 to 4 territories from the natal site (Daniels 1997, Daniels and Walters 2000a). Males are even more sedentary, since many of them adopt the helping strategy. About 70 percent of males become breeders on the natal territory or an immediately adjacent one (Daniels 1997).

Once a male acquires a breeding position, by whatever pathway, he almost invariably holds it until his death (Walters *et al.* 1988a). Females, however, regularly practice breeding dispersal: roughly 10 percent of breeding females switch groups between breeding seasons each year (Walters *et al.* 1988a, Daniels and Walters 2000b). Females invariably depart when their sons inherit breeding status on their territory, but usually remain when a helper unrelated to them inherits breeding status. Females also are likely to leave if their mate dies and there are no helpers to assume the breeding vacancy, rather than pair with an immigrant replacement male, although not all do so. This may be a means to avoid young males as mates (Daniels and Walters 2000b, below). Also, young females (age one or two) that experience reproductive failure are likely to move (Daniels and Walters 2000b). Like first-year birds, dispersing adult females occasionally move very long distances (Walters *et al.* 1988b), but typically move to a neighboring group (Walters *et al.* 1988a, Daniels 1997).

Reproduction

Red-cockaded woodpeckers are highly monogamous. The group produces a single brood, and the breeding male and female within the territory are almost invariably the genetic parents of all offspring (Haig *et al.* 1993, 1994b). There is no evidence that helpers ever sire offspring, and the frequency of extra-pair fertilization involving individuals outside the group is among the lowest yet recorded in birds (Haig *et al.* 1994b).

Typical values of reproductive parameters, and the range of variation among years and populations, are available from several published studies (Lennartz *et al.* 1987, Walters *et al.* 1988a, Walters 1990, DeLotelle and Epting 1992, LaBranche and Walters 1994, DeLotelle *et al.* 1995, James *et al.* 1997) and project final reports (North Carolina Sandhills and coastal North Carolina, Walters and Meekins 1997, Walters *et al.* 1997, 1998; Eglin Air Force Base and Apalachicola National Forest, Florida, Hardesty *et al.* 1997). Unless otherwise indicated, values reported below represent a summary of data from these sources.

Not all groups attempt nesting in a given year. On average about 10 percent of the groups do not nest, but this ranges from as low as 3 percent to as high as 21 percent. Groups with young breeders, especially one-year-old males, are especially likely to forego nesting (Walters 1990). If the group does nest, the eggs are usually laid in the most recently completed cavity available, which typically is the breeding male's roost cavity (Conner *et al.* 1998a). If the nest fails, the group may renest. On average about 30 percent of nest failures are followed by a second attempt, but annual variation in the rate of renesting is high. There are records of a group making a third nesting attempt following two failed nests, and of a group attempting a second brood after a successful first nest (LaBranche *et al.* 1994, Schillaci and Smith 1994, reviewed by Phillips *et al.* 1998), but both are exceedingly rare (Phillips *et al.* 1998). Equally rare are instances of two nests of a single pair in existence at the same time (Rossell and Britcher 1994, R. Conner *et al.*, unpublished, J. Walters, unpublished). It seems that almost any odd variation of the typical reproductive process can occur in rare instances. Other examples include two females residing together within a group and laying clutches synchronously in a common nest, or laying in separate nests. Successful instances of the former, but not the latter, have been observed. Such instances are of theoretical interest because they constitute plural breeding, which is characteristic of more complex types of cooperative breeding systems (Emlen 1991).

Normally, however, one brood is produced as a result of one or perhaps two nesting attempts involving only two parents. Most groups that attempt nesting fledge young, as nest failure rates are low for a species in the temperate zone, although fairly typical for a primary cavity nester (Martin and Liu 1992, Martin 1995). Nest failure rates average about 20 percent, and this is fairly consistent among years and among populations. Nest predation, nest desertion, and loss of nest cavities to cavity kleptoparasites appear to be the primary causes of nest failure. Failure rate is higher during the egg stage than during the nestling stage, which suggests that nest desertion, rather than nest predation or loss of cavities to kleptoparasites, is the major cause of failure (Ricklefs 1969). The relative frequencies of these three causes of nest loss have never been measured directly, however.

Nest predation rates may be lower than in other cavity nesters because of the protection provided by the resin barrier around the cavity, which clearly interferes with climbing by snakes (Rudolph *et al.* 1990b). The frequency of nest predation may vary regionally, although there is no direct evidence of this. One possibility is that it is higher in areas where most cavities are in species other than longleaf, and thus where the resin barrier is diminished (Conner *et al.* 1998a), for example in Arkansas (Neal 1992).

In contrast to nest predation, nest desertion may be more common than in other cavity nesters because of the complex social system and resulting intense competition for breeding vacancies (see below) characteristic of this species. Lennartz *et al.* (1987) suggested that nest failure is often associated with repeated territorial intrusions by conspecifics, and other forms of social disruption. Immigrants often associate with groups as affiliated floaters or unrelated helpers (Walters *et al.* 1988a). Such individuals are a particularly likely source of social disruption that might cause groups to forego nesting, or fail if they do attempt to nest (DeLotelle and Epting 1992).

The primary cavity kleptoparasites linked to nest failure are red-bellied woodpeckers (*Melanerpes carolinus*), red-headed woodpeckers (*M. erythrocephalus*), eastern bluebirds (*Sialia sialis*), and southern flying squirrels (*Glaucomys volans*). These species are known to usurp nest cavities from red-cockaded woodpeckers and to destroy nests in cavities they usurp. Occasionally, red-headed woodpeckers, red-bellied woodpeckers, and flying squirrels may consume eggs and small nestlings (Jackson 1994).

Although red-cockaded woodpecker groups produce broods fairly reliably, these broods are relatively small. This is because clutch size is modest and, more importantly, because partial brood loss is greater than in other species of primary cavity nesters in the United States (LaBranche and Walters 1994). Most clutches contain 2 to 4 eggs, although the full range is 1 to 5 eggs. Even larger clutches are occasionally reported, but these probably (and in some cases certainly) result from two females laying in the same nest (see above). There is variation among populations in clutch size, with population averages ranging from 2.9 to 3.5 eggs, but there does not appear to be a regular geographic pattern in this variation.

Incubation begins before the clutch is complete, and eggs hatch asynchronously (Ligon 1970). As often occurs in species with asynchronous hatching, partial brood loss occurs soon after hatching. Some reduction in brood size is due to failure of eggs to hatch, but much of it is due to mortality of nestlings within the first few days after hatching. The relative frequencies of these forms of loss are not known precisely, and neither are the mechanisms producing the mortality. Eggs may fail to hatch because they are infertile, but it is likely that some do not hatch because the birds cease incubating them after the first eggs hatch. It is also likely that the last young to hatch often starve. A recent study, the first to use video cameras mounted in modified artificial cavities, found that youngest nestlings were most likely to die (Sanders 2000). This study also found no evidence of sibling aggression, so it appears improbable that siblicide is a regular component of partial brood loss.

Partial brood loss, measured by dividing the number of fledglings by the number of eggs in successful nests, averages about 40 percent. It is, however, highly variable among years and among populations. This is one parameter that appears to exhibit systematic geographic variation. Partial brood loss tends to be higher in coastal populations compared to inland ones, and in southern populations compared to northern ones. Population averages vary from around 30 percent in a northern, inland population (North Carolina Sandhills) to about 50 percent in a southern, coastal population (Eglin Air Force Base in Florida), and 59 percent in central Florida.

The average number of young fledged from successful nests is about two in northern populations. Broods of 1 to 4 are common, and rarely five young are fledged from a single nest. Because some groups do not nest and others fail in their attempts, the average number of young produced per group is about one-half fledgling less, ranging from 1.4 to 1.7 among populations, and from 1.0 to 1.9 among years within populations. Thus one can expect about 1.5 young to be produced per group in northern populations. Productivity in Florida populations typically is somewhat less, due largely to greater partial brood loss. In Florida most groups fledge only one or two young, occasionally three. Annual values range from 0.9 to 1.6, and the typical value for a Florida population is about 1.2 fledglings per group per year.

For the first several days after fledging, the young birds are somewhat reluctant to fly, and spend considerable time perched high up in the pines, clinging to the trunk. Parents and helpers sometimes forage some distance away from the young at this time, but return frequently to feed them. During this initial period, the fledglings often do not return to the cluster with the adults in the evening, but instead roost in the open wherever the adults leave them at the end of the day. The next morning, the adults return and locate the fledglings, and resume feeding them.

By the end of the first week out of the nest, however, the young are much more active, and move with the adults as the group travels through the territory. Frequently fledglings will follow adults closely, and beg loudly for food as the adult forages. They may even displace the adult from a particularly productive foraging location. Fledglings often are highly aggressive toward one another, and clear dominance hierarchies are evident among siblings. Males, which are recognizable from their red crown patches, usually are dominant to females. Most of the aggression consists of a dominant fledgling displacing a subordinate from an adult that is carrying food or foraging. The fledglings gradually begin to obtain food for themselves, but continue to beg for food and squabble with each other for some time. It is not unusual to see young being fed two months after fledging, and young are occasionally seen begging as late as the subsequent winter (Ligon 1970).

The sex ratio among fledglings has been reported as biased toward males in a South Carolina population (Gowaty and Lennartz 1985), biased toward females in a Florida population (Epting and DeLotelle, unpublished) and unbiased (i.e., 1:1) in three North Carolina populations (Walters 1990, unpublished, LaBranche 1992) and another Florida population (Hardesty *et al.* 1997). Examination of data on fledgling sex ratios from other populations across the region reveals similar variability (R. DeLotelle, unpublished). It has been proposed that in some cooperatively breeding birds sex ratios are biased toward the helping sex as an adaptive evolutionary strategy (Gowaty and Lennartz 1985, Emlen *et al.* 1986, Lessells and Avery 1987, Ligon and Ligon 1990). This hypothesis has been referred to as the repayment model (Emlen *et al.* 1986). However, in a close examination of the repayment model, Koenig and Walters (1999) found it unable to account for sex ratios in red-cockaded woodpeckers and that the model itself may not be correct. Also, the model does not explain the observed variation in sex ratios among populations of red-cockaded woodpeckers. Generally the cause of this variation is poorly understood, and in particular the relationship between other demographic factors and fledgling sex ratios remains unknown. Sex ratio likely will continue to be of theoretical interest, but it has little bearing on management.

As discussed previously, many fledglings remain with the group through their first year and beyond, and become helpers. But even young that disperse in their first year may remain with the group for many months. Some young disperse in late summer, only weeks after fledging. However, most of those who have not yet departed by the onset of cooler weather in autumn remain with their natal group through the winter, and disperse in late February, March or even April. Although both natal and breeding dispersal can occur at any time, the two primary periods during which movement occurs are just before and just after the breeding season.

Helpers contribute substantially to both incubating eggs and feeding young, and their presence increases productivity. Groups with helpers produce more young than groups without helpers, but this is due in part to an association between the presence of helpers and high territory quality, as well as actual contributions of helpers to reproduction. The best estimate of the helper effect, controlling for effects of territory quality, is that productivity is increased by 0.39 fledglings per group per year by the presence of a helper, and by an additional 0.36 fledglings by the presence of a second helper (Heppell *et al.* 1994). For unknown reasons, the usual positive effect of helpers on productivity seems to be lacking in two of the Florida populations (DeLotelle and Epting 1992, Hardesty *et al.* 1997, but see James *et al.* 1997).

The mechanism by which helpers increase productivity is not entirely clear. One might assume that since helpers contribute substantially to feeding, groups with helpers should be able to raise larger broods. Indeed, in some cooperative breeders feeding by helpers results in higher provisioning rates, and reduced partial brood loss. In others, however, feeding by helpers instead results in reduced feeding effort by the breeders, and positive impacts of helpers are due to reduced nest failure rather than reduced partial brood loss (Emlen 1991). The latter scenario may characterize red-cockaded woodpeckers, but the evidence is equivocal. Lennartz *et al.* (1987) reported that higher productivity by groups with helpers on the Francis Marion National Forest was due to reduced partial brood loss. The extent of partial brood loss also is related to the age of the breeders (see below), however, and breeder age can be confounded with presence of helpers in small data sets. Using a much larger sample, and controlling for the age of the female breeder, Reed and Walters (1996) found that in the North Carolina Sandhills higher productivity of groups with helpers was not due to reduced partial brood loss. Instead, groups with helpers were more likely to attempt nesting, and less likely to fail. Khan (1999) found, for this same population, that feeding by helpers resulted in less feeding by parents rather than more food being delivered to nestlings.

Reproductive success is strongly affected by age in both sexes. Young birds are less successful than old birds, and this is manifested in all components of reproduction. That is, young birds are less likely to attempt nesting, more likely to fail, and suffer more partial brood loss. Productivity of one-year-old birds of both sexes is especially poor, but reduced productivity is evident through age three, and the effect is somewhat stronger in males. Ages 4 to 8 are the peak reproductive years, as productivity is reduced somewhat at ages 9 and beyond in both sexes. This may represent senescence (see below).

Mortality

Data on mortality rates come from the same sources as data on reproduction (see above). Good estimates are available from completely marked populations or subpopulations, and patterns are clear and consistent. For a bird of its size residing in temperate regions, the red-cockaded woodpecker exhibits exceptionally high survival rates. Survival rates of adult male helpers and breeders generally are about 5 percent higher than that of breeding females. There is distinct geographic variation in survival similar to that observed for partial brood loss. Survival rates are about 75 percent for males and 70 percent for females in the northern, inland population in the North Carolina Sandhills, about 80 percent and 75 percent respectively in coastal populations in North Carolina, and 86 percent and 80 percent respectively in central Florida. Such an association between increased survival and reduced fecundity is common in animal life histories. Annual variation in adult survival within populations is sufficiently small that it can largely be attributed to random chance rather than changes in environmental conditions (Walters *et al.* 1988a). This level of variation can have large effects in small populations, however, and it appears that there are occasional poor years in which survival is substantially reduced. Also, some populations are vulnerable to periodic catastrophic mortality due to hurricanes (see 2C).

With survival rates as high as these, it comes as no surprise that some individuals live to old ages. A captive female lived to 17 years (J. Jackson, pers. comm.), and a male in the North Carolina Sandhills lived to 16 years of age in the wild (J. Carter III, pers. comm.). The number of very old birds is less than one might expect, however, because red-cockaded woodpeckers apparently experience senescence. In the North Carolina Sandhills survival rates fall to around 50 percent beginning at age 9 in females and age 11 in males. Survival of one-year-old males is also reduced, but only if they are breeders: helper males of age one have typical high survival rates. Survival is fairly constant at ages 1 to 10 in males, and 1 to 8 in females.

Survival during the first year is more prone to underestimation than survival at subsequent ages, due to the greater possibility of dispersal out of the sampling area. Nevertheless, it is quite clear that survival rates are much lower during the first year than thereafter. In three North Carolina populations, survival of males during the first year ranges from 46 percent to 57 percent, and of females from 36 percent to 45 percent. Within a population, survival of males is 10 to 15 percent higher than survival of females. It is not clear whether geographic variation in survival during the first year exists, although there is some evidence that survival is higher in Florida (DeLotelle and Epting 1992). Survival during the first year is affected by the proportion of individuals dispersing rather than remaining as helpers (dispersing lowers survival), and by the number of available breeding vacancies (survival improves as the number of vacancies increases), as well as by the physical environment. This makes it more difficult to detect geographic variation.

Differences between age-sex classes suggest that dispersal is associated with reduced survival. By regressing survival against the proportion of birds dispersing among various categories of females, Daniels and Walters (2000b) estimated the mortality cost of movement for breeding females in the North Carolina Sandhills at 33 percent. That is, dispersal between breeding seasons adds another 33 percent to the probability of mortality above what is expected for sedentary birds. Specifically, the expected survival rate for females that do not move is 74 percent, whereas that for females that do move is 41 percent. This is a surprisingly high cost, given the short distances that most individuals move. This result may reflect the intensity of competition for breeding vacancies, the benefits of belonging to a group, or perhaps the benefits of ready access to a suitable roost cavity.

Overall the mortality pattern is fairly typical of cooperatively breeding avian species. It is characterized by relatively low survival during the first year, especially of dispersers; relatively high survival of breeders and helpers; and senescence at the end of the life span. Compared to non-cooperative species, survival of both juveniles and adults is high, and the life span is long.

Population Dynamics

The population dynamics of the red-cockaded woodpecker are intimately related to the species' unusual social system (Walters 1990, 1991). In demographic terms, population dynamics are strongly affected by the presence of a large class of non-breeding adults, helpers. Helpers provide a pool of replacement breeders in addition to young of the year, and thereby act as a buffer between mortality and productivity in regulating population size. That is, the number of breeding groups in one year is not strongly affected by either productivity or mortality in the previous year. Instead, the size of the helper class is affected by these variables, while the number of potential breeding groups remains remarkably constant. If mortality exceeds productivity, the number of helpers will decrease, because the number of replacement breeders drawn from the helper class will exceed the number of fledglings recruited into it. If productivity exceeds mortality, the opposite will occur, and the number of helpers will increase. Therefore average group size is an important indicator of population health, as it indicates the potential to maintain the size of the breeding population in the face of fluctuations in mortality and productivity. Of course the strength of the buffering effect of helpers depends on the size of the helper class. In small populations the number of helpers may be so few that poor survival or reproduction can have a direct, negative effect on the size of the breeding population (Lennartz and Heckel 1987, DeLotelle *et al.* 1995).

In evolutionary terms, adoption of the helping strategy is closely linked to patterns of territory occupancy (Walters 1990, 1991). Remaining on the natal territory as a helper can be viewed as a strategy, involving delayed reproduction and dispersal, and altered dispersal behavior, to acquire a breeding position. Helpers stay at home and wait for a breeding vacancy to arise in their vicinity, either on the natal territory or a neighboring one (Walters *et al.* 1992b). This strategy is thought to be an effective one when competition for breeding vacancies is intense (Zack and Rabenold 1989). Further, the intense competition for breeding vacancies that characterizes cooperative breeders is thought to result from unusually large variation in territory quality (Stacey and Ligon 1991, Emlen 1991, Koenig *et al.* 1992).

In red-cockaded woodpeckers, variation in territory quality is related to the presence of cavities. Because cavities take so long to construct, an individual does better to acquire a breeding position on an existing territory containing suitable cavities than to occupy vacant habitat and construct new cavities (Walters 1991, Walters *et al.* 1992a, Conner and Rudolph 1995a). Thus habitat lacking suitable cavities is poor quality, and habitat with existing, suitable cavities is high quality. The birds ignore poor quality habitat, even though they could excavate cavities and then reproduce successfully there, and compete intensely for openings in high quality habitat. When artificial cavities are added to unoccupied but otherwise suitable habitat, it immediately becomes high quality habitat, and is quickly occupied (Copeyon *et al.* 1991, Walters *et al.* 1992a).

The implication of this view of population dynamics is that the breeding population size (usually measured as the number of potential breeding groups) is determined by the number of high quality territories, which depends on the number and distribution of suitable cavities. This is consistent with the behavior of populations during the species' decline (Walters 1991), as well as with recent increases in some populations under new management. The dominant feature in population declines has been gradual abandonment of territories rather than poor survival or reproduction. In many cases it is clear that territory abandonment was related to loss of cavities to tree death or cavity enlargement, or to encroachment by hardwood midstory (Jackson 1978b, Van Balen and Doerr 1978, Conner and Rudolph 1989, Costa and Escano 1989). With so many threats to cavities, it was easy to lose territories, and thus populations declined, despite the continued presence of helpers and good productivity on those territories that remained suitable. Often territories are occupied by an unpaired male for a period prior to abandonment, so that response to loss of cavities and other adverse events is delayed (Jackson 1994). This may be because once territories deteriorate, young birds no longer remain as helpers and females no longer consider them acceptable, but the breeding male refuses to leave. The territory is no longer acceptable to dispersing males, however, so once the original breeding male dies, which may be many years later, the territory is finally abandoned.

New groups on new territories arise by two processes, pioneering and budding (Hooper 1983). Pioneering is the occupation of vacant habitat by construction of a new cavity tree cluster, which according to the view of population dynamics just presented, is expected to be rare. Budding is the splitting of a territory, and the cavity tree cluster within it, into two. Budding is common in many other cooperative breeders, and might be expected to be more common than pioneering in red-cockaded woodpeckers, since the new territory contains cavities from the outset.

The available data indicate that budding indeed is more common than pioneering, and that pioneering is quite rare. In the North Carolina Sandhills, the observed rate of pioneering over 16 years is one event per 1572 existing groups per year, and in Croatan National Forest in coastal North Carolina, over 7 years it is one event per 332 existing groups per year (J. Walters, unpublished). These translate into population growth rates of 0.06 percent and 0.3 percent per year. However, at nearby Marine Corps Base Camp Lejeune, the rate of pioneering over 10 years has been one event per 46 existing groups per year, a population growth rate of 1.5 percent per year (J. Walters, unpublished). During these same periods, rates of population growth through budding have been 0.6 percent, 2.1 percent, and 0.6 percent for the North Carolina Sandhills, Croatan National Forest, and Marine Corps Base Camp Lejeune respectively. Combining budding and pioneering, growth rates are 0.7 percent, 2.4 percent, and 2.2 percent per year respectively. During the years when the North Carolina Sandhills population was declining (1980 to 1984) the growth rate through these processes was 0.1 percent per year, whereas over the subsequent years, when the population was stable, it was 0.9 percent. A population growth rate of 10 percent per year through these processes was reported for the Francis Marion National Forest (Hooper *et al.* 1991a). In this case pioneering and budding events were inferred rather than directly observed, unlike in North Carolina, and it is possible that the rate of population growth was overestimated. Still, this study suggests that the rate of population growth through budding and pioneering potentially can be substantially greater than what has been observed in North Carolina.

Why the rates of budding and pioneering vary so much is a mystery. It appears from the North Carolina data that rates may be higher in small populations (Croatan, Lejeune) than in large ones (Sandhills), but this is inconsistent with the data from the Francis Marion. Another interpretation is that the rates are higher where turnover of breeders is less, and thus opportunities to replace deceased breeders are fewer. A third hypothesis is that budding and pioneering are stimulated by burning specifically, or habitat improvement generally. This is consistent with the North Carolina data in that rates have been higher in recent years in the Sandhills and Lejeune, following reintroduction of growing season fire, and lower in the last several years on Croatan, since burning during the growing season there has been reduced. A fourth hypothesis is that conditions for population growth may be more favorable in flatwoods habitat than in sandhills habitat.

Rates of budding and pioneering may vary for unknown reasons, but it is clear that they are almost always quite low. These rates were too low to counter losses of territories during the 1970's and 1980's when populations were declining, and they limit the potential for recovery currently, even if losses of territories can be prevented. Thus it is easy to understand why, until the advent of artificial cavity construction, populations generally have been stable or declining rather than increasing.

Understanding that population size is determined by the number of territories with suitable cavities makes designing management to increase populations straightforward (Copeyon *et al.* 1991, Walters 1991). To prevent loss of occupied territories, existing cavity trees should be protected, so that a sufficient number of suitable ones are maintained at all times. This can involve eliminating encroaching hardwoods, protecting cavities with restrictors, or replacing lost cavities with artificial ones. To increase the number of suitable territories, cavities can be added in unoccupied habitat, such as abandoned territories with existing cavities and completely vacant areas. In theory it might be possible to rehabilitate abandoned territories by placing restrictors on existing cavities or eliminating hardwoods. In practice, however, only recently abandoned territories seem to be reoccupied without the addition of new cavities (Doerr *et al.* 1989). This may be because cavities deteriorate if unused for long periods. Therefore, for both abandoned territories and vacant habitat, usually the only effective means to create a suitable territory is to construct new artificial cavities in open pine habitat.

Where a management strategy based on maintaining and creating suitable territories has been followed, it has been effective in increasing populations. There have been successes at Eglin Air Force Base (Hardesty *et al.* 1997, J. Walters *et al.*, unpublished), Osceola National Forest (USFWS, unpublished), Marine Corps Base Camp Lejeune (Walters *et al.* 1995), Fort Stewart (T. Beaty, unpublished), Fort Benning (M. Barron, unpublished), Noxubee National Wildlife Refuge (J. Tisdale, unpublished), and Piedmont National Wildlife Refuge (R. Shell, unpublished). Rates of population increase are similar across sites, suggesting that a rate of increase of 10 percent per year is perhaps the best that can be achieved (without resorting to translocation). It may be that the pool of new breeders (i.e., helpers, floaters, and first-year birds) generally is not large enough to permit higher rates of increase.

The current understanding of population dynamics suggests not only that management designed to increase the number of suitable territories will be effective, but also that management designed instead to increase productivity and survival will be ineffective in most circumstances. Thus measures designed to thwart nest predators, prevent cavity kleptoparasitism (except to prevent cavity enlargement), or eliminate predators of fledglings and adults often will be ineffective in promoting population growth. Such measures may be necessary, however, in intensively managed, extremely small populations where every individual is critically important. The population at the Savannah River Site provides the best example of successful, intensive management of a small population (Haig *et al.* 1993, Franzreb 1997).

Like so many other characteristic traits of this species, the origin of its complex social system and unusual population dynamics can be traced back to its most unique feature, excavation of cavities for roosting and nesting in live pine trees. The understanding of these relationships that has been achieved is cause for optimism about the future of the species. Unlike for so many other species, it appears that our understanding of the species' biology is sufficient to construct a management strategy likely to produce recovery, and recent results support this supposition. Ability to implement this strategy is now the key to recovery.

C. Population and Species Viability

A viable species is one that can reasonably be expected to avoid extinction over a long period of time. Similarly, a viable population is one that is self-sustaining over a long period. For any endangered species, achieving species viability is the ultimate conservation goal, and the ultimate objective of a recovery plan such as this one. How species viability relates to population viability is dependent on population structure. Species viability may be achieved by maintaining a number of independent viable populations and/or by maintaining a network of interacting populations, none of which are viable on their own. We conclude that, for red-cockaded woodpeckers, the appropriate strategy is to maintain a number of independent demographically viable populations and a number of interacting populations within and between recovery units to promote genetic viability. Here we discuss information about population structure that led us to these conclusions, and then how population viability is best achieved.

Population Structure

Given the historic distribution of its habitat and comments by early naturalists about its abundance, it is highly likely that red-cockaded woodpeckers originally were distributed fairly continuously over broad areas. Since the birds are so sedentary (see 2B), one presumes that originally there may have been considerable genetic substructure within populations, but that distinct, genetic population boundaries were lacking. That is, genetic similarity probably changed gradually with distance, rather than suddenly at population boundaries. In fact, it may have been difficult to even delineate distinct populations.

Such is not the case currently. Now the species is distributed largely as distinct populations, with large gaps of unoccupied land between them. Most of these populations are quite small, and only a few are of more than modest size (see map insert and Tables 5, 6, 7, and 9). Typical dispersal distances of both sexes are sufficiently short to maintain genetic substructure within populations even under current conditions. Daniels and Walters (2000a) found that an individual's close relatives are highly concentrated within three territories of the natal site. Thus one can expect genetic similarity to change with distance within populations, as opposed to the uniform structure that occurs when mating is random within populations.

Although this species is highly sedentary compared to other birds, some individuals move long distances (Walters *et al.* 1988a). There is sufficient documentation (Walters *et al.* 1988b, Conner *et al.* 1997c, Ferral *et al.* 1997, R. Costa, pers. comm.) to conclude that long-distance movements between populations are rare but regular events, and that the birds can move through seemingly inhospitable habitat. It appears that movement from small populations into large ones is much more common than the reverse. Because of this, and the rarity of such movements, they are of little consequence demographically; that is, their contribution to sustaining populations is trivial. However, they may be frequent enough to be important genetically, and may function to maintain genetic variability within populations. Producing immigrants that contribute to this function may be one of the primary purposes that small support populations serve.

The most reasonable conclusion, based on current information, is that demographically, populations of red-cockaded woodpeckers function as closed populations. That is, their persistence depends totally on within-population demography, and not at all on exchange between populations. Thus red-cockaded woodpeckers do not exhibit any of the various types of metapopulation structure (Stith *et al.* 1996). Local extinction followed by natural recolonization from another population is extremely unlikely for this species. (The event closest to natural recolonization was the appearance of a male from the Savannah River Site within a recruitment cluster on Fort Gordon, two years after the Fort Gordon population was extirpated. This dispersal event would not likely have resulted in the formation of a breeding pair without the use of translocation.)

Further, immigration rates are too low for one population to rescue another from extinction as occurs in another cooperatively breeding woodpecker, the acorn woodpecker (*M. formicivorous*; Stacey and Taper 1992). Neither are immigration rates high enough to enable source-sink relationships between populations. However, in areas of low density (e.g., northeastern North Carolina), widely scattered groups considerable distances apart may function as a single population. Dispersal distances are longer when population density is lower (Daniels 1997), apparently because the distance moved is a function primarily of the number of groups encountered rather than of habitat, mortality or speed of movement. Thus migration between two sizeable populations only 24.2 km (15 mi) apart may be rare (e.g., only one movement between the Camp Lejeune and Croatan National Forest populations in North Carolina over 11 years), whereas two groups 24.2 km (15 mi) apart in an area of low density (e.g., only one other group between them) may exchange individuals regularly.

Red-cockaded woodpecker populations should not be viewed as closed genetically, however. Nearly all probably experience some immigration, much of it from smaller support populations. Rates of immigration and genetic relationships between populations are not well enough known to determine precisely the rate of gene flow, nor its effect on genetic variability within populations. All that can be said is that the existence of gene flow needs to be considered when evaluating the genetic viability of populations (see below).

There are, however, both allozyme (Stangel *et al.* 1992, Stangel and Dixon 1995) and random amplified polymorphic DNA (RAPD) data (Haig *et al.* 1994a, 1996) available that reveal general genetic relationships between populations. These data indicate that most (93 percent, Haig *et al.* 1994a) genetic variation occurs among individuals within populations. Genetic differences between populations increase somewhat with geographic distance, but there is little geographic structure to genetic variability. Genetic differences between populations are greater than is typical of birds, but equivalent to those in other endangered birds. However, populations do not exhibit unique alleles. Some small populations exhibit reduced heterozygosity, but not all do, and generally there is no consistent relationship between population size and genetic variability (Stangel and Dixon 1995). All of this information is consistent with recent isolation of populations in a formerly continuously distributed species, with low levels of gene flow between populations. Populations probably are diverging genetically and losing variability currently, but isolation evidently is too recent for them to differ much yet.

Threats to Population Viability

Information on population structure indicates that the best approach to viability is to manage for independent populations that are individually viable, with appropriate recognition of low levels of gene flow between populations. To assess population viability, generally four threats are considered: (1) demographic stochasticity, (2) environmental stochasticity, (3) catastrophes and (4) genetic drift and inbreeding (Shaffer 1981, 1987). All four threats must be adequately addressed to ensure viability. Here we examine each threat, treating demographic stochasticity and environmental stochasticity together as demographic considerations, and catastrophes and genetic concerns as separate issues. In the previous recovery plan (USFWS 1985) only catastrophes and genetic factors were considered.

Demographic Considerations

Demographic stochasticity refers to effects of random events on the reproduction and survival of individuals, whereas environmental stochasticity refers to effects of unpredictable events that alter vital rates. For example, if every individual has a 50 percent probability of annual survival, in a population of 20 individuals 10 will not die each year. Instead some years by chance nine will die, in others eleven and so forth. This is demographic stochasticity, which is analogous to sampling error. It may be that in years with severe winters the probability of survival is only 30 percent, whereas in years with mild winters it is 70 percent. This is an example of environmental stochasticity.

Demographic stochasticity is inevitable, but is usually considered to be a threat only to small populations, i.e., less than 50 individuals (Meffe and Carroll 1997). Environmental stochasticity varies widely in strength, depending on the species and the nature of its interactions with its environment. Viability in the face of these threats usually is assessed by incorporating them in simulations of population dynamics, and determining the probability of extinction over long time periods in populations of various sizes. The chief obstacle to a comprehensive viability analysis previously has been lack of a suitable population model. Standard, simple population models do not incorporate the social complexity of the species, notably the buffering effect of the large, nonbreeding helper class (see 2B). These complexities can be handled by stage-based matrix models (Caswell 1989, McDonald and Caswell 1992). Application of these models to red-cockaded woodpeckers has produced important insights about population behavior and management (Heppell *et al.* 1994, Maguire *et al.* 1995). But even these models do not incorporate critically important spatial dynamics resulting from helpers filling breeding vacancies only on or very near their natal territory. A model that assumes that nonbreeders fill breeding vacancies randomly within the population cannot be expected to portray population dynamics accurately enough to perform viability analysis.

The advent of spatially-explicit, individual-based simulation models in ecology provides a tool capable of handling the complex population dynamics of red-cockaded woodpeckers (DeAngelis and Gross 1992, Judson 1994, Dunning *et al.* 1995). These models are not without their faults, a notable one being the large number of parameters that must be accurately estimated if model results are to be trusted (Conroy *et al.* 1995). A spatially-explicit, individual-based model of the population dynamics of red-cockaded woodpeckers has been developed by Letcher *et al.* (1998), using data from the North Carolina Sandhills.

Letcher *et al.* (1998) used their model to assess effects of demographic stochasticity on populations of various sizes and spatial distributions. Their most notable result was the strong effect of spatial structure on viability. If territories were highly clumped, populations of as few as 25 groups were remarkably persistent, whereas if territories were scattered, populations as large as 169 groups declined. New group formation through budding and pioneering (see 2B), which was not then incorporated into the model, would presumably be sufficient to counter the small declines experienced by the largest populations. Still, the model predicts that demographic stochasticity will be a threat to populations as large as 100 groups if spatial structure is poor, but will not be a threat to populations as small as 25 groups if spatial structure is favorable. Recent analyses indicate that even smaller populations, as small as 10 groups, can be remarkably persistent if the territories are maximally clumped (Crowder *et al.* 1998, Walters et al. 2002b). These model results are consistent with empirical evidence. Across the range it seems that small aggregates of groups persist surprisingly well, whereas small, low-density populations always seem to decline. Even in somewhat larger populations, loss of isolated groups is a problem (Conner and Rudolph 1991b).

We conclude that demographic stochasticity is, as usual, a threat only to small populations. However, the threshold of vulnerability varies considerably with spatial structure. Vulnerable populations may be twice the typical size, or half the typical size, depending on the configuration of the population. It certainly is possible to avoid this threat for populations as small as 25 groups, and it may be possible to avoid it for populations of only 10 groups. Managers therefore should strive to aggregate their populations, and to avoid isolation of groups, where isolation is defined as being beyond the dispersal range of helpers. Based on data from the North Carolina Sandhills (Walters *et al.* 1988a, Daniels 1997), 3.2 km (2 mi) appears to be a reasonable standard to use for the maximum dispersal range of helpers (less than 10 percent of helpers [17 of 240] dispersed more than 3.2 km [2 mi]; Daniels 1997). This maximum dispersal distance refers to habitat that contains no barriers to dispersal. The ideal spatial configuration is one in which every group is within dispersal range of helpers from several other groups.

Evaluating environmental stochasticity is more difficult. Letcher *et al.*'s (1998) model is suitable for this purpose, but accuracy of results will depend not only on the validity of the model, but also on estimates of the magnitude of stochasticity. Typically stochasticity is incorporated as annual variation, and therefore the appropriate variance of each demographic parameter must be determined. It is quite clear from available data that annual variation in productivity is considerable, but annual variation in mortality appears to be fairly small (Walters *et al.* 1988a).

Preliminary analyses of population viability incorporating environmental as well as demographic stochasticity have recently been completed using the model developed by Letcher *et al.* (1998). In these analyses, the magnitude of environmental stochasticity was estimated from observed annual variation in the North Carolina Sandhills population, and annual variation in productivity, adult survival, and fledgling survival was incorporated (Crowder *et al.* 1998, Walters et al. 2002b). Budding was incorporated into the simulations as well. These results suggest that populations of 100 or fewer groups are vulnerable to extinction, even when territories are maximally clumped. Populations of 250 or more groups are not vulnerable to environmental stochasticity, according to these simulations, even if territories are not highly clumped. Viability of populations between 100 and 250 groups depends on spatial configuration as well as population size, although this has not yet been analyzed in detail.

Clearly, more analyses are necessary before a more precise viability criterion can be defined, but results at hand permit some important conclusions. First, as expected, populations must be considerably larger to avoid the threat of environmental stochasticity than they need be to avoid the threat of demographic stochasticity. Second, the population sizes necessary to achieve viability against these two demographic threats are much smaller than is typical. This is an intuitive result, since the presence of helpers can be expected to dampen oscillations in the breeding population caused by variation in productivity and breeder survival. Years of poor productivity, or low breeder survival, will lead to a reduction in the size of the helper class rather than a reduced number of potential breeding groups. Third, the level of assistance, in the form of translocated birds, required to avoid extinction of small populations may be low enough to be feasible. Fourth, spatial configuration becomes increasingly important to viability as populations become smaller.

It is encouraging that population sizes required to avoid demographic threats to viability fall within a range that is achievable. Producing populations of two thousand groups, were that required, would be inconceivable. Managing to produce populations of 250 or more potential breeding groups with a favorable spatial structure, on the other hand, is a realistic goal. Indeed a few populations already match this description.

Genetic Considerations

There are two genetic threats to population viability. The first, inbreeding depression, threatens only small populations, whereas the second, genetic drift, can threaten even large populations (reviewed in Lande 1995). Inbreeding depression reduces the survival and productivity of individuals, and results from the segregation of partially recessive, deleterious alleles. The resulting negative effect on population dynamics increases vulnerability to extinction. The amount of inbreeding depression depends on the rate of inbreeding and the opportunity for selection to purge recessive lethal and semi-lethal mutations (Lande 1995). Genetic drift results in the loss of genetic variation, which may reduce a species' ability to adapt and persist in a changing environment, and thereby its viability over long time periods. The rate of loss is inversely related to population size and mutation rate, and viability is achieved when the population size is large enough that loss to drift is in equilibrium with gain from mutation.

The red-cockaded woodpecker is one of the few species for which inbreeding depression has been demonstrated in wild populations, as opposed to assumed from theoretical considerations. In the North Carolina Sandhills, productivity of both closely related (i.e., coefficient of relationship greater than 0.125) pairs and their inbred progeny is substantially lower than that of unrelated pairs and their progeny (Daniels and Walters 2000a). This is due to both reduced hatching rates of eggs and reduced survival of fledglings to age one year. These are precisely the sort of traits one expects to be affected by segregation of partially recessive, deleterious alleles, and in fact reduced hatching rate is the classical manifestation of inbreeding depression in domestic birds (Daniels and Walters 2000a).

Although inbreeding depression is clearly a threat to red-cockaded woodpecker populations, its effects may not yet be evident due to the recent nature of reductions in population size. The available genetic data indicate that most small populations do not yet exhibit high levels of homozygosity (see above). Furthermore, Stangel and Dixon (1995) found no evidence that small populations were experiencing increased morphological variability. They examined fluctuating asymmetries of paired characters, which are often used as an indicator of developmental stability (Leary and Allendorf 1989). Developmental instabilities are thought to be one of the manifestations of inbreeding depression.

Although it appears that there has not yet been sufficient time for the various manifestations of inbreeding depression to become prevalent, they can be expected to increase in the near future in populations that remain small and isolated. Franklin (1980) suggested that populations with an effective size of 50 individuals or less would be vulnerable to inbreeding effects. Since the red-cockaded woodpecker can be characterized as a species in which large populations have been reduced suddenly to small size, it is reasonable to apply this standard to this species. That is, it is unlikely that previous selection has already purged recessive alleles from red-cockaded woodpecker populations. Instead, this species probably is quite vulnerable to this threat.

Effective size refers to an idealized population in which individuals mate randomly and all contribute equally to reproduction. In this hypothetical ideal population, all individuals pass on an equal number of their genes to subsequent generations. Effective size is a theoretical standard used to estimate the retention and loss of genetic variation in a real population. The effective population size itself is never measured directly; it is calculated using formulas based on genetic theory and demographic data collected from real populations.

The actual population size is almost always higher than the effective size, because several characteristics of animals and populations act to make the genetic contribution of individuals to subsequent generations unequal. For example, some pairs or individuals may consistently produce more offspring than others, and some individuals live longer than others. It is mainly this variation in reproductive success that makes effective size less than actual size.

Thus, it is possible to calculate the effective size of a population if its demography is known. Such calculations indicate that for red-cockaded woodpeckers, the actual population size needed to achieve an effective size of 50 individuals is 31 to 39 potential breeding groups, depending on the details of the demography of particular populations (Reed *et al.* 1988b, 1993, D. Heckel and M. Lennartz, unpublished). According to Franklin's (1980) suggestion that an effective size of 50 is necessary to withstand threats from inbreeding depression, stable or increasing populations of 40 or more potential breeding groups are not threatened by inbreeding depression.

Daniels *et al.* (2000) came to a fairly similar conclusion by using the spatially explicit model developed by Letcher *et al.* (1998). They estimated inbreeding levels over time in red-cockaded woodpecker populations of various sizes and rates of immigration. In their simulations, mean inbreeding increased rapidly in very small, declining populations with no immigration, but remained tolerably low in closed, stable populations of 100 occupied territories. Moderately high levels of immigration were required to stabilize small declining populations and maintain reasonable inbreeding levels (kinship coefficients less than 0.10). That is, inbreeding depression is not expected to affect populations that are receiving 2 or more migrants per year. In the absence of immigration, Daniels *et al.* (2000) found that a stable population of 50 to 100 or more breeding groups was necessary to avoid inbreeding depression. Thus, based on the work by Daniels *et al.* (2000) as well as Franklin's (1980) initial suggestion, we conclude that stable or increasing populations of at least 40, and possibly as many as 100 potential breeding groups—or an immigration rate of 2 or more migrants per year—are required to protect against inbreeding depression.

The population size necessary to avoid loss of genetic variation due to genetic drift, however, is much larger. Franklin (1980) first proposed that an effective size of 500 individuals would allow maintenance of long-term viability, because loss of genetic variation from drift would be offset by the creation of new variation through natural mutation. Recently, however, this number has been a topic of some debate (Lande 1995, Franklin and Frankham 1998, Lynch and Lande 1998, Allendorf and Ryman, in press). Lande (1995) indicated that only populations with an effective size of over 5000 individuals can be expected to maintain viability in the absence of immigration, because not all mutations are beneficial. Others argue that an effective population size of 500 to

1000 individuals is sufficient (Franklin and Frankham 1998). At issue is the potential effects of harmful mutations: Franklin and Frankham (1998) consider these effects negligible, but others have suggested that slightly deleterious mutations are capable of causing population extinction even at effective sizes of several hundreds (Lande 1994, Lynch *et al.* 1995, Lynch and Lande 1998). The debate will likely continue, but a reasonable conclusion is that only populations with actual sizes in the thousands, rather than hundreds, can maintain long-term viability and evolutionary potential in the absence of immigration (Allendorf and Ryman, in press).

Thus, without immigration, populations of red-cockaded woodpeckers that have reached recovery goals may still be susceptible to loss of genetic variability through genetic drift. One practical way to reduce this threat is to promote immigration, both natural (from support and other core populations) and artificial (from translocation). Sufficient connectivity among populations, in the order of 1 to 10 migrants per generation in each direction (0.25 to 2.5 migrants per year), can maintain genetic variation and long-term viability for the species (Mills and Allendorf 1996). Populations connected by this level of immigration maintain genetic variation equal to that of one population as large as the sum of the connected populations (F. Allendorf, pers. comm.). As populations increase, natural dispersal among them will likely increase, but determining actual rates of natural immigration is a critical research need.

A second practical way to reduce the effects of genetic drift is to recover the species as quickly as possible. Loss of genetic variation increases with decreasing population size, but such loss also increases dramatically if populations remain small over time (Hartl 1988). Current efforts to increase populations, and the lack of such efforts, have substantial effects on the total genetic variation that will be retained by the species in the future.

Finally, one population, Central Florida Panhandle, may be large enough at delisting to retain its genetic variability despite genetic drift. This population will harbor 1000 potential breeding groups at delisting. For red-cockaded woodpeckers, 1000 potential breeding groups is considered equivalent to an effective population size of 1280 to 1560 individuals (Reed *et al.* 1988b, 1993). Several researchers consider a population of this effective size capable of maintaining genetic variability (Franklin and Frankham 1998, Allendorf and Ryman, in press).

Catastrophes

Catastrophes are rare, irregularly occurring events that produce extreme changes in demography and population dynamics. There are two types of catastrophes that threaten red-cockaded woodpecker populations: catastrophic winds (hurricanes, downbursts, and tornadoes) and outbreaks of southern pine beetles. The beetles kill cavity trees, but not birds—at least not directly. It is possible that loss of foraging habitat and cavity trees to beetles could alter survival and productivity of woodpeckers, but this has not been demonstrated. Outbreaks of sufficient size to constitute a catastrophe at the population level will probably be restricted to small populations dependent on tree species other than longleaf pine. Longleaf is sufficiently resistant to beetles to preclude outbreaks large enough to constitute a catastrophe. In other habitat types, the only real threat to population viability is loss of cavity trees, and this can be countered by construction of artificial replacement cavities. Appropriate forest management can minimize the likelihood of catastrophic outbreaks.

Hurricanes, however, are the greatest catastrophic threat to population viability. The devastation wrought by Hurricane Hugo on the population inhabiting the Francis Marion National Forest demonstrated all too clearly that such storms can produce catastrophic changes in mortality (Hooper *et al.* 1990). Further, by eliminating all cavity trees on many territories Hugo resulted in a catastrophic increase in the rate of territory abandonment, beyond that attributable to mortality alone. Because of the distribution of red-cockaded woodpeckers, most populations face a significant risk from hurricanes, although there is little risk to some inland populations (Hooper and McAdie 1995). That hurricanes will regularly strike woodpecker populations is inevitable, and therefore any strategy to ensure species and population viability must address this form of catastrophe specifically.

The first element in addressing the hurricane threat is to reduce risk to the species as a whole by maintaining a number of populations that are broadly spaced geographically, and including as many inland populations as possible among them (Hooper and McAdie 1995). The second element is to reduce risk of extinction of individual populations through rehabilitation following the catastrophes that occur. The Hugo experience demonstrates that it is possible, albeit at considerable expense, to reduce impacts at the population level and facilitate recovery to approach pre-storm levels through proper management immediately following the storm (Watson *et al.* 1995). The critical activity is to construct artificial cavities quickly, and distribute them so that as few territories as possible are completely lacking in cavity trees. This will maximize the number of territories that remain occupied, which is the most critical component of population dynamics. It is anticipated that one or two recovery populations, as well as a number of support populations, will be in the process of recovering from storms at any given time (Hooper and McAdie 1995). Some support populations may be lost to hurricanes, despite proper rehabilitation efforts, but recovery populations should not be.

The third and final element in addressing the hurricane threat is to manage individual populations at risk to reduce their vulnerability to wind damage. Hooper and McAdie (1995) offer a number of suggestions, such as reducing access of wind into stands and creating conditions for growth that favor development of greater wind resistance. More research in this area is needed before a detailed policy can be developed, but managers of populations at risk should consider the factors discussed by Hooper and McAdie (1995) in developing their forest management plans.

A Strategy for Species Viability

The strategy to recover the red-cockaded woodpecker consists of recovering a number of individual populations, designated recovery populations, to levels at which they are individually viable against environmental stochasticity. Populations large enough to be resilient to environmental stochasticity will also be able to withstand threats from demographic stochasticity and inbreeding. Currently, our best estimate of the population size necessary to withstand effects of environmental stochasticity is 250 potential breeding groups. However, this is a minimum estimate based on model simulations, and it may contain some error. To be conservative, a number of larger populations (350 potential breeding groups) will exist at the time of recovery. These two population sizes, 250 and 350 potential breeding groups, are probably insufficient to avoid loss of genetic variation through genetic drift, at least in the absence of immigration. (Some researchers consider 350 breeding groups the minimum size necessary to produce enough novel variation to offset loss from drift).

There are several strategies to reduce the loss of genetic variation as much as possible. First, recovery populations should be increased as far beyond the above population sizes as the habitat base will allow. Second, populations should be recovered as rapidly as possible, because loss of genetic variation increases with the length of time that populations remain small. Third, recovery populations represent the full range of habitat types now occupied by red-cockaded woodpeckers, and this range will aid the conservation of local genetic resources. Finally, dispersal between populations should be facilitated to the fullest extent possible. We have increased the total number of designated recovery populations identified in the 1985 recovery plan (USFWS 1985) in part to enhance the likelihood of natural dispersal among these populations once the species is recovered. We stress the importance of support populations as sources of immigrants to replace lost variability, and that support populations should be maintained until and after recovery. We recognize that translocation may need to be employed to maintain genetic variation within populations and species-wide, if natural dispersal is found to be insufficient.

Support populations should include at least 40 to 100 potential breeding groups, depending on spatial configuration, in order to eliminate demographic stochasticity and inbreeding depression as threats to their existence. If they can be maintained at even higher levels, their likelihood of extirpation due to environmental stochasticity will be reduced. Support populations that cannot meet the 40 to 100 size criterion can still serve the purpose of providing genetic variability to other populations, but extirpation of some of these is anticipated. We recommend that they be maintained at the largest size the habitat base will support.

The value of support populations depends on their genetic and spatial relationship to recovery populations. Value cannot be assessed precisely until more information about actual immigration, or how probability of immigration depends on distance and intervening habitat type, is available. The number of support populations required for each recovery population cannot be determined until information on levels of gene flow necessary to compensate for lost genetic variability is available. In the meantime, all support populations, including those of less than 40 potential breeding groups, should be considered necessary to species viability.

The designated recovery populations were selected to eliminate the risk of extinction to the species as a whole due to hurricanes. Measures designed to reduce vulnerability to wind damage and to rehabilitate populations following storms should be sufficient to prevent extirpation of those individual recovery populations at risk. However, some support populations may be lost to hurricanes, with risk being a function of population size, location, and expected frequency of storms.

Populations must be managed to achieve favorable spatial configuration, as well as large size. Specifically, groups should be clustered to the extent possible, so that each group has multiple other groups within 3.2 km (2 mi). Special attention should be paid to the edges of the population, to keep isolation of individual groups there to a minimum.

Habitat restoration within populations is a critical aspect of species recovery. Populations are limited by available cavities and by the quality of foraging habitat. Limitation by available cavities has been documented by experimental research (Walters *et al.* 1992). Limitation by quality of foraging habitat is evidenced by smaller territories in areas where the habitat is better (see 2E). Without restoration of nesting and foraging habitat, species viability is not achievable.

In summary, the strategy to achieve species viability is to maintain a number of recovery populations within each recovery unit that, with immigration, are individually viable to genetic and demographic threats. Development and maintenance of viable recovery populations is dependent on restoration and maintenance of appropriate habitat. The threat to species viability from hurricanes is substantially reduced by maintaining a sufficient number of recovery populations, including inland ones, so that anticipated, periodic catastrophic reductions in some recovery populations do not threaten the species as a whole.

D. CAVITIES, CAVITY TREES, AND CLUSTERS

Red-cockaded woodpeckers are unique among North American woodpeckers in that they nest and roost in cavities they excavate in living pines (Steirly 1957, Short 1982, Ligon *et al.* 1986). This unusual behavior is thought to have evolved in response to the scarcity of snags and hardwoods in the fire-maintained pine ecosystems of the southeast (Ligon 1970, Jackson *et al.* 1986). Excavation of cavities in live pines has given rise to additional unusual and complex behaviors, ranging from cooperative breeding (Walters *et al.* 1992a; see 2B) to daily excavation of resin wells to create resin barriers against predatory rat snakes (*Elaphe obsoleta,* Ligon 1970, Dennis 1971b, Jackson 1974, 1978a, Rudolph *et al.* 1990b). Use of live pines is also the primary reason why the species requires mature pines, the loss of which has resulted in endangerment. Cavities are an essential resource for red-cockaded woodpeckers throughout the year, because they are used for both nesting and roosting. Thus, a thorough understanding of cavity tree ecology is fundamental to red-cockaded woodpecker biology, management, and recovery. This section describes current knowledge in support of the guidelines for management of cavity trees and clusters presented in 8F.

Cavity Excavation and Selection of Cavity Trees

Excavation of cavities in live pines is an amazingly difficult task. Birds must first select an old pine (Jackson and Jackson 1986, Conner and O'Halloran 1987, DeLotelle and Epting 1988, Rudolph and Conner 1991), then excavate through 10 to 15 cm (4 to 6 in) of live sapwood, avoid dangerous pine resin that seeps from the cavity during excavation, and construct a cavity completely contained within the heartwood (Jackson 1977, Hooper *et al.* 1980, Conner and Locke 1982, Conner and O'Halloran 1987, Hooper 1988, Hooper *et al.* 1991b). Cavity excavation typically takes many years (Jackson *et al.* 1979, Rudolph and Conner 1991, Conner and Rudolph 1995a, Harding 1997).

The difficulty of cavity excavation is considered a major factor in the evolution of cooperative breeding in red cockaded woodpeckers (Walters 1990, Walters *et al.* 1988a, 1992a, 1992b; see 2B). Birds cannot easily exploit previously unoccupied habitat and build cavities, and so competition for territories with existing cavities is unusually intense. Young males delay reproduction and remain on their natal territory as helpers to increase their likelihood of obtaining a breeding site with existing cavities (Walters 1990, Walters *et al.* 1988a, 1992b). Natural formation of groups in previously unoccupied habitat (pioneering, Hooper 1983) is rare; its estimated annual rate is less than 3 percent of total groups in a population under current conditions (Walters 1990; see 2B).

Red-cockaded woodpeckers use a variety of pine species as cavity trees including longleaf, loblolly, shortleaf, slash, pond, pitch (*P. rigida*), and Virginia pines (*P. virginiana*; Steirly 1957, Lowery 1960, Mengel 1965, Sutton 1967, Hopkins and Lynn 1971, Jackson 1971, Murphy 1982). Longleaf, loblolly, and shortleaf pines are the most common species used for cavity trees and longleaf is considered preferred (Lowery 1960, Hopkins and Lynn 1971, Jackson 1971, Baker 1981, Bowman *et al.* 1997). All cavities are excavated in live pines, but occasionally woodpeckers roost and even nest in cavities in trees that have recently died (Hooper 1982, Patterson and Robertson 1983, R. Costa, pers. comm.).

Red-cockaded woodpeckers are able to exploit the resin of the live pine to protect against predation of nests and adults by arboreal snakes (Ligon 1970, Dennis 1971b, Jackson 1974, 1978a, Rudolph *et al.* 1990b). The birds create and maintain resin wells, or wounds in the cambium, to coat the trunk with resin which then effectively interferes with the snakes' ability to climb the tree (Rudolph *et al.* 1990b).

Longleaf pine may be preferred for use as cavity trees because it produces more resin and can sustain resin flow for more years than other southern pines (Wahlenburg 1946, Hodges *et al.* 1977, 1979, Bowman and Huh 1995, Ross *et al.* 1995). The production of more resin affords the birds greater protection against snakes, and also provides the tree with greater protection against insects such as southern pine beetles (Hodges *et al.* 1979). Annual survival of longleaf cavity trees was twice that for loblolly and shortleaf cavity trees in east Texas, in part because of longleaf pine's greater resistance to southern pine beetles (Conner and Rudolph 1995a). Because of higher survival and the ability to sustain resin flow over time, longleaf pines may remain in use as cavity trees for several decades—much longer than shortleaf or loblolly pines (Conner and Rudolph 1995a, Harding 1997).

Cavity excavation time appears to be longer in longleaf pines than in either loblolly or shortleaf pines. In Texas, excavation time averaged 6.3 years in longleaf pines, two to three times greater than the average times for loblolly and shortleaf pines (Conner and Rudolph 1995a). In North Carolina, excavation times for cavities in longleaf averaged from 10 to 13 years, and from 6 to 9 years for loblolly (Harding 1997). Cavity excavation is an intermittent process, with month-long or longer breaks to allow resin flow to subside through resinosis (saturation of sapwood with hardened resin; Conner and Rudolph 1995a). Thus, longleaf may require longer excavation times because of its greater resin flow (Conner and Rudolph 1995a). Variation in estimated excavation times may result from geographic variation in resin flow (Harding 1997), itself a function of site and tree factors (Hodges *et al.* 1979, Ross *et al.* 1995), or from variation in research methods.

Selection of and Requirement for Old Trees

Red-cockaded woodpeckers select and require old pines for cavity excavation (Jackson and Jackson 1986, Conner and O'Halloran 1987, DeLotelle and Epting 1988, Rudolph and Conner 1991). Age of cavity trees depends on the ages of pines available, but there is a minimum age, generally 60 to 80 years depending on tree and site factors, below which use as a cavity tree is highly unlikely or simply not possible (DeLotelle and Epting 1988, Hooper 1988, Rudolph and Conner 1991). Currently, cavity trees average roughly 80 to 150 years in age and can be much older (Rudolph and Conner 1991, Hedrick 1992). Cavity trees are generally the oldest trees available in today's forests (Jackson *et al.* 1979, Engstrom and Evans 1990, Rudolph and Conner 1991), and the optimal age for cavity trees may be well above the average age of cavity trees under current forest conditions. For example, red-cockaded woodpeckers in national forests of Texas continue to select the oldest trees available for initiation of cavities as the forests have aged 20 years during the course of study (Rudolph and Conner 1991).

One reason red-cockaded woodpeckers require old trees for cavity excavation is that they need sufficient heartwood diameter at preferred cavity heights to construct the cavity completely within the heartwood. Cavities must be completely within the heartwood to prevent pine resin in the sapwood from entering the chamber (Jackson and Jackson 1986, Clark 1993), and the estimated minimum amount of heartwood required is 14.0 to 15.2 cm (5.5 to 6 in; Conner *et al.* 1994). Preferred cavity heights generally range from 6.1 to 15.2 m (20 to 50 ft; Baker 1971b, Hopkins and Lynn 1971, Hooper *et al.*

1980, Conner and O'Halloran 1987), a possible adaptation to minimize likelihood of ignition by frequent fire (Conner and O'Halloran 1987, Clark 1992, Conner *et al.* 1994). The age of the tree determines heartwood diameter at cavity height, as older pines have more heartwood at greater heights. In eastern Texas, longleaf pines between 70 and 90 years old had adequate heartwood at appropriate heights to contain a cavity (Conner *et al.* 1994). Fifty year-old longleaf pines examined by Clark (1992) had insufficient heartwood for cavity excavation.

A second reason that woodpeckers select old trees for cavity excavation is that old pines have a higher frequency of infection by red heart fungus, and the associated decay of the heartwood becomes more advanced as the tree ages (Wahlenburg 1946). Woodpeckers can and do excavate cavities into undecayed heartwood (Beckett 1971, Conner and Locke 1982, Hooper 1988, Hooper *et al.* 1991b), but the presence of red heart fungus can substantially reduce the time required for cavity excavation (Conner and Rudolph 1995a). In Texas, for example, average excavation times for cavities in pines with and without decayed heartwood were 3.7 and 5 years, respectively (Conner and Rudolph 1995a).

Heartwood decay by red heart fungus was not frequently found in longleaf cavity trees in Texas until they were over 120 years old (Conner *et al.* 1994). Red heart is a very slow growing fungus (Affeltranger 1971, Conner and Locke 1982, 1983), and at least 12 to 20 years may be required between initial inoculation and the decay of sufficient heartwood to house a cavity (Conner and Locke 1983). Also, red heart fungus enters the heartwood of the tree through heartwood in large branches, and so trees must be old enough to have large branches before bole heartwood can be infected (Affeltranger 1971, Conner and Locke 1982). However, regional differences may exist in the ages and rates at which pines become infected with heartwood decaying fungi. A study in Texas reported a 46 percent infection rate for 50 longleaf cavity trees that averaged 126 years in age (Conner *et al.* 1994), whereas this rate was more than doubled for similarly aged longleaf cavity trees in South Carolina (97 percent infection rate for trees averaging 130 years in age; Hooper 1988).

Red-cockaded woodpeckers actively select pines with heartwood decayed by red heart fungus (Steirly 1957, Jackson 1977, Conner and Locke 1982, Hooper 1988, Hooper *et al.* 1991b, Rudolph *et al.* 1995). In fact, red-cockaded woodpeckers are able to detect and locate cavities in the specific area of the bole that is infected (Rudolph *et al.* 1995). Preference for decayed heartwood results in the selection of cavity trees that are older than necessary for them to have enough heartwood to contain a cavity (Hooper 1988, Hooper *et al.* 1991b, Rudolph *et al.* 1995). For example, cavity trees in Texas averaged 24.8 cm (9.75 in) in heartwood diameter, considerably larger than the 15.2 cm (6 in) estimated minimum (Rudolph *et al.* 1995). In fact, preference for red heart infection rather than age itself may drive the general preference for old trees (Hooper 1988).

Red-cockaded woodpeckers have been shown to select pines that have thinner sapwood and greater heartwood diameters than pines generally available nearby (Conner *et al.* 1994). This is also related to age: such trees are older, growing more slowly, and usually have a higher rate of red heart infection than pines not used for cavity excavation. Diameter growth of trees typically accelerates annually as younger trees mature, attains a maximum, and slows as trees approach maturity (Kramer and Kozlowski 1979). Heartwood diameter increases significantly with tree size and age in both loblolly and longleaf pines (Clark 1992, 1993).

Old growth pines are relatively rare throughout the south. Old growth remnants (both single trees and stands) within today's forests are critically important habitat and will continue to be so over the next 20 to 30 years, until second and third-growth forests mature and potential cavity trees become more widely available. Woodpeckers require potential cavity trees in abundance throughout the landscape, because of currently high mortality of natural cavity trees and high rates of damage to existing cavities by pileated woodpeckers (*Dryocopus pileatus*; Conner *et al.* 1991a, Conner and Rudolph 1995b, Saenz *et al.* 1998; see 2F).

Selection of Trees with High Resin Production

Red-cockaded woodpeckers are known to select, as cavity trees, pines that have higher resin flow than surrounding pines (Bowman and Huh 1995, Conner *et al.* 1998a). Moreover, breeding males select the cavity tree with the highest resin flow for use as the nest tree (Conner *et al.* 1998a). Thus, woodpeckers benefit from pines with high resin production potential, likely indicated by high crown volume and crown weight (Conner and O'Halloran 1987). Ross *et al.* (1997) showed that longleaf pine cavity trees in stands with low densities and on forest edges produced significantly more resin than similar cavity trees within interior forest stands with higher stem densities. Several studies have observed the tendency of red-cockaded woodpeckers to place their cavities near forest edges and in areas of low tree densities (Conner and O'Halloran 1987, Conner *et al.* 1991b, Ross *et al.* 1997), presumably because of higher resin flow in these locations.

The Cavity Tree Cluster

Each red-cockaded woodpecker in a group roosts in a cavity year-round, and it is usually the breeding male's cavity that holds the group's nest in the spring. The aggregation of active (in use) and inactive (previously used) cavity trees within an area defended by a single group is called the cluster (Walters *et al.* 1988a). This aggregation of cavity trees is dynamic, changing in shape as new cavity trees are added through excavation and existing cavity trees are lost to death or a neighboring group. To protect cavity trees, a buffer zone of continuous forest, 61 m (200 ft) in width, is generally established around the minimum convex polygon containing a group's active and inactive cavity trees. For this recovery plan, the term cluster is defined as the minimum convex polygon containing all of a group's cavity trees *and* the 61 m (200 ft) buffer surrounding that polygon. The minimum cluster area size is 4.05 ha (10 ac), as some clusters may only contain one cavity tree. To facilitate record keeping and protection, individual cavity trees within a cluster are commonly marked with metal numbered tags, painted for easy detection, and mapped.

Disturbance within the Cluster

Human-caused disturbances in cluster areas during the nesting season may disrupt red-cockaded woodpecker nesting activities, decrease feeding and brooding rates, and cause nest abandonment. Such activities may include but are not limited to all-terrain and other off-road vehicles, motorized logging equipment, and other vehicles that make excessive noise and disturbance to which the woodpecker groups have not previously become accustomed. Use of vehicles and other activities throughout the year may cause indirect impacts to red-cockaded woodpeckers through excessive soil compaction, damage to cavity tree roots, and disturbance of the groundcover. Soil compaction and root damage elevate cavity tree mortality (Nebeker and Hodges 1985, Hicks *et al.* 1987, Conner *et al.* 1991a); changes in the groundcover may affect prey abundance (Collins 1998), nutrient value of prey (James *et al.* 1997), and fire frequency and intensity through changes in fuel.

Geographic Variation in Habitat

There is geographic variation in nesting and roosting habitat of red-cockaded woodpeckers. The largest populations tend to occur in the primarily longleaf pine forests and woodlands of the Coastal Plains and Carolina Sandhills (Carter 1971, Hooper *et al.* 1982, James 1995, Engstrom *et al.* 1996). Woodpeckers are also found in shortleaf/loblolly forests of the Piedmont, Cumberlands, and Ouachita Mountain regions (Mengel 1965, Sutton 1967, Steirly 1973). Pine habitat occupied by red-cockaded woodpeckers covers a wide moisture gradient ranging from hydric slash pine (*P. elliottii* var. *densa)* flatwoods in Florida (Beever and Dryden 1992, Bowman and Huh 1995) to dry ridge and mountain tops in Oklahoma (Masters *et al.* 1989, Kelly *et al.* 1993), Alabama, and Mississippi. Density of pine overstory in areas occupied by red-cockaded woodpeckers varies from fairly dense in Texas (Conner and O'Halloran 1987, Conner and Rudolph 1989), to sparse in the Orlando, Florida vicinity (DeLotelle *et al.* 1987), to extremely low in the Big Cypress National Preserve (Patterson and Robertson 1981).

Structure of Vegetation within Clusters

Alteration of the natural fire regime during the past century has caused fundamental changes in the vegetation structure of upland habitats throughout the south. These changes include a gradual encroachment of hardwoods, increasing dominance of off-site pine species such as slash and loblolly, and more densely wooded forests in general (Jackson *et al.* 1986, Ware *et al.* 1993). Loblolly pine was present historically, but forests dominated by loblolly were very rare; its presence and dominance has increased dramatically as a result of fire suppression (White 1984). Each of these changes is detrimental to red-cockaded woodpeckers, and hardwood encroachment especially is a major cause of the species' decline and endangered status (see 1A).

The association of red-cockaded woodpeckers with open, park-like pine woodlands has long been known (Thompson and Baker 1971, Van Balen and Doerr 1978, Locke *et al.* 1983, USFWS 1985). Encroachment of hardwood midstory causes abandonment of cavity trees and clusters (Beckett 1971, Hopkins and Lynn 1971, Van Balen and Doerr 1978, Locke *et al.* 1983, Hovis and Labisky 1985, Conner and Rudolph 1989, Loeb *et al.* 1992). Cluster abandonment has been documented when hardwood and pine midstory basal area exceeds 5.7 m^2/ha (25 ft^2/ac; Conner and Rudolph 1989, Loeb *et al.* 1992). Negative effects of midstory growth above 3.7 m (12 ft) have also been shown (Hooper *et al.* 1980).

Thus, effective midstory control is an absolute prerequisite to management, conservation, and recovery of red-cockaded woodpeckers throughout their range. Such control is not an easy task. After seven decades of fire suppression, many clusters have developed an extensive hardwood component with an impressive underground root stock, particularly in the more mesic sites where loblolly and shortleaf pines are the dominant tree species (Conner and Rudolph 1989). Repeated prescribed burning during the late dormant or early growing season is an effective means to remove hardwoods and restore native groundcovers, and has the least detrimental impacts on soil structure and desired groundcovers (Provencher *et al.* 2001a, 2001b, see 3G). However, excessive quantities of hardwoods (or very large trees) may require removal by hand, mechanical means (Conner *et al.* 1995), one-time herbicide application (Conner 1989), or a combination of these methods prior to restoration burning. Chemical and/or mechanical techniques may be useful if rapid midstory reduction is required, for example if a cluster has been recently abandoned or supports only a solitary male because of excessive hardwoods. If chemical and/or mechanical techniques are used, it is important that regular prescribed burning follows these treatments. Maintenance of open habitat structure is best achieved through use of early to mid growing-season fire fueled by native grasses; late growing season fire can be detrimental to overstory pines (Sparks *et al.* 1998, 1999).

Reduction of hardwood midstory and thinning of overstory pines in clusters outside of the nesting season does not negatively affect red-cockaded woodpeckers (Conner and Rudolph 1991a), but mechanical removal of midstory should not be done when red-cockaded woodpeckers are nesting (Jackson 1990). If clusters have been abandoned due to unsuitable habitat conditions, they should be conserved and restored to suitable midstory conditions to increase the probability of reoccupation by woodpeckers (Doerr *et al.* 1989).

Red-cockaded woodpeckers can tolerate some hardwood overstory trees (basal area less than 2.3 m^2/ha; 10 ft^2/ac) within clusters (Hooper *et al.* 1980, Hovis and Labisky 1985, Conner and O'Halloran 1987). Small numbers of overstory hardwoods or large midstory hardwoods at low densities are consistent with historic landscapes in some habitats, and do not have the same negative effects on red-cockaded woodpeckers as the dense hardwood midstories resulting from fire suppression. Oak inclusions and upland hardwood species, such as post oak (*Quercus stellata*) and bluejack oak (*Q. incana*), occur naturally in association with the pine ecosystems of the south. Such species are integral components of the southern pine ecosystem and should not be cut in the name of red-cockaded woodpecker management.

Stream drainages, with associated shrub and midstory layers and hardwoods, are also integral parts of the southern pine ecosystems. However, woodpeckers may not be able to tolerate the complex vegetative structure of stream drainages near cavity trees. Therefore, management of cavity tree habitat for red-cockaded woodpeckers should be primarily focused in upland portions of the forest landscape. Stands developed and managed to recruit new woodpecker groups or replace cluster habitat should be located away from stream drainages whenever possible.

Density of pines in clusters varies according to habitat type, geography, and silvicultural history. The sparsest woods occupied by red-cockaded woodpeckers are the hydric slash pine woodlands of south Florida (Beever and Dryden 1992). Slightly more dense are the clusters in longleaf woodlands of south and central Florida; average basal area of clusters in these Florida longleaf woodlands currently ranges from 1.8 to 5.7 m^2/ha (8 to 25 ft^2/ac; DeLotelle *et al.* 1983, Shapiro 1983, Hovis and Labisky 1985, Bowman *et al.* 1997). For clusters in longleaf pine woodlands north of Florida, estimated average basal area ranges from 9.2 to 13.8 m^2/ha (40 to 60 ft^2/ac) of basal area (Crosby 1971, Hopkins and Lynn 1971, Thompson and Baker 1971). Clusters in natural loblolly and/or shortleaf pine forests average slightly higher densities (Thompson and Baker 1971, Hooper *et al.* 1980, Conner and O'Halloran 1987, Conner and Rudolph 1989).

Woodpecker cluster stands are typically less dense than surrounding stands (Crosby 1971, Thompson and Baker 1971, Grimes 1977, Locke *et al.* 1983, Shapiro 1983, Wood 1983, Hovis and Labisky 1985, Conner and O'Halloran 1987, Conner *et al.* 1991b, Loeb *et al.* 1992, Bowman *et al.* 1997) and they may be the least dense stands available. For example, Conner *et al.* (1991b) reported a preference for seed-tree and shelterwood cuts for cavity excavation in longleaf pine woodlands. For clusters, basal areas as low as 9.2 m^2/ha (40 ft^2/ac) in longleaf stands and from 9.2 to 13.8 m^2/ha (40 to 60 ft^2/ac) in shortleaf/loblolly stands are suitable (Conner *et al.* 1991b). However, seed-tree and shelterwood cuts with excessive pine or hardwood midstory are not acceptable as nesting habitat.

There are several reasons why red-cockaded woodpeckers might select stands with relatively low pine density as cluster sites. Pines in low-density stands grow larger in diameter, have greater crowns and root systems, and higher resin flow. Such pines are more resistant to wind damage and attacks by bark beetles, may be used as cavity trees at younger ages, and provide woodpeckers with greater protection against predation. In addition, sparse woods may have a greater proportion of area in grass and forb groundcovers than more dense forests, and these groundcovers in turn affect arthropod abundance (Collins 1998) and the ability of the stand to carry fire. Another reason for the preference for sparsely wooded stands, apart from the above benefits, may be that the low density of pine itself is a reflection of frequent fire.

Cavity Tree Mortality and Protection

Southern Pine Beetles

Infestation by southern pine beetles is the major cause of cavity tree mortality in loblolly and shortleaf pines (Conner *et al.* 1991a). Cavity trees are lost to southern pine beetles during epidemics, such as the death of 350 cavity trees including more than 50 entire clusters during the early 1980's in the Sam Houston National Forest (Conner *et al.* 1991a, 1997a). Cavity trees are also lost to southern pine beetles at endemic population levels, at a lower but steady rate (Conner *et al.* 1997a). Loss of cavity trees resulting from both epidemic and endemic southern pine beetles can substantially impact woodpeckers, particularly small populations in the loblolly and shortleaf pines of Texas, Arkansas, Louisiana, Mississippi, and elsewhere (Conner and Rudolph 1995b, Rudolph and Conner 1995).

Factors that increase risk to cavity trees and other important, mature pines in the cluster to southern pine beetle infestation include physical disturbance of soils and roots during thinning and midstory reduction, high density of pines within the cluster, and excessive hardwood midstory outside the cluster (Thatcher *et al.* 1980, Nebeker and Hodges 1985, Hicks *et al.* 1987, Conner *et al.* 1997a).

Fortunately, pines with artificial cavities, used to mitigate losses of cavity trees to southern pine beetles, are not infested at a rate significantly different from pines with naturally excavated cavities (Conner *et al.* 1998b). Risk of beetle infestation can be reduced by favoring pines with high resin producing ability, by pine thinning, and by minimizing disturbance during periods of high beetle activity (Mitchell *et al.* 1991). Loblolly and shortleaf pine stands should be maintained at basal areas less than 18.4 m^2/ha (80 ft^2/ac) or an average spacing of at least 7.6 m (25 ft) between pines in mature stands, to retard the spread of beetle infestations (Thatcher *et al.* 1980, Hicks *et al.* 1987, Nebeker and Hodges 1985, Mitchell *et al.* 1991). For southern pines, defense against bark beetle attack is positively related to the trees' ability to produce oleoresins (Lorio 1986). Because of differences in resin production, longleaf pines are much less susceptible to beetle attack than loblolly and shortleaf pines, and shortleaf pines are less susceptible than loblolly.

Other Causes of Mortality

Wind is the second greatest cause of cavity tree mortality in non-hurricane situations (Conner *et al.* 1991a). Cavity trees can be uprooted or snapped by high velocity winds. Patterns of harvest near clusters should be carefully planned to avoid funneling wind toward cavity trees (Conner *et al.* 1991a, Conner and Rudolph 1995c). A forest buffer of uncut trees greater than 61 m (200 ft) wide around cavity trees is adequate protection to minimize wind damage, wind snap, and wind throw during isolated severe summer thunderstorms (Conner and Rudolph 1995c).

Hurricane winds are a major threat to coastal woodpecker populations (Engstrom and Evans 1990, Hooper *et al.* 1990, Hooper and McAdie 1995, Lipscomb and Williams 1995). For example, when Hurricane Hugo struck the Francis Marion National Forests in South Carolina during September 1989, it destroyed 87 percent of the cavity trees, 67 percent of the woodpeckers, and 70 percent of the foraging habitat (Hooper *et al.* 1990, Hooper and McAdie 1995). Drilled and inserted artificial cavities (Copeyon 1990, Allen 1991, Taylor and Hooper 1991), having just been developed, enabled the rapid recovery of the Francis Marion population (Watson *et al.* 1995). Conservation of inland populations and many separate coastal populations will minimize the risk of extinction from hurricanes (USFWS 1985, Hooper and McAdie 1995). Hooper and McAdie (1995) also suggest that pines needed for future nesting habitat be grown in open conditions to promote the development of large crowns, extensive root systems, and strong boles. Another strategy to minimize impacts from hurricane winds is to avoid the creation of openings greater than 10.1 ha (25 ac) in or near forests managed for red-cockaded woodpeckers in hurricane-prone areas.

The third major cause of cavity tree mortality is fire. Managers must take appropriate measures to protect cavity trees from prescribed burns and wildfires so that loss is minimized. Foremost among these protective measures is regular burning within the cluster and around cavity trees, to keep fuel at acceptable levels. Other techniques are described in 8K.

Implications for Management

Cavities, cavity trees, and cavity tree clusters currently limit red-cockaded woodpecker populations, and thus their careful management is foremost in woodpecker conservation and recovery. Red-cockaded woodpeckers require large old trees as nesting and roosting sites, in habitat that is free of pine and hardwood midstory. Each cavity tree is an important resource that must be protected, and until potential cavity trees become more widely available, additional cavities and clusters must be judiciously provided through the use of artificial cavity technology. Hardwood encroachment causes abandonment of cavity tree clusters, with direct effects on population status. Encroaching hardwoods must therefore be controlled, preferably by frequent, early to mid growing season fire. These management actions—protection of existing cavity trees, provisioning of artificial cavities and clusters as appropriate, and hardwood control—form the basis of red-cockaded woodpecker management (see 8B, 8E, 8F, and 8K for more information). Loss of cavity trees and hardwood encroachment were primary factors in the decline of the species throughout its range (see 1A). Removal of these limiting factors is therefore fundamental to recovery.

E. FORAGING ECOLOGY

Our understanding of the foraging ecology of red-cockaded woodpeckers is increasing, although much work remains to be done. Natural geographic variation in forest ecology and woodpecker demography as well as the highly altered structure of today's forests make documenting habitat preferences and requirements a complex and challenging task. Despite these difficulties, a body of research has been developed describing foraging ecology and habitat relationships of red-cockaded woodpeckers. Here, we summarize research into diet, habitat selection, and habitat effects on fitness. In 8I, we present guidelines for providing foraging habitat that is suitable in quality and quantity based on current knowledge. Further research will help us to better understand foraging habitat requirements and may result in revisions of present guidelines.

Diet and Prey Abundance

Diet of Adults and Nestlings

Over 75 percent of the diet of red-cockaded woodpeckers consists of arthropods, especially ants and roaches, but also beetles, spiders, centipedes, true bugs, crickets, and moths (Beal *et al.* 1941, Baker 1971a, Harlow and Lennartz 1977, Hanula and Franzreb 1995, Hess and James 1998, Hanula and Engstrom 2000, Hanula *et al.* 2000b). Ants are particularly common in the diet of adults, comprising over half the stomach contents of adults and sub-adults in the Gulf coast region (Beal *et al.* 1941) and the Apalachicola National Forest in Florida (Hess and James 1998). Other arthropods comprised an estimated 34 percent and 17 percent, respectively, of the adult diet in these two studies (Beal *et al.* 1941, Hess and James 1998). *Crematogaster ashmeadii* was the most prominent of the ant species in the diet of red-cockaded woodpeckers in the Apalachicola, comprising 74 percent of the ant biomass taken (Hess and James 1998). Species composition of arthropod prey taken by adults elsewhere in the range has not yet been evaluated.

Fruits and seeds make up the small remaining portion of the adult diet. Red-cockaded woodpeckers have been known to eat the fruits or seeds of pines (*Pinus spp.*), poison ivy (*Rhus radicans*), magnolia (*Magnolia spp*.), myrtle (*Myrica spp*.), wild cherry (*Prunus serotina*), wild grape (*Vitus spp*.), blueberry (*Vaccinum spp*.), and blackgum (*Nyssa sylvatica*). Fruits and seeds comprised 14 percent by volume of the stomach contents of adults collected throughout the year in the Gulf Coastal Plain (Beal *et al.* 1941). Similarly, fruits and seeds made up 16 percent of the yearly diet of adults in Florida (Hess and James 1998). Plant material was rarely seen in the diets of woodpeckers in the Francis Marion National Forest of South Carolina (Hooper and Lennartz 1981).

The diet of nestlings also consists principally of arthropods, and fruits may be given on occasion (Baker 1971a, Harlow and Lennartz 1977, Hanula and Engstrom 2000, Hanula *et al.* 2000b). Large arthropod prey are commonly fed to nestlings in addition to or instead of ants (Hanula and Franzreb 1995, Hess and James 1998, Hanula and Engstrom 2000, Hanula *et al.* 2000b), and there is some evidence that breeding groups increase their reproductive success by feeding large prey (Schaefer 1996). In the Apalachicola National Forest, the diet of nestlings (as estimated by stomach contents) consisted mainly of roughly equal proportions of ants, beetles, spiders, and centipedes (Hess and James 1998). In several populations in Georgia and South Carolina, wood roaches were the most common item fed to nestlings, comprising from 26 to 62 percent of the nestling diet (as estimated from photographs of feeding visits; Hanula and Franzreb 1995, Hanula and Engstrom 2000, Hanula *et al.* 2000b).

Prey Selection, Location, and Abundance

Red-cockaded woodpeckers generally capture arthropods on and under the outer bark of live pines and in dead branches of live pines. Pines that have recently died are also a notable source of prey (Ligon 1968, Hooper and Lennartz 1981, Schaefer 1996, Bowman *et al.* 1997). Red-cockaded woodpeckers rarely excavate through the bark of live pines to capture prey, but do excavate into dead branches (Ligon 1968, Ramey 1980, Hooper and Lennartz 1981, Porter and Labisky 1986, Schaefer 1996).

Differences in foraging behavior between the sexes in red-cockaded woodpeckers are well documented (Ligon 1970, Hooper and Lennartz 1981, Engstrom and Sanders 1997, Hardesty *et al.* 1997). Males commonly forage in the crown of the tree, and are often on dead branches. Females commonly forage on the trunk, especially the lower trunk, and rarely forage on dead branches. This difference may serve to expose males and females, separately, to the areas of the tree with highest concentrations of arthropods (Hooper 1996, Hanula and Franzreb 1998). Recently, C. Rudolph (pers. comm.) suggested that foraging behaviors differ by social status as well as sex. Breeding males may spend more time in the inner crown of the tree, whereas helper males may forage more on the crown's outer branches (C. Rudolph, pers. comm.).

Several studies have assessed abundance and location of potential prey of red-cockaded woodpeckers (Hooper 1996, Hanula and Franzreb 1998, Hess and James 1998, Hanula *et al.* 2000a). Relative abundance of arthropods changes depending on the part of the tree sampled. On the boles of the tree, the most abundant arthropods were true bugs, spiders, and roaches (Hooper 1996). On live branches, roaches, spiders, beetles and ants were most common (Hooper 1996). Ants appear to be by far the most common arthropod on dead branches (Hooper 1996, Hanula and Franzreb 1998). A large proportion of the arthropods on pine trees have gotten there by crawling up from the ground, which points to the condition of the ground cover as an important factor influencing abundance of prey for red-cockaded woodpeckers (Hanula and Franzreb 1998).

Thus, several studies have documented a variety of arthropod species in the diet of red-cockaded woodpeckers, and others have described patterns of arthropod abundance and distribution. Whether birds are selecting prey species in greater proportion than their availability remains unknown. Assessing prey selection is extremely difficult, in large part because of extraordinary variability in the distributions of arthropods but also because each method of studying diet has its bias. In addition, diets of both adults and nestlings are highly variable: ants, for example, comprised from 0 to 94 percent of the stomach contents of nestlings and from 4 to 95 percent of the stomach contents of adults in Florida (Hess and James 1998). Nor is it clear whether plant material is a preferred or sub-optimal food. Plants may be selected to fill a nutritional need or exploited when prey is scarce.

Factors Affecting Prey Abundance

Arthropod abundance and biomass increases with the age and size of pines (Hooper 1996, Hanula *et al.* 2000a). Whether this relationship continues to increase with age, or levels off and declines at some threshold age, is an issue of some controversy at the present time (R. Conner, pers. comm.). Hanula *et al.* (2000a) found that arthropod abundance per tree increased linearly with stand age, and that biomass per tree increased until approximately age 60 after which it began to decline. This study showed a similar, positive relationship between arthropods and tree diameter, and negative relationships between density of pines and arthropod abundance and biomass per tree. It is not yet clear which factors—size, age, and/or density—are more important in determining arthropod abundance and distribution. Further research is required before the relationships among tree age, size, and density and prey abundance are fully understood.

Fire frequency also affects arthropod abundance and diversity. Large-scale, well-replicated research into longleaf pine ecosystem restoration in Florida documented increases in densities of herb-layer arthropods as a result of prescribed burning, and proposed their use as indicators of restoration success (Provencher *et al.* 2001a). In Texas, the abundance of arthropods on the boles of shortleaf and loblolly pines was higher in stands with grass and forb groundcover than in stands with substantial hardwood midstory (Collins 1998). Hanula *et al.* (2000a) documented positive relationships between tree age and the abundance of both herbaceous groundcovers and insects, although there were no direct relationships between measures of herb and insect abundance. Other studies have emphasized that the effects of fire on arthropods vary by species; that is, fire can have negative, neutral, or positive effects on various insects (New and Hanula 1998, J. Hanula, pers. comm.).

Most importantly, several recent studies have shown a positive relationship between fire frequency (as shown by groundcover) and fitness of red-cockaded woodpeckers (James *et al.* 1997, 2001, Hardesty *et al.* 1997). James *et al.* (2001) specifically documented an increase in fledging rate following the reintroduction of growing season fire, relative to control plots burned during the dormant season.

Frequent fire increases fitness of red-cockaded woodpeckers through more than one mechanism: first, by reducing hardwoods, and secondly, by increasing abundance and perhaps nutrient value of prey (James *et al.* 1997, Provencher *et al.* 1998, but see Hanula *et al.* 2000). The increase in insect abundance is at least partially independent of the reduction in hardwoods. James *et al.* (1997) revealed this independence by showing an effect of fire on fitness in a study area that had few hardwoods. Provencher *et al.* (1998) documented two to seven-fold increases in insect densities following growing season fire of hardwood-encroached longleaf stands. They then showed that reductions in hardwoods by herbicides and mechanical felling did not result in similar increases in insect densities until the stands were burned during the growing season (Provencher *et al.* 2001a). Thus, frequent growing season fire may be critically important in providing red-cockaded woodpeckers with abundant prey.

Selection of Foraging Habitat

Throughout their range, red-cockaded woodpeckers use open pine habitats for foraging. Considerable geographic variation in habitat types exists, illustrating the species' ability to adapt to a wide range of ecological conditions within the constraints of mature or old growth, open southern pine ecosystems. Red-cockaded woodpeckers use such natural habitat types as longleaf pine savannahs, flatwoods, sandhills, and clayhills; slash pine savannahs and flatwoods; pond and/or slash pine pocosins; shortleaf pine savannahs and forests, and shortleaf/loblolly pine savannahs and forests (Nesbitt *et al.* 1978, Ramey 1980, DeLotelle *et al.* 1983, Hooper and Harlow 1986, Porter and Labisky 1986, Bradshaw 1995, Epting *et al.* 1995, Bowman *et al.* 1997). Red-cockaded woodpeckers also use loblolly pine forests for foraging, although historically pure stands of loblolly were rare (White 1984). Longleaf pine ecosystems provide the optimal habitat for red-cockaded woodpeckers and were historically the most extensive habitat type (Conner *et al.* 2001).

Red-cockaded woodpeckers show a strong preference for living pines as foraging substrate (Hooper and Lennartz 1981, Porter and Labisky 1986, Jones 1994, Bowman *et al.* 1997). Pines used for foraging include longleaf, slash, loblolly, shortleaf, Virginia, and pond. Sand pine may be used rarely (Hardesty *et al.* 1997), and cypress is used on occasion, averaging an estimated 10 percent of foraging time in south-central Florida (Nesbitt *et al.* 1978, DeLotelle *et al.* 1983). Hardwoods are also used on occasion. Use of hardwoods typically accounts for 0 to 5 percent of foraging time (Hooper and Lennartz 1981, Repasky 1984, Porter and Labisky 1986, Bradshaw 1995, Hardesty *et al.* 1997). Reports of somewhat higher use include 7 percent of foraging time in Louisiana (Jones 1994) and 12 percent in Kentucky (Zenitsky 1999). Thus, hardwoods comprise a trivial or minor component of foraging substrate for red-cockaded woodpeckers throughout their range.

Dying and recently dead pines are an important foraging resource for red-cockaded woodpeckers (Ligon 1968, Hooper and Lennartz 1981, Schaefer 1996, Bowman *et al.* 1997). Pines infested with or recently killed and vacated by southern pine beetles may be an especially important, though unpredictable, food source in shortleaf and loblolly habitats (Schaefer 1996). Red-cockaded woodpeckers feed on southern pine beetles themselves, especially pupae in the bark. The birds also feed on adults and larvae of secondary attackers to beetle-infested trees, such as long-horned beetles

(*Cerambycidae*) and metallic wood-boring beetles (*Buprestidae*). However, southern pine beetle epidemics can cause dramatic losses of critical nesting habitat. If beetle populations are large and pines near cavity trees (or cavity trees themselves) are infested, some pines are generally removed in the attempt to control growing beetle infestations and prevent loss of nesting and foraging habitat.

Selection of Tree Species

Whether red-cockaded woodpeckers prefer to forage on a particular species of pine has not been clearly demonstrated, and it may be that no such preference exists. Previous research has yielded conflicting results, all of which could be confounded by other factors such as tree age and size, density of surrounding trees, and presence of hardwood midstory. Longleaf pine stands were selected over slash pine stands in northern Florida (Porter and Labisky 1986), but elsewhere in Florida slash pines were selected over longleaf (Nesbitt *et al.* 1978). Bowman *et al.* (1997) suggested that slash pine in south central Florida may provide important foraging in addition to longleaf. In the North Carolina Sandhills, woodpeckers did not select trees based on tree species, but over 90 percent of available pines were longleaf (Walters *et al.* 2000, 2002a). Woodpeckers in coastal North Carolina did not select among longleaf, loblolly, and pond pines, even though the proportion of loblolly and pond pines together averaged over 20 percent of available pines (Zwicker and Walters 1999). Finally, it may be that in habitats that were traditionally longleaf, dominance of longleaf was sufficient to retard the evolution of selection among pine species by red-cockaded woodpeckers. Future research in habitat containing mixed pine species both historically and currently would help document the presence or absence of this behavior.

Selection of Older and Larger Trees

All studies examining selection of individual trees by foraging red-cockaded woodpeckers have found that the birds select large, old trees over small, young trees (Hooper and Lennartz 1981, Porter and Labisky 1986, DeLotelle *et al.* 1987, Bradshaw 1995, Jones and Hunt 1996, Engstrom and Sanders 1997, Hardesty *et al.* 1997, Zwicker and Walters 1999, Walters *et al*. 2000, 2002a). Reports vary as to the specific sizes at which trees are avoided and preferred. Also, some researchers suggest that all trees over a specific size (generally, 25.4 cm [10 in] dbh) are equal in foraging value (Hooper and Harlow 1986), whereas others suggest that foraging value of trees increases continually with increasing size and age of trees (Engstrom and Sanders 1997, Hardesty *et al.* 1997, Doster and James 1998, Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Such disagreements are likely due to differences in study methods and to differences in available habitat, because what the birds select or avoid must always be a subset of what is available. Available habitat changes because of natural geographic variation but also because of variation in the extent of forest alteration (e.g., fire suppression and tree cutting). Despite the disagreements, it is clear that tree age and size strongly influence selection of pines for foraging. Results of previous studies are summarized below.

Reported sizes below which trees are avoided (that is, used less than their availability) varies from 12.7 cm (5 in) dbh in coastal South Carolina (Hooper and Lennartz 1981) to 20.3 and 25.4 cm (8 and 10 in) dbh in northwest Florida (Porter and Labisky 1986, Hardesty *et al.* 1997) and Louisiana (Jones and Hunt 1996), and 25.4 cm (10 in) dbh in the North Carolina Coastal Plain and Sandhills (Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Reported sizes above which trees are selected (used more than their availability) include 20.3 and 25.4 cm (8 and 10 in) dbh in northwestern Florida (Porter and Labisky 1986, Hardesty *et al.* 1997), 25.4 cm (10 in) dbh in coastal South and North Carolina (Hooper and Lennartz 1981, Zwicker and Walters 1999), 30.5 cm (12 in) dbh in southwestern Georgia (Engstrom and Sanders 1997), the North Carolina Sandhills (Walters *et al.* 2000, 2002a), coastal Virginia (Bradshaw 1995), and Arkansas (Doster and James 1998), and 40 cm (15.7 in) in Louisiana (Jones and Hunt 1996). Again, these differences are due in part to differences in available habitat, because what the birds select or avoid depends on what is there.

Fewer studies have assessed specific ages at which individual pines are avoided or selected, although several more have assessed effects of average stand age (see below). Age and size of trees are highly correlated, at least until age 80 or greater (Platt *et al.* 1988b, Walters *et al.* 2000), and at present it is not known whether tree age, size, or both age and size is most important to foraging woodpeckers. In the Coastal Plain and Sandhills of North Carolina, trees under 60 years in age were avoided whereas those over 60 years (Coastal Plain) and 70 years (Sandhills) were selected (Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). In northwestern Florida, trees less than 50 years in age were avoided, trees 50 to 150 years in age were used in proportion to their availability, and trees 150 years in age and older were preferred (Hardesty *et al.* 1997).

A preference by woodpeckers for the oldest and largest trees available has been shown in several studies (Hardesty *et al.* 1997, Engstrom and Sanders 1997, Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Bradshaw (1995) also reported a preference for the largest trees, although he combined all trees over 30.5 cm (12 in) dbh into one category. Such preference for the oldest and largest trees available suggests that tree selection by red-cockaded woodpeckers may be operating in either of two ways: (1) woodpeckers always select the oldest and largest trees in any habitat, or (2) an optimal size and age exists above which selection becomes equal, but this optimum remains unseen because currently these trees are not generally available in meaningful amounts (Zwicker and Walters 1999). In contrast, other studies report that selection tapers off above middle-aged, medium-sized trees—suggesting that middle-aged trees are of equal importance to the oldest and largest trees (Hooper and Lennartz 1981, Hooper and Harlow 1986). Again, such disagreements are likely due to differences in study methods and available habitat. As public forests regain an old growth component and research methods are standardized, biologists will likely reach a consensus on what ages and sizes of trees are preferred by foraging red-cockaded woodpeckers.

Patch Selection

Habitat selection at a scale larger than individual trees, but smaller than stands, is referred to here as patch selection. Patch selection by red-cockaded woodpeckers has been explored in three studies. Bowman *et al.* (1997) found that woodpeckers foraged in patches containing fewer but larger trees than patches chosen randomly. Walters *et al.* (2000, 2002a) found that woodpeckers used patches containing larger trees and lower hardwood midstory than unused patches. Doster and James (1998) found that red-cockaded woodpeckers prefer to forage in patches containing larger pines, a lower overstory pine density, and less hardwood midstory than randomly chosen patches nearby.

Stand Selection

Use of stands by red-cockaded woodpeckers is influenced by the size of the stand, stand age, density of pines, density of large pines, fire history (hardwood midstory), season, and proximity to cavity trees and territorial boundaries (Hooper and Harlow 1986, Porter and Labisky 1986, DeLotelle *et al.* 1987, Epting *et al.* 1995, Bradshaw 1995, Walters *et al.* 2000, 2002a). Two studies documented a positive relationship between stand use and stand age after controlling for effects of cavity trees and territorial boundaries (DeLotelle *et al.* 1987, Epting *et al.* 1995). Porter and Labisky (1986) reported that preferred stands were much older than avoided stands (mean stand age = 72 and 18 years, respectively). Similarly, Jones (1994) reported that stands of trees less than 50 years old were avoided, and stand use increased continually with increasing stand age (Jones 1994, Jones and Hunt 1996). Hooper and Harlow (1986) also reported a positive effect of stand age on use but considered it to be weak.

Stand use and density of all pines may be positively related if densities are generally low (DeLotelle *et al.* 1987) and unrelated or negatively related if densities are high (Hooper and Harlow 1986, Bradshaw 1995). Effects of pine density on stand use also changes depending on the size of trees in question: increasing density of large trees is beneficial (Hooper and Harlow 1986, Bradshaw 1995, Walters *et al.* 2000, 2002a), whereas high densities of small pines are detrimental (Porter and Labisky 1986, Walters *et al.* 2000, 2002a). For example, stand use increased with increasing density of pines greater than or equal to 30.5 cm (12 in) dbh in Virginia (Bradshaw 1995), 35.6 cm (14 in) dbh in central North Carolina (Walters *et al.* 2000, 2002a), and 22.9, 35.6, and 48.3 cm (9, 14, and 19 in) dbh in coastal South Carolina (Hooper and Harlow 1986, although they considered these effects to be weak and, for the largest size class, due mainly to the presence of cavity trees.) Stand use decreased with increasing densities of pines less than 25.4 cm (10 in) dbh in central North Carolina (Walters *et al.* 2000, 2002a); similarly, dense stands of young trees (average 559 stems/ac and 18 yrs in age) were avoided in northwest Florida (Porter and Labisky 1986).

Hardwoods appear to have a negative influence on stand use. Stand use decreased with increasing density of hardwoods in several studies (Hooper and Harlow 1986, Epting *et al.* 1995, Bradshaw 1995, Jones and Hunt 1996), and stand use was negatively influenced by the average height of midstory hardwoods in North Carolina (Walters *et al.* 2000, 2002a). Jones and Hunt (1996) found that stands in which greater than 10 percent of canopy trees were hardwoods were avoided.

Finally, during the non-breeding season red-cockaded woodpeckers may travel long distances to access open stands of large pines, whereas during the breeding season birds may use stands containing smaller pines or a greater hardwood component if they are near nest cavities (Bradshaw 1995, Jones and Hunt 1996).

Home Range and Habitat Quality

Size of home ranges of red-cockaded woodpeckers have been described over much of the species' range and in several habitat types (Hooper *et al.* 1982, Wood 1983, Nesbitt *et al.* 1983, Repasky 1984, Porter and Labisky 1986, DeLotelle *et al.* 1987, Epting *et al.* 1995, Bradshaw 1995, Engstrom and Sanders 1997, Bowman *et al.* 1997, Hardesty *et al.* 1997, Doster and James 1998, Walters *et al.* 2000, 2002a). In studies with sample sizes of over 10 groups, average year-round home range size was estimated to be 83.0 ha (205 ac) in south-central North Carolina (Walters *et al.* 2000, 2002a), 87.0 ha (215 ac) in coastal South Carolina (Hooper *et al.* 1982), roughly 80.1 ha (198 ac) in coastal Georgia (Epting *et al.* 1995), 129.0 ha (319 ac) in central Florida (DeLotelle *et al.* 1995), and 108.9 ha (269 ac) in northwestern Florida (Hardesty *et al.* 1997). In addition, notable studies among those estimating home range based on fewer than 10 groups include one study in the northern edge of the species' current range (Bradshaw 1995), one in the southern edge of the species current and historic range (Nesbitt *et al.* 1983), and one in extremely rare old growth longleaf forest in southwest Georgia (Engstrom and Sanders 1997). Bradshaw (1995) reported that average year-round home range size for 6 groups in coastal Virginia was 120.2 ha (297 ac); Nesbitt *et al.* (1983) estimated that summer range for 5 groups in south Florida was 144.5 ha (357 ac); and Engstrom and Sanders (1997) reported that home range size for 7 groups in old growth forest in southwest Georgia was 46.9 ha (116 ac), the smallest average size yet reported (based on all-day follows). Also, Doster and James (1998) reported an average home range of only 24.7 ha (61 ac) for 5 groups of woodpeckers in shortleaf pine habitat of Arkansas, but this estimate was not based on all-day follows because rough terrain inhibited data collection.

Thus, home ranges in Florida tend to be larger than those farther north (DeLotelle *et al.* 1987, Hardesty *et al.* 1997), and those in fire-maintained old growth forest are substantially smaller than those in second-growth (Engstrom and Sanders 1997). Larger samples would be helpful in confirming these effects, but are not available for specific cases (e.g., Virginia Coastal Plain, old growth forest). Together these results suggest that the natural size and density of pines as well as degree of forest alteration (such as history of harvests and fire suppression) impact home range size. The size of a home range or territory may also increase if it is not constrained by the presence of neighboring groups (DeLotelle *et al.* 1987).

Several studies have related variation in home range (or territory) size within a population to habitat characteristics of the home range (Hooper *et al.* 1982, Bowman *et al.* 1997, Hardesty *et al.* 1997, Walters *et al.* 2000, 2002a). Hooper *et al.* (1982) reported that for 24 groups in coastal South Carolina, territory size generally increased with increasing pine density and basal area. In contrast, Hardesty *et al.* (1997) reported that for 25 groups in northwest Florida, home range size decreased with increasing pine density and basal area. Walters *et al.* (2000, 2002a) found home range size of 30 groups in south-central North Carolina was independent of pine density and basal area, but increased with increasing invasion by hardwoods. Thus, home range size depends on the quality of available foraging habitat: less habitat is needed if the quality of that habitat is high. Increasing pine density may be beneficial if pine density is low, or detrimental if density is high. This inverse relationship between quality and quantity of foraging habitat provides important evidence that foraging habitat can limit red-cockaded woodpecker populations, and underscores the critical need to restore quality of foraging habitat (F. C. James, pers. comm.).

In summary, studies of home range size suggest that red-cockaded woodpeckers require from 40.5 to 161.9 ha (100 to 400 ac) per group, depending upon the quality of foraging habitat, and that high quality foraging habitat has an open structure with an intermediate pine density and sparse or absent hardwood midstory. These characteristics of high-quality foraging habitat are consistent with those suggested by analyses of patch and stand selection (above) and group fitness (below). Moreover, this evidence points to the limitation of woodpecker populations by the quality of their foraging habitat, and illustrates the need for broad-scale habitat restoration.

Group Fitness and Habitat Quality

Understanding the relationships between group fitness (e.g., reproductive success, group size, adult survival) and quantity and quality of foraging habitat is key to formulating appropriate foraging guidelines for red-cockaded woodpeckers. However, current habitats are quite altered from original conditions, and this altered state diminishes our ability to see effects of habitat on group fitness and to determine an optimal amount of foraging habitat. Also, at least two other factors are important to group fitness: presence of helpers (Lennartz *et al.* 1987, Walters 1990, Neal *et al.* 1993a, Beyer *et al.* 1996) and increasing age and experience of breeders (Lennartz *et al.* 1987, Walters 1990, DeLotelle and Epting 1992) are known to increase reproduction. Finally, habitat effects are hard to identify because sample sizes are low, in number of groups studied and/or number of years with which group fitness is estimated. Substantial variation in reproduction can be attributed to stochastic environmental events (e.g., Neal *et al.* 1993a), which can mask other effects in small samples. Despite constraints of available habitat, confounding effects of other factors, and low power due to small samples, important progress has been made in determining effects of habitat quality on fitness.

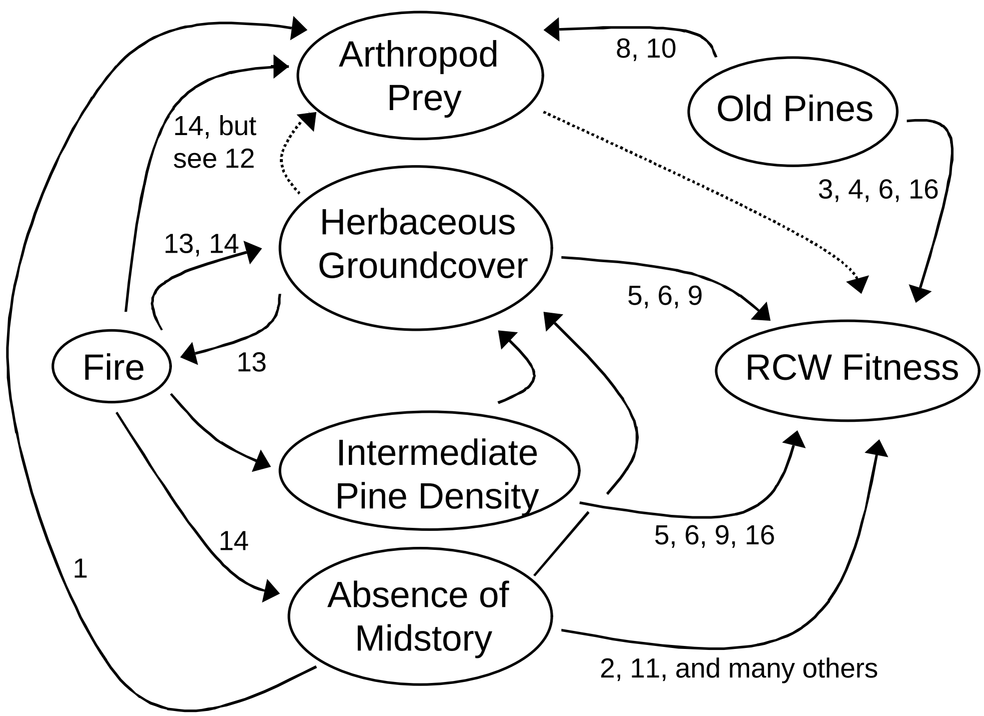
Several aspects of foraging habitat may affect group fitness. First, territory or home range size has been shown to affect group size and/or reproduction in some populations (DeLotelle and Epting 1992, Hardesty *et al.* 1997, USFWS 1985) but not in others (James *et al.* 1997, Walters *et al.* 2000, 2002a). For two studies reporting an influence of home range/territory size on fledgling production, much of the effect appears to have come from whole brood loss or failure to nest (DeLotelle and Epting 1992, Hardesty *et al.* 1997). This suggests that there is a threshold home range size below which reproduction becomes difficult, and it is possible that studies not showing this effect did not sample below the threshold. Home range size for successfully and unsuccessfully nesting groups in northwest Florida averaged 126.3 and 72.4 ha (312 and 179 ac) respectively (Hardesty *et al.* 1997); a threshold home range size for this population under current habitat conditions would fall between these two estimates.

Effects of home range size on fitness vary, of course, with the quality of foraging resources. This point is best illustrated by the large, healthy groups on home ranges averaging only 46.9 ha (116 ac) in the fire-maintained, old growth longleaf forest of the Wade Tract, GA (including considerable overlap among home ranges, Engstrom and Sanders 1997). These groups have the smallest average home range and the highest average group size and reproduction yet reported (average group size 3.0 to 3.6; average fledglings from successful nests 2.3 to 2.5; Engstrom and Sanders 1997). In addition, effects of foraging habitat on group fitness may interact with the general health of the population. For example, Conner and Rudolph (1991b) reported that loss of foraging habitat affected group size in small isolated populations but not in larger populations.

Recent research has revealed that fire history of the foraging habitat affects group fitness in several different ways (Figure 1). Group size and/or reproduction is negatively affected by dense stands of pines (Hardesty *et al.* 1997, James *et al.* 1997, 2001, Walters *et al.* 2000, 2002a), positively related to percent of ground covered by wiregrass (*Aristida spp.*) or forbs (Hardesty *et al.* 1997, James *et al.* 1997), and negatively related to increasing hardwood midstory (Walters *et al.* 2000, 2002a). At Eglin Air Force Base in Florida, reproduction was negatively affected by pine density above 16.1 m^2 of basal area per ha (70 ft^2/ac). Similarly, group size in the North Carolina Sandhills was negatively affected by density of pines less than 35 cm dbh (14 in; Walters *et al.* 2000, 2002a). Frequent fire increases the quality of foraging habitat in several ways: it provides an open structure by reducing density of overstory and midstory pines and hardwoods, it encourages grass and forb groundcovers, and it may also increase nutrient cycling through the ecosystem and the nutrient content of prey (James *et al.* 1997; Figure 1).

Finally, group fitness increases with increasing numbers of old trees in the foraging habitat (Figure 1). In Louisiana, density of groups, group fitness, and the number of old growth trees (90 to 120 years in age) were all strongly positively related (Conner *et al.* 1999). In Texas, group size increased with increasing area of pines greater or equal to 60 years in age both within 400 meters of the cluster (Conner and Rudolph 1991b) and at a larger, regional scale (520 to 5200 ha, Rudolph and Conner 1994). Similarly, in central North Carolina group size increased with increasing density of flat-tops (very old pines) in home ranges (Walters *et al.* 2000, 2002a). Effects of habitat quality on group size are of utmost importance, because of stabilizing effects of helpers on population dynamics, the increase in reproduction in larger groups, and decrease in groups consisting of solitary males.

FIGURE 1. Relationships among fire, habitat components, arthropods, and fitness of red-cockaded woodpeckers (RCW) as illustrated by a summary of research. Solid lines indicate a positive effect (direct or indirect) that has been documented in at least one study; dotted lines indicate potential effects not yet documented. Numbers refer to the citations listed below.



1. Collins 1998
2. Conner and Rudolph 1989
3. Conner and Rudolph 1991b
4. Conner *et al.* 1999
5. James *et al.* 1997
6. James *et al.* 2001
7. Hanula and Franzreb 1998
8. Hanula *et al.* 2000
9. Hardesty *et al.* 1997
10. Hooper 1996
11. Loeb *et al.* 1992
12. New and Hanula 1998
13. Platt *et al.* 1988
14. Provencher *et al.* 1998, 1999, 2001
15. Rudolph and Conner 1994
16. Walters *et al.* 2000, 2002a

Other studies have not found a relationship between group fitness and the amount and quality of foraging habitat as measured by traditional variables such as the number and basal area of pines greater than 25 cm (10 in) dbh (Hooper and Lennartz 1995, Beyer *et al.* 1996, Ferral 1998, Wigley *et al.* 1999).

At the present time, we recognize that fitness of woodpecker groups increases if they have substantial amounts of foraging areas that are burned regularly and have little or no hardwood midstory, an abundant grass and forb groundcover, low densities of small and medium-sized pines and higher densities of large old pines. Again, these results are consistent with those from studies of tree selection, patch selection, stand selection, and home range/habitat quality relationships (see above).

Geographic Variation in Foraging Habitat

There is substantial geographic variation in habitat occupied by red-cockaded woodpeckers. Historically, longleaf pine ecosystems were the most common habitat type and still support most of the largest remaining populations (Carter 1971, Hooper *et al.* 1982, James 1995, Engstrom *et al.* 1996). Within these longleaf pine habitats there is variation in structure and species composition according to soil type and moisture. Red-cockaded woodpeckers also exist in other habitat types including shortleaf pine communities of Arkansas and Oklahoma (Wood 1983, Masters *et al.* 1989, Kelly *et al.* 1993, Hines and Kalisz 1995, Zenitsky 1999), transitional zones of the Piedmont (Steirly 1957), pond pine communities of eastern North Carolina (J. Carter III, pers. comm.), native hydric slash pine system of south Florida (Beever and Dryden 1992), and loblolly forests in many areas (e.g., Hooper and Harlow 1986). Despite natural geographic variation in habitats, the basic ecology of red-cockaded woodpeckers remains unchanged throughout their range: red-cockaded woodpeckers select old pines in open stands for nesting and foraging, and the open structure that characterizes nesting and foraging habitat is best maintained by frequent, growing season fire.

Longleaf Pine Communities

Species composition and structure of longleaf pine communities vary according to interacting moisture, soil, and fire factors. Frequently burned sites with deep sandy soils support what are variously known as sandhill, high pine, or xeric sand communities. These xeric sand communities are found throughout the southeast, on alluvial sands, recently exposed terraces, and relict dunes of the entire Coastal Plain as well as along the fall line that marks the transition between Coastal Plain and Piedmont in the Carolinas and Georgia. Two distinct longleaf ecosystems occur on these deep sandy soils: xeric and subxeric longleaf pine woodlands (Peet and Allard 1993, Christensen 2000). Xeric longleaf pine woodlands are characterized by widely scattered longleaf pines, a sparse midstory of turkey (*Quercus laevis*) and bluejack oaks, and sparse groundcovers dominated by wiregrasses (*Aristida stricta* north of the Congaree/Cooper rivers in South Carolina and *A. beyrichiana* to the south, Peet 1993). Within this xeric woodland type, five series have been identified (Peet and Allard 1993): fall line, Atlantic, and southern (Gulf) xeric longleaf woodlands, and Atlantic and Gulf maritime longleaf woodlands. Subxeric longleaf pine woodlands contain the above species as well as many more that are adapted to somewhat moister conditions (Christensen 2000). This ecosystem type dominated much of the Coastal Plain uplands prior to European settlement (Ware *et al.* 1993, Christensen 2000). Peet and Allard (1993) identified three series within the subxeric ecosystem type: fall line, Atlantic, and Gulf subxeric longleaf pine woodlands.

Mesic longleaf pine communities include flatwoods and savannahs, which differ from each other mainly in structure. Savannahs are characterized by an open canopy and grass groundcover, whereas flatwoods have a somewhat denser canopy and a midstory of shrubs and subcanopy trees (Christensen 2000). The primary cause of variation between flatwoods and savannahs is interacting effects of fire and soil moisture (Peet and Allard 1993). There is no generally accepted classification of these mesic longleaf pine communities (Christensen 2000). Southern flatwoods include saw palmetto (*Serenoa repens*), gallberry-fetterbush (*Ilex glabra-Lyonia lucida*), and fern phases. If burned more frequently, these flatwoods may become more like savannahs (Christensen 2000). Longleaf pine savannahs in the Atlantic and Gulf regions contain many endemic species (Peet and Allard 1993, Walker 1993, Christensen 2000), and species diversity for these community types is among the highest in North America (Walker and Peet 1983).

All of these longleaf community types can support red-cockaded woodpeckers if sufficient old growth and mature pines are available for cavity trees. However, researchers have suggested that in some locations, such as sites of low productivity, extremely dry or wet locations, red-cockaded woodpeckers may need more foraging habitat than those in mesic habitats (Hardesty *et al.* 1997, DeLotelle *et al.* 1987, 1995). These researchers have observed very large home ranges in some locations, possibly because arthropods are limited by sparse groundcovers or low pine density. Expansion of home range size in these habitat types may be a response to low site productivity or a result of past alteration of the forest through overharvest or fire suppression. Low site productivity can also affect how an ecosystem recovers following alteration (Provencher *et al.* 1997, 1998, 2001). Whether the effect is natural or human-induced, some populations of red-cockaded woodpeckers in wet or very dry sites are using more foraging habitat. Further research is required before we fully understand how differences in longleaf pine community types influence the foraging ecology of red-cockaded woodpeckers.

Shortleaf Pine Communities

Shortleaf pine communities supporting red-cockaded woodpeckers are found in the Ouachita Mountains of Arkansas and Oklahoma (McCurtain County Wilderness Area and Ouachita National Forest) and in eastern Texas (parts of Sam Houston National Forest, Davy Crockett National Forest, and the W. G. Jones and I. D. Fairchild State Forests). The western edge of the Cumberland Plateau in Kentucky (Daniel Boone National Forest) supported red-cockaded woodpeckers in shortleaf pine habitats until severely impacted by southern pine beetles in the summer of 2000. Shortleaf pine communities are fire maintained, with a two-layered structure of pine overstory and diverse bunchgrass groundcover much like those of longleaf communities. Loblolly and other pines may be present as secondary components. Unlike most longleaf pine woodlands, many shortleaf pine communities supporting red-cockaded woodpeckers are in regions of complex topography (Masters *et al.* 1989, 1995, Kalisz and Boettcher 1991, Hines and Kalisz 1995, Zenitsky 1999). These rugged areas have steep and narrow ridges, and communities dominated by shortleaf pine are confined to slopes of southern and western exposure and to the ridgetops (Masters *et al.* 1989, Foti and Glenn 1991, Kalisz and Boettcher 1991). Mesic sites such as drainages and north-facing slopes are typically dominated by white oak (*Quercus alba*) and some maples (*Acer* spp.; Masters *et al.* 1989, Foti and Glenn 1991).

Historic shortleaf pine/bunchgrass communities have sustained massive intrusion by hardwoods as a result of fire suppression and exclusion, and this intrusion has caused precipitous declines of red-cockaded woodpeckers in these regions (Masters *et al.* 1989, 1995). Return intervals of fire prior to European settlement have been estimated as 3 to 6 years for shortleaf pine ecosystems in rugged terrain (Masters *et al.* 1995). Reintroduction of fire, using a prescribed burning program patterned after the precolonial fire regime, is vital to the survival and recovery of red-cockaded woodpeckers in these regions (Masters *et al.* 1989, 1995).

Several studies indicate that foraging behavior of red-cockaded woodpeckers in shortleaf habitat is similar to that of woodpeckers on the coastal plain. Woodpeckers foraging on shortleaf pines select large old trees in patches that have less hardwood midstory than the surrounding forest (Murphy 1982, Doster and James 1998, Zenitsky 1999). One study of the once critically endangered and now extirpated population in Kentucky reported a preference for hardwoods as foraging substrate, for 2 of 5 groups during the 1991 nesting season only (Hines and Kalisz 1995). However, further research in this population showed no such effect (Zenitsky 1999). Again, the severe decline of red-cockaded woodpeckers in Kentucky (prior to 1997) and other shortleaf habitats was directly related to hardwood encroachment (Masters *et al.* 1989, 1995), and their foraging behavior did not appear to differ from red-cockaded woodpeckers elsewhere in the range (Murphy 1982, Doster and James 1998, Zenitsky 1999).

Red-cockaded woodpeckers can tolerate some overstory hardwoods in foraging habitat, and even in clusters if more than 15.2 m (50 ft) from cavity trees. Inclusions of xeric hardwood species such as post, blackjack (*Quercus marilandica*), and other oaks (*Quercus* spp.), especially in shortleaf forests, are natural components of the ecosystem and do not need to be totally removed for woodpecker management. However, such hardwoods must remain a minor component overall. In the shortleaf forests of Oklahoma, precolonial density of hardwoods was an estimated 4.6 to 5.7 m^2 basal area per ha (20 to 25 ft^2/ac; Masters *et al.* 1995). Such densities should be considered maximum for red-cockaded woodpecker management. Estimated pine basal area of precolonial Oklahoma is similar to that of longleaf forests, at 8.0 m^2/ha (35 ft^2/ac; Masters *et al.* 1995).

Loblolly Pine Habitats

Because of fire sensitivity, loblolly pine historically was much less widespread than today (White 1984, Landers 1991, Christensen 2000). Prior to fire suppression, loblolly pine was a minor component of riparian and other mesic forests in the coastal plain and a secondary component of mixed pine and pine hardwood forests in interior uplands. Forests dominated by loblolly were rare and restricted to a portion of southern Arkansas and perhaps eastern Virginia/northeastern North Carolina (White 1984, Christensen 2000). Currently, because of fire suppression during the past century and silvicultural practices favoring the species (White 1984), loblolly pine is the dominant pine throughout the southeast, in areas that were historically covered by longleaf pine, shortleaf pine, and shortleaf/loblolly pine forests (White 1984). These off-site loblolly pine forests have provided and continue to provide important resources for red-cockaded woodpeckers. However, ample opportunities exist for the careful restoration of site-appropriate pines in areas currently dominated by off-site loblolly. Foraging ecology of red-cockaded woodpeckers in off-site loblolly is consistent with that of red-cockaded woodpeckers in predominantly longleaf forests: red-cockaded woodpeckers foraging on loblolly select older pines in open stands (e.g., Hooper and Harlow 1986, Zwicker and Walters 1999). The rare forests dominated by natural, historically occurring loblolly pine warrant special consideration and conservation. Foraging ecology of red-cockaded woodpeckers within this habitat type has not been addressed.

Pond Pine Communities

The remaining pond pine communities that support red-cockaded woodpeckers are found primarily in northeastern North Carolina (J. H. Carter III, pers. comm.). Pond pines were likely sparsely distributed in the upland shrub bogs known as pocosins, but fire suppression has led to increased pine density and hardwood encroachment. Foraging requirements of red-cockaded woodpeckers in this habitat type have not been studied at all. Management of woodpeckers in pond pines is complicated by the catastrophic nature of the natural fire regime, dangerous accumulation of fuels during years of fire suppression, southern pine beetle outbreaks, and high rates of cavity enlargement by pileated woodpeckers (J. H. Carter III, pers. comm.). Reintroduction of fire is required for continued survival and recovery of woodpeckers in these habitats, but further research is necessary to determine best methods of prescribed burning and foraging habitat requirements.

South Florida Slash Pine Communities

Native slash pine communities support red-cockaded woodpeckers in south Florida (Beever and Dryden 1992). This subspecies of slash pine (*Pinus elliottii* var. *densa*) is the only native pine in this region and is similar to longleaf in both appearance and fire resistance. Native slash pine has a grass stage and large taproot as does longleaf pine (Landers 1991). Much of the native slash used by red-cockaded woodpeckers is in hydric communities (Beever and Dryden 1992). It may be that slash pine replaces longleaf pine in this region because it can better tolerate very wet conditions.

For red-cockaded woodpeckers, native slash pine habitats differ from those farther north in that the pines are generally smaller and may be more sparsely distributed (Patterson and Robertson 1981, Beever and Dryden 1992, Landers and Boyer 1999). The largest size that south Florida slash pines achieve, even in old growth woodlands, is typically 20 to 30 cm (8 to 12 in). Cavity trees in this habitat type are much smaller than normally found in other habitats (Beever and Dryden 1992, Bowman and Huh 1995). However, the presence of fire and old trees in both nesting and foraging areas are critically important here as elsewhere.

Woodpeckers in native slash pine have not been well studied. Preliminary research has indicated that home ranges of birds in native slash pine are larger than those in other habitats (Patterson and Robertson 1981, Beever and Dryden 1992), but the relationship between habitat requirements and habitat quality has not been investigated in this forest type. Thus, it is not known whether larger home ranges in south Florida result from degraded habitat, natural differences in habitat quality, population density, or even lack of cavity trees. Although further research is necessary to determine the cause of large home ranges in south Florida, results from studies elsewhere suggest that as habitat quality increases, the size of these home ranges will decrease. It is likely that, as pine density, age, and herbaceous groundcovers of south Florida slash pine woodlands increase, resident woodpeckers will still require more foraging habitat than woodpeckers in most other regions but less than they appear to be using at the present time.

Slash pine (*Pinus elliottii* var. *elliottii*) was historically a minor component of coastal pine forests. It is a mesic pine that was generally found in damp swales, narrow drainages, and along pond margins within longleaf pine forests (Landers 1991, Christensen 2000). Slash pine is now much more widespread than historically, as a result of fire suppression and aggressive planting programs. Off-site slash pine forests support small numbers of red-cockaded woodpeckers in some areas. Restoration of these sites to site-appropriate pines would be beneficial; however, caution must be used to avoid unnecessary impacts to red-cockaded woodpeckers (Ferral 1998, see 3G).

Previous Management Guidelines

Previous guidelines for management of foraging habitat (USFWS 1985, Henry 1989) emphasized the number of pines greater than 25.4 cm (10 in) dbh that should be provided each group of woodpeckers, in stands meeting some broad criteria (e.g., overstory hardwoods 50 percent or less of canopy tree basal area, pines 30 years in age or greater). These guidelines were important and useful in several ways: the guidelines provided much-needed protection against overharvest of pines; they stressed that red-cockaded woodpeckers require a large quantity of land and they furnished this large quantity of land fairly successfully; and they represented the best estimate of foraging requirements available from research at that time. However, these guidelines were also flawed in some ways: the actual number of pines recommended was based on one population and a small sample (n=18); the guidelines may have encouraged high densities of small and medium sized pines now known to be detrimental; and most importantly, researchers have been unable to detect any relationship between the total number or total basal area of pines greater or equal to 25.4 cm (10 in) dbh within a group's foraging area and measures of fitness such as group size or reproduction (e.g., Hooper and Lennartz 1995, Beyer *et al.* 1996, Wigley *et al.* 1999). This continued failure to find any relationship between fitness and total number of small and medium sized pines strongly suggests that these variables are not the best way to measure quality or quantity of foraging habitat.

This last point – the lack of relationship between number of pines greater than 25.4 cm (10 in) dbh and group size and/or reproduction—is shown clearly in an analysis recently performed by R. Hooper (unpublished), combining data from nine data sets for a total of 198 groups with mean group size greater or equal to 2 adults. In only two of the data sets did mean number of pine stems greater or equal to 25.4 cm (10 in) dbh approach the standard of 6350 pines set by the 1985 Recovery Plan (USFWS 1985), and one of those data sets determined the original standard. With one exception (Hooper and Lennartz (1995) lacked habitat data for individual groups), these data were pooled for regression analyses of number of pine stems greater or equal to 25.4 cm (10 in) dbh against mean fledglings produced and mean group size. These regressions were significant or nearly significant, but they explained a trivial amount of the variation in independent variables (mean fledglings: df = 1, 196; $R^2 = .02$; $P < 0.05$; mean group size: df = 1, 179; $R^2 = .04$; $P < 0.01$). Thus, number of young fledged and group size were at best weakly related to the number of pine trees $\geq$ 25.4 cm (10 in) dbh available to the various groups, and unspecified factors accounted for 98 percent of the variation in number of young fledged and 96 percent of the variation in the group size. Thus, number of pines greater or equal to 25.4 cm (10 in) dbh is not a particularly good measure of foraging habitat requirements.

Implications for New Management

Supplying good quality foraging habitat is a critical aspect of red-cockaded woodpecker recovery, especially over the long term, as immediate threats from cavity and cluster limitation are reduced. Our understanding of what constitutes good quality foraging habitat comes from a synthesis of research into selection of foraging habitat and effects of habitat characteristics on group fitness.

Both habitat selection and group fitness are influenced by the structure of the foraging habitat. Important structural characteristics include (1) healthy groundcovers of bunchgrasses and forbs, (2) minimal hardwood midstory, (3) minimal pine midstory, (4) minimal or absent hardwood overstory, (5) a low to intermediate density of small and medium sized pines, and (6) a substantial presence of mature and old pines (e.g., Figure 2). Thus, the quality of foraging habitat is defined by habitat structure. Although geographic variation in habitat types exist, these structural characteristics of good quality habitat remain true for all geographic regions and habitat types. Previous guidelines

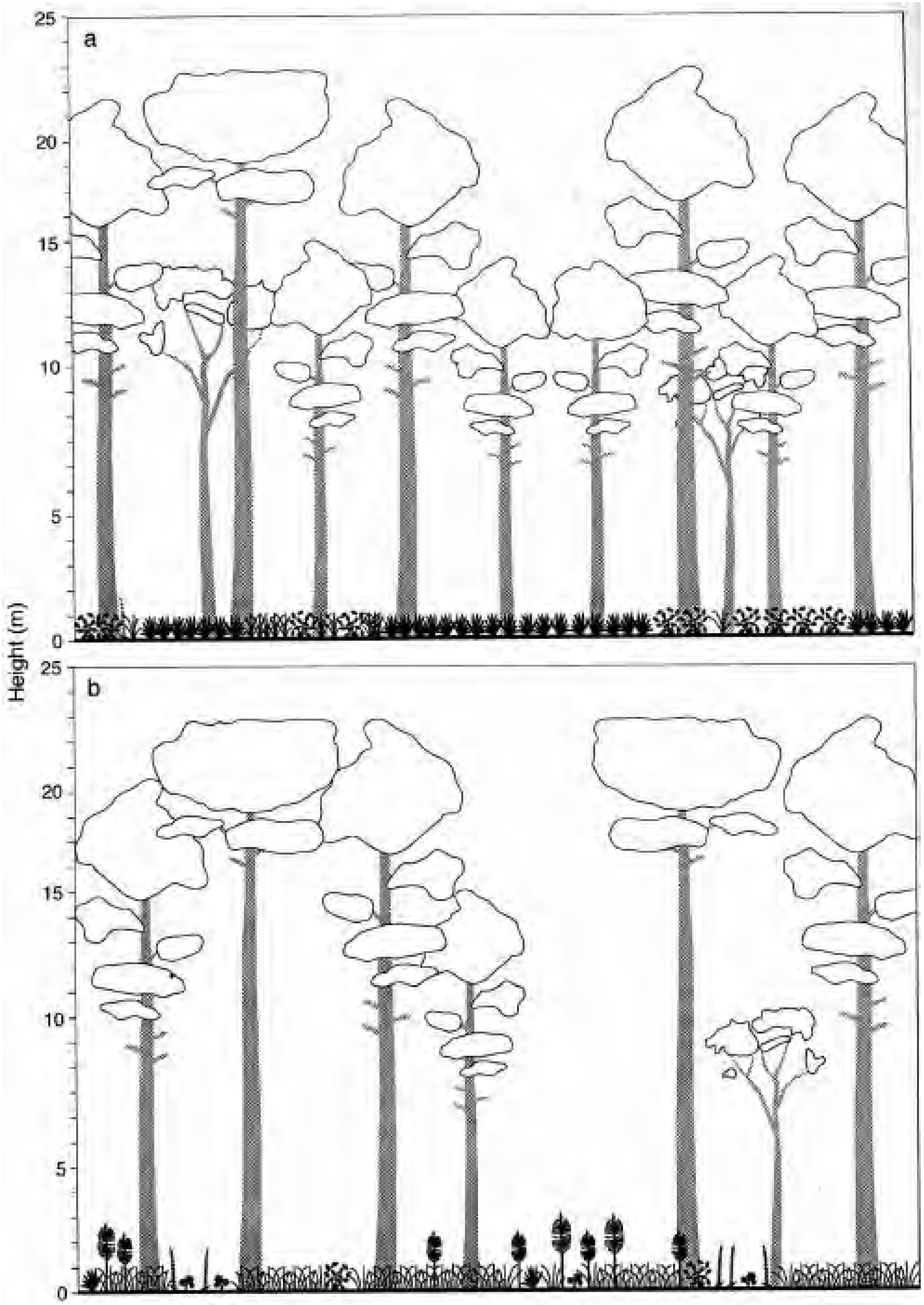


FIGURE 2. Diagrams of (a) adequate and (b) good foraging habitat, as illustrated by James *et al.* (2001). Copyright Ecological Applications; used with permission.

stressed quantity of foraging habitat, as defined by number of medium and large trees. Here we expand this emphasis to include habitat quality, as defined by habitat structure, and use area metrics to address quantity. Red-cockaded woodpeckers require foraging habitat that is suitable in both quantity and quality.

Quantifying habitat structure (and thus habitat quality) is more complex than simply requiring a given amount of habitat or number of trees, because habitat structure is measured by multiple variables. Guidelines for foraging habitat (see 8I) are based on the quantification of structural characteristics to the best of current abilities. Frequent fire can facilitate the restoration and maintenance of all but one of these structural characteristics (mature and old pines), and may provide further benefits by increasing the availability of nutrients. In addition, appropriate silvicultural methods will protect, throughout the landscape, the mature and old trees on which red-cockaded woodpeckers thrive.

F. Community Ecology: Cavity Kleptoparasitism, Cavity Enlargement, and Predation

Red-cockaded woodpeckers are a keystone species of fire-maintained southern pine ecosystems because the cavities they create influence the presence or abundance of a suite of cavity-dwelling species in an otherwise cavity-poor environment (Rudolph *et al.* 1990a, Conner and Rudolph 1995a). Excavation of cavities into live pines by red-cockaded woodpeckers requires a relatively long period of time (Jackson *et al.* 1979, Conner and Rudolph 1995a, Harding 1997). Thus, these cavities are in high demand (Dennis 1971a, Harlow and Lennartz 1983, Rudolph *et al.* 1990b, Loeb 1993, Conner et al. 1997b). Approximately 27 species of vertebrates are known to use cavities excavated by red-cockaded woodpeckers (Table 4; Baker 1971b, Beckett 1971, Dennis 1971a, Hopkins and Lynn 1971, Jackson 1978a, Belwood 1981, Harlow and Lennartz 1983, Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995, Conner et al. 1997b, Loeb and Hooper 1997, Phillips and Gault 1997). Many of these vertebrates use either enlarged (below) or abandoned cavities, but red-bellied woodpeckers, red-headed woodpeckers, eastern bluebirds, several other bird species, and southern flying squirrels use normal, unenlarged cavities that red-cockaded woodpeckers could also use. Southern flying squirrels are generally the most commonly observed species in red-cockaded woodpecker cavities other than red-cockaded woodpeckers (Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995, Laves and Loeb 1999, Mitchell *et al.* 1999), although these observations were made during daylight hours. Eastern bluebirds were more common than flying squirrels in coastal South Carolina (Loeb and Hooper 1997).

Cavity Kleptoparasitism

If a cavity created and used by red-cockaded woodpeckers is usurped by another species, the interaction between that species and red-cockaded woodpeckers is termed cavity kleptoparasitism (Kappes 1997). Until recently, authors have referred to this

TABLE 4. Species using normal and enlarged cavities excavated by red-cockaded woodpeckers[1].

Taxon	**Species**	**Scientific Name**
Birds	Wood duck	*Aix sponsa*
	Tufted titmouse	*Baeolophus bicolor*
	Northern flicker	*Colaptes auratus*
	Pileated woodpecker	*Dryocopus pileatus*
	American kestrel	*Falco sparverius*
	Red-bellied woodpecker	*Melanerpes carolinus*
	Red-headed woodpecker	*Melanerpes erythrocephalus*
	Great crested flycatcher	*Myiarchus crinitus*
	Eastern screech owl	*Otis asio*
	Red-cockaded woodpecker	*Picoides borealis*
	Carolina chickadee	*Poecile carolinensis*
	Eastern bluebird	*Sialia sialis*
	White-breasted nuthatch	*Sitta carolinensis*
	Brown-headed nuthatch	*Sitta pusilla*
	European starling	*Sturnus vulgaris*
Mammals	Wagner's mastiff bat	*Eumops glaucinus floridanus*
	Southern flying squirrel	*Glaucomys volans*
	Evening bat	*Nycticeius humeralis*
	Raccoon	*Procyon lotor*
	Eastern gray squirrel	*Sciurus carolinensis*
	Eastern fox squirrel	*Sciurus niger*
Reptiles/Amphibians	Corn snake	*Elaphe guttata*
	Rat snake	*Elaphe obsoleta*
	Broadhead skink	*Eumeces laticeps*
	Five-lined skink	*Eumeces spp.*
	Gray treefrog	*Hyla spp.*
	Lizard spp.	Lacertilia
Invertebrates	Honeybee	*Apis mellifera*
	Spider spp.	Arachnida
	Wasp spp.	Hymenoptera
	Ant spp.	Hymenoptera
	Moth spp.	Lepidoptera
	Mud daubers	Sphecidae

[1]Sources: Baker 1971b, Beckett 1971, Dennis 1971a, Hopkins and Lynn 1971, Jackson 1978a, Belwood 1981, Harlow and Lennartz 1983, Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995, Conner et al. 1997b, Loeb and Hooper 1997, Phillips and Gault 1997.

interaction as cavity competition (e.g., Ligon 1970, Jackson 1978a, Carter *et al.* 1983, Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995), but the term cavity kleptoparasitism is more correct (Kappes 1997). As Kappes (1997) explains, competition describes an interaction in which both species exhibit a negative effect from the presence of the other. Because cavity usurpers are acquiring a limited resource created by another species, the interaction provides benefits for the usurping species and negative effects on red-cockaded woodpeckers. Kleptoparasitism is the appropriate term for such a positive-negative relationship.

Cavity kleptoparasitism may negatively affect individual woodpeckers or woodpecker groups on occasion (see below). Occasional loss of nests or cavities is unlikely to have population-level impacts in red-cockaded woodpecker populations that are healthy and of medium to large size. However, critically small populations or isolated groups may not be able to tolerate high rates of kleptoparasitism. Also, effects of kleptoparasites may vary with habitat quality. Further research is needed into relationships among kleptoparasites, habitat quality, and red-cockaded woodpecker abundance.

Red-bellied Woodpeckers

Red-bellied woodpeckers are a common cavity kleptoparasite of red-cockaded woodpeckers (Neal *et al.* 1992, Kappes 1997). Usurpation of cavities by red-bellied woodpeckers may result in open roosting for red-cockaded woodpeckers. For example, Kappes (1997) observed 15 adults open roosting during a winter in Florida; 14 of these 15 had suffered loss of cavities to red-bellied woodpeckers. However, how much open roosting may affect survival or territory occupancy is not yet known. Rates of kleptoparasitism by red-bellied on red-cockaded woodpeckers may vary inversely with habitat quality (F. James, pers. comm.). Similarly, red-cockaded woodpeckers in optimal habitat are likely to suffer less impact from each usurpation event. Thus, increasing the overall quality of the habitat for red-cockaded woodpeckers may be an effective means of controlling effects of cavity usurpation by red-bellied woodpeckers. Retention of snags and provision of nest boxes may reduce effects of red-bellied woodpeckers as well (Loeb and Hooper 1997, below).

Southern Flying Squirrels

Reported rates of occupancy of red-cockaded woodpecker cavities by southern flying squirrels range from 9 to 34 percent (Dennis 1971a, Rudolph *et al.* 1990a, Loeb 1993, Laves and Loeb 1999, Mitchell *et al.* 1999). Southern flying squirrels prefer active cavities with non-enlarged entrance tunnels over those with entrance tunnels enlarged (Rudolph *et al.* 1990a, Loeb 1993), and cavity inserts over natural cavities (Lotter 1997). From among active cavities, southern flying squirrels prefer cavities with enlarged chambers over those with regular chambers (Rossell and Gorsira 1996).

Southern flying squirrels could potentially affect red-cockaded woodpeckers through usurpation of cavities or through predation. There is disagreement among researchers over whether cavity usurpation has any negative effects. Some suggest that cavity usurpation lowers nest attempts (Loeb and Hooper 1997), but others have found no evidence that the presence or abundance of southern flying squirrels increases open roosting or decreases nest attempts (Rudolph *et al.* 1990a, Conner *et al.* 1996, Laves 1996, Mitchell *et al.* 1999). Whether or not flying squirrels are significant predators of red-cockaded woodpecker nests is discussed below.

It has been suggested in the past that southern flying squirrels increase with increasing hardwood midstory (Conner and Rudolph 1989, Loeb *et al.* 1992). Yet, Conner *et al.* (1996) observed regular use of red-cockaded woodpecker cavities by southern flying squirrels in loblolly-shortleaf pine habitat with and without hardwood midstory and in open longleaf pine habitat that was nearly devoid of hardwood vegetation. Southern flying squirrels are abundant and ubiquitous, and at the present time the influence of plant species composition and vegetative structure on flying squirrel distributions is not understood.

Reducing Impacts from Cavity Kleptoparasites

The availability of snags may reduce potential impacts of cavity kleptoparasites on red-cockaded woodpeckers. Rates of cavity kleptoparasitism appear to be inversely related to the density of snags within clusters (Harlow and Lennartz 1983, Kappes and Harris 1995). Placement of nest boxes within cavity tree clusters may have a similar effect of lowering use of red-cockaded woodpecker cavities by other species (DeFazio *et al.* 1987, Loeb and Hooper 1997). Improving overall habitat quality and increasing woodpecker density may also reduce effects of kleptoparasites.

Cavity Enlargement

Enlarged cavities are those whose entrance tunnels have been widened by one of several species of woodpeckers (Conner *et al.* 1991a, Neal *et al.* 1992). Cavity enlargement is generally done by pileated woodpeckers, but red-bellied and red-headed woodpeckers and northern flickers also enlarge cavities created by red-cockaded woodpeckers (J. H. Carter III, pers. comm.). Pileated woodpeckers greatly expand entrance tunnels and can also enlarge the cavity chamber if sufficient heartwood is present (Conner *et al.* 1991a). Over a period of thirteen years in the Angelina National Forest in eastern Texas, pileated woodpeckers enlarged 41 percent (114 of 276) of unprotected natural red-cockaded woodpecker cavities (Saenz *et al.* 1998).

Cavity enlargement by pileated woodpeckers can have strong negative impacts on individual red-cockaded woodpeckers and, more importantly, on the entire population. Red-cockaded woodpeckers will abandon their clusters if damage to cavities by pileated woodpeckers is great. However, the enlarged cavities created by pileated woodpeckers provide important habitat for many other relatively large secondary cavity users, such as American kestrels (*Falco sparverius*), eastern screech owls (*Otus asio*), and fox squirrels (*S. niger;* Conner *et al.* 1997b, Saenz *et al.* 1998). In fact, just as red-cockaded woodpeckers are the primary source of cavities for other similar-sized cavity users, pileated woodpeckers are key to the availability of cavities for large cavity-nesting species (Saenz *et al.* 1998). Therefore, the challenge to management is to reduce the effects of cavity enlargement on red-cockaded woodpeckers without overly impacting large cavity-nesting species of concern.

Why pileated woodpeckers enlarge cavities is unknown. Enlarged cavities are rarely used by pileated woodpeckers for roosting or nesting (Conner et al. 1997b). Saenz *et al.* (1998) suggest that pileated woodpeckers are attracted to trees bearing signs of woodpecker excavation, but that heavy resin flow often prevents complete nest excavation. Damage by pileated woodpeckers decreases with increasing availability of snags in the general area (Saenz *et al.* 1998), just as rates of cavity kleptoparasitism may decrease with increasing snags. Thus, managers should retain snags throughout lands managed for red-cockaded woodpeckers and consider their protection during prescribed burns.

Cavity damage by pileated woodpeckers may also be related to human disturbance. Initial attempts at midstory control within the cluster may attract pileated woodpeckers if midstory outside the cluster is excessive (J. H. Carter III, pers. comm., R. Costa, pers. comm.). Again, restoration of high quality habitat for both foraging and nesting may reduce impacts from pileated woodpeckers.

Cavity Restrictors

Metal plates that restrict the entrance diameter of red-cockaded woodpecker cavities (Carter *et al.* 1989) can be used to rehabilitate some currently unsuitable cavities or to prevent the enlargement of currently suitable cavities (see 3B). Although these plates may prevent further damage by larger species of woodpeckers, they will not deter the use of cavities by southern flying squirrels or other small species of birds. When cavity availability is limited (less than four suitable cavities per group or less than one suitable cavity per group member) and enlargement by pileated woodpeckers is common, use of cavity restrictors is absolutely essential to protect existing cavities from enlargement and rehabilitate cavities with minor to moderate entrance enlargement. Use of restrictors to prohibit use of cavities by red-bellied woodpeckers is not recommended (see 3B).

Restrictors require careful monitoring on an annual basis, to ensure that negative effects on red-cockaded woodpeckers are minimized (see 3B). For this reason, their use must be judicious rather than haphazard or wholesale. In addition, enlarged cavities that have been abandoned for several years should not be restricted or should have any existing restrictors removed, so that they may be available to secondary cavity nesters.

Similarly, if cavities are not limited, then restrictors are not necessary and some enlarged cavities can be tolerated.

Predation

Rat Snakes

Red-cockaded woodpeckers excavate resin wells around cavity entrances to create a coat of fresh resin, typically extending several meters below and above the entrance and occasionally to the ground. They also scale loose bark from the bole of the cavity tree and nearby pines. During the 1970’s, several biologists realized that these behaviors serve to protect the nests against predation by rat snakes (Ligon 1970, Dennis 1971b, Jackson 1974, 1978a), and in the late 1980’s Rudolph *et al.* (1990a) documented experimentally the effectiveness of the resin barrier against climbing rat snakes.

Rat snakes are excellent tree climbers (Jackson 1976) and frequently prey on cavity-nesting birds (Fitch 1963, Jackson 1970). They attempt to climb cavity trees and cavity trees with nests more often than expected by chance alone, evidence that rat snakes are able to detect which trees contain cavities and also which cavity trees contain nests (Neal *et al.* 1993b). Sometimes, rat snakes are able to breach the resin barrier and prey on cavity contents such as eggs, nestlings, or even adults (Jackson 1978a, Neal *et al.* 1993b, 1998).

However, reports of individual predation events by rat snakes on red-cockaded woodpeckers are relatively scarce, and there is no evidence that such predation affects woodpeckers at the population level. For example, there was no difference in average reproduction between nests in cavity trees fitted with snake exclusion devices and untreated cavity trees over three years in the longleaf pines of northwest Florida (L. Phillips, unpublished). It is likely that the resin barrier is a highly effective means of deterring rat snakes, especially in longleaf pine.

Southern Flying Squirrels

Although flying squirrels are known to eat eggs of red-cockaded woodpeckers on occasion (Harlow and Doyle 1990), there is little consistent evidence that flying squirrels significantly depress reproduction of red-cockaded woodpeckers. Two experimental studies have been conducted comparing reproductive success of red-cockaded woodpeckers in clusters with and without squirrel removal (Laves and Loeb 1999, Mitchell *et al.* 1999). Laves and Loeb (1999) reported lowered reproduction in clusters without squirrel removal, resulting from increased whole brood loss in one year and increased partial brood loss in the following year. Mitchell *et al.* (1999) reported no difference in overall reproduction between clusters with and without squirrel removal, but noted increased partial brood loss in clusters that had squirrels removed. In addition, Conner *et al.* (1996) did not detect any relationship between abundance of southern flying squirrels and reproductive success of red-cockaded woodpeckers in eastern Texas. No study has yet shown an effect of flying squirrels on red-cockaded woodpeckers at the population level (Mitchell *et al.* 1999). Thus, it appears that impacts of flying squirrels on red-cockaded woodpeckers are not strong, at least in the populations in which they have been assessed.

Indirect Interactions

Red-cockaded woodpeckers, their cavity kleptoparasites, and nest predators such as rat snakes likely have direct and indirect interactions among them (J. Kappes, pers. comm.). Predation by snakes on kleptoparasites may reduce potential impacts of kleptoparasites on red-cockaded woodpeckers. Snake predation could potentially cause red-bellied woodpeckers or other cavity nesters to shift nest sites to snags, which are less easily climbed than live pine trees. Further research is required before we begin to understand such complex species interactions.

Implications for Management

In general, predator control is not an effective method of achieving stabilization or increases in bird populations, because predators rarely regulate population size in birds (Côté and Sutherland 1997). For red-cockaded woodpeckers, predators were not among the original causes of decline, and their removal will not result in population increases. Only habitat restoration, including prescribed burning, protection of mature and old growth trees, and cavity provisioning, can stabilize and increase populations by removing the original causes of decline.

Critically small populations, however, may not be able to withstand the loss of an occasional nest to predation by southern flying squirrels or rat snakes. For these populations, predator management techniques (see 3C) may be considered, but should not take the place of more fundamental management. Such methods are not appropriate in larger populations, because they may cause unintentional harm and can focus attention and resources away from habitat management and restoration. Further research into both direct and indirect species interactions is desirable before managers use predator exclusion techniques. Such exclusion may have unanticipated consequences, including negative effects on red-cockaded woodpeckers (J. Kappes, pers. comm.). Effects of such actions are simply not sufficiently understood to warrant their widespread use. Those who choose to use predator management techniques in small populations are encouraged to apply an experimental approach with adequate controls.

In contrast, cavity enlargement by pileated woodpeckers can have population-level effects in even fairly large populations by causing cluster abandonment. Restrictors (see 3B) are an essential management tool to be used judiciously in appropriate circumstances, with proper maintenance. Whether cavity kleptoparasitism by red-bellied woodpeckers negatively affects red-cockaded woodpecker populations requires further study. Effects of cavity kleptoparasitism by flying squirrels are under debate but are not considered strong or consistent enough to warrant flying squirrel removal or exclusion except perhaps in critically small populations (less than 30 potential breeding groups). Provision of nest boxes is a non-invasive technique that may help reduce effects of cavity kleptoparasitism (Loeb and Hooper 1997). Some evidence suggests that any effect of red-bellied woodpeckers (F. C. James, pers. comm.) and southern flying squirrels (Loeb and Hooper 1997) may increase with habitat degradation. In general, maintaining good quality nesting and foraging habitat (see 8F, 8I), providing sufficient numbers of suitable, unenlarged or restricted cavities (8E), and retaining snags in the landscape are the best management tools to reduce possible effects of occasional predation and cavity kleptoparasitism and to control the far more serious impacts from cavity enlargement.

G. THE ROLE OF FIRE IN SOUTHERN PINE ECOSYSTEMS

Fire is an integral component of the southern pine/bunchgrass ecosystems of the southeastern United States, and fire suppression is a principal factor in the decline of these ecosystems and characteristic species such as red-cockaded woodpeckers (see 1A). In this section, we review the history of fire in the region and the fire dependence of the species comprising southern pine ecosystems. In 3F, we discuss prescribed fire and red-cockaded woodpecker management, including description of ignition techniques, benefits to other species, and concerns about negative impacts. Guidelines for using prescribed fire in the management of red-cockaded woodpeckers are presented in 8K.

History of Fire in the Southeast

Fire is a natural ecosystem component that gained and lost importance in North America as the glaciers retreated and advanced. Pyrophytic vegetation in what is now the southeastern United States evolved in response to fires ignited by lightning long before the last glacial retreat roughly 10,000 years ago (Komarek 1968, 1974, Ware *et al.* 1993). Aboriginal people immigrated into the region during the last glacial period, and so the development and spread of fire-dependent ecosystems as the last glaciers retreated were influenced by both climate and the presence of Native Americans (Delcourt *et al.* 1993, Frost 1993, Ware *et al.* 1993). Modern plant assemblages have remained relatively stable for the past 6,000 years (Webb 1988, Frost 1998), despite some oscillations in fire frequency caused by minor changes in climate (Frost 1998). Thus, the ecosystems in place at the time of European exploration of North America had been in place for thousands of years (Frost 1998), and those in the southeastern region were shaped primarily by fire.

Prior to European colonization, there were few natural firebreaks in the southeast, and so fires burned for extended periods and over large regions. Return intervals for these natural fires were as frequent as 1 to 3 years in much of the Atlantic and Gulf Coastal Plains, and as frequent as 4 to 6 years in Upper Gulf Coastal Plains and the

Piedmont (Wahlenburg 1946, Frost 1998). Some areas, such as slopes with northern aspect and wetlands, may have burned at frequencies of 7 to 25 years (Frost 1998).

Fire intensity is intimately related to fire frequency, and together they are a primary determinant of ecosystem structure and species composition. Over much of the southeast, frequent fires were low in intensity, as evidenced by the species adaptations and structure of longleaf and shortleaf communities (below). In some regions, fires were less frequent and of stand-replacing intensity. Such areas support pines that are adapted to stand-replacing fires, such as sand, Table Mountain (*P. pungens*), pitch, and pond pines (Landers 1991). Only the latter two species are used by red-cockaded woodpeckers. Occasionally, some patches of longleaf and shortleaf communities may have undergone stand-replacing fires as a result of unusually long fire intervals. Thus, precolonial longleaf and shortleaf ecosystems were likely mosaics of mostly multi-aged woodlands with occasional even-aged stands (Landers 1991). Community species composition and tree density varied as functions of the fire regime, moisture gradient, and soil fertility.

The relative role of Native Americans in augmenting the lightning fire regime likely varied regionally, depending upon the frequency of lightning fire (Frost 1998). Native Americans may have shifted the seasonality of fire from the lightning season to include fires in fall and winter as well (Higgins 1986, Frost 1998). In general, however, it is not necessary to distinguish the exact contributions of anthropogenic and lightning fire to understand the role of fire in shaping and maintaining the ecosystems of the southeast. Native Americans were an integral component of these developing ecosystems for the 10,000 years of the Holocene.

Like the Native Americans, early European settlers also used fire as a tool, practicing slash and burn agriculture throughout the southeast during the 18th and 19th centuries. Farmers and ranchers continued to use fire to improve grazing quality for free ranging livestock into the first half of the 20th century, setting fires primarily in the early spring (Otto 1986, Frost 1993). As timber surpassed cattle in economic importance, however, fire was increasingly seen as the enemy of the woodland manager. Fire detection and suppression systems were instituted, and large fires became increasingly rare.

Much of the 20^{th} century was a time of active, aggressive fire suppression. Increasing human-made firebreaks such as roads, fields, and power lines also reduced the extent of natural fires and fire frequency. Prescribed fire was recognized by some as an important tool to reduce the risk of catastrophic wildfire (Sachett 1975) and was occasionally used to improve game habitat (Stoddard 1935), but these fires were set in the winter months. Dormant season fires were not as effective as natural, intense, growing season fire in maintaining the open pine woodlands and savannahs that red-cockaded woodpeckers require. By the 1960's, fire suppression and exclusion threatened the existence of the species.

Fire Dependence and Adaptation

Many species of the southern pine-bunchgrass ecosystems show adaptations to frequent, low intensity fires, including red-cockaded woodpeckers. A fundamental adaptation of red-cockaded woodpeckers to fire is the excavation of roost and nest cavities in live pines, a behavior that may have evolved in response to the lack of snags and hardwoods in fire-maintained pine systems (Ligon 1970, Jackson *et al.* 1986). This ability to excavate cavities in live pines is not only important to red-cockaded woodpeckers but also to the many other species that use these cavities in the otherwise cavity poor environment (Brennan *et al.* 1995, Conner *et al.* 1997a; see 2F). Excavation of cavities in live pines has in turn led to the complex and unusual cooperative breeding system of red-cockaded woodpeckers (Walters 1990, Walters *et al.* 1992a; see 2B). A second adaptation of red-cockaded woodpeckers to fire is the abandonment of cavity clusters in the presence of substantial hardwood midstory. This may be a mechanism for avoiding the dangerous fires that will inevitably occur when the midstory is ignited. The severe impact and continuing threat of fire suppression to red-cockaded woodpeckers are discussed in 1A and 1B.

Plants of the southern pine ecosystems are well adapted to and require frequent burning. Many groundcover plants require growing season fires for flowering and fruit and seed production (Platt *et al.* 1988a, Streng *et al.* 1993, Walker 1993). Platt *et al.* (1988a) showed that herbaceous plants undergoing growing season fire not only increased flower production but also increased synchronicity of flowering, facilitating pollination and reducing risk of hybridization. Populations of these herbaceous plants, therefore, are regulated by fire. Ferguson (1998) recounted a typical example of a population of Florida skullcaps (*Scutelleria floridana*) reduced to three individuals which then swelled to over 100 individual plants following a growing season fire. Walker (1993) lists nearly 400 rare, mostly herbaceous plants of longleaf pine communities, of which over 90 percent are adapted to growing season fire. Diversity of herbaceous plants in longleaf systems place these among the most highly diverse ecosystems in North America (Walker and Peet 1983, Peet and Allard 1993). This diversity is maintained by frequent fire and severely threatened by fire suppression (Christensen 1981, Ware *et al.* 1993, Peet and Allard 1993, Glitzenstein *et al.* 1998b, Walker 1998). Over 120 species of plants associated with red-cockaded woodpecker habitats are currently on the regional list of proposed, endangered, threatened, and sensitive species (USFS 1995).

Pine trees in general are noted for being fire-adapted, but longleaf and south Florida slash pines in particular are extremely well adapted to fires of high frequency and low intensity (Landers 1991). Adaptations providing these two species with resistance to fire damage include the grass stage of seedlings, a large taproot, special bark characteristics, absence of branches below the crown, and the typical clumped arrangement of needles at the growing tips of branches (Wahlenburg 1946, Landers 1991). Longleaf and south Florida slash pine seedlings maximize taproot growth and minimize early height growth; the reverse is true of loblolly pine (Landers 1991). In addition, fire enhances seed germination and seedling establishment. Reproduction of longleaf and development of longleaf seedlings is especially enhanced by growing-season fire, as evidenced by long-term research into the reproduction of longleaf pine in the Escambia Experimental Forest, Alabama (W. D. Boyer, pers. comm.). Finally, both fire-adapted species facilitate the ignition and spread of fire by producing highly resinous, long needles and shedding them frequently (Platt *et al.* 1988b, 1991, Noss 1989, Landers 1991). This facilitation of fire maintains environmental conditions that are beneficial to these species but detrimental to competitors. Through its profound influence on the fire regime, longleaf pine is a key species in the longleaf pine communities (Platt *et al.* 1988b, 1991, Noss 1989, Landers 1991). Fire suppression and the resulting invasion of hardwoods have altered almost all longleaf pine ecosystems (Frost 1993).

Engstrom (1993) reported 36 species of mammals and 86 species of birds (35 permanent residents, 22 winter residents, and 29 breeders) characteristic of southeastern longleaf pine ecosystems. Many of these animals, and many more plant species, are threatened by fire suppression. USFS (1995) reported that 56 animal species associated with red-cockaded woodpecker habitats are currently on the regional list of proposed, endangered, threatened, and sensitive species. In addition, entire associations of species have been affected, such as the threatened gopher tortoise (*Gopherus polyphemus*) and the 13 listed and candidate species of animals that depend on gopher tortoise burrows (USFS 1995). Fire benefits shortleaf pine communities as well, although these have not received as much research attention as longleaf systems. Masters *et al.* (1998) reported that species richness and diversity of small mammals increased in relation to midstory reduction and prescribed fire, and no species was adversely affected by fire.

Guyer and Bailey (1993) reported 34 amphibian and 38 reptilian species that are closely associated with longleaf pine forests. Thirty-five percent of the amphibians and reptiles inhabiting longleaf pine forests, and 56 percent of the longleaf pine specialist species, were listed by at least one conservation agency as being of special concern. Fire suppression was identified as a primary cause of the decline of these species.

There is growing evidence that frequent fire may increase arthropod diversity and abundance (Folkerts *et al.* 1993, Collins 1998, Provencher *et al.* 1997, 2001). Groundcovers maintained by frequent fire may support more arthropods than areas with a hardwood midstory (Provencher *et al.* 1997, 2001, Collins 1998), although populations of some species, especially those in the leaf litter, may initially decline after burning. Provencher *et al.* (1997, 2001) suggest that invertebrate densities may increase following fire because resprouting plant tissue contains higher levels of nitrogen relative to carbon than older tissue (Christensen 1993), thus providing more palatable forage. It has been hypothesized that nutrient content of arthropods increases also, following the release by fire of nitrogen and other nutrients into the soil (James *et al.* 1997).

Implications for Management

Fire is an essential element of southern pine ecosystems, critical to the maintenance of habitat for red-cockaded woodpeckers and many other species. Frequent fire has helped to shape and maintain some of the most highly diverse ecosystems outside the tropics. However, natural fire can no longer maintain suitable habitat for red-cockaded woodpeckers and associated species, because the fragmentation of landscapes has reduced fire spread, duration, and therefore fire frequency. Thus, prescribed fire is a fundamental solution to the conservation of red-cockaded woodpeckers and their ecosystems. To maximize benefits, the frequency, intensity, and season of prescribed fire should mimic the historic natural fire regime as closely as possible (see 3F).

3. MANAGEMENT TECHNIQUES

A. POPULATION MONITORING

Population monitoring is a critical component of the conservation and recovery of red-cockaded woodpeckers. Effective monitoring begins with explicit identification of monitoring objectives, the appropriate metrics to be used in meeting objectives, and familiarity with necessary sampling and monitoring techniques. It is then up to managers and researchers to apply these standards in good faith. Finally, monitoring results must be compared to stated objectives. It is the responsibility of the Red-cockaded Woodpecker Coordinator to evaluate monitoring results within the framework of recovery objectives (1 – 6, below), using information reported annually by managers and researchers (Annual Reports, below). Fortunately, red-cockaded woodpeckers are more easily monitored than most species because of their conspicuous active cavity trees and the exceptional stability of territory locations.

Here we identify six objectives for population monitoring: (1) to determine population status and trend; (2) to qualify for and evaluate translocation; (3) to evaluate management techniques other than translocation, using an experimental approach (adaptive management); (4) to measure impacts of activities not related to species management; (5) to document success or failure of mitigation; and (6) to conduct research. Appropriate metrics, monitoring techniques, and other information for each of these objectives are given below. Guidelines for population monitoring are given in 8C. Guidelines for monitoring cavity availability are given in 8E, and banding protocol is presented in Appendix 2. Many activities conducted for monitoring purposes require federal permits (see Appendix 1) and may require state permits as well.

Population Size and Trend

Determination of population size and trend is a primary objective of monitoring red-cockaded woodpecker populations. Such determination is the foundation of assessing progress toward recovery goals. Critical thresholds of population sizes are described in Recovery Criteria (6). Recommended rate of population increase and critical values of population declines are identified and defined in 8A.

The two metrics most important to monitoring population size and trend are number of potential breeding groups and number of active clusters. We define and describe these two metrics below, along with associated variables. Together these two metrics give a reasonable assessment of population health. Monitoring group size and/or reproductive success is not necessary to determine population size and trend. We provide protocol for the monitoring of group size and reproductive success in Appendix 2, should managers and researchers choose to evaluate these parameters as well. Monitoring group size and reproductive success is strongly recommended for critically small populations (less than 30 potential breeding groups) on public lands, and required for those populations receiving translocated birds for population augmentation (below).

Number of Active Clusters

An active cluster is a cluster in which one or more of the cavity trees exhibit fresh resin as a result of red-cockaded woodpecker activity or in which one or more red-cockaded woodpeckers are observed. Number of active clusters is a traditional measure of population size, and is generally known exactly rather than estimated. However, because this metric gives no information as to the status of the group occupying each cluster (e.g., potential breeding group, solitary male, or captured cluster), it is best accompanied by estimates of number of potential breeding groups (below).

Counting the number of active clusters consists of two management actions: (1) evaluating the activity status of known clusters (cluster activity checks) and (2) surveying for new clusters. Here we give brief protocols for each.

Cluster Activity Checks.--Activity status of each known cluster is assessed during the breeding season or just prior to it (March – July), by one or more experienced red-cockaded woodpecker biologists. It is conducted during those months because populations are lowest then and because consistency in data collection is vital to accurately assessing and comparing population trends.

All potentially active clusters are checked for evidence of red-cockaded woodpecker activity. Potentially active clusters are all clusters active within the last 5 years and all inactive clusters, including recruitment clusters, that have undergone restoration of appropriate habitat structure and/or cavity installation within that time. Evidence of activity includes fresh resin on one or more cavity trees as a result of red-cockaded woodpecker activity or the presence of one or more birds. Within each cluster, all cavities that have been active within the last 5 years are evaluated until an active cavity is located or birds are observed. If all cavities are inactive in a cluster that is normally active, a thorough search for new cavity trees is conducted in suitable habitat within 0.4 km (0.25 mi) of the cluster center.

The accuracy of this metric, number of active clusters, can be compromised if cavity trees are inappropriately assigned into clusters. Cluster designation requires at least some intense monitoring initially (see Reed *et al.* 1988a).

Number of active clusters is to be counted in all red-cockaded woodpecker populations, but the recommended frequency of cluster activity checks varies with population size. These recommendations are given in management guidelines for population monitoring (8C). To save time and effort, other monitoring activities can be conducted at the time cluster activity checks are conducted. Chief among these are evaluating the availability of suitable cavities (8E) and estimating the number of potential breeding groups (below).

Surveys for New Cavity Trees and Clusters.--Comprehensive surveys for new cavity trees and clusters within occupied and potentially occupied habitat can be conducted at approximately 10-year intervals, by trained personnel following specific protocol. During these surveys, all clusters that have been inactive for more than five years are checked for activity also. In most habitat types, surveys are best conducted by foot, using transects spaced to allow overlapping visual coverage of all potential cavity trees (pines at least 60 years in age, in pine and pine-hardwood stands regardless of tree density). Proper spacing of transects varies with overstory density, midstory density and height, and terrain. Aerial surveys, by helicopter or small fixed wing aircraft, are useful in certain habitats such as pocosin or bays where access by foot is difficult. Such surveys, performed by experienced observers, can locate most clusters containing multiple cavity trees but rarely detect all cavity trees in a cluster or all clusters. In other words, aerial surveys document the presence of cavity trees but not their absence. Ground surveys are used to verify the results of aerial surveys and to locate all cavity trees in detected clusters.

Initial surveys for active cavity trees and clusters are a fundamental step in beginning management of red-cockaded woodpecker populations. However, repeated surveys for new clusters in previously unoccupied habitat are not recommended at this time. In recent years, this management action has yielded little return for substantial investment (R. Costa, pers. comm.), presumably because most forests are currently quite young and because pioneering by red-cockaded woodpeckers is rare (see 2B).

Number of Potential Breeding Groups

An active cluster may contain a potential breeding group, a solitary male, or be captured by a neighboring group. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young. A solitary male is an adult male occupying a cluster without a mate. A captured cluster is one that does not support its own group, but is kept active by a member or members of a neighboring group. Increasing proportions of active clusters without potential breeding groups are early indicators of population decline. For this reason, number of potential breeding groups is a critically important metric. In small populations that are sampled completely, number of potential breeding groups is known exactly. In larger populations that are not sampled completely, number of potential breeding groups is estimated. Here we give directions on monitoring techniques to determine or estimate number of potential breeding groups, followed by a discussion of sampling methods.

Number of potential breeding groups is assessed during the breeding season by conducting (1) nest checks in active clusters until nesting is documented and (2) morning follows in active clusters in which no nesting is observed. Nest checks are periodic visits to active clusters during the breeding season, and consist of (1) lightly scraping on active cavity trees in an effort to flush incubating birds, (2) listening for nestlings begging for food, (3) inspecting potential nest cavities using a video probe or climbing equipment, and/or (4) watching for adults carrying food to a cavity. Nest checks are conducted every 7 to 11 days until a nest is detected. If nesting is documented, the cluster supports a potential breeding group and no further nest checks are required (unless reproductive success is being monitored, see below and Appendix 2). It is important that frequency of nest visits and the date of their initiation are consistent across years to allow accurate determination of population trend.

Morning follows are required for each active cluster in which no nest has been documented by the middle of the breeding season. Morning follows are roughly equivalent to “group checks” described by the U.S. Forest Service (USFS 1995). The target group is observed for a half an hour to an hour, immediately after the birds exit their cavities in the morning, to determine group status. Group status is classified as (1) potential breeding group, indicated by two or more birds that remain together and peacefully interact; (2) solitary male, indicated by a bird that remains solitary for the duration of the follow; or (3) captured cluster, indicated by no birds or a bird that roosted in the target cluster but joined a neighboring group. Care must be taken to accurately classify the group. Red-cockaded woodpeckers roosting extra-territorially in clusters occupied by one or more residents, captured clusters, and territorial conflicts can confuse the observer and result in erroneous status classifications. If doubt as to group status exists, the follow time is extended or the follow is repeated on another day. Two observers may be necessary if two clusters are located very close together or if cavity trees within a cluster are spread over a large area. If an extended follow or several follows fail to adequately yield the status of a group, managers may choose to color-band one or more adults to determine group status without doubt. Morning follows are preferable to evening roost checks because evening checks can miss group members that are roosting in unknown cavity trees or in neighboring clusters.

Currently, nest checks in combination with morning follows are considered sufficient to estimate number of potential breeding groups, and more intensive monitoring such as color-banding of adults and nestlings is considered unnecessary for this purpose. Of course, this approach must be implemented conscientiously if sound data are to be collected. If, in the future, it appears that nest checks and morning follows are not being implemented well, use of color-bands to estimate number of potential breeding groups may be recommended.

Sampling.--Recommended sample sizes for estimating number of potential breeding groups vary according to population size. These recommendations are given under Population Monitoring Guidelines (8C). Sample sizes may be adjusted in the future as more information concerning annual variation and sampling error is obtained. Currently, most estimates of solitary males and captured clusters are derived from populations that are color-banded, not monitored using the combination of nest checks and morning follows described above.

The best method of sampling to estimate number of potential breeding groups is to select a random sample annually, without replacement, from the set of all potentially active clusters (defined above). Stratified random sampling is to be used whenever it is suspected that some groups are consistently experiencing different conditions than others. Examples of consistently different conditions include differences in natural habitat type, past or present habitat management or silvicultural treatments, or human activities such as military training. Stratified random sampling is achieved by dividing the area to be sampled into homogeneous habitat types, habitat management history, or human activity levels. These strata are then sampled in proportion to the number of clusters that they contain, with the total combined sample equal to recommended sample size. Information concerning individual strata is limited if within-strata sample sizes are small, but accuracy of population-level parameters can be greatly increased in heterogeneous populations by using this method. Input from a wildlife statistician is strongly recommended.

Annual random sampling without replacement, stratified where appropriate, is our recommended sampling method to estimate number of potential breeding groups for populations that are not undergoing any banding. For populations in which some adults and nestlings are being banded, changing the sample annually is inefficient. For these populations, we recommend that a random sample without replacement be selected once every 5 years, and that this sample remain fixed for that 5-year period. Stratified random sampling at 5-year intervals should be used wherever appropriate. Again, consulting with a wildlife statistician is recommended.

Translocation

Translocation is described in 3D and guidelines for its use are given in section 8H and Appendix 3. There are several objectives for monitoring as part of a translocation program. First, a sample of groups is monitored to identify specific birds available for translocation. Second, eligibility status of the donor population must be evaluated and specific impacts of translocation must be assessed. Third, populations receiving translocated birds from donor populations are intensively monitored to qualify for the translocation program, to evaluate translocation success, and, potentially, to assess population-level benefits of this management technique. Similarly, in populations that are undergoing translocation of birds within the population, recipient clusters or target areas are monitored to evaluate translocation success and potentially to assess population-level benefits. We discuss each of these objectives in turn below.

Translocation of red-cockaded woodpeckers requires state and federal endangered species and bird banding permits (see Appendix 1). Specific protocols, available from the Red-cockaded Woodpecker Recovery Coordinator, are followed, and all translocation attempts are reported to the Recovery Coordinator through the Annual Report process.

Identification of Available Birds

Birds potentially available for translocation are identified by color-banding entire groups and determining group composition. This is required whether the bird is to be translocated within the population or to another population. Protocol for the banding of adults and nestlings are presented in Appendix 2. Group composition is determined by color-band observation throughout the breeding season and again by morning follows (described above) conducted just prior to the removal of birds to assess status of individuals and to determine whether the group in question meets the criteria for bird availability (see 8H). It is estimated that three to five groups will have to be banded to identify one bird available for translocation. All translocated birds are to be color-banded.

Assessing Impacts to the Donor Population

Ideally, impacts on the donor population of removing birds for translocation are assessed through the experimental approach of adaptive management (discussed in more detail below). Using this approach, donor populations are divided into one or more treatment blocks that undergo removal of birds, and one or more control areas from which no birds are removed. These assignments should be as free as possible of potentially confounding effects, such as systematic differences in habitat type or quality. Treatment and control areas are then randomly sampled at a sample size large enough to support statistical comparison. As a minimum, monitoring of samples consists of cluster activity checks and nest checks/morning follows, to derive number of active clusters and number of potential breeding groups. Preferably, all groups within the treatment and control areas are color-banded so that effects on group size and/or reproductive success (Appendix 2) can be estimated. Statistical comparisons can then be made of the proportion of clusters remaining active from one year to the next, the proportion of clusters retaining potential breeding groups from one year to the next, average group size, and/or reproductive success between treatment and control areas. Statistically significant differences in these variables will be important documentation of translocation impacts.

Currently, such experimental assessment of translocation impacts is strongly recommended but not required for participation in the translocation program. The minimum level of monitoring for donor populations is the same as that described for determining population size and trend above: monitoring number of active clusters and potential breeding groups through cluster activity checks, nest checks, and morning follows for a randomly selected sample of the size recommended in 8C, Table 11. Additionally, knowledge of group composition is required of the groups donating birds to determine bird availability (see above). If a negative change in population status is documented by this level of monitoring, such that the population no longer meets the criteria necessary to be a donor population as listed in 8H, the donor population may not contribute birds for translocation until the criteria are once again met. Without the experimental approach described above, it will not be known whether the change in population status is specifically due to removal of birds. However, regardless of the cause of the change, once a population no longer meets eligibility criteria no more birds can be removed until these criteria are once again met.

Monitoring Success of Translocations

Monitoring success of translocations is a critical aspect of the translocation program (3D, 8H). A translocation event is considered successful if the translocated bird obtains a breeding position in the target area, and the target area is defined according to the explicitly stated objective of each translocation. For more information on defining translocation success, see 3D and 8H. Once a translocated bird is released, no observations are required until the following breeding season. Observations of translocated birds should be minimized to reduce disturbance as much as possible.

Populations must be completely color-banded to qualify for population augmentation (receiving birds from donor populations). This requirement helps to ensure that recipient populations are managed at an intensity level appropriate to the great value inherent in the individual red-cockaded woodpeckers being translocated. This requirement also ensures that translocation success is accurately evaluated. Monitoring group size and reproductive success through complete color-banding (Appendix 2) yields knowledge of group composition necessary to accurately track status and location of translocated individuals.

For within-population translocations, monitoring requirements are less intensive. Groups within target areas should be banded to track success of the translocation. Donor groups have to be color-banded to identify available birds. Regular monitoring for size and trend is conducted as described above.

In addition to documenting the success or failure of an individual translocation event, monitoring can be used to better understand the benefits of translocation to recovering populations. Here the question is, how and how much does translocation contribute to population increases? Again, assessment of treatment effects is best achieved through the experimental approach of adaptive management. Such an approach consists of dividing the population into treatment areas receiving birds and control areas to which no birds are translocated. Treatment and control areas are best monitored by color-banding, which gives excellent estimates of group size, reproductive success, and change in proportions of active clusters and potential breeding groups. Statistically significant differences in these important metrics would provide important evidence of population-level benefits of translocation.

Such an approach may be difficult to use in populations undergoing population augmentation because only critically small populations (less than 30 potential breeding groups) are eligible to receive birds from donors. Thus, sample sizes of treatment and control areas would be low. Also, translocated birds may potentially appear anywhere within the population, and therefore treatment and controls may be difficult to delineate. Still, an experimental approach applied in any population undergoing translocation could potentially supply extremely valuable information on this management technique, whether the birds are sourced within or outside the population.

Evaluating other Management Actions

Population monitoring can be used to evaluate effects of other management actions as described for assessing population-level benefits of translocation, above. Such an approach is the foundation of adaptive management, in which management itself is conducted as an experiment and is responsive to new information gathered in this way. Delineated sections of populations receive treatment, and metrics such as group size and reproductive success (Appendix 2) or changes in proportions of active clusters and potential breeding groups (Population Size and Trend, above) are evaluated for statistically significant differences between treatments and controls. Some management activities that should be assessed in this way include restoration of site-appropriate pine species and pine thinning. Certain management activities, such as frequent prescribed burning, midstory reduction, and maintenance of suitable cavities, are to be applied in all clusters and therefore are not to be subjected to experiments.

Evaluating Impacts of Activities other than Species Management

Documentation of specific impacts of non-management activities on red-cockaded woodpeckers requires intensive monitoring. Examples of activities that may impact red-cockaded woodpeckers are development (e.g., roads, golf courses, housing areas), military training (e.g., impact areas, mechanized training, bivouacs, etc.), and timber management practices (e.g., thinnings, harvests). Monitoring is often required to document effects of the implementation of Reasonable and Prudent Alternatives and Reasonable and Prudent Measures pursuant to Section 7 of the Endangered Species Act.

Intensive monitoring of potential impacts consists of collecting data on cluster activity, group status, group size and composition, and reproductive success. Often, this intensive monitoring is restricted to affected clusters and sometimes neighboring clusters. This is usually done in assessing incidental take (see 4A) as related to a given activity, but such studies are often inadequate to provide definitive evidence of the cause of losses, especially since some losses may not manifest until years after the initial impact.

Impacts to woodpecker groups are best measured by an experimental approach in which treated clusters are paired with control clusters. We recommend these experiments be designed by biologists experienced with the study population, using input from a wildlife statistician. Simple monitoring of affected groups, as described above, can only document their continued existence. Experiments, however, may reveal impacts to group size or reproduction and can identify causes of effects as well.

Mitigation Monitoring

Monitoring may be required for implementation of Habitat Conservation Plans pursuant to Section 10 of the Endangered Species Act and for actions taken to offset violations of Section 9 of the Act. These cases generally require the use and documentation of specified monitoring actions. For further information concerning mitigation, see 4A.

Monitoring for mitigation includes (1) monitoring of clusters to be impacted and the neighboring clusters, and (2) monitoring of the population containing the mitigation site. The level of monitoring for impacted and neighboring clusters is determined on a case-by-case basis. Monitoring of the population containing the mitigation site is typically intensive, consisting of complete color-banding and assessment of cluster activity, potential breeding groups, group size, and reproductive success. Documentation of newly created groups requires comprehensive knowledge of the current distribution of woodpecker clusters and groups within the subject population.

This comprehensive knowledge of the population to contain the mitigation site is needed prior to the installation of artificial cavities. If artificial cavities are placed too close to another group (0.4 km [0.25 mi] or less), the provisioned site is likely to be captured by the adjacent group and no new group will be formed. If artificial cavities are placed too far from other groups (more than 1.6 to 3.2 km [1 to 2 mi]), the likelihood of woodpeckers finding the new site is reduced unless translocation is used.

Comprehensive knowledge of the mitigation site is also necessary for accurate determination of new group formation. Formation of a new group cannot be assumed from simply observing red-cockaded woodpeckers in the provisioned site unless the birds observed are known not to be part of a previously existing group. Birds from adjacent groups can be expected to routinely forage around and within the new site and may cross-roost in the new cluster. Mitigation is successful only when monitoring clearly demonstrates that a new group (of equivalent status to the group impacted, solitary male or potential breeding group) has been formed and that it represents a net gain of one group in the area occupied by the provisioned site and all immediately adjacent territories (within 3.2 km [2 mi]). The newly established group has to remain in the cluster for at least six months, including the breeding season, or there is evidence of nesting (i.e., one or more eggs are laid). Such determination is only possible through intensive monitoring including color-banding (Appendix 2).

Research Monitoring

Research monitoring is used to investigate all aspects of the biology of red-cockaded woodpeckers, including, but not limited to, demography, social behavior, and habitat use. Color-banding of red-cockaded woodpeckers is often conducted. Research monitoring that involves handling, banding, or disturbance of red-cockaded woodpeckers requires the appropriate state and federal endangered species and bird banding permits. Typically, but depending on the circumstances, a Section 7 consultation and/or Section 10 Scientific Research Permit may be required.

Annual Reporting of Monitoring Results

Managers are required to submit an Annual Red-cockaded Woodpecker Population Data Report (hereafter referred to as Annual Report) to the Red-cockaded Woodpecker Recovery Coordinator containing results of their annual monitoring efforts. Such reporting is a critical aspect of woodpecker management and recovery.

B. CAVITY MANAGEMENT: ARTIFICIAL CAVITIES AND RESTRICTOR PLATES

Loss of cavities and cavity trees was a primary cause of the decline of red-cockaded woodpeckers, and is a substantial threat currently (see 1A, 1B). Today's forests simply do not contain sufficient numbers of mature and old growth trees for populations to remain stable or increase in the absence of human intervention. Red-cockaded woodpeckers will abandon clusters if sufficient suitable cavities are not available. Cluster abandonment can lead directly to population extirpation (Costa and Escano 1989), because populations of red-cockaded woodpeckers are regulated by the number of potential breeding groups rather than by annual variation in reproduction and survival (Walters 1991; see 2B), and because natural formation of new clusters is very slow at least under current conditions of relatively young forests and small populations (see 2B). Therefore, cavity management through the use of artificial cavities and restrictor plates is absolutely critical to the conservation of most populations.

Cavity ecology, including reassons why the birds need mature and old growth trees, is discussed in 2D. Community ecology, including the use and enlargement of red-cockaded woodpecker cavities by other species, is discussed in 2F. In this section, we describe the various methods of artificial cavity installation and their respective advantages and disadvantages, and also show how restrictor plates are used. Guidelines for the use of artificial cavities and restrictor plates are presented in 8E.

Artificial Cavities

Artificial cavities for red-cockaded woodpeckers were developed in the late 1980's and early 1990's (Copeyon 1990, Copeyon *et al.* 1991, Allen 1991, Taylor and

Hooper 1991), and have since revolutionized management of red-cockaded woodpeckers. Prior to their development, biologists were unable to address the severe limitation in cavities impacting most populations, and therefore had little ability to slow, much less reverse, the decline of the species. With the advent of artificial cavity technology, cavities and entire clusters can be provided. In combination with aggressive habitat management, cavity management can stabilize and increase populations.

The power of the new technology to conserve and protect red-cockaded woodpeckers was illustrated soon after development, when Hurricane Hugo destroyed nearly 90 percent of the cavity trees on the Francis Marion National Forest in 1989. Rapid and extensive use of drilled cavities and cavity inserts following the devastation saved a large proportion of the population and allowed for population growth in subsequent years (Watson *et al.* 1995). During the 1990's, many other populations were stabilized, and some increased, through cavity provisioning in combination with prescribed burning. In addition, other recently developed conservation and management tools such as translocation, mitigation, and Habitat Conservation Plans are based to a large degree on the use of artificial cavities.

However, artificial cavities have not always been used effectively. Widespread and haphazard installation of artificial cavities can have negative impacts on red-cockaded woodpeckers and their potential cavity trees, and misdirects valuable management efforts and funds. Before artificial cavities are installed, managers should have a clear understanding of population dynamics in this species, especially the role of cavities and the effects of spatial structure on population growth or decline (see 2B, 2C). In addition, managers need to be well versed in the benefits and drawbacks of the various installation methods, so that they know what to expect of cavities already installed in their populations and can choose the appropriate method for additional cavities. Finally, proper maintenance of artificial cavities is essential (e.g., Montague et al. 1995).

There are basically four methods of constructing artificial cavities: Copeyon-drilled cavities and starts, cavity inserts, and modified drilled cavities. Copeyon-drilled cavities and starts were developed at North Carolina State University (Copeyon 1990). Cavity inserts were developed at the Southeastern Forest Experiment Station of the U.S. Forest Service, Clemson University (Allen 1991). Taylor and Hooper (1991) created the modified version of Copeyon's drilled cavity.

Basically, drilled cavities are constructed by drilling two tunnels: first, an entrance tunnel that the birds will use, and second, an access tunnel that is then used by the drill operator to ream out the cavity chamber. The access tunnel is plugged and sealed after the chamber is constructed. The two drilled methods, Copeyon and modified drilled, differ in the dimensions of the access tunnel and consequently in their durability. Drilled starts are drilled entrance tunnels with a widened interior. Cavity inserts are pre-fabricated nest boxes inserted into an opening in the tree created with a chainsaw. More detailed descriptions of these techniques are given below, followed by a comparison of their relative merits and applications.

Construction of Copeyon-drilled Cavities and Starts

The Copeyon-drilled method of cavity construction is illustrated in Figures 2 and 3. Candidate trees for Copeyon-drilled cavities must have at least 15.2 cm (6 in) of heartwood and no more than 8.9 cm (3.5 in) of sapwood, and less sapwood is preferred.

To construct the cavity, a gasoline-powered drill equipped with a wood-boring bit 5.1 cm (2 in) in diameter is used to excavate an entrance tunnel through the sapwood and into the heartwood, at a slightly upward angle. The same bit is used to begin a second tunnel 5.1 to 10.2 cm (2 to 4 in) above the entrance tunnel. This access tunnel is then continued at a downward angle of roughly 60 degrees, using a 4.2 cm (1.65 in) bit, until the back of the entrance tunnel is intersected and 7.5 to 10 cm (3 to 4 in) below the entrance tunnel have been opened to form a rudimentary chamber. The rudimentary chamber is then hollowed out, using the 4.2 cm (1.65 in) bit, to complete the cavity. The extent to which a cavity approaches the shape and dimensions of a naturally excavated cavity depends on the width of sapwood, the diameter of the heartwood core, and the skill of the drill operator. Care must be taken to avoid drilling into the sapwood at the front of the cavity chamber, by drilling at too steep an angle, or at the rear of the cavity, by drilling too deep.

The access tunnel is sealed with wood plugs and non-toxic wood putty. A thin, flexible wood veneer called “wiggle board” may be used to line the entrance tunnel instead of wood putty. A comprehensive maintenance schedule is required in the weeks immediately following construction, to inspect for resin leakage.

Upon completion of the cavity, resin wells are drilled with a 1.3 cm (0.5 in) twist bit or cut with a knife or chisel, and the area several feet above and below the cavity is scraped with a bark knife or hoe blade to give the tree the reddish appearance of an active red-cockaded woodpecker cavity tree. Non-toxic white or almond paint is sprayed below resin wells, above and below the cavity entrance, and completely around the tree bole in the vicinity of the cavity to simulate natural pine resin.

Drilled starts are constructed using the above method to create an entrance tunnel (Figure 3). The access tunnel and cavity chamber are not constructed. Instead, a 4.2 cm (1.65 in) bit is used to enlarge the rear of the entrance tunnel (within the heartwood) to give the red-cockaded woodpecker room to excavate the cavity chamber. Such an advanced start may be large enough for a red-cockaded woodpecker to roost within, and red-cockaded woodpeckers can complete a drilled start in several months to a year (J. Carter III, pers. comm., Harding 1997). Drilled starts can be placed in trees with too much sapwood and/or too little heartwood to accept a drilled cavity.

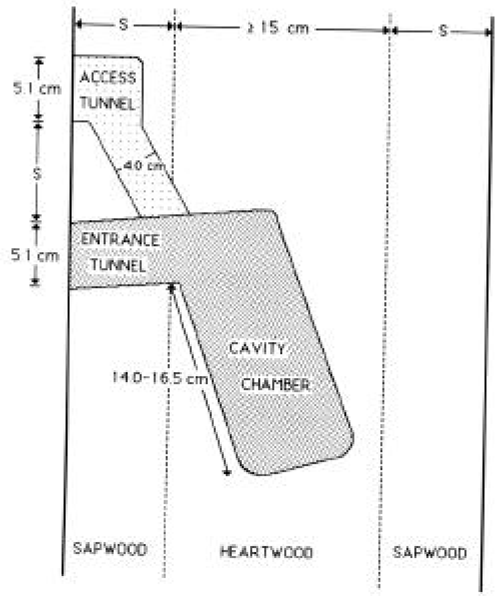


FIGURE 3. Diagram of Copeyon-drilled cavity (Copeyon 1990). Copyright Wildlife Society Bulletin; used with permission.

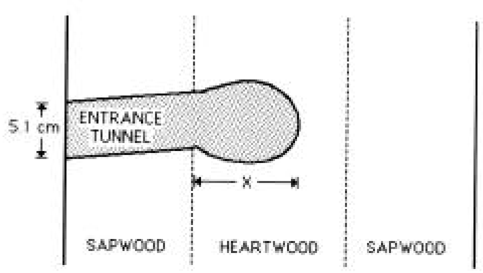


FIGURE 4. Diagram of Copeyon-drilled start (Copeyon 1990). Copyright Wildlife Society Bulletin; used with permission.

Construction of Modified Drilled Cavities

Taylor and Hooper's (1991) modification of Copeyon's drilled cavity technique differs from the original technique in that larger bits are used to begin the access tunnel (8.9 cm [3.5 in] bit) and to construct the vertical access tunnel and cavity chamber (7.6 cm [3 in] bit). Using this technique, most of the access tunnel and cavity chamber can be excavated at once. Resin wells are created and the trunk is painted to resemble a natural cavity tree just as described above.

Construction of Cavity Inserts

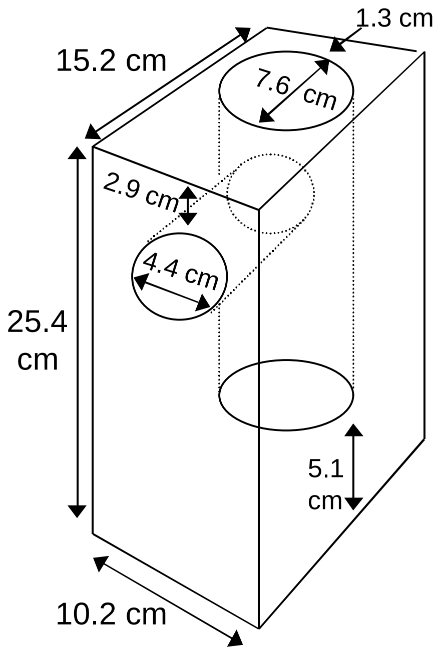
The cavity insert (Allen 1991) is a completely different approach to cavity construction. In this method, a chainsaw is used to cut a rectangular opening in a pine tree, and a wooden block with a pre-drilled cavity is inserted into the opening (Figure 4). The cavity insert is secured in the tree with wooden wedges and non-toxic wood putty. A full frontal restrictor plate is used to prevent damage by pileated woodpeckers. Because inserts may be placed in trees that are mostly sapwood, the insert must be heavily coated with a non-toxic waterproof sealant to prevent resin leakage through small, sometimes imperceptible, cracks into the cavity chamber. Cavity inserts are held primarily within the sapwood of the tree, and so can be placed in pines that have little heartwood. Trees of at least 38.1 cm (15 in) in diameter at cavity height are required. (If trees of this size are not available, use the drilled cavity or drilled start technique). Resin wells are created, and the trunk is scraped and painted to simulate a natural cavity tree.

Southern yellow pine (*Pinus* spp.) is the preferred wood to use in constructing inserts. In the past, western red cedar (*Thuja plicata*) was used, but we now suggest using southern yellow pine as it is a harder wood than western red cedar.

Comparison of Construction Methods

Preliminary work evaluating the four methods of cavity provisioning was conducted in the Francis Marion National Forest (Hooper *et al*., unpublished), an appropriate location for such an investigation because of the large-scale provisioning of all cavity types following Hurricane Hugo. Although the population increased rapidly following the devastation of Hugo (Watson *et al.* 1995), a declining trend has been present since 1996 (USFWS, unpublished). Aging of the artificial cavities is considered a potential contributing factor to recent declines, in addition to problems implementing the prescribed burning program.

FIGURE 5. Diagram of a cavity insert (adapted from Allen 1991). Full restrictor plate and non-toxic coating, both required on all inserts, are not illustrated here.



Hooper *et al.'s* (unpublished) data suggests that Copeyon-drilled cavities and starts remain in use for a remarkably long period. After an average of 8.5 years, more than two-thirds of Copeyon-drilled cavities remained in use, and one quarter of the remaining available Copeyon-drilled cavities were in use as nest cavities. Half of all the original drilled starts were in use as cavities 8.5 years later, and one quarter of the remaining available cavities that were originally drilled starts were in use as nest cavities. Cavity inserts did not exhibit the same durability. Just less than half of cavity inserts remained in use after 8.5 years, and none were used as nest cavities. However, cavity inserts were installed in clusters of consistently lower quality than those in which drilled cavities were placed (D. Allen, pers. comm.). Because clusters receiving inserts had suffered heavier hurricane damage and had virtually no old pines remaining after the storm, comparisons of durability between inserts and drilled cavities are biased by differential habitat quality. Modified drilled cavities showed the lowest durability of all cavity types, without the same systematic bias in habitat quality. Less than one third of modified drilled cavities were used an average of 7.3 years later, and none as nest cavities.

Differences in cavity survival did not appear to result from differential mortality of trees holding the various cavity types (Hooper *et al.*, unpublished). Less than 2 percent of pines with artificial cavities died from structural failure of the tree bole resulting from cavity installation, and this did not differ between trees containing inserts and those with drilled cavities. Cavity trees with inserts did not appear to suffer more damage from wind or physiological stress than other cavity trees, a conclusion also reached by Lowder (1995). Instead, lowered survival of inserts was due to higher rates of flooding and cavity enlargement. Inserts were not fitted with full restrictor plates (below), which would have reduced enlargement rates considerably. Almost half of all inserts had the interior altered by the birds to the point where the insert was breached and the tree itself was visible. Such expansion did not appear to affect the activity status of the inserts.

Lowered survival of modified drilled cavities was due to high rates of damage to the entrance tunnel and access plug. The larger access plug was far more likely to rot, and the septum between the access plug and entrance tunnel was more likely to be altered by decay or by other woodpeckers, than were those of Copeyon-drilled cavities. Enlargement of completed drilled starts was negligible.

Recommended Construction Methods

In light of the current value of cavity trees and potential cavity trees, we have formulated careful guidelines for the construction of artificial cavities (see 8E). Copeyon-drilled cavities are recommended for cavity provisioning if pines with sufficient heartwood are available. Managers may choose to drill starts instead of cavities if the cavities are not likely to be needed for a year or more. (Drilled starts over one year in age were found to be as useful to the birds as Copeyon-drilled cavities; Hooper *et al.*, unpublished.) Use of inserts is recommended when cavities are needed rapidly and there are no pines old enough to support a Copeyon-drilled cavity. Use of the modified drilled method of cavity construction is to be avoided.

Use of either method of artificial cavity installation, cavity inserts or drilled cavities, requires conscientious and careful application with special attention to potential problems specific to each method. Inserts require a full restrictor plate and heavy coating with a non-toxic waterproof sealant. All inserts must be inspected carefully for cracks prior to and following installation; any damaged inserts should be discarded. Flooding of inserts can be minimized by using restrictors, by constructing entrance tunnels at a slightly upward angle, and by drilling a drainage hole, 0.95 cm (0.375 in) in diameter from the lower front of the box to the bottom of the cavity chamber. Finally, red-cockaded woodpeckers have a tendency to breach the cavity chamber of inserts. This behavior has the potential to result in resin-related deaths, although it is likely that such breaching occurs slowly enough to allow resinosis (saturation of sapwood with hardened resin; see Conner and Rudolph 1995a), and that resin leaks into the cavity chamber are rare.

When Copeyon-drilled cavities and starts are used, it is imperative that they be screened for at least one month following installation and checked for resin leaks as described below. All artificial cavities and starts must be inspected and maintained as described below and in section 8E.

Cavity Screening, Resin Leakage, and Maintenance Checks

All drilled starts and drilled cavities must be screened with heavy wire mesh (0.64 by 0.64 cm [0.25 by 0.25 in]) to prevent access by red-cockaded woodpeckers for at least four weeks after installation to ensure that no resin is leaking into the cavity chamber. If leaks are detected, cavities must remain screened and additional checks conducted. Persistent resin leakage into entrance tunnels can be treated using repeated scraping, applications of wood putty, replacement of wooden veneer, or redrilling with a 5.1 cm (2 in) diameter bit. If the leak is severe, cavities should be blocked with a wooden plug at least 7.6 cm (3 in) long and replaced elsewhere. Artificial cavities and starts should be constructed during the non-growing season (except in emergencies) to reduce the likelihood of resin leakage.

All artificial cavities, including inserts, and drilled starts should be checked for latent resin leakage during the first growing season after installation. If this check is negative no further maintenance checks are required for drilled starts and cavities unless the entrance tunnel begins to heal over from lack of red-cockaded woodpecker use. If an entrance tunnel is redrilled or scraped, screen it again as described above. Inactive artificial starts and cavities require periodically redressing of resin wells and rescraping of bark to enhance the likelihood of discovery and occupation by red-cockaded woodpeckers.

Cavity Height, Orientation, and Location

In general, artificial cavities should be placed as high as the recipient trees will allow, within the range of natural cavity heights in the surrounding habitat. Height of drilled cavities may be limited by the amount of heartwood present, and height of inserts may be limited by tree diameter; both will vary according to local conditions. For example, sites with low site index such as sandhills will support only low cavities. Cavities should be oriented so that the entrance faces west, because natural cavities show a tendency to be oriented in this direction (Locke and Conner 1983).

Cavities should be constructed within 66 m (200 ft) of existing cavity trees to maintain the integrity of the cluster. Inserts should not be placed in pines less than 45 years old, because the growth of the tree could damage the insert and possibly result in a dangerous situation. Additionally, inserts are not to be placed in relicts, flat-tops, and very old pines; these extremely valuable trees should be left for natural excavation or, if absolutely necessary, used to support drilled cavities.

Number and Definition of Suitable Cavities

Carrie *et al.* (1998) found that group size of red-cockaded woodpeckers in Louisiana increased with the number of cavities provisioned, and recommended a minimum of three to four suitable cavities per cluster. Results of the study more clearly supported the use of four suitable cavities rather than three as a minimum. A minimum of four suitable cavities per cluster has also been the traditional policy of the U.S. Fish and Wildlife Service. We therefore recommend that each cluster contain at least four suitable cavities. This recommendation does not apply to populations that have met the population goals identified in delisting criteria or in site-specific management plans.

A suitable cavity has a single entrance, an entrance tunnel that is not enlarged, a cavity chamber that is not enlarged, a solid base, and is dry and free of debris. In addition, the cavity plate must not contain large amounts of dead wood (Carrie *et al.* 1998). Relict, enlarged, or any suspect cavities must not be considered suitable for use by red-cockaded woodpeckers.

Restrictor Plates

The cavity restrictor was developed at North Carolina State University in the mid-1980's (Carter *et al.* 1989), to prevent and repair the enlargement of red-cockaded woodpecker cavity entrances. Cavity restrictors are square or rectangular metal plates with an inverted U-shaped or circular opening, 3.8 to 4.4 cm (1.5 to 1.75 in) wide, in the center of the plate. Typically, they are made of approximately 22-gauge stainless steel, aluminum, or sheet metal; expanded metal and quarter-inch hardware cloth are also suitable. Restrictors range in size from 7.6 by 7.6 cm (3 by 3 in) to much larger. Smaller restrictors are used for starts and cavity entrances that show little damage, while the largest sizes are used for enlarged cavities and to cover the front of cavity inserts. Cavity inserts are now fitted with full restrictor plates prior to installation.

The inverted U-shape opening was the original design (Carter *et al.* 1989). The opening extends from the entrance hole to the bottom of the restrictor plate, allowing the birds' feet to contact the tree surface when entering and exiting the cavity. If restrictor plates with circular openings are used, the metal directly below the opening of the entrance tunnel must be removed to allow the birds a secure foothold. Care must be taken to ensure that this metal is not so rough or jagged as to cause injury to the birds' toes or feet. Smooth, slick metal below the entrance is a deterrent to red-cockaded woodpecker use and may completely prevent use of some cavities.

For natural and drilled cavities, restrictors are attached to the tree with nails or screws at all four corners placed in pre-bored holes. Wood screws (1.3 cm [0.5 in] long) are preferred over nails because they allow easy repositioning of the restrictor with minimal damage. Screws or nails longer than 2.54 cm (1 in) should not be used because the cavity chamber may be breached, creating a hazard for cavity occupants. Restrictors are often painted brown with a non-toxic paint in order to blend with the tree.

The primary use of restrictors is to repair or prevent enlargement of cavity entrances (see also 2F), usually done by pileated woodpeckers but occasionally by red-bellied and red-headed woodpeckers, northern flickers (*Colaptes auratus*), and gray squirrels (*Sciurus carolinensis*. Pileated woodpeckers can seriously damage cavities in just minutes, and can completely destroy cavities in less than an hour, but the reasons for this behavior remain unknown. Further, pileated woodpeckers may damage some cavities in a cluster, while leaving others unharmed. Some cavities, or entire clusters, can exist undamaged for years in areas frequented by pileated woodpeckers, then suffer a sudden onset of damage. In extreme circumstances, pileated woodpeckers can damage or destroy most or all cavities in a cluster, leading to cluster abandonment. Commonly, a cluster suffers chronic damage over several years, leading to cluster instability and eventual abandonment. Because of the critical importance of suitable cavities to red-cockaded woodpeckers, use of restrictors to prevent and repair damage is an essential element of management for many populations. The number of cavities restricted in a cluster will vary according to circumstances, and may range from none to all cavities present. Knowing when to use restrictors to prevent damage, and when their use is not necessary, is a skill gained from experience and good judgment.

Whereas pileated woodpeckers can destroy red-cockaded woodpecker cavities by doubling the diameter of the entrance tunnel and exposing the cavity chamber, red-bellied woodpeckers, red-headed woodpeckers, and flickers normally enlarge cavity entrance tunnels and cavity chambers only enough to allow access. Over several years, these species can modify a cavity so that red-cockaded woodpeckers will rarely, if ever, use it. Although some rate of loss of red-cockaded woodpecker cavities due to modification by other species is natural, red-cockaded woodpeckers cannot always tolerate such losses in today's forests. In small, declining, or isolated populations, any loss of suitable cavities may not be tolerable. It will usually be necessary to use restrictors to repair enlargement by these species in such populations.

In the past, restrictors were sometimes used to exclude some avian cavity kleptoparasites, such as red-bellied woodpeckers, red-headed woodpeckers, and European starlings (*Sturnus vulgaris*), from cavities with either enlarged or unenlarged entrance tunnels. Variation in diameter of natural entrance tunnels allows access of some individuals or species to some cavities. For instance, both male and female red-bellied woodpeckers can enter some natural, unenlarged entrance tunnels, while only the slightly smaller females can access others. Eastern bluebirds and southern flying squirrels can access all cavities. However, use of restrictors on unenlarged cavities to exclude cavity kleptoparasites is not recommended, because of danger to red-cockaded woodpeckers. The difference between excluding a starling and excluding or entrapping a red-cockaded woodpecker is a matter of millimeters. Several deaths of adult red-cockaded woodpeckers resulting from entrapment in restricted cavities have been documented in the North Carolina Sandhills (J. Carter III, pers. comm.). In many cases, the affected red-cockaded woodpecker had successfully entered the cavity, but could not exit. Given that population-level impacts of cavity kleptoparasitism have not been demonstrated (Kappes 1993, Conner *et al.* 1996, Mitchell *et al.* 1999; see 2F), there is little justification for use of restrictors to exclude kleptoparasites.

Restrictors must be inspected annually, because restrictors that have loosened or come out of place are a serious hazard to red-cockaded woodpeckers and have resulted in multiple deaths throughout their range (R. Costa, pers. comm.). Injury and death can result from feet, wings, or legs of birds being caught under the edges or corners of restrictors. In populations where annual monitoring can not be accomplished, restrictors will not be used. Restrictors may have subtle costs as well: examination of a limited number of adult red-cockaded woodpeckers using restricted cavities showed visual evidence of excessive bill wear (J. H. Carter III, pers. comm.). Raulston *et al.* (1996) concluded that restrictors did not affect woodpecker survival or bill wear, but this was a small, short study and further research is warranted. With proper inspection and maintenance, restrictors may help keep a cavity in use for many years (Wood *et al.* 2000).

In summary, restrictors are an important management tool, but they must be used in the appropriate situations only, installed by experienced personnel, and monitored annually. Widespread use of restrictors without specific need for them is not recommended, because they are potentially dangerous. Cavity restrictors are best used to prevent or repair enlargement of cavities by pileated woodpeckers. In small populations, their use against cavity damage by other species may also be necessary. Restrictors should not be used to prevent starlings and other woodpeckers from using the cavity, because red-cockaded woodpeckers can be entrapped as well.

C. Predator and Cavity Kleptoparasite Control

Red-cockaded woodpecker populations that are healthy and of medium to large size require no predator control and few measures to combat cavity kleptoparasites. Predators and cavity kleptoparasites were not among the original causes of the decline of red-cockaded woodpeckers, and their removal or control will not result in population or species recovery. Critically small populations, however, may not be able to tolerate even occasional loss of nests or cavities. Managers of critically small populations (less than 30 potential breeding groups) may choose to use predator management techniques, but only in concert with aggressive management of foraging and nesting habitat.

But, managers should be aware that predator exclusion devices may have unexpected consequences, since indirect interactions among predators, kleptoparasites, and red-cockaded woodpeckers are not understood. For this reason, use of snake exclusion techniques is generally discouraged. Snake exclusion devices should only be considered for trees containing newly installed artificial cavities or on active trees with a minimal resin barrier that are likely to be used as nest sites. If predator management is conducted, use of an experimental approach with adequate controls is strongly encouraged.

Methods of predator and kleptoparasite control are described in this section, and guidelines for their use are presented in 8G. A general discussion of predation, cavity kleptoparasitism, and cavity enlargement is given in 2F, and use of restrictors to control cavity enlargement is described in 3B and 8E. Most control measures used in red-cockaded woodpecker populations have been designed for one of two taxa: flying squirrels and rat snakes. Methods vary from lethal measures to non-invasive techniques such as bark shaving (Saenz *et al.* 1999), provision of nest boxes (Loeb and Hooper 1997), and retention of snags (Kappes and Harris 1995). In general, the least invasive techniques are preferred.

Exclusion of Rat Snakes

Three artificial methods of excluding rat snakes from cavity trees have been explored: snake nets, snake excluder devices (SNEDs), and the bark-shaving technique. Snake nets were developed by Neal *et al.* (1993b, 1998), and consist of a folded nylon monofilament net stapled to cavity trees at roughly 1.5 m (5 ft) above the ground. Rat snakes attempting to climb cavity trees get entrapped in the nets and soon die from heat stress. Red-cockaded woodpeckers can also get caught in these nets. Samano *et al.* (1998) reported the death of four red-cockaded woodpeckers and the entrapment of a fifth (rescued by biologists) in snake nets in a single year. Because of the documented danger to red-cockaded woodpeckers and the lethal effects on snakes, use of snake nets is prohibited.

Snake excluder devices (SNEDs) were developed by Withgott *et al.* (1995), and consist of a strip of lightweight aluminum flashing attached to the trunk of the cavity tree at ground level or up to 1.5 m (5 ft) above the ground. Withgott *et al.* (1995) used a 60 cm (23.6 in) wide band of aluminum flashing that they wrapped around and stapled to the bole of cavity trees. Prior to stapling the flashing in place, the bark on the bole of the cavity tree was scraped to smooth the surface and permit a tighter fit. The bark was also scraped relatively smooth about 30 cm (1 ft) above and below each SNED after installation. SNEDs proved to be highly effective in preventing climbing by rat snakes, and did not appear to affect use of the tree by red-cockaded woodpeckers (Withgott *et al.* 1995). Neal *et al.* (1998) reported numerous over-climbs of SNEDs on red-cockaded woodpecker cavity trees in Arkansas and Mississippi that were fitted with narrow metal flashing (less than 0.9 m [3 ft]), whereas only one over-climb occurred on 92 cavity trees fitted with metal flashing greater than 0.9 m (3 ft) wide. Thus, SNEDs greater than 0.9 m (3 ft) wide appear to be an effective, non-lethal method to reduce rat snake predation on red-cockaded woodpecker nest cavities. SNEDs require adequate annual maintenance, to check for dangerous tears in the aluminum and to remove any resin accumulation.

Bark-shaving was recently developed by Saenz *et al.* (1999) as an effective means of deterring climbing by rat snakes. A very sharp draw knife is used to shave the bark around the circumference of the tree in a 1 m (3.3 ft) band, at breast height, to eliminate furrows and rough surfaces without cutting into the cambium (Saenz *et al.* 1999). Breast height was chosen for ease of execution. This technique proved to be nearly 100 percent effective in experimental trials, and the one over-climb event occurred 3 ½ months after shaving on a tree that had developed a rough surface again (Saenz *et al.* 1999). Reshaving prevented the snake from climbing this tree again. Thus, bark-shaving can be used at the start of the nesting season or upon installation of artificial cavities, to give roughly three months of additional protection. Care must be taken not to damage the cavity tree by cutting into xylem tissue. Also, resistance to fire may be decreased by bark-shaving (Saenz *et al.* 1999), and any cavity tree thus treated should be well protected against fire.

The resin barrier created by red-cockaded woodpeckers is an extremely effective means of excluding rat snakes from cavity trees, especially in highly resinous longleaf pines (Ligon 1970, Dennis 1971b, Jackson 1974, 1978a, Rudolph *et al.* 1990a). In longleaf pine habitats, no additional measures are needed to control rat snakes regardless of population size. For critically small populations (less than 30 potential breeding groups) in pine types other than longleaf, managers may choose to install snake excluder devices or use the bark-shaving technique on trees likely to be used as nest trees. Managers may also choose to use bark-shaving to provide short-term protection against snakes when installing artificial cavities. Bark-shaving may be especially useful just before the nesting season, to protect active artificial cavity trees that do not yet have a resin barrier.

In summary, use of snake exclusion techniques should be restricted to pines containing newly installed artificial cavities, or pines with minimal resin but likely to be used as nest sites, in critically small populations. Use of snake exclusion techniques in other situations is discouraged.

Exclusion of Southern Flying Squirrels

Southern flying squirrel excluder devices (SQEDs) were developed by Montague *et al.* (1995), and consist of sheets of aluminum flashing that are wrapped around the cavity tree above and below the cavity entrance. Small portions of the flashing extend perpendicular to the bole of the pine tree. If kept clean of hardened pine resin, the SQEDs serve as an effective barrier and deny squirrel access to red-cockaded woodpecker cavities when they climb up and down the bole of cavity trees (Montague *et al.* 1995, Loeb 1996). However, a "skilled" flying squirrel can fly directly to a cavity entrance if adjacent pines are sufficiently close to permit a glide path. SQEDs require inspection and maintenance at least yearly, to ensure no dangerous tears develop and to keep them free from resin. Again, use of SQEDs is not necessary in populations of 30 or more potential breeding groups.

Montague *et al.* (1995) recommended that cavities reclaimed from southern flying squirrels be vacuumed to remove chewed pine needles and squirrel feces that are typically present in cavities with squirrels. Cavity cleaning may increase the probability that red-cockaded woodpeckers will reoccupy the cavity.

Lethal vs. Non-lethal Methods of Control

Rat snakes, southern flying squirrels, and other predators and kleptoparasites are all important components of southern pine ecosystems. Measures to control these species should not be applied in all areas managed for red-cockaded woodpeckers. Large and medium-sized populations located in areas of quality habitat should have sufficient reproduction and population size to easily offset any losses caused by predation and kleptoparasitism.

However, in critically small populations (less than 30 potential breeding groups) where appropriate habitat is in the process of being restored, or where populations are being reintroduced, predator and kleptoparasite management may be applied. Retention of snags and creation of nest boxes are important management options (Harlow and Lennartz 1983, DeFazio *et al.* 1987, Kappes and Harris 1995, Loeb and Hooper 1997). Use of lethal devices and euthanasia to control predators and kleptoparasites is discouraged.

D. TRANSLOCATION

Translocation is the artificial movement of wild organisms between or within populations to achieve management objectives. It is an important tool for the management and recovery of red-cockaded woodpeckers, if used in the appropriate situations and in the appropriate manner. In this section, we describe the reasons for using translocation and give a brief review of its use and success in red-cockaded woodpecker management. Guidelines for its use are presented in 8H.

Translocation of red-cockaded woodpeckers has four specific applications for which it is best suited: (1) augmentation of a population in immediate danger of extirpation, (2) development of a better spatial arrangement of groups, to reduce isolation of groups or subpopulations, (3) reintroduction of birds to suitable habitat within their historic range, and (4) management of genetic resources. We refer to the first application as population augmentation. This consists of moving birds from a healthy donor population to a critically small recipient population (less than 30 potential breeding groups). We refer to the second application as strategic recruitment, which is achieved by moving birds from within or between populations to recruitment clusters strategically located to link groups and subpopulations. All translocations, including those intended to augment a population, should serve to develop better spatial arrangements of groups.

Population augmentation is a means of buffering at-risk recipient populations against effects of demographic and environmental stochasticity (see 2C), which can result in extirpation of critically small populations regardless of other management efforts. This management action also serves to counteract the inbreeding depression that can reduce the persistence of very small, isolated populations (Haig *et al.* 1993, Daniels *et al.* 2000). Augmentation is not necessary for larger populations because they are not so highly vulnerable to stochastic events (other than catastrophes).

Strategic recruitment is a means to develop the beneficial spatial arrangements that can dramatically increase persistence and health of red-cockaded woodpecker populations (Conner and Rudolph 1991b, Crowder *et al.* 1998, Letcher *et al.* 1998, Walters et al. 2002b). Linking isolated groups and subpopulations with newly established breeding groups in strategically located recruitment clusters may be a slow process, because each new cluster must be within helper dispersal distance of active clusters. However, over time strategic recruitment can optimize spatial arrangements of groups within populations.

Reintroduction is the establishment of new populations in restored habitat within the species historic range. Reintroduction is currently being used experimentally to establish a new population in northern Florida (Hagan and Costa 2001), but at this time it is not a management technique available for widespread use. Establishment of new populations is not a criterion for delisting the species. Still, reintroduction can have a critical role in restoration of historic communities and conservation of local species diversity.

For the purposes of population augmentation or strategic recruitment, a potential mate can be moved to a cluster inhabited by a solitary individual (mate provisioning), or potential pairs can be moved simultaneously to unoccupied clusters. Reintroduction of birds is best accomplished by simultaneously translocating multiple potential pairs to suitable habitat (Carrie *et al.* 1999, Hagan and Costa 2001). Another current application of translocation is its use for mitigation (see 4A). Future use of the technique may include the translocation of individuals among recovered populations and essential support populations to counteract species-wide genetic drift (see 2C).

Benefits and Drawbacks to Translocation

Translocation has its benefits and drawbacks. It can be an important method to counteract loss of genetic variation but may also serve to disrupt valuable local genetic resources (Haig *et al.* 1994a, Hedrick 1995). It is an especially useful tool in the management of red-cockaded woodpeckers, because population dynamics in this species are regulated by the number of potential breeding groups in a population, not the annual number of young produced (Walters 1991; see 2B). Therefore, some juvenile birds may be moved without affecting the overall population size or trend. However, impacts to the donor areas and populations must be carefully evaluated and controlled (Griffith *et al.* 1989, Haig *et al.* 1993). Most importantly, translocation must not be used as a substitute for habitat management and restoration, two more difficult but much more fundamental management tasks (e.g., Pitelka 1981, Meffe 1992). Causes of population decline should always be identified and removed before translocation is attempted (Short *et al.* 1992, Meffe 1992, Caughley 1994).

Translocation can potentially disrupt local adaptations and genetic coadaptation. Local adaptations to environmental conditions confer highest fitness to individuals remaining in a specific area, whereas genetic coadaptation gives highest fitness to those individuals retaining coadapted gene complexes. Coadapted gene complexes are sets of genes that evolved together and impart greater fitness than the sum of each individual gene's contribution. A coadapted gene's effect depends on the presence of one or more other genes (Templeton *et al.* 1986). In red-cockaded woodpeckers, there is no direct evidence of local adaptations or coadaptation, but researchers have documented some genetic structure across the species' range (Stangel *et al.* 1992, Haig *et al.* 1994a, 1996, Stangel and Dixon 1995). Restricting translocations to short geographic distances only is important to the conservation of local genetic resources (Haig *et al.* 1994a).

Translocation can also spread parasites. Fortunately, the prevalence of blood parasites in red-cockaded woodpeckers is low, and cavities are relatively free of blood-feeding insects (Pung *et al.* 2000).

Thus, in general, translocation of red-cockaded woodpeckers is a short-term tool to be used in specific crisis situations with utmost caution and only after habitat suitable in quality and quantity exists (Griffith *et al.* 1989, Kleiman 1989) and habitat management plans emphasizing frequent fire are fully implemented. In addition, translocation may have a long-term application among recovered populations to counteract species-wide genetic drift, if natural dispersal is deemed insufficient for adequate gene flow. Translocations for this purpose require careful planning to offset effects of genetic drift without affecting local genetic resources (see Hedrick 1995).

History of Translocation of Red-cockaded Woodpeckers

Prior to the development of artificial cavities (Copeyon 1990, Allen 1991) and translocation (DeFazio *et al.* 1987), many managers and biologists were pessimistic about the long-term persistence of red-cockaded woodpeckers (Ligon *et al.* 1986, Escano 1995). In particular, there was little hope of conserving and restoring the many small, declining populations. Recently, however, most populations have been stabilized and/or increased (Hooper *et al.* 1990, Richardson and Stockie 1995, Watson *et al.* 1995, Walters and Meekins 1997, Walters *et al.* 1997, USFWS unpublished). For some small populations, increases in population size were achieved through aggressive habitat management and cavity provisioning without resorting to translocation (Richardson and Stockie 1995, Watson *et al.* 1995, Walters and Meekins 1997, Walters *et al.* 1997, USFWS unpublished). However, the stabilization and increase of other critically small populations has required the use of translocation in concert with intensive habitat and cavity management (DeFazio *et al.* 1987, Allen *et al.* 1993, USFWS unpublished).

Initially, translocations were performed as emergency efforts to rescue individual birds from military construction impacts (e.g., Odom *et al.* 1982) or loss of habitat to timber harvests (e.g., Reinman 1984). These early efforts met with very little success, and several authors criticized the use of translocation especially as mitigation for destruction of occupied clusters (Cely 1983, Jackson *et al.* 1983). Odom (1983) concluded, “red-cockaded woodpecker relocation is not recommended as a management tool at this time”, but also noted its potential and called for further research. Following these initial attempts in the early 1980's, experiments were performed in the late 1980's and early 1990's to test translocation methods and its usefulness as a recovery tool (Allen *et al.* 1993, Costa and Kennedy 1994).

Perhaps the best known of these experiments in translocation was the extremely intensive effort to conserve and restore the critically endangered red-cockaded woodpecker population in the Savannah River Site in South Carolina (Allen *et al.* 1993, Gaines *et al.* 1995, Franzreb 1999). By late 1985, this population was reduced to one breeding pair and two solitary males (DeFazio *et al.* 1987) and aggressive management was begun, including habitat management, cavity installation, and translocation (Gaines *et al.* 1995). From 1986 to 1995, 54 red-cockaded woodpeckers were translocated, including 21 translocated from four donor populations outside the study area and 33 from within the population (Franzreb 1999). By 2000, the Savannah River Site population consisted of 31 potential breeding groups (P. Johnston, pers. comm.). Clearly, translocation was an important part of the dramatic change in this population’s status.

Following the success of the Savannah River Site translocation attempts (Allen *et al.* 1993), the Southern Region of the U.S. Forest Service decided to implement red-cockaded woodpecker translocations as a management tool in 1989 (Escano 1988). Because the Apalachicola National Forest in Florida contained the largest and only recovered red-cockaded woodpecker population, it was chosen as the primary donor population. From 1989 to 1992, 18 red-cockaded woodpeckers were translocated from the Apalachicola NF to seven other national forest units (Hess and Costa 1995).

Recently, translocation has been used with great success in the reintroduction of one population and to augment several extremely small populations. Reintroduction of red-cockaded woodpeckers into Avalon Plantation in Florida, beginning in 1998, has resulted in a population of 7 potential breeding groups in 2001 (Hagan and Costa 2001). The population at the Joseph W. Jones Ecological Research Center was increased, using translocation, from a solitary male in 1998 to 5 breeding pairs in 2001, and Southlands Experimental Forest increased from three males in 1997 to 8 potential breeding groups in 2001. Other recent examples of the successful use of translocation to augment critically small populations include increases in the Chickasawhay National Forest and Fort Jackson. Currently, translocation remains an important crisis management tool to be used with caution in appropriate circumstances.

Translocation Success

Efforts to measure the success of translocation as a management technique have been hampered by inconsistent data collection and differing definitions of success (Costa and Kennedy 1994). Definitions of success have varied, ranging from the individual being present soon after release to the fledging of offspring the following breeding season (Costa and Kennedy 1994). To further confuse the issue, definitions of success must change depending upon the objective of the translocation: for augmentation of a critically small population, reproduction of a translocated bird anywhere in the population is considered successful; however, if the objective is strategic recruitment of a new group by translocating birds from within the population to a specific area, then reproduction of those individuals in an area other than the target area is not considered a success.

Currently, the average estimated success rate for translocation is roughly 50 to 60 percent, for various meaningful definitions of success including presence in the recipient cluster in the following breeding season (Hess and Costa 1995), evidence of breeding in the following season or of pair-bonding just prior to the breeding season (Costa and Kennedy 1994), and remaining at or near the release site for 30 days (Franzreb 1999). Similarly, Franzreb (1999) reported that roughly half of adults and subadults (25 of 49) translocated to and within the Savannah River Site reproduced somewhere within that population. Higher success has been reported for simultaneous movement of multiple pairs (50 to over 70 percent present in the following breeding season; Carrie *et al.* 1999, Hagan and Costa 2001, USFWS unpublished), an encouraging development in translocation methods for red-cockaded woodpeckers and one which has been emphasized for other species as well (Griffith *et al.* 1989). Reproduction specifically at the recipient cluster is currently estimated to have occurred in 27 percent of translocations conducted between 1989 and 1995 (48 of 178, Edwards and Costa, in review).

Success of translocations has increased as methods have improved. Information is slowly accumulating on the effects of age, sex, and other factors such as distance, habitat condition, and the number of birds released on the likelihood of successful translocation. This research has been invaluable in formulating both a regional translocation strategy and specific guidelines for the movement of birds. Researchers agree that moving females to territories with solitary males, and moving potential pairs simultaneously, are the most successful types of movements (Rudolph *et al.* 1992, Allen *et al.* 1993, Costa and Kennedy 1994, Hess and Costa 1995, Hagan and Costa 2001, Edwards and Costa, in review). Birds are less likely to return to their original cluster if moved more than roughly 19.3 km (12 mi; Allen *et al.* 1993, Franzreb 1999). Other factors, such as insufficient number or poor condition of recipient cavities, problems in transport, and problems at the time of release, reduce success of translocations (Hess and Costa 1995). Finally, Rudolph *et al.* (1992) suggested that simultaneous movement of multiple pairs (5-10) might increase success. Again, this method has yielded encouraging results. Carrie *et al.* (1999) reported a success rate, defined as birds present in the following breeding season, of over 70 percent (12 of 17) after releasing multiple potential pairs in the Sabine National Forest. Other translocations of multiple pairs have shown success rates from 50 to over 70 percent as well (USFWS unpublished); for example, of 13 individuals translocated to the Joseph W. Jones Ecological Research Center in Georgia between 1999 and 2001, 10 remained in the beginning of the 2001 breeding season (J. Stober, pers. comm.).

In summary, it is apparent that translocation has an important but very specific role in the conservation and recovery of red-cockaded woodpeckers. It is not to be used as a substitute for more fundamental management actions that provide good quality foraging and nesting habitat. In the presence of good quality foraging and nesting habitat, translocation can be an effective short-term tool to counteract effects of demographic and environmental stochasticity and a useful measure over the long-term to reduce loss of genetic variation in isolated populations. Translocation is best performed by moving multiple pairs of juvenile red-cockaded woodpeckers, simultaneously, to recruitment clusters that are strategically located to improve the spatial structure of the population.

E. SILVICULTURE

Silviculture is the theory and practice of controlling the establishment, composition, structure, and growth of forests to achieve management objectives (Smith 1986). It was developed primarily for the purpose of timber production, but can be used for other purposes including biological conservation (Smith 1986, Thompson *et al.* 1995). Silviculture is an important tool for the management of red-cockaded woodpeckers with or without the additional goal of timber production. Today's forests differ substantially in structure and species composition from the precolonial forests that supported red-cockaded woodpeckers in abundance (Conner and Rudolph 1989, Foti and Glenn 1991, Ware *et al.* 1993, Masters *et al.* 1995, Noel *et al.* 1998). Second growth forests can be dense, can contain many small young trees and few large old trees, and often have a complex vertical structure. Proper silviculture can restore and maintain the open, two-layered habitat required by red-cockaded woodpeckers. In this section, we discuss the compatibility and usefulness of silvicultural methods to management and recovery of red-cockaded woodpeckers. We give guidelines for the use of silviculture in 8J.

Conservation and recovery of red-cockaded woodpeckers are compatible with timber production within certain constraints (Rudolph and Conner 1996, Engstrom *et al.* 1996, James *et al.* 1997, 2001, Hedrick *et al.* 1998). Suitable forest structure and function must be retained to support red-cockaded woodpecker populations. Suitable forest structure includes a substantial amount of large pines, low densities of small and medium sized pines, sparse or absent hardwood midstory, and abundant diverse herbaceous groundcovers (Hardesty *et al.* 1997, James *et al.* 1997, 2001, Hedrick *et al.* 1998, Walters *et al.* 2000, 2002a). Foremost among important functions of southern pine forests is the ability to carry frequent growing season fires (Platt *et al.* 1988b, Engstrom *et al.* 1996).

Silvicultural methods can be divided into three systems: even-aged, two-aged, and uneven-aged management. Two-aged is sometimes included within even-aged management. Each system has several possible methods of regeneration, the simultaneous harvest and establishment of tree reproduction (Thompson *et al.* 1995). Even-aged management includes clearcutting, standard seed tree, and standard shelterwood methods. Two-aged management includes modified seed tree and irregular shelterwood methods, and uneven-aged management includes single tree selection and group selection methods. Several researchers have assessed the compatibility of these methods with restoration and maintenance of habitat for red-cockaded woodpeckers (USFWS 1985, Lennartz 1988, Walker and Escano 1992, Walker 1995, USFS 1995, Rudolph and Conner 1996, Engstrom *et al.* 1996, Hedrick *et al.* 1998). The suitability of each method varies with forest type, silvicultural history, ownership, and management objectives. Silvicultural systems also differ in how production of habitat is sustained over time. It is critical to sustain habitat in perpetuity for recovery of red-cockaded woodpeckers.

Silvicultural Systems

Even-aged Management

Even-aged management is the culture of trees of one age class in a given stand (Helms 1998). The forest is regulated at the landscape level, with equal areas in each age class. Regeneration methods of even-aged management differ in the amount of residual trees remaining after harvest. Clearcutting is the removal of all commercially valuable trees on site. In standard seed tree and shelterwood methods, residual trees are left standing as seed sources after the initial harvest and are removed following the establishment of reproduction. Regardless of regeneration method, intermediate thinnings are made to improve growth and health of trees by reducing tree density (Smith 1986, Walker 1995). Modified seed tree and irregular shelterwood are not included as even-aged management in this document (see Two-aged Management below).

Clearcutting, standard seed tree, and standard shelterwood methods are not generally compatible with management to recover red-cockaded woodpeckers, except when used to restore native, site-appropriate pines. The U.S. Forest Service now discourages use of clearcutting (USFS 1995). Even-aged silviculture results in fragmented habitat, and red-cockaded woodpeckers are especially sensitive to negative impacts of habitat fragmentation because of their cooperative breeding system (see 2B). Even-aged silviculture renders stands unsuitable as nesting or foraging habitat for decades. Even with long rotations, even-aged silviculture results in stand-level removal of the large old trees most important to red-cockaded woodpeckers. Even-aged silviculture can be useful in the removal of off-site pine species to restore native pines (see 3G). If within occupied habitat, such restoration is best limited to small areas (Ferral 1998).

Two-aged Management

Two-aged management is a modification of even-aged management in which two age classes exist in a given stand (Smith 1986, Rudolph and Conner 1996). Two-aged stands are created by modified seed tree and irregular shelterwood methods, which are similar to corresponding standard methods except that residual trees are never harvested. In two-aged management, 15 to 25 pines/ha (6 to 10 pines/ac) or more are left as residual trees. The forest is regulated in the same way as in even-aged management. Intermediate thinnings are important to reduce stand density and open the forest structure.

Modified seed tree and irregular shelterwood methods are compatible with management of red-cockaded woodpeckers (Conner *et al.* 1991b, Rudolph and Conner 1996, Hedrick *et al.* 1998). Two-aged silviculture promotes the growth of old and even very old trees in every stand, and older trees are important to both nesting and foraging (see 2D, 2E). Prescribed burning can be conducted throughout much of the forest without fear of damaging young pines, because pine reproduction is concentrated in limited areas. This is a strong advantage in forests of loblolly and/or shortleaf pines which are sensitive to fire when young (Farrar 1996, Hedrick *et al.* 1998). Finally, two-aged silviculture can open up the forest and establish lower pine densities preferred by red-cockaded woodpeckers (Conner *et al.* 1991b). Irregular shelterwood and modified seed tree methods are the cornerstone of restoration of the shortleaf pine/bluestem grass (*Andropogon* and *Schizachyrium* spp.) ecosystem on the Ouachita National Forest in Arkansas (USFS 1996).

Modified seed tree and irregular shelterwood methods have some drawbacks in their application for red-cockaded woodpecker management. The older residual pines are subject to increased windthrow, especially the more shallow rooted pine species (Smith 1986), and increased lightning strikes. In longleaf stands, however, mortality of residual pines is not likely to be greater than that of similarly aged pines in other stands (Boyer 1979). A second drawback to modified seedtree/shelterwood silviculture is that reduction in canopy cover may reduce needle litter, an important fuel (Engstrom *et al.* 1996). Also, an excessive pine midstory can develop, with detrimental effects on cluster occupancy (see 2D) and suitability of the stand for foraging (see 2E). Dense pine regeneration, even under residual pines, renders the stand unsuitable for foraging and such stands are not considered foraging habitat until the pine regeneration can be thinned considerably (see 8I and 8J for specific description of the pine size class distributions that are considered foraging habitat). Frequent prescribed burning can be an important tool to control density of pine regeneration.

Finally, modified seed tree and irregular shelterwood methods may not retain sufficient densities of large trees for newly regenerated stands to qualify as foraging habitat (see 8J). When using these methods in the presence of red-cockaded woodpeckers, long rotations or a greater number of residual pines are necessary to provide suitable foraging habitat.

Uneven-aged Management

Uneven-aged management results in stands with at least three age classes (Smith 1986, Helms 1998). Reproduction occurs throughout the forest in gaps created by the harvest of single trees or groups of trees (regeneration by single tree and group selection, respectively). If group selection is used, patches of trees removed are generally below 0.8 ha (2 ac) in size. The forest is regulated at the stand level, usually by either timber volume or stand structure. The forest can be regulated using one of several methods, including regulating by timber volume using the volume/guiding diameter limit (V-GDL) method (Reynolds 1959, Baker *et al.* 1996, Farrar 1996, Guldin and Baker 1998) or by stand structure using the BDq method (Marquis 1978, Baker *et al.* 1996, Farrar 1996, Guldin and Baker 1998). Another method of uneven-aged silvicultural management is the Stoddard-Neel approach (Mitchell *et al.* 2000).

The V-GDL method uses periodic inventories to measure tree growth, which is then established as the allowable harvest. The guiding diameter limit is the size above which the volume of trees meets the allowable cut. All trees above the guiding diameter limit are not necessarily cut; for every tree above the limit retained, an equal volume of trees below the limit are harvested (Farrar 1996, Guldin and Baker 1998). According to Guldin and Baker (1998), the classic marking rule for this method is to “cut the worst trees and leave the best”. In general, the V-GDL method of regulation is somewhat subjective and therefore can be difficult to apply (Farrar 1996, Guldin and Baker 1998).

The BDq method uses three parameters to describe the target after-cut stand structure: residual basal area (B), maximum diameter retained (D), and the ratio of number of stems in a given size class to those in the next larger class (q). The priority of these parameters is in the order given, so that trees above the maximum diameter are retained if residual basal area cannot be met without them (Baker *et al.* 1996, Farrar 1996, Guldin and Baker 1998). If the structure of the residual stand closely corresponds to q, the stand has a negative exponential (inverse-J) size distribution and is said to be well-balanced (Guldin and Baker 1998). Both q and D can be adjusted to increase the presence of large old trees to meet management objectives (Farrar 1996). The BDq method is preferred over the V-GDL method for most uses because it provides an objective means of monitoring the smaller size classes (Farrar 1996, Guldin and Baker 1998).

The Stoddard-Neel approach is a subjective method that has not been specifically quantified, but has the following characteristics (Mitchell *et al.* 2000). Perpetuation of the forest ecosystem as a whole is the overriding goal of management. Each tree is individually assessed according to its contributions to the ecosystem and the surrounding landscape. Harvest is considered only after it can be conducted without compromising conservation goals, and after that point, only harvesting a portion of the annual incremental growth is allowed. Specific harvest limits are set and reviewed every 10 years. Criteria for individual tree retention include pines with old growth characteristics, older canopy dominants, and longleaf pines in mixed pine stands. Criteria for individual tree selection include some defective trees, those with low crown vigor, and the promotion of an open, multi-aged canopy structure. Openings vary in size ranging from 0.1 ha to 0.2 ha (0.25 ac to 0.5 ac). Salvage logging of dead trees is allowed only if applied toward the allowable cut, and some dead and downed trees are maintained throughout the forest.

Uneven-aged management is compatible with restoration and maintenance of red-cockaded woodpecker habitat (Engstrom *et al.* 1996, James *et al.* 2001). Uneven-aged management can provide large old trees throughout the landscape. Densities of small and medium sized pines can be controlled to avoid detrimental effects on red-cockaded woodpeckers. Frequent prescribed burns can be used to control hardwoods and maintain herbaceous groundcovers in longleaf forest types. For loblolly and shortleaf forests, it is harder to use prescribed fire in uneven-aged stands because of fire sensitivity of young pines and the presence of young pines throughout the landscape (Rudolph and Conner 1996, Hedrick *et al.* 1998). However, prescribed burning at intervals of variable length may be used successfully in these forest types (Cain 1993, Farrar 1996, 1998, Cain *et al.* 1998). Annual and biennial fires interspersed with periods of up to 5 years without fire may effectively control midstory and encourage herbaceous groundcovers while allowing for reproduction of loblolly and shortleaf pines (Cain 1993, Cain *et al.* 1998). The Red Hills region of south Georgia and north Florida supports a large population of red-cockaded woodpeckers in longleaf systems effectively managed with a combination of single tree and group selection methods (Engstrom and Baker 1995, Engstrom *et al.* 1996). Finally, uneven-aged management has been used successfully to remove off-site pine species and restore native site-appropriate pines (e.g. McWhorter 1996).

There are several drawbacks in the application of uneven-aged silviculture to the management of red-cockaded woodpeckers. The number of harvests, and consequently habitat disturbance, can be greater than that of two-aged management (Rudolph and Conner 1996) although this is not necessarily so (Engstrom *et al.* 1996, Farrar 1996, W. D. Boyer, pers. comm.). In fact, W. D. Boyer (pers. comm.) states that the number of entries in longleaf stands under uneven-aged management can be fewer than in stands under even-aged management.

Application of prescribed fire is difficult or at least somewhat complex in uneven-aged stands of loblolly and shortleaf pines, and therefore hardwoods may become a problem (Rudolph and Conner 1996, Hedrick *et al.* 1998). Finally, selection systems, just like even-aged management, can result in the harvest of the old, large trees most valuable to red-cockaded woodpeckers. With careful application these drawbacks can be minimized.

Low Intensity Management

Some woodpecker populations exist in forests that are not managed for timber production. Low-intensity management for the primary purpose of biological conservation uses frequent growing season burns to control hardwoods, prepare the site for pine reproduction, and encourage beneficial native, site-appropriate groundcovers. Natural disturbances such as wind-throw and lightning strikes establish gaps in the canopy for reproduction and recruitment to occur. Hurricanes may occasionally create larger openings. Longleaf, shortleaf, and other pines on native sites are suited for low intensity management.

Some forests may require restoration prior to the application of this silvicultural method. Hardwood midstories and/or overstories may need reduction or removal. Herbaceous groundcovers may need to be restored, and dense pine stands will require thinning to densities suitable for red-cockaded woodpeckers.

Low intensity management is advantageous for red-cockaded woodpeckers because conservation is the primary goal. Low-intensity management offers aesthetic and recreational benefits as well, because the low tree density and healthy herbaceous layer are generally appealing to the public. Low-intensity management does not have the monetary benefits of timber production.

Pine Density

Pine densities generally recommended for timber production by uneven-aged management are 10.3 to 17.1 m^2 basal area per ha (45 to 75 ft^2/ac) in longleaf systems and somewhat higher for shortleaf and/or loblolly (Farrar 1996). Pine density before and after selection cutting generally remains within this range. Even-aged and two-aged management typically result in pine densities of 18.3 to 27.4 m^2/ha basal area (80 to 120 ft^2/ac) or more (Farrar 1996), and after cutting densities are often reduced to below 2.6

m^2/ha (20 ft^2/ac). In addition, second-growth forests are generally more dense than old growth woodlands (Ware *et al.* 1993, Masters *et al.* 1995, Noel *et al.* 1998).

For management of red-cockaded woodpeckers, it is important that densities of small and intermediate-sized pines (<35 cm, or 14 in dbh) be reduced, and the largest trees protected (Walters *et al.* 2000, 2002a, James *et al.* 2001). Two recent studies of foraging ecology in longleaf ecosystems documented increases in fitness of woodpeckers in more open habitat and at lower pine densities (Walters *et al.* 2000, 2002a, James *et al.* 2001). Thinning suppressed pines opens the forest structure, promotes desired herbaceous groundcovers, and increases effects of prescribed burning. However, further experimental research on silvicultural treatments, with adequate controls, is urgently needed to better understand the appropriate habitat structure to support healthy red-cockaded woodpecker populations (F. C. James, pers. comm.).

Further research is also necessary to assess effects of pine densities on foraging ecology of woodpeckers in shortleaf and loblolly systems. For shortleaf and loblolly forest types, pine densities below 18.4 m^2/ha (80 ft^2/ac), or an average spacing of at least 7.6 m (25 ft) between pines in mature stands, are very important in reducing risks of southern pine beetle infestations (Thatcher *et al.* 1980, Nebeker and Hodges 1985, Hicks *et al.* 1987, Belanger *et al.* 1988, Mitchell *et al.* 1991).

Priority for Leave Trees

Leave trees are those that remain standing after thinnings and harvests. Benefits to red-cockaded woodpeckers can be increased by preferentially leaving trees important to them. These important trees include old and very old pines (relict and remnant pines and flat-tops), potential cavity trees (pines over 60 years in age), and pines scarred by turpentine harvest or lightning.

Site Preparation

Regardless of the silvicultural system used, some form of site preparation is necessary to establish pine reproduction. Site preparation removes vegetation and other organic material to expose the mineral soil required for seed germination. Prescribed burning is the preferred method of site preparation, because it mimics natural processes, minimizes disturbance to the soil, and promotes native, site-appropriate herbaceous groundcovers beneficial to red-cockaded woodpeckers (see 2E). Prescribed burning during the growing season induces flowering of many native herbaceous plants (Platt *et al.* 1988a; see 2G) and enhances reproduction of longleaf pines much more so than winter burning (W. D. Boyer, pers. comm.).

Prescribed burning within one year of a good pine seed crop is generally the only site preparation needed, if hardwoods are well under control. If prescribed burning cannot be used, the Bracke scarifier-mounder or a roller drum chopper has fewer impacts on soil profiles and plant communities than do discing, root raking, windrowing, and bedding. Bracke-mounding is a relatively non-invasive technique by which small mounds rather than plow lines are created to expose the mineral soil. Chemical treatments are sometimes used for site preparation as well, but effects of herbicides on native groundcovers are largely unknown (Litt *et al.* 2000, 2001). Any method of site preparation that disturbs the soil will favor ruderal, disturbance-tolerant grasses and forbs over desired species such as wiregrass (Provencher *et al.* 1998, 1999, 2001b), and recovery of groundcovers can be exceedingly slow. For example, Provencher *et al.* (1997, 1998) estimated that recovery of groundcovers following selective harvest of longleaf pine can take 50 years in deep sandy soils.

F. PRESCRIBED BURNING

Because of fundamental changes in the landscape and natural fire regime of the southeast, prescribed burning is and will continue to be the primary means of restoring and maintaining fire in southern pine ecosystems (Frost 1998). Prescribed burning provides benefits for a suite of species characteristic of southern pine ecosystems, and is an essential management tool for the conservation and recovery of red-cockaded woodpeckers (Robbins and Myers 1992, Costa 1995a). By reducing dangerous fuel loads, prescribed burning is also a vitally important component in the protection of human life and property from extreme wildfire.

Red-cockaded woodpeckers are rightly termed an umbrella or flagship species, because their protection and management provides for the conservation of entire ecosystems and the hosts of associated species within. It is especially prescribed burning, but also retention of old growth and mature trees, that provides critical support for associated species. To maximize these benefits, the frequency, intensity, season, and variability of prescribed fire should mimic the historic natural fire regime as closely as possible (Masters *et al.* 1996).

In this section, we briefly review the benefits of prescribed burning to red-cockaded woodpeckers and other species of southern pine ecosystems, and then address concerns about possible negative effects on some animals. We also review the application of prescribed fire to the landscape and its use in habitat restoration. A general discussion of the history and role of fire in southern pine ecosystems is given in 2G. Guidelines for the use of prescribed burning are given in 8K.

Benefits of Prescribed Burning

Benefits to Red-cockaded Woodpeckers

Red-cockaded woodpeckers require open woodlands for nesting and roosting cavities. Hardwood encroachment eventually results in the abandonment of clusters and severe population decline or extirpation (Beckett 1971, Hopkins and Lynn 1971, Van

Balen and Doerr 1978, Locke *et al.* 1983, Hovis and Labisky 1985, Conner and Rudolph 1989, Costa and Escano 1989, Loeb *et al.* 1992, Masters *et al.* 1995). Encroachment of hardwoods and woody shrubs also degrades the quality of foraging habitat (James *et al.* 1997, Walters *et al.* 2000, 2002a). Prescribed burning, especially during the growing season, is a highly effective means of controlling such hardwood and shrub encroachment. Prescribed burning can effectively control hardwoods and shrubs without damaging the herbaceous layer and soils, and can be much less expensive than other restoration methods (Provencher *et al.* 2001b). Prescribed fire also has direct benefits to herbaceous plants in southern pine communities by initiating flowering (Platt *et al.* 1988a). Fire helps maintain a healthy native plant community, which in turn leads to increased fitness of red-cockaded woodpeckers (Hardesty *et al.* 1997, James *et al.* 1997, 2001). The mechanism for increased fitness of red-cockaded woodpeckers in the presence of abundant herbaceous groundcovers has not been documented, but one proposal for such a mechanism is increased abundance and/or nutrient content of prey (James *et al.* 1997).

Benefits to Associated Species

Many plants and animals associated with southeastern pine communities are threatened by loss of habitat through fire suppression and conversion to other land uses. Management for red-cockaded woodpeckers directly supports these sensitive, threatened, and endangered species. Currently, over 120 species of plants and 56 animal species associated with red-cockaded woodpecker habitats are on the regional list of proposed, endangered, threatened, and sensitive species (USFS 1995). Many more herbaceous plants of longleaf communities are rare in today's landscape (Walker 1993), nearly all of which are adapted to growing season fire. Thirty-five percent of the amphibians and reptiles inhabiting longleaf pine forests, and 56 percent of the longleaf pine specialist species, were listed by at least one conservation agency as being of special concern (Guyer and Bailey 1993). Fire suppression was identified as a primary cause of the decline of these species.

Fire benefits shortleaf pine communities as well, although these have not received as much research attention as longleaf systems. Masters *et al.* (1998) reported that species richness and diversity of small mammals increased in relation to midstory reduction and prescribed fire, and no species was adversely affected by fire. Similarly, King (1982) reported increased abundance and diversity of small mammals in loblolly/shortleaf pine forests of the Georgia Piedmont in response to frequent prescribed fires.

Prescribed burning directly benefits bird species associated with open pine woodlands such as Bachman's sparrows (*Aimophila aestivalis*), brown-headed nuthatches (*Sitta pusilla*), pine warblers (*Dendroica pinus*), prairie warblers (*D. discolor*), and red-headed woodpeckers (Engstrom *et al.* 1984, Jackson 1988, Wilson *et al.* 1995, Conner and Dickson 1997, Allen 2001). Bachman's sparrows, in particular, are in decline throughout most of their range and respond strongly to management for red-cockaded woodpeckers (Dunning and Watts 1990, Gobris 1992, Plentovich *et al.* 1998). Bird species associated with riparian habitats within open pine woodlands, such as Carolina wrens (*Thryothorus ludovicianus*), white-eyed vireos (*Vireo griseus*), common yellowthroats (*Geopthlypis thrichas*), and hooded warblers (*Wilsonia citrina*), can benefit from prescribed burning as well (Engstrom *et al.* 1984, Conner and Dickson 1997, Allen 2001). Riparian habitats within open pine forests, when frequently burned, support increased density and diversity of shrubs, a likely cause of increased abundance of associated bird species (Allen 2001). Additionally, many songbird species of southeastern pine communities prefer burned over unburned forests for nesting sites (White *et al.* 1999).

Concerns about Negative Effects

Increasing use of prescribed fire has prompted concern among some land managers, researchers, and the general public. A common anxiety is that prescribed burning during the growing-season may have detrimental effects on non-target species. Managers perceive negative impacts on game species, including losses of nests of ground-nesting birds such as northern bobwhites (*Colinus virginianus*) and wild turkeys (*Meleagris gallopavo*), and reduction of hard mast forage for game birds, white-tailed deer (*Odocoileus virginianus*), and black bear (*Ursus americanus*) among others. However, these concerns have not been substantiated. In fact, increases in abundance of bobwhites and wild turkeys after the introduction of growing season burns have been reported in many areas (Landers *et al.* 1995, Palmer and Hurst 1998). Prescribed burning and pine thinning benefit white-tailed deer by increasing the production of available forage and preferred woody browse to more than four times that of untreated areas (Masters *et al.* 1996).

One immediate effect of growing season fire is the destruction of nests, and this has caused some concern. However, for species associated with southeastern pine habitats, the benefits of prescribed burning far outweigh the occasional loss of nests. Improved habitat quality enables higher population densities, whereas fire suppression substantially lowers the abundance of these bird species (Allen 2001). Saving some nests through fire suppression can serve no purpose if the birds have no habitat in which to exist. In addition, many birds adapted to southeastern pine habitats, such as Bachman's sparrows, pine warblers, prairie warblers, and others, readily renest upon loss of a nest. Game birds such as wild turkeys and northern bobwhites also readily renest (Vangilder and Kurzejeski 1995, Harper and Exum 1999). This behavior acts to minimize any negative effect that fire can have.

There also has been some concern about possible effects of management for red-cockaded woodpeckers on neotropical-nearctic migratory birds. Some species of neotropical-nearctic migrants have experienced declines in recent decades (Robbins *et al.* 1989, Sauer and Droege 1992, Peterjohn and Sauer 1994). In response, conservation biologists and land managers have focused on these species. However, in the southeastern coastal plains, neotropical migrants of greatest management concern are largely associated with bottomland riparian forests (Hunter *et al.* 1994), whereas resident bird species of concern are associated with mature open pine forests and benefit from woodpecker management (Dunning and Watts 1990, Hunter *et al.* 1994, Wilson *et al.* 1995, Tucker *et al.* 1996). A study of the response of breeding bird communities to red-cockaded woodpecker management in southern Mississippi reported that 7 of the 9 bird species that benefited from woodpecker management were pine-grassland species under regional or national decline, whereas all 4 species benefiting from fire suppression were relatively common forest interior species exhibiting stable or increasing trends (Burger *et al.* 1998). In addition, almost all species of birds that increase abundance under fire suppression, such as red-eyed vireos (*V. olivaceous*), black-and-white warblers (*Mniotilta varia*), and Acadian flycatchers (*Empidonax virescens*), also use frequently burned riparian habitats within open pine ecosystems (Allen 2001). Finally, even species that are considered interior forest species may benefit from management for red-cockaded woodpeckers that includes prescribed fire. For example, Powell *et al.* (2000) reported increased abundance of wood thrushes (*Hylocichla mustelina*) on plots treated with pine thinning and prescribed fire relative to control plots in the Georgia Piedmont. The authors went on to suggest that such management contributed to the stability of the study population and recommended its use to stabilize other declining populations in the state.

Thus, management for red-cockaded woodpeckers benefits other resident bird species of concern without impacting those neotropical migrants that are in decline. Managers should not hesitate to conduct prescribed burns for fear of impacts to neotropical migratory birds. Neotropical-nearctic migrant species of concern will best be conserved not by fire suppression but by the protection of habitats most important to them, such as southeastern bottomland hardwoods and northeastern boreal forests.

Close proximity of human development to forests supporting red-cockaded woodpecker populations presents significant risks of natural fire to human property and human lives. Frequent prescribed burning is a critically important technique to reduce risk of extreme natural fire and increase human safety. Risks associated with prescribed burning can be reduced through careful application and other techniques (e.g., Feary and Neuenschwander 1998), and if properly planned and implemented prescribed burns can be safely used to manage natural habitats and protect human life and property. Benefits to human safety and to the entire ecosystem far outweigh risks, if fires are planned and conducted with caution and guidelines are followed (see 8K).

Season of Prescribed Burning

As stated above, the frequency, intensity, season, and variability of prescribed fire should mimic the historic natural fire regime as closely as possible (Masters *et al.* 1996). Growing season fire is emphasized throughout this document because it is commonly believed that most historic fires occurred during the lightning season. Early to mid growing season fire typically has stronger benefits for native, site-appropriate groundcovers than dormant season fire. Late growing season fire may have detrimental impacts on overstory pines and is not as effective in reducing midstory root stock and promoting native groundcovers (Sparks *et al.* 1998, 1999). Sparks *et al.* (1998, 1999) found late dormant season burns more effective than late growing season burns in reducing hardwoods and restoring herbaceous groundcovers in the Ouachita Highlands. Spring burns had much higher reproduction of longleaf pines and development of longleaf pine seedlings than did summer or winter burns in the Escambia Experimental Forest of Alabama, and hardwood development was virtually non-existent in stands undergoing spring burns (W. D. Boyer, pers. comm.). Season of prescribed burns may vary according to specific management objectives (e.g., initial fuel reduction), but the overriding goal of prescribed burning programs in southeastern pine ecosystems should be the institution of a fire regime that best recovers and maintains an abundant, diverse, native, and site-appropriate herbaceous layer to the ecosystem in question.

Application of Fire to the Landscape

Aerial and ground ignition are the two most common methods used to apply fire to the landscape. Ground ignition is the more common of the two because it requires less financial resources and training. However, aerial ignition is becoming increasingly popular because more area can be burned per unit time, and the smoke dispersal is improved.

Ground ignition is accomplished by one or more techniques. Hand-held drip torches are most common, either used alone or in combination with other techniques such as mechanical torches mounted to all-terrain vehicles (ATVs). Using all-terrain vehicles increases the efficiency of ground burning operations, but entails greater safety risks than hand held torches. Caution must be exercised when using ATVs in forest stands with excessive midstory, hidden stumps, or large amounts of downed timber, and operators should be trained in vehicle use. Recently, several safety improvements have been made to ATV-mounted torches, and managers considering their use should contact state and federal agencies to learn more about these improvements. Use of ATVs in areas supporting gopher tortoises may negatively impact that species.

Aerial ignition can be a very efficient method of burning large areas in a few hours. One example of a successful prescribed burning program using aerial ignition is that of the Carolina Sandhills National Wildlife Refuge (Ingram and Robinson 1998). Aerial ignition is generally accomplished through the use of a helicopter equipped with a helitorch or a plastic sphere dispenser (PSD). The helitorch uses a gel-like substance (alumi-gel) which is ignited and dispensed from a torch suspended from the helicopter. The PSD uses an apparatus mounted inside the helicopter that disperses individual spheres about 3.8 cm (1.5 in) in diameter; these spheres ignite in a few seconds once on the ground. The use of the PSD method requires a second person, other than the pilot, to operate the PSD machine. Over a thousand hectares (several thousand acres) can be burned per hour using either technique. Each technique has advantages and disadvantages; local experts should be contacted to discuss their use in various regions of the woodpecker’s range.

Aerial ignition requires considerably greater protection of cavity trees than does ground ignition, because aerially ignited fires vary much more in fire intensity. If raking or mowing is used as a method of securing red-cockaded woodpecker cavity trees within an aerial-ignition burn unit, this should be done for a distance of 6.1 m (20 ft) or more from the cavity trees. Even greater distances may be required if the area has not already undergone frequent burning and the habitat requires restoration. In this case, all clusters should be burned using ground ignition before aerial ignition of the larger burning unit.

Restoration Burning and the Reintroduction of Fire

Restoring seriously degraded habitat is perhaps the most challenging application of prescribed fire in the management of red-cockaded woodpeckers, but it can be highly successful if performed with commitment and cooperation. Wade *et al.* (1998) describe four cases in which fire has been successfully reintroduced under seemingly insurmountable circumstances: (1) reintroduction of fire to an area that was not burned for over 50 years; (2) intentional use of a high-intensity stand replacement fire; (3) burning following a major hurricane, and (4) burning within a residential subdivision. Similarly, fuel reduction and restoration of plant communities has been accomplished in many state parks in Florida (Stevenson 1998).

Restoration burns are commonly used to reduce or remove dense hardwood midstories. These burns are usually more intense than other controlled burns, and it is especially important that adequate fire suppression equipment be on site in these instances. Clusters on deep, sandy soils, with a dense hardwood midstory and a sparse accumulation of ground fuels, can be effectively treated with a restoration burn during the growing season. Key to success of this management action is a thorough understanding of fire behavior in those fuel types under a variety of weather conditions. The use of fire for restoration purposes often requires burning under very specific weather parameters including those conditions identified as extreme fire weather conditions. Typically, these parameters include modest to high wind speeds, a low relative humidity, and low fuel moistures. Use of prescribed burns under these conditions requires extensive experience in the application of growing season fire and should only be attempted by experienced burners.

G. HABITAT RESTORATION

Ecological restoration is the process of returning ecosystem properties such as composition, structure, function, and dynamics to altered ecosystems. These properties are restored to within their estimated unaltered natural range of variation or, alternatively, to within ranges of variation that are capable of sustaining desired ecosystem components and processes. Thus, ecosystem restoration is rooted in the understanding and representation of natural variation in communities, ecosystems, and landscapes (White and Walker 1997). Identification of ecosystem composition, structure, function, and dynamics to be restored is achieved through the selection of appropriate reference criteria

(White and Walker 1997). A variety of reference information can be derived from existing reference sites, historical data, and on-site evidence (Meffe and Carroll 1997, White and Walker 1997). However, spatial scale is important in considering natural variation. Restoration should be performed with both regional and local variation under consideration.

For red-cockaded woodpeckers, restoration of good quality habitat is vital to the recovery of the species. Loss of habitat was primary among the original causes of decline (see 1A), and the widespread increases necessary for recovery cannot be achieved without large-scale restoration of habitat. Habitat loss was caused by removal of the original old growth forest, fire suppression, reproductive failure of longleaf pine, and conversion of longleaf and other native, site-appropriate pine species to plantations of off-site species. Methods of site preparation have also substantially altered native groundcovers in woodpecker habitats.

Reintroduction of a fire regime patterned after historic fires is central to the restoration of native southeastern pine ecosystems—that is, habitat for red-cockaded woodpeckers. Prescribed fire should mimic the frequency, intensity, seasonality, and variability of natural historic fire in order to maximize benefits to the fire-adapted species of southeastern pine communities. Restoration of fire to the landscape aids in restoring appropriate habitat structure and species composition. Prescribed fire facilitates the reproduction, growth, and maintenance of longleaf, shortleaf, and other native, site-appropriate pine species, and can reestablish highly diverse native groundcovers. The restoration of these species, in turn, facilitates frequent fire—an important function—in the system. Other important management tools in habitat restoration include thinning to restore historic pine densities; protecting, planting and seeding native, site-appropriate pines and groundcovers; and the use of site preparation methods that minimize soil disturbance.

One problem in specifying desired components and structure for ecosystem restoration is lack of information concerning historic communities and alteration of existing reference sites (White and Walker 1997, Walker 1998). Longleaf pine woodlands have been reduced to less than 5 percent of their original area, and longleaf ecosystems with intact groundcovers are even more rare (Frost 1993). Species lists and structural analyses of remnant longleaf pine ecosystems (e.g. Peet and Allard 1993, Noel *et al.* 1998) are critical. Other ecosystem types supporting red-cockaded woodpeckers, such as shortleaf and native slash pine communities, require further research attention as well. Despite these difficulties, researchers have assembled a body of information that can be used to identify general desired future conditions for southern pine ecosystems supporting red-cockaded woodpeckers. Key components of these conditions include: (1) native, site-appropriate canopy pine species, (2) old growth pines, (3) lower density of canopy pines than in most second and third-growth forests, and (4) healthy forb and bunchgrass groundcovers.

Restoration of Native Canopy Pines

Loss of native pines, especially longleaf but also shortleaf pine, has occurred throughout the range of red-cockaded woodpeckers. Loblolly and slash pines are native to the southeastern United States, but were restricted primarily to mesic sites and were rarely dominant in precolonial forests (White 1984, Christensen 2000). Restoration of native, site-appropriate pines is an important component of red-cockaded woodpecker management and recovery, primarily because these pines provide superior habitat and facilitate critical, frequent fire (Platt *et al.* 1988b). Restoration of native pine communities is a crucial aspect of ecosystem management also (see 3H). Restoration of longleaf pine has been identified as a high priority in the management of national forests. Over 40,000 ha (100,000 ac) of national forests were restored to longleaf pine between 1988 and 1997, a 20 percent increase over 1988 levels (McMahon *et al.* 1998). An additional 140,000 ha (350,000 ac) are to be restored over the next 90 years, representing a future increase of 60 percent over 1988 levels (McMahon *et al.* 1998). Expanded use of growing-season fire is an important part of this restoration program (McMahon *et al.* 1998).

Size of Restoration Areas

An important consideration in the restoration of native, site-appropriate pine species is the size of the area to be restored. Restoration work should not result in impacts to red-cockaded woodpeckers, either through direct loss of habitat or habitat fragmentation (Ferral 1998, F. James, pers. comm.). Clearcuts near active red-cockaded woodpecker clusters or recruitment clusters that are performed for this purpose should be no larger than 16 ha (40 ac), and use of smaller patches are recommended. Clearcuts as large as 32 ha (80 ac) are acceptable if they are at least 1.6 km (1 mi) from active or recruitment clusters.

Restoration Methods

General information about longleaf restoration is presented in Hermann (1993) and Kush (1998), and further details can be obtained from the Longleaf Alliance (Rt. 7, Box 171, Andalusia, AL, 36420; Gjerstad *et al.* 1998). In addition, the USDA Forest Service offers information and incentives to state managers and private landowners considering the restoration of native, site-appropriate pine species through the State and Private Forestry Programs (McMahon *et al.* 1998).

The first step in the restoration of site-appropriate pines to an area currently supporting off-site species is the removal of the off-site pines (typically loblolly and slash, but also Virginia and sand pines) through small clearcuts or group selection. Site preparation (preferably prescribed burning) rids the area of non-merchantable pines and undesirable hardwoods while establishing proper conditions for planting (see below and 8J for further discussions of site preparation). Seedlings or seeds to be planted in the site should be from an appropriate source for the local area to maintain genetic integrity and to enhance the likelihood of success (Schmidtling *et al.* 1998).

Restoration of Historic Pine Densities

Many of today's forests are densely stocked (Boyer and Farrar 1981, Landers *et al.* 1990, Noel *et al.* 1998). Density of pines in historic forests was substantially lower, as estimated from old survey data, travelers' accounts, and current old growth remnants (Foti and Glenn 1991, Masters *et al.* 1995, Noel *et al.* 1998). For example, precolonial densities for shortleaf pine forests in the Ouachita Mountains have been estimated at roughly 8 m^2 per ha (35 ft^2/ac) pine basal area and 6 m^2/ha (25 ft^2/ac) of hardwood basal area (Foti and Glenn 1991, Masters *et al.* 1995). Some old growth forests in rich sites may have carried pine basal areas near 23 m^2/ha (100 ft^2/ac) or more, but the overall structure was open because the individual pines were so large. Not only are second-growth stands more dense than old growth forests, but they typically have lower variability in density across the stand (Noel *et al.* 1998).

In the absence of active management, second-growth forests may not shift toward an old growth structure for decades or even centuries (Noel *et al.* 1998). Second-growth longleaf forests studied by Noel *et al.* (1998) contained an overrepresentation of pines 20.3 to 40.6 cm (8 to 16 in) in dbh, and trees of these sizes were characterized by extremely low mortality and very slow growth. Thus, change in habitat structure was unlikely to occur naturally in the near future. However, researchers and managers are not always sure of the best method or methods to restore appropriate pine densities. Selective removal of small groups of trees is recommended for xeric longleaf forests, but flatwoods longleaf may require more research to develop restoration methods (Noel *et al.* 1998). Prescribed burning, patterned after the historic fire regime, can contribute to long-term restoration of appropriate pine (and hardwood) densities (Noel *et al.* 1998).

Restoration of Native Groundcovers

Longleaf pine ecosystems are famous for their highly diverse groundcovers (Walker and Peet 1983, Simberloff 1993, Peet and Allard 1993, Glitzenstein *et al.* 1998b, Walker 1998). These fire-dependent ecosystems contain nearly one quarter of all the plant species in North America, including high numbers of endemic species (Mitchell *et al.* 2000). Restoring and maintaining this diversity is a primary goal of ecological restoration in the southeast. Native, site-appropriate groundcovers have important benefits to red-cockaded woodpeckers: native grasses are pyrogenic (Platt *et al.* 1988b, Noss 1989), and native groundcovers may support more diverse and abundant arthropods than encroaching hardwoods (Provencher *et al.* 1997, 1998, Collins 1998). Also, an ecosystem approach to managing red-cockaded woodpeckers and their habitat emphasizes the conservation of native, site-appropriate diversity.

Vegetation native to longleaf and shortleaf pine ecosystems may be best restored and maintained through the use of frequent growing season fire. Loss of groundcover diversity in the absence of fire is well documented (Christensen 1981, Ware *et al.* 1993, Peet and Allard 1993, Glitzenstein *et al.* 1998b, Walker 1998), and single fires are not sufficient to restore species diversity (Glitzenstein *et al.* 1998b). Prescribed fire is necessary to remove decades of litter accumulation and expose the mineral soil for seedling germination and early seedling growth (Walker 1998). In addition, prescribed fire opens the forest floor to sunlight, by reducing off-site hardwoods and shrubs and reducing the density and stature of on-site hardwoods and shrubs. Growing season fire stimulates flowering and fruit production of native groundcover plants (Platt *et al.* 1988a, Streng *et al.* 1993). Finally, benefits of fire may be increased by restoring natural variability in the fire regime (Walker 1998).

Hardwood Control

Key to restoration of native groundcovers is the initial control of existing hardwoods. Prescribed burning during early to mid-growing seasons may be the most cost-effective method of reducing hardwoods (Provencher *et al.* 2001b). In situations requiring rapid midstory removal, such as in clusters recently abandoned or supporting only a solitary male because of excessive hardwoods, mechanical and/or chemical methods of hardwood reduction may be in order (Conner 1989, Conner *et al.* 1995, Provencher *et al.* 2001b). However, such methods should be used with extreme caution to minimize disturbance to soils, pine tree roots, and desired native herbaceous species. If chemical and/or mechanical means of midstory reduction are used for rapid hardwood reduction, the area in question should soon be included in a prescribed fire program to restore and maintain appropriate herbaceous groundcovers.

Both herbicides and mechanical methods can result in increased abundance of disturbance-tolerant, ruderal species such as broom sedge (Provencher *et al.* 1998, 1999, 2001). In a study at Eglin Air Force Base, researchers compared three hardwood reduction treatments, including the commonly used herbicide, hexazinone, in a well-replicated large-scale experiment. They found that herbicide use increased disturbance-tolerant species while causing significant declines in common important species such as gopher apple (*Licania michauxii*), dwarf huckleberry (*Gaylussacia dumosa*), little bluestem (*Schizachyrium* spp.) and various legumes (e.g., Florida milk-pea, *Galactica floridana*). Some of these effects still persisted after four years and following the application of growing season fire (Provencher *et al.* 1999). Moreover, effects of herbicides on rare plant species are not known (Litt *et al.* 2000, 2001). In a recent review of all available studies on the impacts of herbicides on vegetation, only two, including Provencher *et al.* (1999), comprehensively documented the effects of herbicides across all species, including rare species (Litt *et al.* 2000, 2001). Litt *et al.* (2000, 2001) concluded that herbicide effects on plant species of management concern generally cannot be evaluated at this time. Use of herbicides to control hardwoods is also discussed in USFS (1989).

Handtools such as chainsaws or brushhooks will have minimal impacts on native species, but excessive use of heavy machinery should be avoided. In one study, repeated passes with a double drum chopper to remove scrub oaks (*Quercus* spp.) killed 50 percent of the existing wiregrass (Outcalt and Lewis 1990). In this same study, single passes with a light single drum chopper had little effect on groundcovers. Roller choppers may have increased effects on mesic sites (Glitzenstein *et al.* 1993). Use of heavy-duty mowers or grinders mounted on rubber-tired tractors may have fewer negative impacts than roller chopping.

With sufficient expertise, prescribed fire can be used to control even serious hardwood problems. Effects of fire vary with its intensity, frequency, and season, and although restoration of the historic fire regime is the desired goal, initial control of hardwoods may require manipulation of fire frequency, intensity, and season beyond those of historic fire (Robbins and Myers 1992). For example, Masters *et al.* (1995), in their recommendations for the reintroduction of fire into the shortleaf pine forests of the McCurtain County Wilderness Area in Oklahoma, called for initial use of dormant season burns to acclimate the old growth pines to fire. These were to be followed by high frequency growing season fires to remove small stems, and then by large-scale fires initiated after longer burn intervals to hasten return to precolonial conditions. Sparks *et al.* (1998, 1999) found late dormant season burns preferable to late growing season burns in reducing hardwood root stock and promoting grasses and forbs. To use fire successfully, managers must have solid understanding of the frequency, intensity, variability, and season of fire necessary to achieve management objectives, and specifically identify these in the planning of a prescribed burning program.

Site Preparation

As mentioned above, mechanical and/or chemical methods of site preparation can have detrimental effects on native groundcover plants (discussed in Glitzenstein *et al.* 1993, Provencher *et al.* 1999). Effects of site preparation methods can vary depending on characteristics of the specific site, especially soil moisture content. In general, mechanical and chemical site preparation increase weedy species, and repeated use can reduce or eliminate native species. Site preparation that leads to soil disturbance will favor more ruderal, weedy, disturbance-tolerant species at the cost of sensitive species (Provencher *et al.* 1998, 1999), and recovery rates for native groundcovers may approach 50 years in xeric soils (Provencher *et al.* 1997, 1998). Windrows and other methods that create piles are among the most destructive of mechanical site preparation methods. Roller chopping may have minimal impacts on xeric sites, especially if light machines are used (described above, Outcalt and Lewis 1990), but may be more damaging on wetter sites. Bracke-mounding has lower impacts than roller chopping. Bracke-mounding is a relatively non-invasive technique by which small mounds rather than plow lines are created to expose the mineral soil. Use of heavy-duty mowers or grinders mounted on rubber-tired tractors may also have lower impacts on soils and tree roots than roller chopping. However, site preparation is best performed using prescribed fire in order to minimize disturbance.

Direct Seeding and Planting

Not all of the desired plant species may return through the use of prescribed fire alone, depending on the degree of habitat alteration and the availability of natural seed sources. Progress has been made in the restoration of specific species using direct seeding and planting. For example, Hattenbach *et al.* (1998) reported successful use of direct seeding of wiregrass and several other groundcover species in the restoration of the Apalachian Bluffs and Ravines Preserve in Florida. Other examples of successful restoration of desired groundcover plants are described by Glitzenstein *et al.* (1998a, 1998b) and Bissett (1998). Researchers stress the need for frequent fire prior to and during restoration efforts to create required conditions for germination and to promote flowering. Direct seeding and planting is a labor-intensive technique conducted at very small scales. Thus, protection of existing native groundcovers should always be the first option.

H. ECOSYSTEM MANAGEMENT

Ecosystem management has been defined in many ways (reviewed by Meffe and Carroll 1997), but its various definitions contain common themes. In general, ecosystem management is an expansion of single-species or traditional management methods to include broader ecological, socioeconomic, and institutional perspectives. Meffe and Carroll (1997), in their review of ecosystem management, have developed the following composite definition:

> Ecosystem management is an approach to maintaining or restoring the composition, structure, and function of natural and modified ecosystems for the goal of long-term sustainability. It is based on a collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework defined primarily by natural ecological boundaries.

This definition summarizes important aspects of ecosystem management common to various definitions (e.g., Grumbine 1994, Christensen *et al.* 1996), including:

1. *Conservation of biological diversity and ecological integrity.* Targets of conservation include all natural levels of organization, from genes through landscapes; the complex interactions among these levels; natural disturbance regimes; and ecosystem functions. Both natural and modified landscapes have these conservation targets.

2. *Long-term sustainability.* Sustainability, over generations and centuries, is of overwhelming importance. It should always be a clearly identified objective that is incorporated into management planning.

3. *Collaboration.* Successful ecosystem management requires cooperation among federal, state, and local agencies, tribal governments, corporations, and individuals.

4. *Desired future conditions.* Desired future conditions are determined based on historical, ecological, and cultural considerations. This vision should be specifically identified and incorporated into management planning.

5. *Ecological perspective.* Excellent science is a foundation of ecosystem management.

6. *Socioeconomic perspective.* Ecosystem management recognizes that humans are a fundamental component of the natural world, and that conservation must protect human rights as well as biological diversity. Local and indigenous people should be involved in decision-making at the outset and throughout the management process, and impacts of management actions on people must always be evaluated. Excellent social science, therefore, is also a foundation of ecosystem management.

7. *Institutional perspective.* Institutions must be flexible, to respond to changing needs and new information. Flexible administration and legislation that properly reflects human values is the third foundation of ecosystem management.

8. *Natural ecological boundaries.* Precise definitions of ecosystems are not required for ecosystem management; rather, boundaries should reflect some natural border of interest (such as a watershed or mountain range, Meffe and Carroll 1997). Therefore, ecosystem management is generally conducted at larger geographic scales than traditional management. Also, management across political boundaries can be conducted only through cooperative efforts.

9. *Adaptive management.* An important component of ecosystem management not specifically identified in Meffe and Carroll's (1997) definition is its ability to adapt to changing environmental conditions and new information. The fundamental basis of adaptive management is experimental research, complete with adequate reference sites and controls. Adaptive management requires feedback from consistent and intensive biological monitoring, and indicator species must be carefully chosen to reflect management goals.

Ecosystem Management and Red-cockaded Woodpeckers

Current management for red-cockaded woodpeckers is, in many ways, an ecosystem approach. Long-term sustainability is the primary objective of management recommended in this recovery plan, and desired future conditions that will support long-term sustainability are identified herein. Cooperation among federal agencies (specifically, the U.S. Fish and Wildlife Service, the U.S. Forest Service, the U.S. Departments of Defense and Energy, and the National Park Service) is required in the management of core and essential support recovery populations. Cooperation of federal, state, and local agencies, corporations, and individuals is being fostered for the management of red-cockaded woodpeckers on state and private lands. Finally, ecological borders are used for recovery units and form the basis of the translocation strategy.

Moreover, management for red-cockaded woodpeckers provides strong benefits for entire ecosystems. Such benefits are mainly the result of broad-scale prescribed burning programs and broad-scale silviculture that restores open conditions and retains old trees throughout the landscape. In addition, cavities created by red-cockaded woodpeckers or supplied to them through management are used by a host of secondary cavity species. Ecologically, single-species management of red-cockaded woodpeckers merges with ecosystem management for three main reasons: (1) red-cockaded woodpeckers are an indicator species whose population trends can mark the health of southern pine ecosystems (Provencher *et al.* 2001a); (2) red-cockaded woodpeckers are an umbrella species, whose protection provides simultaneous protection for many associated species; and (3) red-cockaded woodpeckers are a keystone species whose presence influences the presence and/or abundance of other species (secondary cavity users) in the community.

However, some aspects of current woodpecker management have not yet been expanded to the level of the ecosystem. One example of current management that is not consistent with an ecosystem approach is management of predation and cavity kleptoparasitism. Managers of several red-cockaded populations have instituted predator and kleptoparasite control programs, but no research has assessed management impacts on these other species or on indirect interactions among community members. Ecosystem management protects viable populations of all native species in the region. More information concerning the population dynamics of predators and cavity kleptoparasites, and their impacts on red-cockaded woodpeckers in general, is required before methods of control can be considered part of an adaptive, ecosystem-based strategy. At present, the U.S. Fish and Wildlife Service is recommending that methods of control be non-lethal, and used only in critically small populations of red-cockaded woodpeckers (see 8G).

The primary example of current management that is not consistent with an ecosystem approach is the continued focus of most management actions, especially prescribed burning and retention of old trees, within the cluster rather than throughout the landscape. Burning and retaining old trees only in small patches provides only limited benefits to other members of southern pine communities. Moreover, such patch-based management has had detrimental effects on red-cockaded woodpeckers as well, including decreased value of foraging habitat (James *et al.* 1997, Walters *et al.* 2000, 2002a), increased cavity damage by pileated woodpeckers (Saenz *et al.* 1998), and increased mortality of cavity trees due to pests such as southern pine beetles (Conner *et al.* 1997a). Fundamental change in the scale of prescribed burning and beneficial silvicultural practices is required for both ecosystem management and the recovery of red-cockaded woodpeckers.

Some management actions must continue to be applied at the level of individual territories or aggregations of territories rather than at a landscape scale. That is, some aspects of single-species management continue to be critical to the recovery of red-cockaded woodpeckers. Chief among these are cavity management (see 8E), establishment of strategically placed recruitment clusters (8B), and translocation (8H). Predator and cavity kleptoparasite control is a single-species management technique also, but it differs from those listed above in that it can potentially disrupt natural ecosystem processes and impact other native species.

Thus, at present red-cockaded woodpeckers are best managed with a combination of single-species and ecosystem management. In addition, other members of southern pine communities benefit substantially from such management. Once red-cockaded woodpeckers attain recovery, single-species methods may not be required. Currently, we hope that ecosystem management by itself, including continued monitoring of red-cockaded woodpeckers, will provide long-term sustainability for all members of southern pine communities. However, at this time we simply do not know what management will be needed after delisting. Our understanding of future management needs will increase as the species recovers.

4. CURRENT STATUS AND CONSERVATION INITIATIVES

A. PRIVATE LANDS

Conservation of red-cockaded woodpeckers on privately owned lands is an important part of species recovery (Costa 1995b, 1997, Bonnie and Bean 1996, Bonnie 1997), although primary support for recovery is provided by federal properties (4C). Red-cockaded woodpeckers on private lands have inherent ecological, cultural, and historical value. Groups and populations of red-cockaded woodpeckers on private lands also have substantial value as reservoirs of genetic resources, sources of immigration for other populations, and as stepping stones to facilitate dispersal between other populations. In addition, prior to species recovery, many populations on private lands will have a key role in translocation programs, as either donors or recipients of red-cockaded woodpeckers. Currently, 23 percent of all red-cockaded woodpecker groups are located on private lands. However, other than the prohibition against take (below), nothing in the Endangered Species Act requires private landowners to participate in active conservation. Thus the role of private landowners in species recovery is important but voluntary.

The voluntary nature of active conservation on the part of private landowners has some benefits. Private lands conservation arising from local participants can be more meaningful and longer lasting than attempts at regulating private land use by federal authorities. The most successful conservation programs are those that strike a balance between voluntary participation and federal control. For endangered species, private landowners require a mechanism for resolving land use conflicts; however, mitigation to help offset adverse impacts to listed species must be adequate and federally supervised (Bean and Wilcove 1997). Flexibility, with appropriate boundaries, can foster genuine conservation interest on the part of local landowners and reduce the resentment that is a common result of enforcement of federal regulations (Bean and Wilcove 1997, Bonnie 1997). For example, volunteer participants in Safe Harbor programs (below) have shown increased concern for red-cockaded woodpeckers on their lands (Bonnie 1997). Raising awareness, incentives, and the removal of disincentives are key factors facilitating the rise of conservation among private individuals (USFWS 1979, 1985, Bonnie and Bean 1996, Kennedy *et al.* 1996).

These benefits of voluntary conservation were recognized, encouraged, and incorporated into a private lands conservation strategy by the U.S. Fish and Wildlife Service during the 1990's (Costa 1995b; described below). Some early efforts may have fallen short of conservation goals (Bonnie 1997), but with continual improvements the private lands conservation strategy of the U.S. Fish and Wildlife Service has shown remarkable success.

The Endangered Species Act and Private Landowners

Federal law does not require private landowners to participate in the recovery of threatened and endangered species but does prohibit their 'take' (Section 9a of the Act). The term, take, means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (Section 3.18 of the Act). Habitat destruction and alteration may be considered forms of take where they are the proximate and foreseeable cause of death or injury to members of the species, following a Supreme Court ruling on this issue (Sweet Home vs. Babbitt). The Endangered Species Act does provide a mechanism for take of endangered species on private lands if that take is "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity" (Section 10a of the Act). Incidental take may be permitted by the U.S. Fish and Wildlife Service only after the applicant submits a detailed Habitat Conservation Plan (HCP) that includes steps to be taken to minimize and mitigate impacts from the proposed actions (Section 10a). Thus, the U.S. Fish and Wildlife Service has formulated guidelines for mitigation of impacts to red-cockaded woodpecker groups (below). Still, incidental take permits are issued rarely, because generally alternatives to incidental take exist, and the Act requires the evaluation of alternatives and their use if appropriate (Section 10a). Federal properties are not involved in the incidental take permitting process, but rather must consult with the U.S. Fish and Wildlife Service on proposed actions that may have the potential to result in incidental take (Section 7a of the Act).

Recent Trends and Current Status

Despite continued protection under the Endangered Species Act, the decline and local extirpation of red-cockaded woodpeckers on private lands has been well documented across their range. Reports from North Carolina (Carter 1974, 1990, Carter *et al.* 1983, 1995), South Carolina (Cely and Ferral 1995), Georgia (Baker 1981, 1995), Arkansas (James and Neal 1989), Texas (Ortego and Lay 1988), Florida (Baker 1983), and range wide (Thompson 1976, Ligon *et al.* 1986, James 1995) show declines and local extirpations into the early 1990's. These losses are the result of a variety of factors including loss and fragmentation of habitat, fire suppression and resultant changes in habitat structure, and vulnerability to environmental and demographic stochasticity because of small population size. Currently, there are 1296 known active clusters on private lands in 11 states (Costa and Walker 1995, USFWS unpublished), and the existence of up to 280 additional groups is considered likely.

The Private Lands Conservation Strategy

The private lands conservation strategy was developed by the U.S. Fish and Wildlife Service in response to the realization that red-cockaded woodpeckers on private lands were important to the recovery of the species, and that their loss was a significant biological problem (Costa 1995b, 1997). Moreover, the U.S. Fish and Wildlife Service recognized that conservation of red-cockaded woodpeckers on private lands would require a multi-faceted approach based on conservation science and innovative conservation partnerships (Costa 1995b, 1997). The strategy has been aggressively implemented, modified as necessary based on new scientific findings, and regularly evaluated to ensure goals are being achieved. Five primary objectives of the private lands strategy are to (1) increase the acreage of private land under management for red-cockaded woodpeckers; (2) maintain or increase the larger populations on private lands, (3) establish healthy, spatially aggregated, and protected groups of woodpeckers to offset losses, (4) foster and develop corporate partnerships between and among federal, state, and private parties responsible for and interested in red-cockaded woodpecker recovery and (5) increase, via translocation, the size of populations on state and federal lands (Costa 1995b). This last objective does not imply that federal properties are appropriate mitigation sites, but private lands do occasionally contribute birds to public properties as part of the regional translocation strategy.

The implementation of the private lands strategy between the U.S. Fish and Wildlife Service and private land conservation partners since 1992 has helped to slow, stabilize, and in some cases reverse population declines among woodpeckers on privately owned lands. It has resulted in significantly increased protection for many woodpecker groups and their habitat on privately owned lands, and raised the possibility that such protection can become the normal standard rather than the exception. Finally, the private lands strategy has resulted in the creation of strong and effective partnerships with a multitude of diverse partners. Currently, 509 red-cockaded woodpecker groups on 140,608 ha (347,439 ac) of private lands are protected, in agreements involving 139 private landowners. These agreements provide protection for 40 percent of the known red-cockaded woodpeckers on private lands. Additionally, several landowners in signed and pending agreements have agreed to increase their existing populations. These increases could result in 71 additional groups.

The development of the private lands strategy began in the early 1990's, with initial attempts to protect woodpeckers on forest industry lands (Costa 1995b). In 1992, the first Memorandum of Agreement (below) was signed with an industrial forest landowner in an effort to protect approximately 90 groups in Arkansas and Louisiana (Wood and Kleinhofs 1995). Seven other Memoranda of Agreement followed (Costa 1997). These are ‘no-take’ agreements under which a corporation agrees to protect occupied habitat and conduct some habitat management (Bonnie 1997, Costa 1997). Since 1995, the U.S. Fish and Wildlife Service has shifted from Memoranda of Agreement to Habitat Conservation Plans (HCPs; Bonnie 1997, Costa 1997), in which incidental take of existing and/or future woodpecker groups is permitted in exchange for management of occupied and unoccupied habitat. Habitat Conservation Plans, authorized under Section 10 of the Endangered Species Act, can involve a variety of landowners, including timber and other corporations, private citizens, and developers. Two forms of HCPs currently exist: individual plans and statewide plans. More recently, Safe Harbor agreements have become the primary tool for conservation of red-cockaded woodpeckers on private lands (Bonnie 1997, Costa and Kennedy 1997, Costa 1999, Costa *et al.* in press).

Memoranda of Agreement

Memoranda of Agreement (MOAs) are legal conservation agreements between the U.S. Fish and Wildlife Service and corporate landowners. The agreement outlines management actions by which the corporation can satisfy responsibilities under the Endangered Species Act and the U.S. Fish and Wildlife Service’s guidelines for habitat management, and meet corporate objectives for land management. These management actions typically include population monitoring, management and retention of current and future nesting habitat, maintenance of adequate foraging habitat, and research and educational initiatives. Several MOAs also include state or other federal agencies as cooperators. Motivation to enter into such agreements includes reduced risk of litigation, prestige and satisfaction associated with conservation efforts, and consolidation of populations and responsibility (Costa and Edwards 1997). Currently, over 12,990 ha (32,100 ac) of habitat and 83 active woodpecker clusters are managed under Memoranda of Agreement.

Individual Habitat Conservation Plans

Individual Habitat Conservation Plans allow the ‘incidental take’ of red-cockaded woodpecker groups with mitigation, as authorized under the Endangered Species Act. Both the plan and the associated mitigation are funded by the landowner. Early HCPs for individual landowners were criticized because the mitigation required was not considered sufficient to offset the permitted loss of groups (Bonnie 1997). These critics correctly identified two major faults of early mitigation efforts. First, occupation of the newly established clusters was not assured. Second, the creation of clusters on federal properties did not truly mitigate damage to privately owned clusters, because federal agencies are already required to conserve (recover) their populations. In response to these criticisms, the current policies governing the use of mitigation (below) require that one occupied cluster be established for each active cluster harmed or removed. In addition, new groups are established on private lands when possible (below).

TABLE 5. Number of active red-cockaded woodpecker clusters (ACT, 2000) on private properties that harbor or are capable of harboring ten or more active clusters and are currently under partnerships with the U.S. Fish and Wildlife Service. These properties are all designated significant support populations (see 7). Also listed are the property owners, property population goal, and type of agreement.

Property (State)	**Owner**	**ACT 2000**	**Goal**	**Type**[1]
Arcadia Plantation (SC)	Private Landowner	11	11	SH
Avalon Plantation (FL)	Turner Endangered Species Fund	7	25+	MOA
Bates Hill Plantation (SC)	Private Landowner	12	12	SH
Brookgreen Gardens (SC)	Brookgreen Gardens	6	10	SH[2]
Brosnan Forest (SC)	Norfolk Southern Railroad	75	100	SH
Brushy Creek (TX)	International Paper	3	20	SH
Calloway Tract (NC)	The Nature Conservancy	5	10	SH
Crossett Forest (AR/LA)	Plum Creek Timber Company	82	92	MOA
Curtis H. Stanton Energy Center (FL)	Orlando Utilities	7	10	----
Friendfield Plantation (SC)	Private Landowner	10	14	SH
Good Hope Plantation (SC)	Private Landowner	12	12	SH
Hobcaw Barony (SC)	B. W. Baruch Foundation	23	23	SH
J. W. Jones Ecological Research Center (GA)	Ichauway, Inc.	6	10+	SH
Medway Plantation (SC)	Private Landowner	14	14	SH
Palmetto-Peartree Preserve (NC)	Conservation Fund	25	25+	CE
Piney Grove Preserve (VA)	The Nature Conservancy	3	10+	SH
Plum Creek Conservation Area (AR)	Plum Creek Timber Company	26	30	HCP
Potlach Corporation Lands (AR)	Potlach Corporation	20	30	HCP
Prince George (SC)	Prince George Foundation	3	10	SH
Red Hills (GA/FL)	Various Landowners	180	180	SH[3]
Scrappin' Valley (TX)	Temple Inland Corporation	8	14	SH
Southern Pines/Pinehurst (NC)	Various Landowners	47	47	SH
Southlands Experimental Forest (GA)	International Paper	8	30	HCP
TOTAL: 22 Properties in 8 States		**588**	**729**	

[1]Safe Harbor (SH), Memorandum of Agreement (MOA), Conservation Easement (CE), or Habitat Conservation Plan (HCP). See text for more detail.

[2] Pending.

[3] Over 30 landowners harbor 180 active clusters, some of which are enrolled in Safe Harbor, some are pending enrollment, and more enrollments are anticipated.

Since 1995, the U.S. Fish and Wildlife Service has authorized ten incidental take permits for non-industrial forest landowners. Under these permits, 27 groups of red-cockaded woodpeckers may be impacted or removed, pending completion of mitigation. Mitigation for these groups includes the probable establishment of 52 new groups through creation of recruitment clusters and/or translocation of juveniles to unoccupied clusters (Costa 1997).

The U.S. Fish and Wildlife Service has also issued three individual HCPs for industrial forest landowners. These plans provide current protection for 64 groups and potential long-term protection for 90 groups of red-cockaded woodpeckers.

Statewide Habitat Conservation Plans

Currently, statewide Habitat Conservation Plans (not including statewide Safe Harbor, below) permit the incidental take of demographically isolated groups only. Defining demographic isolation for this purpose is not an easy task. It is known that isolation of red-cockaded woodpecker groups results in decreased likelihood of group survival. However, research into the isolation of groups has been designed to identify spatial arrangements that increase population persistence, not to identify a statewide standard for incidental take (Bonnie 1997). Establishing a threshold measure of isolation above which groups would be available for statewide incidental take is a matter of some debate, and requires further research attention.

Safe Harbor

The Safe Harbor program has been an immense success for both landowners and red-cockaded woodpeckers (Bonnie 1997, Costa 1997, 1999, Costa *et al.* in press). Red-cockaded woodpecker Safe Harbor permits have been issued for the sates of Texas, South Carolina, and Georgia, the six-county Sandhills region of North Carolina, and a Nature Conservancy preserve in Virginia (Lohr 2000, Costa *et al.* in press). Louisiana and Alabama have draft plans, Florida has initiated the plan development process, and two individual landowners in Florida and Mississippi are working on agreements with the U.S. Fish and Wildlife Service (Costa *et al.*, in press). Under a Safe Harbor agreement, a landowner agrees to actively manage nesting and foraging habitat (i.e., a safe harbor) for the number of active red-cockaded woodpecker clusters equal to those present when the agreement is initiated (i.e., the baseline). Landowners must also agree to enhance existing habitat and/or improve additional potential woodpecker habitat, typically through the use of prescribed fire and cavity management. In turn, the landowner receives an incidental take permit, authorizing a land use change, for any additional woodpecker groups that may occupy the property in the future as a result of beneficial management practices. Thus, private landowners are free to manage their properties with prescribed fire, thinnings, lengthened timber rotations, or other actions that may benefit red-cockaded woodpeckers without fear of additional land-use restrictions.

Eligible landowners enrolled in Safe Harbor agreements may choose to enter into mitigation banking (below), and increase their baseline in exchange for a mitigation fee. This can be a powerful incentive for private landowners to join a Safe Harbor program and aggressively manage their lands for red-cockaded woodpeckers (Bonnie and Bean 1996, Kennedy *et al.* 1996, Costa and Kennedy 1997). Mitigation banks can be established only by following the guidelines presented below.

As of 2001, 191 groups, 48 landowners, and 58,005 ha (143,272 ac) in South Carolina, 50 groups, 53 landowners, and 14,354 ha (35,455 ac) in North Carolina, 17 groups, 19 landowners, and 6,029 ha (14,891 ac) in Texas, 8 groups, 3 landowners, and 13,142 ha (32,461 ac) in Georgia, and 3 groups, 2 landowners, and 734 ha (1,812 ac) in Virginia were enrolled in Safe Harbor agreements (Costa *et al*. in press). Many of these groups provide important support for nearby recovery populations.

Mitigation

No Net Loss of Groups

The philosophy guiding mitigation policy is that there be no net loss of red-cockaded woodpecker groups, and a primary objective is to assure that the status of the species as a whole is better following mitigation than before. Mitigation of impacts to red-cockaded woodpeckers is generally achieved through the establishment of a woodpecker group in another location, for every group that is affected by the proposed action. In general, the minimum required ratio of newly established to impacted groups is one to one. For the ten HCP permits issued to date, this ratio has been two to one (Costa 1997). Preservation credits, discussed below, are an exception to the required one to one ratio.

Mitigation Site

The location in which new groups are established is known as the mitigation site. This term refers to both the actual recruitment clusters and the population that contains the newly established groups. Four factors are important to the choice of mitigation sites: geographic location, ownership class (i.e., prior commitment to recovery), degree of protection in place, and amount of available habitat (i.e., maximum future population size). Mitigation within the recovery unit is preferred, to serve ecological goals and reduce costs. However, the Fish and Wildlife Service may approve mitigation outside recovery units on a case-by-case basis.

The first priority for ownership class of mitigation sites is private and state lands. When all opportunities to mitigate on private and state lands within the above geographic restrictions have been exhausted, federal lands shall be considered. Mitigation on federal properties will be conducted only if it is the sole appropriate option within the recovery unit. In general, the use of federal properties as mitigation sites for impacts on private lands is strongly discouraged. Additionally, the U.S. Fish and Wildlife Service prefers that mitigation sites have a degree of protection greater than that of impacted groups.

Mitigation sites must have sufficient habitat to support at least 10 groups of red-cockaded woodpeckers in territories that are aggregated, not isolated, in space. Only with a highly aggregated spatial structure do populations of 10 woodpecker groups have any reasonable chance of persisting over periods of 20 years or more (Crowder *et al.* 1998, Walters et al. 2002b). Mitigation sites may consist of multiple, adjacent properties under private or state ownership. Potential mitigation sites directly adjacent to red-cockaded woodpecker populations on federally owned lands may qualify even if the site has a capacity of less than 10 groups, providing the site and federally owned population has a combined capacity of 10 or more groups.

Mitigation Groups

Mitigation groups are those newly established in exchange for permission to impact groups, on a one-to-one basis as discussed above. Mitigation groups must have equivalent breeding status as impacted groups. In other words, if an impacted group consists of a solitary male, then only a solitary male needs to be established for mitigation, but if an impacted group consists of a potential breeding group, then a potential breeding group must be established as the mitigation group. Helpers do not need to be “replaced”.

Mitigation groups are typically established prior to the impact on existing groups. However, incidental take may occur prior to successful mitigation if legally binding implementation agreements and performance bonds are in place. A mitigation group is considered established if evidence of breeding is detected or if the same potential breeding group or solitary male remain in the mitigation cluster for six months including a breeding season (April – July).

Mitigation Credits, Mitigation Banks, and Preservation Credits

Several tools to facilitate mitigation exist, including mitigation credits, mitigation banks, and preservation credits. A mitigation credit is earned once a mitigation group has been established (one credit is equal to one group), and is used by impacting an existing group. A mitigation credit can be used immediately after earning or stored in a mitigation bank to be used in the future. Mitigation credits stored in a bank can also be made available for sale to third parties requesting a permit to impact an existing group or groups. A mitigation bank is the mitigation site in which new groups are established. Guidelines for mitigation sites (above) apply to mitigation banks. Mitigation banks may be owned by a single or multiple landowners, but must have approved habitat management plans including regular prescribed burning and cavity management in place.

Finally, a preservation credit is earned by increasing the protection of one to three existing groups in exchange for the incidental take of one group. Increased protection may take the form of private land conservation easements, direct land acquisition, and subsequent transfer to protected/managed public land agencies or other conservation programs that ensure protection, but must be in place for perpetuity. In addition, preservation groups must benefit from population monitoring and habitat management, including frequent prescribed burning (8K), cavity and cluster management (8E, 8F), and provision of foraging habitat that meets the recovery standard (8I). Perpetual protection of one to three groups in excellent habitat in exchange for the loss of one group is considered an improvement in the conditions faced by red-cockaded woodpeckers as a whole, in agreement with the overall objective of mitigation policy.

The specific ratio for preservation credits is determined on a case-by-case basis. Variables used to calculate this ratio include location, population size, trend, viability, and ownership, forest type, breeding status, and available foraging habitat. The final ratio is based on a careful comparison of the status of these variables for both the impacted population and the mitigation site. These variables are used to ensure that the biological value of the group being impacted is replaced or improved upon by the mitigation group.

Funding for Mitigation

Mitigation is funded by the landowner performing the action that will impact woodpecker groups. Mitigation costs include a management endowment sufficient to cover habitat management, such as prescribed burning, for the mitigation groups for 5 years (one full generation for red-cockaded woodpeckers). Other costs include the initial provisioning of cavities and initial midstory control in the recipient cluster as well as the costs of translocating juvenile birds to create mitigation groups and translocating resident adults from affected clusters upon successful mitigation.

Other Incentive Programs

Several programs other than Safe Harbor Agreements are available to assist private landowners in management of their lands, but unlike Safe Harbor these are not designed directly for red-cockaded woodpeckers. However, programs that could potentially benefit woodpeckers are available through the Farm Services Agency, Natural Resources Conservation Service, U.S. Fish and Wildlife Service, and state forestry and wildlife agencies. Local offices of the administering agency or organization should be contacted for information about future sign-ups and eligibility requirements.

Farm Service Agency

The Conservation Reserve Program offers annual rental payments and cost-share assistance to plant permanent areas of grass and trees on land that is subject to erosion, and to improve soil, water, and wildlife resources. Assistance for up to 50 percent of costs is available for the 10 to 15 year contracts. This program is most applicable to agricultural lands. However, some management practices implemented under these programs could benefit red-cockaded woodpeckers.

Natural Resources Conservation Service

Landowners who participate in the Wetlands Reserve Program may sell a conservation easement or enter into a cost-share restoration agreement to restore and protect wetlands. Landowners receive financial incentives to enhance wetlands in exchange for retiring marginal agricultural land. In addition to farmland, eligible lands include production forestland where hydrology has been altered, riparian areas that link protected wetlands, and lands adjacent to protected wetlands that contribute significantly to wetland functions and values. The program offers landowners three options: permanent easements, 30-year easements, and restoration cost-share agreements of at minimum 10-year duration. Landowners continue to control access to the land—and may lease the land—for hunting, fishing, and other recreational activities requiring no development.

The Wildlife Habitat Incentives Program is designed to help private landowners develop and improve wildlife habitat on their lands. Participating landowners work with the Natural Resources Conservation Service to prepare a wildlife habitat development plan in consultation with the local conservation district. The plan describes the landowner’s goals for improving wildlife habitat, a list of practices, a schedule for installing them, and steps necessary to maintain the habitat for the life of the agreement. The participant enters into a cost-share agreement usually lasting at least 10 years. The landowner agrees to maintain the cost-shared practices and allows monitoring to judge the effectiveness of the practice. The U.S. Department of Agriculture agrees to provide technical assistance and pay up to 75 percent of the cost of identified practices.

The Environmental Quality Incentives Program is for farmers and ranchers who face serious threats to soil, water, and related natural resources. The program offers financial, educational, and technical help to install or implement structural, vegetative, and management practices called for in 5 to 10-year contracts. Eligible lands include cropland, rangeland, pasture, forestland, and other farm or ranch lands where the program is delivered. Cost-sharing may provide up to 75 percent of the funds for certain conservation practices.

The Forestry Incentives Program is intended to assure the nation's ability to meet future demand for sawtimber, pulpwood, and quality hardwoods. The program pays cost sharing of up to 65 percent (with a limit of $10,000 per person per year) for tree planting, timber stand improvement, and site preparation for natural regeneration. The state forester provides technical advice in developing a management plan and helps find approved vendors, if needed, for completing the work. Private, non-industrial landowners who own less than 4,047 ha (1,000 ac) are eligible to participate in the program. However, this program is available only in selected counties.

U.S. Fish and Wildlife Service

The Partners for Wildlife Program provides technical and financial assistance to private landowners that are restoring and enhancing fish and wildlife habitat. Program emphasis is on restoration of historic vegetation and hydrology. Seventy percent of the project area must reflect the historic vegetation and hydrology while 30 percent may consist of wildlife enhancement activities. Landowners must sign a minimum of 10-year agreement for some projects, and a 25-year agreement for restoration projects.

State Forestry Agencies

The Forestry Stewardship Program is intended to stimulate management of non-industrial, private forestland using multiple-use concepts. This technical assistance program provides management recommendations to fit the landowner's objectives for forest management. Wildlife habitat, water quality, and soil protection are examples of objectives that can be incorporated into the landowner's management plan. The Stewardship Incentives Program is intended to reimburse landowners for 75 percent of the cost of certain forest management practices, including those intended to improve habitat for endangered species. However, cost-share funding through the Stewardship Incentives Program is currently unavailable in many states.

State incentive programs administered by the respective state forestry agencies often emphasize reforestation. Through reforestation, however, other objectives of the landowner, such as creation or enhancement of habitat for red-cockaded woodpeckers, can be addressed. Some state wildlife agencies also administer incentive programs. Examples include Kentucky's Habitat Improvement Program and Arkansas' Acres for Wildlife Program. Not all state forestry or wildlife agencies within the range of the red-cockaded woodpecker offer incentive programs.

B. STATE LANDS

Status and Distribution

As of 2000, there were an estimated 631 active clusters of red-cockaded woodpeckers on 44 state-owned properties in 7 states (USFWS, unpublished; Table 6). Largest concentrations of woodpeckers on state lands occur in Florida, North Carolina, and South Carolina.

During the 1970's, Jackson (1978b) found that approximately 300 clusters, or 8.6 percent of all reported clusters, were located on lands owned by state or local governments. These clusters were distributed across ten states, with the largest concentrations occurring in Florida and South Carolina. Seven of the remaining eight states had less than 12 clusters on state or local lands. Costa and Walker (1995) estimated that 384 active clusters occurred on state lands in 8 states. Although it is clear that several states have, by 2000, lost all woodpeckers on state lands, comparison of current population sizes with those from the 1970's is hampered by inconsistent survey techniques and increasing survey effort across time (Cely and Ferral 1995, Ortego *et al.* 1995, J. Cely, pers. comm.).

Conservation of woodpeckers on state lands is improving, but much progress remains to be made. Habitat management plans, including population goals, have not yet been established for all state lands. Through interviews with state land managers and biologists, J. Hovis (pers. comm.) found that most state agencies have implemented a prescribed burning regime on their lands inhabited by red cockaded woodpeckers. Beyond this, however, the level of management and population monitoring varies considerably both within and among states. For example, some state lands have never been surveyed completely for cavity trees, whereas others have been surveyed but the demography of the resident red-cockaded woodpecker population is unknown. Today, only a few populations on state lands have been intensively managed and/or monitored on a long-term basis. These include the McCurtain County Wilderness Area in Oklahoma (M. Howery, pers. comm.), the Sandhills Game Lands in North Carolina (Walters *et al.* 1988a), and the Sand Hills State Forest in South Carolina (Ferral 1998).

Recovery Role

State lands can contribute to the recovery of the red-cockaded woodpecker in numerous ways. Some state lands will contribute by being part of a designated recovery population. For example, in North Carolina the Holly Shelter Game Lands is part of a primary core population and the Sandhills Game Lands is part of an essential support population. In South Carolina, the Sand Hills State Forest is part of a secondary core population. Several state properties in South/Central Florida are designated essential support populations (see 7). Other state lands throughout the range of red-cockaded woodpeckers contribute to the conservation and recovery of the species as significant and important support populations (see 7).

Finally, state lands can contribute to recovery as mitigation sites (see 4A). Through the mitigation process, red-cockaded woodpecker populations on state lands could be enhanced or restored. Establishing state lands as mitigation sites, however, would require a commitment from the state agencies involved to monitor and manage their woodpecker populations on a long-term basis. Unfortunately, many state agencies have neither the personnel nor funds required to fill such a commitment. Although mitigation monies could be used to finance some management and monitoring activities,

TABLE 6. Number of active red-cockaded woodpecker clusters (ACT, 2000) on state properties, by state. Also listed is estimated potential size (number of active clusters). Except where noted, potential size is based on an agency estimate or property goal identified in a draft or approved red-cockaded woodpecker management plan, or submitted in an Annual Report (2000).

State	Property Full Name	ACT 2000	Potential Size[2]
Arkansas	Pine City Natural Area	1	2[1]
	subtotal	1	2
Florida	Babcock/Webb Wildlife Management Area	27	240[1]
	Blackwater River State Forest	26	≥45
	Camp Blanding Training Site	14	25
	Central Florida Reception Center – South Unit	1	1[1]
	Goethe State Forest	30	150
	Hal Scott Preserve	7	15[1]
	J. W. Corbett/Dupuis Wildlife Management Area	13	90[1]
	Kicco Wildlife Management Area	1	1[1]
	Ochlockonee River State Park	3	3[1]
	Picayune Strand State Forest	3	25[1]
	Platt Branch Mitigation Park	4	7[1]
	St. Sebastian River State Buffer Preserve	8	25
	Tate's Hell State Forest	29	400[1]
	Three Lakes Wildlife Management Area	51	125[1]
	Withlacoochee State Forest - Citrus Tract	46	100
	Withlacoochee State Forest - Croom Tract	5	30
	subtotal	268	1282
Louisiana	Alexander State Forest	5	5
	subtotal	5	5
North Carolina	Bladen Lakes State Forest	3	3[1]
	Holly Shelter Game Lands	38	38
	Johnston Community College	1	1
	Jones Lake State Park	1	4
	McCain Tract	5	7
	Sandhills Game Lands	134	160
	Singletary Lake State Park	4	6
	Weymouth Woods State Nature Preserve	7	13
	subtotal	193	232
Oklahoma	McCurtain County Wilderness Area	12	44
	subtotal	12	44

Table continued next page.

TABLE 6 (cont.). Number of active red-cockaded woodpecker clusters on state properties.

State	Property Full Name	ACT 2000	Potential Size[2]
South Carolina	Cheraw State Fish Hatchery	1	1
	Cheraw State Park	7	25
	Hampton Plantation State Park	1	1[1]
	Lewis Ocean Bay Heritage Preserve	2	10[1]
	Longleaf Pine Heritage Preserve	2	4[1]
	Manchester State Forest	3	3[1]
	Persanti Island	3	3[1]
	Sand Hills State Forest	51	~143[1]
	Sandy Island	32	35[1]
	Santee Coastal Reserve	8	16
	Santee State Park	1	7[1]
	Webb Wildlife Center	12	30[1]
	Wedge Plantation	2	2[1]
	Yawkey Wildlife Center	8	15[1]
	subtotal	133	295
Texas	Huntsville State Fish Hatchery	1	1[1]
	I. D. Fairchild State Forest	4	7
	W. G. Jones State Forest	14	14
	subtotal	19	22
	TOTAL	**631**	**1882**

[1]Potential size based on U.S. Fish and Wildlife Service or responsible agency's estimate derived by dividing the area of currently or potentially suitable upland pine on the property by 81 ha (200 ac) per cluster.

[2] Except for those potential sizes identified as goals in approved agency management plans, all other potential population sizes are non-binding and subject to change pending approval of site-specific management plans.

long-term programs on state lands will require additional funding. Accordingly, state agencies should be encouraged to seek Section 6 funds through the U.S. Fish and Wildlife Service to initiate or enhance their activities on state lands with red-cockaded woodpeckers.

Conservation of Biodiversity within States

Whereas recovery of red-cockaded woodpeckers as a species is founded on distribution of large populations throughout the species range, biologists and managers working at the state level must set priorities for conservation of biodiversity based on political (state) boundaries. We emphasize that small populations with a minor designated role in species recovery may be critical in conserving biodiversity at the state level.

C. FEDERAL LANDS

Conservation of red-cockaded woodpeckers as a species depends primarily on the conservation of populations on federal lands, for several reasons. First, the vast majority of red-cockaded woodpeckers in existence today are on federal lands (Costa and Walker 1995, James 1995; see Table 7). Second, federal properties contain most of the land that can reasonably be viewed as potential habitat for red-cockaded woodpeckers (USFWS 1985). Third, existing legislation, especially the Endangered Species Act (Section 7) but also the National Forest Management Act and others, require that federal agencies conserve listed species and maintain biodiversity within their lands. In the Endangered Species Act (Section 3), conservation is defined as “the use of all methods and procedures necessary to bring an endangered species or threatened species to the point at which the measures provided pursuant to this act are no longer necessary.” Thus, to the extent that legislation reflects public perception, it is the public’s view that recovery of endangered species and conservation of biodiversity is a responsibility of the federal government to be conducted primarily on publicly owned lands under federal control. This is a difficult task, as it requires the protection of biodiversity at or near precolonial levels on minute remnants of the habitat base. Private landowners can contribute substantially to conservation, but such contributions above the required protection against direct harm (take) are voluntary (see 4A).

Federal properties supporting populations of red-cockaded woodpeckers include national forests, military installations, national wildlife refuges, a national preserve, and a Department of Energy property. As of 2000, there were an estimated 3698 active clusters of red-cockaded woodpeckers on 55 federally owned properties in 9 states (USFWS, unpublished; see Table 7). National forests support the majority of core woodpecker populations required for delisting and therefore have a uniquely important role in the recovery of red-cockaded woodpeckers. Second to national forests in recovery importance are the military installations. National wildlife refuges have a smaller but important role in woodpecker recovery, as do the remaining occupied federal properties.

National Forests

Current Status and Trends

Currently, there are 24 populations of red-cockaded woodpeckers partly or wholly supported by national forests (see map insert and Table 7), ranging in size from 6 active clusters (Shoal Creek Ranger District of the Talladega National Forest) to 486 active clusters (Apalachicola Ranger District, Apalachicola National Forest). An additional national forest property, the Talladega Ranger District of the Talladega National Forest, currently harbors no active clusters but red-cockaded woodpeckers will soon be re-established there. The Apalachicola Ranger District, together with the Wakulla Ranger District and other adjoining properties, supports the largest woodpecker population in existence (665 active clusters; see 7, Table 8).

Numbers of active clusters on national forest properties over the past three years are presented in Table 7. Most populations on national forests appear to be stable or increasing, and a few are in decline. In contrast, most populations on national forests were declining until the mid 1980's, and a few were stable (Costa and Escano 1989). Management efforts during the past decade, especially prescribed burning and cavity management, have stabilized most of these populations and led to increases in many. It is very encouraging that the widespread declines have been stabilized. Our challenge now is to increase the populations to sizes necessary for species recovery.

Recent declines have occurred on four national forest properties. On the Talladega Ranger District, the Kisatchie Ranger District, and the Francis Marion National Forest, poor habitat resulting from lack of fire and suitable cavities is considered the primary factor in these recent declines (R. Costa, pers. comm.). The decline in the Vernon Unit, Calcasieu Ranger District is surprising, given the apparent health of the population and its habitat. The reason for this decline is not presently known, but may be the result of differences in field survey and census methods over time, and/or record keeping. Each of these populations has a substantial role in recovery (below, Table 7; see also 7, Table 8) and these declining trends must be reversed.

Role in Recovery

National forests have a vital role in recovery of red-cockaded woodpeckers, because most core populations within recovery units (see 7) are located in national forests. National forests (or ranger districts) containing all or part of a primary core population are the Angelina, Apalachicola (Apalachicola and Wakulla Ranger Districts), Bienville, Croatan, Francis Marion, Kisatchie (Vernon Unit of the Calcasieu Ranger District), Osceola, Sabine, and Sam Houston. Each of these national forests (or ranger districts) will support a population of at least 350 potential breeding groups at the time and after the species is recovered. National forests (or ranger districts) containing all or part of a secondary core population are the Catahoula, Conecuh, Davy Crockett, DeSoto (Chickasawhay and DeSoto Ranger Districts, separately), Homochitto, Oconee, Ouachita, and Talladega (Oakmulgee Ranger District). Each of these national forests (or ranger districts) will support a population of at least 250 potential breeding groups at the time and after the species is recovered. Two national forests—the Ocala in South/Central Florida and the Talladega (Shoal Creek/Talladega Ranger Districts) in the Cumberlands—harbor a support population designated essential to recovery of the species because of the importance of conserving red-cockaded woodpeckers in those regions. Populations on all other national forests, not designated as primary core, secondary core, or essential support populations, are designated significant support populations (see 7). As federally managed support populations, they are required to be increasing at least until the species is recovered. These populations are valuable because they protect against demographic, environmental, and catastrophic events, contain important genetic resources, and facilitate natural dispersal among populations. Because of these contributions, support populations are necessary to bring the species to recovery but will not be required for species viability once core populations reach population goals identified in delisting criteria (see 6A).

Military Installations

Current Status and Trends

At present there are 15 military installations harboring red-cockaded woodpeckers (see map insert and Table 7), ranging from 1 active cluster on Charleston Naval Weapons Station to 301 active clusters on Eglin Air Force Base and 350 active clusters on Fort Bragg. All of these populations appear to be stable or increasing, with the exception of Dare County Bombing Range. Like the populations on national forests, widespread declines among populations on military installations have been stabilized, but substantial increases in population sizes are still required for recovery. In general, the military is managing red-cockaded woodpeckers very effectively. Rates of increase reported from Marine Corps Base Camp Lejeune and Fort Stewart during the 1990's are among the highest yet documented (in the absence of translocation), an encouraging result of intensive, well-planned, and well-executed management.

Role in Recovery

Military installations have a substantial role in recovery and continuing conservation of red-cockaded woodpeckers. Six military installations contain all or part of six primary core populations: Eglin Air Force Base, Fort Benning, Fort Bragg, Fort Polk, Fort Stewart, and Marine Corps Base Camp Lejeune. These primary core populations will contain at least 350 potential breeding groups at the time of and after the species is delisted. Avon Park Air Force Range is a designated essential support population because it supports one of the largest remaining populations in the ecologically unique South/Central Florida Recovery Unit (see 7). Dare County Bombing Range and Camp Mackall are likewise part of essential support populations because of unique or important habitat types. Seven other military installations contain significant support populations, whose increases are important to bringing the species to recovery for reasons described above; however, population goals for these populations are not included in delisting criteria.

National Wildlife Refuges

Current Status and Trends

There are currently 13 populations of red-cockaded woodpeckers partially or wholly contained on national wildlife refuges (see map insert and Table 7), ranging in size from 1 active cluster (Upper Ouachita, Pee Dee, and Black Bayou National Wildlife Refuges) to 116 active clusters (Carolina Sandhills National Wildlife Refuge). Most appear to be stable; several appear to be declining, including Carolina Sandhills, D'Arbonne, and Pocosin Lakes. Substantial increases are required for recovery.

Role in Recovery

National wildlife refuges have a small but important role in recovery of red-cockaded woodpeckers. One refuge (Okefenokee National Wildlife Refuge) contains part of a primary core population, and two refuges contain part of two secondary core populations (Carolina Sandhills and Piedmont National Wildlife Refuges). In addition, two refuges in northeastern North Carolina (Alligator River and Pocosin Lakes National Wildlife Refuges) contain part of a support population designated essential to recovery because of the importance of conserving red-cockaded woodpeckers in the unique habitat type there. The remaining populations partially or wholly on refuge lands are important or significant support populations (see 7) and should be managed for increasing populations. Big Branch Marsh National Wildlife Refuge, containing 15 active clusters at the present time, is notable among support populations on refuge lands because of its location in an ecoregion (Gulf Coast Prairies and Marshes) that currently contains no other woodpeckers.

Other Federal Lands

Two populations of red-cockaded woodpeckers occur on federal lands other than national forests, military installations, and national wildlife refuges. Big Cypress National Preserve harbors a population of 42 active clusters in the ecologically unique native hydric slash pine habitat of south Florida (see map insert and Table 7). Because of its unique habitat, this population is designated an essential support population. The Savannah River Site, controlled by the Department of Energy, contains an increasing population of 34 active clusters and is a secondary core population (see map insert and Table 7). This population will hold at least 250 potential breeding groups at the time of and after delisting.

TABLE 7. Number of active red-cockaded woodpecker clusters (ACT) on federal and tribal properties in 1998, 1999, and 2000, by responsible agency. Also indicated is property goal based on habitat designated for red-cockaded woodpeckers [usually 81 ha (200 ac) per cluster] in agency or site-specific management plans.

		ACT			
Federal Agency	**Property Full Name**	**1998**	**1999**	**2000**	**Goal**
National Park Service	Big Cypress National Preserve	40	41	42	42
	subtotal	40	41	42	42
U.S. Air Force	Avon Park Air Force Range	21	21	21	68
	Dare County Bombing Range	6	9	3	46
	Eglin Air Force Base	280	295	301	500
	Poinsett Weapons Range	5	6	6	30
	subtotal	312	331	331	644
U.S. Army	Camp Mackall	9	11	11	11
	Fort Benning	187	186	219	450
	Fort Bragg	309	350	350	436
	Fort Gordon	2	3	5	25
	Fort Jackson	13	21	24	126
	Fort Polk	45	44	46	179
	Fort Stewart	189	198	212	500
	Military Ocean Terminal Sunny Point	6	6	9	17
	Peason Ridge	25	25	23	120
	subtotal	785	844	899	1864
U.S. Dept of Energy	Savannah River Site	29	31	34	418
	subtotal	29	31	34	418
U.S. Forest Service	Angelina NF	30	30	29	252
	Apalachicola Ranger District, Apalachicola NF	505	486	486	500
	Bienville NF	106	106	104	500
	Catahoula Ranger District, Kisatchie NF	29	31	32	317
	Chickasawhay Ranger District, DeSoto NF	10	13	15	502
	Conecuh NF	13	14	18	309
	Croatan NF	60	58	62	169
	Davy Crockett NF	48	51	53	330
	DeSoto Ranger District, DeSoto NF	6	6	7	368
	Evangeline Unit, Calcasieu Ranger District, Kisatchie NF	68	70	72	231
	Francis Marion NF	368	334	344	453
	Homochitto NF	67	45	51	254
	Kisatchie Ranger District, Kisatchie NF	56	57	29	292
	Oakmulgee Ranger District, Talladega NF	123	115	110	394

Table continued next page.

TABLE 7 (cont.). Number of active red-cockaded woodpecker clusters on federal and tribal properties in 1998, 1999, and 2000.

		ACT			
Federal Agency	**Property Full Name**	**1998**	**1999**	**2000**	**Goal**
U.S. Forest Service (cont.)	Ocala NF	13	18	22	179
	Oconee NF	17	18	20	250
	Osceola NF	54	63	63	462
	Ouachita NF	15	16	21	400
	Sabine NF	22	25	28	262
	Sam Houston NF	168	168	168	541
	Shoal Creek Ranger District, Talladega NF	2		6	~125
	Talladega Ranger District, Talladega NF	1	5	0	~110
	Vernon Unit, Calcasieu Ranger District, Kisatchie NF	196	146	152	302
	Wakulla Ranger District, Apalachicola NF	125	125	138	506
	Winn Ranger District, Kisatchie NF	14	16	18	263
	subtotal	2116	2016	2048	8271
U.S. Fish and Wildlife Service	Alligator River NWR	2	2	3	~20+
	Big Branch Marsh NWR	8	9	15	20
	Black Bayou NWR			1	1
	Carolina Sandhills NWR	125	118	116	193
	D'Arbonne NWR	5	4	2	5
	Felsenthal NWR	15	15	15	34
	Noxubee NWR	37	38	44	88
	Okefenokee NWR	26	29	37	86
	Pee Dee NWR	1	1	1	10
	Piedmont NWR	35	37	39	96
	Pocosin Lakes NWR	4	1	1	50
	St. Marks NWR	6	6	9	71
	Upper Ouachita NWR	1	1	1	1
	subtotal	265	261	284	675
U.S. Marine Corps	Marine Corps Base Camp Lejeune	47	49	59	173
	subtotal	47	49	59	173
U.S. Navy	Charleston Naval Weapons Station	2	2	1	12
	subtotal	2	2	1	12
	TOTAL, FEDERAL PROPERTIES	**3596**	**3575**	**3698**	**12099**
Tribe					
Alabama-Coushatta	Alabama-Coushatta Tribe of Texas			2	2
	TOTAL, FEDERAL AND TRIBAL PROPERTIES			**3700**	**13101**

In summary, federal lands have a fundamental role in the recovery of red-cockaded woodpeckers. Advances in management of red-cockaded woodpeckers on federal lands have led to stabilization of most populations and increases in many. A few populations are still declining. For most populations designated as primary core, secondary core, or essential support populations, substantial increases are required before recovery population goals are reached.

D. Native American Tribal Trust Lands

Currently, there is one Native American Tribe with lands supporting active clusters of red-cockaded woodpeckers. Lands belonging to the Alabama-Coushatta Tribe of Texas presently support two active clusters, and the Alabama-Coushatta Tribal Forestry Department is actively managing for red-cockaded woodpeckers. Native American Tribes have no specifically designated role in recovery of red-cockaded woodpeckers, but are encouraged to participate in recovery efforts to the fullest possible extent.

PART II. RECOVERY

5. RECOVERY GOAL

The ultimate recovery goal is species viability. This goal is represented by delisting. Once delisting criteria are met, it is believed that the size, number, and distribution of red-cockaded woodpecker populations will be sufficient to counteract threats from demographic, environmental, genetic, and catastrophic stochasticity. Therefore, upon delisting the species will be viable over the long-term, at least under the current understanding of these stochastic processes. An interim goal is downlisting from endangered to threatened status.

6. RECOVERY CRITERIA

Population sizes identified in recovery criteria are measured in the number of potential breeding groups. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young. A traditional measure of population size has been number of active clusters. Potential breeding groups is a better measure of population status, because this is the basis of population dynamics in this species, and number of active clusters can include varying proportions of solitary males and captured clusters. Estimates of all three parameters—number of active clusters, proportion of solitary males, and proportion of captured clusters—are required to support estimates of potential breeding groups.

To assist in the transition between these two measures, we have provided a range of numbers of active clusters considered the likely equivalents of the required number of potential breeding groups. Estimated number of active clusters is likely to be at least 1.1 times the number of potential breeding groups, but it is unlikely to be more than 1.4 times this number. Thus, an estimated 400 to 500 active clusters will be necessary to contain 350 potential breeding groups, depending on the proportions of solitary males and captured clusters and also on the estimated error of the sampling scheme. It is expected that all recovery populations will have sampling in place that is adequate to judge potential breeding groups. If this is not the case, only the highest number of active clusters in the range given can be substituted to meet the required population size.

A. DELISTING

Delisting shall occur when each of the following criteria is met. A brief rationale for each criterion is given immediately following this list, and a detailed discussion of species and population viability is presented in 2C. Discussion of the five listing factors identified in the Endangered Species Act (Section 4(a)(1)), and how they are related to red-cockaded woodpecker recovery, is also presented in this section. Definitions and descriptions of terms used in delisting criteria, such as recovery units, primary and secondary core populations, and essential support populations, are given in the next section (7). See Table 8 for population designation. All properties identified as part or all of a recovery population (Table 8) should be managed for maximum size that the habitat designated for red-cockaded woodpeckers will allow. (Maximum size is generally based on 200 ac [81 ha] per group).

Criterion 1. There are 10 populations of red-cockaded woodpeckers that each contain at least 350 potential breeding groups (400 to 500 active clusters), and 1 population that contains at least 1000 potential breeding groups (1100 to 1400 active clusters), from among 13 designated primary core populations, and each of these 11 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size.

Criterion 2. There are 9 populations of red-cockaded woodpeckers that each contain at least 250 potential breeding groups (275 to 350 active clusters), from among 10 designated secondary core populations, and each of these 9 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size.

Criterion 3. There are at least 250 potential breeding groups (275 to 350 active clusters) distributed among designated essential support populations in the South/Central Florida Recovery Unit, and six of these populations (including at least two of the following: Avon Park, Big Cypress, and Ocala) exhibit a minimum population size of 40 potential breeding groups that is independent of continuing artificial cavity installation.

Criterion 4. There is one stable or increasing population containing at least 100 potential breeding groups (110 to 140 active clusters) in northeastern North Carolina and southeastern Virginia, the Cumberlands/Ridge and Valley recovery unit, and the Sandhills recovery unit, and these populations are not dependent on continuing artificial cavity installation to remain at or above this population size.

Criterion 5. For each of the populations meeting the above size criteria, responsible management agencies shall provide (1) a habitat management plan that is adequate to sustain the population and emphasizes frequent prescribed burning, and (2) a plan for continued population monitoring.

Rationale for Delisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift. One primary core population has the potential to harbor 1000 potential breeding groups within the near future; this criterion is included because such a large population may well be resistant to loss of genetic variation through drift. Eleven of 13 primary core populations are required for delisting because it is recognized that at any given time, one or two may be suffering hurricane impacts. Thirteen primary core populations are designated because of available habitat and because this number, together with 10 secondary core populations (below), may serve to facilitate natural dispersal among populations and maximize retention of genetic variability. Primary and secondary core populations provide for the conservation of the species within each major physiographic unit in which it currently exists, with the exception of South/Central Florida. This unit is represented by several, smaller, essential support populations (below). Populations that depend on continuing artificial cavity installation to maintain stable or increasing trends are barred from meeting delisting criteria because this management technique is considered appropriate for short-term management only.

Criterion 2. A population size of 250 potential breeding groups is the minimum size considered robust to environmental stochasticity, and is well above the size necessary to withstand inbreeding and demographic stochasticity. Nine of 10 designated secondary core populations are required for delisting to allow for hurricane impacts.

Criterion 3. This unique habitat type is represented to the extent that available habitat allows. Unique genetic resources are conserved as much as reasonably possible. Because of small size, some of these populations will remain vulnerable to extinction threats and may eventually be lost. The likelihood of extirpation of small populations is minimized by enhancing the spatial arrangement of territories so that they are highly aggregated.

Criterion 4. These unique habitats, and genetic resources contained within this population, will be represented at the time of delisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. Continued habitat management and population monitoring are necessary to ensure that the species does not again fall to threatened or endangered status.

Delisting Criteria and Listing Factors Identified in the Endangered Species Act

The Endangered Species Act (Section 4(a)(1)) identified five factors that threaten or endanger a species, any one of which is justification for listing. At delisting, therefore, none of these factors can exist. We discuss each of these factors below and describe the means by which, if this recovery plan is fully implemented, these factors will not threaten red-cockaded woodpeckers at time of delisting.

Listing Factor A: *the present or threatened destruction, modification, or curtailment of a species' habitat or range*. Red-cockaded woodpeckers are vulnerable to habitat loss and habitat degradation. Habitat loss and degradation were primary factors in the species' original decline (see 1A); these factors resulted from direct conversion of habitat to other land uses, fire suppression, and loss of mature pines within pine woodlands. Direct conversion of habitat no longer occurs on public lands, which form the basis of recovery for red-cockaded woodpeckers. However, currently, lack of frequent fire and mature pines continue to threaten the species on public and private lands (1B). Red-cockaded woodpeckers are most vulnerable to loss and degradation of nesting habitat (2D), but are also vulnerable to loss and degradation of foraging habitat (2E). Addressing these threats is a primary objective of this recovery plan.

Management actions such as artificial cavity installation, prescribed burning, and silviculture that protects old pines are powerful tools critical to restoration of habitat and recovery of the species. As such, these actions are heavily emphasized in management guidelines (8E, 8K, 8J), recovery tasks (9), and throughout the document. Moreover, these critical actions are represented in delisting criteria: a prescribed burning program is explicitly required as part of habitat management plans that must be in place for delisting (criterion 6), whereas a stable or increasing population trend, independent from continuing artificial cavity installation, is required for populations to meet their size requirements (criteria 1-5). A stable or increasing trend independent of continuing artificial cavity installation can only be achieved once large old pines are available in abundance.

Listing Factor B: *overutilization for commercial, recreational, scientific, or educational purposes.* Overutilization was not a factor in the original decline of red-cockaded woodpeckers and it is not currently a threat to species recovery.

Listing Factor C: *disease or predation.* Disease and predation were not factors in the original decline of red-cockaded woodpeckers and neither is currently a threat to species recovery.

Listing Factor D: *inadequacy of existing regulatory mechanisms*. Existing regulatory mechanisms, specifically the Endangered Species Act and the National Forest Management Act, are adequate to ensure the recovery of red-cockaded woodpeckers, assuming this recovery plan is fully implemented.

Listing Factor E: *other natural or manmade factors affecting its continued existence.* Other natural or manmade factors affecting the continued existence of red-cockaded woodpeckers include habitat fragmentation and the threats to viability inherent to small populations. Addressing these threats is a primary objective of this recovery plan.

Habitat fragmentation can result in loss of population viability through disrupted dispersal. Further fragmentation of habitat is safeguarded against by appropriate silvicultural methods (3E, 8J). In addition, management guidelines emphasize maintaining or developing beneficial arrangements of red-cockaded woodpecker groups in space, to enhance dispersal within populations (8B, 8H). Translocation (8H) and installation of recruitment clusters (8B) are important management actions used to create such beneficial spatial arrangements. Threats to viability inherent to small populations are discussed in detail in section 2C. Resistance to these threats is the fundamental basis for target population sizes identified in delisting criteria (1 – 5). The set of populations that will exist at delisting will not be vulnerable to effects of habitat fragmentation nor to stochastic events that threaten small populations. Once delisting criteria have been met, the species will be viable to the fullest degree possible given current scientific understanding.

B. DOWNLISTING

Downlisting shall occur when each of the following criteria is met. Rationale for each criterion is presented immediately following this list. See Table 8 for population designation. All populations identified in downlisting criteria should be managed for maximum size that the habitat designated for red-cockaded woodpeckers will allow. (Maximum size is generally based on 200 ac [81 ha] per group).

Criterion 1. There is one stable or increasing population of 350 potential breeding groups (400 to 500 active clusters) in the Central Florida Panhandle.

Criterion 2. There is at least one stable or increasing population containing at least 250 potential breeding groups (275 to 350 active clusters) in each of the following recovery units: Sandhills, Mid-Atlantic Coastal Plain, South Atlantic Coastal Plain, West Gulf Coastal Plain, Upper West Gulf Coastal Plain, and Upper East Gulf Coastal Plain.

Criterion 3. There is at least one stable or increasing population containing at least 100 potential breeding groups (110 to 140 active clusters) in each of the following recovery units: Mid-Atlantic Coastal Plain, Sandhills, South Atlantic Coastal Plain, and East Gulf Coastal Plain.

Criterion 4. There is at least one stable or increasing population containing at least 70 potential breeding groups (75 to 100 active clusters) in each of four recovery units, Cumberlands/Ridge and Valley, Ouachita Mountains, Piedmont, and Sandhills. In addition, the Northeast North Carolina/Southeast Virginia Essential Support Population is stable or increasing and contains at least 70 potential breeding groups (75 to 100 active clusters).

Criterion 5. There are at least four populations each containing at least 40 potential breeding groups (45 to 60 active clusters) on state and/or federal lands in the South/Central Florida Recovery Unit.

Criterion 6. There are habitat management plans in place in each of the above populations identifying management actions sufficient to increase the populations to recovery levels, with special emphasis on frequent prescribed burning during the growing season.

Rationale for Downlisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift.

Criterion 2. This population size, 250 potential breeding groups, is sufficient to withstand extinction threats from environmental uncertainty, demographic uncertainty, and inbreeding depression. These 6 populations, in combination with the single population identified in criterion (1), will represent each major recovery unit.

Criterion 3. A second population in these coastal recovery units will decrease the species' vulnerability to hurricanes. The West Gulf Coastal Plain is excluded because there are no candidate populations there. The lower size, 100 potential breeding groups, is considered sufficient to withstand threats from demographic uncertainty and inbreeding depression, and is much more quickly attained than 250 potential breeding groups thought necessary to withstand environmental stochasticity.

Criterion 4. These special habitats will be represented at the time of downlisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. This unique region will be represented at the time of downlisting. Forty potential breeding groups is at the lower end of estimates of sizes necessary to withstand inbreeding depression and are considered robust to demographic stochasticity if territories are highly aggregated in space.

Criterion 6. These habitat management plans are necessary to ensure progress toward delisting.

7. RECOVERY UNITS

Recovery units are geographic or otherwise identifiable subunits of the listed entity that individually are necessary to conserve genetic robustness, demographic robustness, important life history stages, or some feature necessary for long-term sustainability of the overall listed entity. The recovery units established for red-cockaded woodpeckers are a surrogate for likely genetic variation and adaptation to local environments, because they are based on changing environmental conditions, i.e., they are geographic areas delineated according to ecoregions (physiographic provinces; see discussion below and map insert). Substantial genetic variation has been documented in red-cockaded woodpeckers across their range, although distinct boundaries for this variation have not been identified. Red-cockaded woodpeckers exhibit a correlation between genetic variation and geographic distance, meaning the farther apart populations are geographically, the greater the genetic variation between or among them. This has been documented using both randomly amplified polymorphic DNA (used as a genetic marker; Haig et al. 1994a, 1996) and allozyme data (Stangel et al. 1992, Stangel and Dixon 1995). As molecular markers gain resolution, we may be able to identify more distinct genetic boundaries, but the correlation between genetic variation and geographic distance is a classic characteristic of species that were once distributed primarily as a continuous population.

Names of recovery units are the same as their respective ecoregion, with one exception (South/Central Florida). There are eleven designated recovery units for red-cockaded woodpeckers. All but two recovery units contain one or more core recovery populations and one or multiple support populations (map insert). The remaining two recovery units contain support populations only. Core populations are classified as primary or secondary based on available habitat and population size required for delisting. In addition to primary and secondary core populations, several support populations are considered essential to species recovery and as such are identified in delisting and downlisting criteria. These essential support populations are not designated primary or secondary cores because of habitat limitations. All other support populations (below) are necessary to protect and maximize genetic and demographic health until the species is delisted.

Maintaining viable populations within each recovery unit is essential to the survival and recovery of red-cockaded woodpeckers as a species, across their range. Conservation of populations in all habitats, forest types, and ecoregions, represented within and by recovery units is critical to species survival and recovery because these varied populations have crucial ecological and genetic values. The loss, or reduction of the likelihood of survival and recovery, of core and essential support populations within one or more of the designated recovery units could not only jeopardize the recovery goals for the individual recovery unit(s), but also jeopardize the recovery of the entire species in several ways.

First, without immigration, no red-cockaded woodpecker population (with the possible exception of the Central Florida Panhandle population) will be large enough to avoid loss of genetic variability through genetic drift. Loss of genetic variation may reduce a species' ability to adapt and persist in a changing environment (ecoregion), and thereby reduce its viability over long time periods. One practical way to reduce the threat of genetic drift is to promote immigration, both natural (dispersal) and artificial (via translocation). Multiple recovery units, harboring all of the habitat types and representing all ecoregions in which red-cockaded woodpeckers currently exist, provide the means to ensure that natural and artificial immigration can occur and be managed.

Second, the vast majority of red-cockaded woodpecker populations are threatened today by demographic stochasticity and will remain so for the foreseeable future. Therefore, the short-term survival of many individual populations in most recovery units is dependent on translocated birds from other recovery units. Because donor populations for many small (less than 30 potential breeding groups), at-risk populations are in adjacent recovery units, actions adversely affecting donor populations in one recovery unit can jeopardize the survival and recovery of populations in other recovery units, thereby jeopardizing the entire species.

A third and significant threat to red-cockaded woodpecker populations are catastrophes, including hurricanes and outbreaks of southern pine beetles, which point to several reasons for identifying and conserving multiple recovery units. First, red-cockaded woodpecker populations in similar habitats/forest types and with more closely related genetic resources may occur in recovery units adjacent to those impacted by the catastrophic event, thus helping ensure that the ability of the species to adapt to these ecological conditions of habitat and forest type would be protected. Second, by maintaining a number of recovery units, with their associated populations, that are broadly spaced geographically, and including as many inland populations as possible, the threat from catastrophic loss is substantially reduced. Additionally, when losses do occur in one recovery unit, other recovery units can be relied upon to supply birds for population restoration programs, thereby ensuring the continued likelihood of survival and recovery of the species.

To achieve and maintain species viability, we must maintain a network of interacting populations within and between recovery units. This strategy will promote natural immigration from support and core populations, over the long-term, within and between recovery units, thereby reducing species' susceptibility to loss of genetic variability through genetic drift. If, in the future, natural immigration rates are determined to be inadequate to reach or maintain genetic variability, artificial immigration (via translocation) within and between recovery units will be necessary to ensure the survival and recovery of red-cockaded woodpeckers. Similarly, the recovery unit system provides the means today and into the future to overcome the threats of demographic stochasticity through translocation. Additionally, the recovery unit system provides the opportunity to respond aggressively to stabilize and restore recovery units and populations impacted by catastrophic events. Thus, the system of recovery units, with respective primary core, secondary core, and support populations, provides the foundation of the strategy to recover red-cockaded woodpeckers.

Recovery Units as the Basis for Jeopardy Analysis in Interagency Consultation

In the past, exceptions from applying the jeopardy standard to an entire species were granted by a U.S. Fish and Wildlife Service Director's memorandum, dated March 3, 1986, for specific populations of a species. Since the mid-1980's, in compliance with the Director's memorandum, we conducted jeopardy analyses for red-cockaded woodpeckers at the level of the population.

Our guidance on this topic changed with the release of our Consultation Handbook in 1998 (USFWS 1998). The Handbook states that when determining whether an action jeopardizes the continued existence of the species, we are to analyze the total impacts of the proposed project on the entire species. However, the Handbook acknowledges that for some wide-ranging species, this analysis can be facilitated by the establishment of recovery units in a final recovery plan. The Consultation Handbook notes that species' recovery plans provide the best available scientific information relative to the areas and environmental elements needed for the species to recover, and may even describe recovery units essential to recovering the species. Given that actions that appreciably impair or preclude the capability of such a recovery unit from providing the survival and recovery functions identified for it in a recovery plan may therefore represent jeopardy to the species, the Consultation Handbook indicates the jeopardy standard may be applied to individual recovery units identified as necessary for survival and recovery of the species in an approved final recovery plan. Thus, the designation of recovery units in recovery plans facilitates recovery both by focusing the species' recovery program on the need to conserve the geographic, demographic, and genetic features of the recovery unit for its contribution to the whole species, and by facilitating the evaluation of potential jeopardy to the species when the survival and recovery of an individual recovery unit is in question.

Ecoregions

Ecoregions (physiographic provinces; Bailey 1983, Bailey *et al.* 1994) are a system of classification based on physiography, the study of the natural features of the earth's surface. Important to physiography and the designation of ecoregions are characteristics of land formation, climate, air and sea currents, and distribution of flora and fauna. Ecoregions are a more finely grained system of classification than the world biome system (Clements and Shelford 1939), for example, but not as fine as classifications according to ecosystems or communities. Although the natural boundaries of ecoregions are generally gradual rather than distinct, for the purposes of classification distinct boundaries have been delineated.

Ecoregions can be used to represent varying climatic and edaphic factors that have likely influenced species evolution over time. For red-cockaded woodpeckers, ecoregions reflect broad areas within which local adaptations and genetic coadaptation have likely occurred. (Genetic coadaptation is the evolution of gene complexes that together impart greater fitness than the sum of each individual gene's contribution. A coadapted gene's effect depends on the presence of one or more other genes; Templeton *et al.* 1986). Thus, major objectives in the use of ecoregions as a basis for recovery units are to identify likely genetic variation and to assure that this variation is conserved to the fullest extent possible.

Translocation

Translocations between populations (see 3D) will be conducted within recovery units and between adjacent recovery units except in rare cases. These rare exceptions include (1) previous agreements between the U.S. Fish and Wildlife Service, private landowners, and state and federal agencies, and (2) no donor population available in the same or adjacent recovery unit. This guideline applies to all translocations, including those intended for population augmentation (3D) and mitigation (4A). The primary objectives, and major benefits, of this guideline are the retention of genetic integrity and the protection of each unit's progress toward recovery. Translocation and/or mitigation must not result in genetic pollution or cause a net loss of groups within any given recovery unit. In addition, controlling maximum distances for translocation will minimize cost, logistical difficulties, and the stress on the birds from transport.

Primary and Secondary Core Populations

Primary Core Populations

Primary core populations are those that will harbor at least 350 potential breeding groups at the time of and after delisting. Populations of this size are above the minimum size considered necessary to withstand threats of extirpation from demographic stochasticity, environmental stochasticity, and inbreeding depression (2C). Populations of this size may not be capable of retaining sufficient genetic variability for long-term viability in the absence of immigration (Lande 1995; 2C), but because retention of genetic variability is a direct function of population size, these primary core populations will retain more variation than secondary core and support populations. Conservation of within-population genetic diversity is a major function of primary core populations.

One primary core population (Central Florida Panhandle) will harbor 1000 potential breeding groups at delisting. This population size may well be resistant to loss of genetic variation through genetic drift.

Although a minimum population size of primary core populations is necessarily identified in delisting criteria, primary core populations should expand to the maximum sizes the habitat designated for red-cockaded woodpeckers will allow, to retain as much genetic variation within the populations as possible (2C). (Maximum size is generally based on 200 ac [81 ha] per group). At downlisting, primary core populations may not necessarily contain 350 potential breeding groups.

There are 12 designated primary core populations, located on federal lands including national forests, military installations, and one national wildlife refuge (see map insert). Some state properties, such as Holly Shelter Game Lands in North Carolina, support important segments of primary core populations.

Secondary Core Populations

Secondary core populations are those that will hold at least 250 potential breeding groups at the time of and after delisting. This population size is the minimum estimate considered necessary to withstand threats of extirpation from environmental stochasticity, and is considered highly robust to threats from demographic stochasticity and inbreeding depression. These populations are not large enough to withstand threats to long-term viability from the process of genetic drift unless immigration is maintained. Secondary core populations should be expanded to maximum population goals based on available habitat to protect genetic resources as much as possible and to provide maximum resilience to environmental effects. Habitat limitations for secondary core populations prevent their designation as primary core populations. Secondary core populations may not necessarily harbor 250 potential breeding groups at the time of downlisting.

There are 11 secondary core populations, located on federal lands including national forests, national wildlife refuges, and Department of Energy lands (see map insert). State lands, such as the Sand Hills State Forest in South Carolina, support important segments of secondary core populations.

Benefits of the Primary and Secondary Core Population Strategy

The 12 primary and 11 secondary core populations of red-cockaded woodpeckers are well distributed throughout the species' range. This widespread distribution serves several critical ecological objectives. First, such a distribution conserves red-cockaded woodpeckers in varied habitats and geographic regions in which they currently exist (above). Second, the wide distribution and relatively high number of populations reduces threat of species extinction from catastrophic events such as hurricanes (see 2C). Finally, secondary and primary core populations together create a network which, when population goals are reached, may facilitate the natural dispersal among populations that is critical to long-term genetic viability (2C).

Red-cockaded woodpeckers are capable of long-distance movements between populations (Walters *et al.* 1988b, Conner *et al.* 1997c, Ferral *et al.* 1997; see 2B), although under present conditions these dispersal events are rare. With increasing population size, natural movements between populations are expected to increase. Primary and secondary core populations at and after delisting will be large and healthy; thus, natural dispersal among recovered core populations may be sufficient to maintain species-wide genetic variability. If not, translocation may have to be conducted to achieve this objective. In the meantime, support populations (below) play a vital role in facilitating gene flow through natural dispersal and translocation.

Primary core, secondary core, and essential support (below) populations are delineated by estimated biological population boundaries. Most of these designated populations are currently functioning, or will function at recovery, as one demographic and genetic unit. If this were not the case, expected resistance to stochastic threats would be compromised. There are four cases, however, in which a defined recovery population may continue to be a composite of relatively isolated subpopulations: (1) Angelina/Sabine Primary Core, (2) Coastal North Carolina Primary Core, (3) Osceola/Okefenokee Primary Core, and (4) Northeast North Carolina/Southeast Virginia Essential Support. For these cases, it remains to be seen whether, as isolated subpopulations grow in size, these designated populations can begin to function as single biological units.

Support Populations

All populations not designated a primary or secondary core are designated support populations. There are three classifications for support populations:

1. Essential support populations are those populations, identified in recovery criteria, that represent unique or important habitat types that cannot support a larger, core population. They are located on federal, state, and, in two cases, private lands in agreement with the U.S. Fish and Wildlife Service (Table 3).

2. Significant support populations are populations, not identified in recovery criteria, that contain and/or have a population goal of 10 or more active clusters. (A population size of 10 active clusters, if highly aggregated in space, has a good probability of persistence over a 20-year time period; Crowder *et al.* 1998, Walters et al. 2002b.) They are located on federal and state lands and on private lands enrolled in agreements with the U.S. Fish and Wildlife Service (see Tables 5 and 9).

3. Important support populations are populations, not identified in recovery criteria, that contain and have a population goal of less than 10 active clusters. They are located on federal and state lands (Table 9) and on private lands enrolled in agreements with the U.S. Fish and Wildlife Service.

All populations of red-cockaded woodpeckers have intrinsic ecological, cultural, and historical value. In addition to these intrinsic values, support populations aid in the conservation and recovery of the species. Support populations are important reservoirs of genetic resources. They help represent natural variation in habitats occupied by red-cockaded woodpeckers. Support populations are an important source of immigrants for core populations to increase retention of genetic variation and could potentially provide a buffer against stochastic loss of core populations. These functions are especially critical now, because many core populations are currently well below the population sizes necessary to withstand threats of environmental, demographic, and genetic uncertainty. Because of small population size of most support populations, extirpation of some due to stochastic events is expected.

Significant and important support populations identified within this plan are defined by ownership, rather than biological population boundaries. Some of the populations listed below may be functioning as part of larger populations. Recovery populations—primary core, secondary core, and essential supports—are defined by estimated biological boundaries rather than ownership.

Management prescriptions for all support populations on public lands will be the same as those applied in core populations. Managers should increase their populations to the maximum the habitat base will support, using the level of monitoring recommended based on population size (see 8C) and the recovery standard for foraging habitat (8I). Management plans for federal and state lands are approved by the U.S. Fish and Wildlife Service (contact the Recovery Coordinator for further information). Support populations on private lands will be managed under Memoranda of Agreement, Habitat Conservation Plans, Safe Harbor Agreements or other management instruments approved by the U.S. Fish and Wildlife Service (contact the Recovery Coordinator for further information). Management prescriptions for these populations depend on agreements.

Individual Recovery Units

For each recovery unit, we list populations identified in delisting criteria below. See Tables 5, 6, and 7, and the map insert, for other populations including those on private, state, and federal properties.

Cumberlands/Ridge and Valley Recovery Unit

The Cumberlands/Ridge and Valley Recovery Unit (Table 8, map insert) contains one essential support population: Talladega/Shoal Creek, which consists of the Talladega and Shoal Creek Ranger Districts of the Talladega National Forest.

East Gulf Coastal Plain Recovery Unit

The East Gulf Coastal Plain Recovery Unit (Table 8, map insert) contains three primary core populations: (1) Central Florida Panhandle, consisting of Apalachicola and Wakulla Ranger Districts of the Apalachicola National Forest, Ochlockonee River State Park, St. Mark's National Wildlife Refuge, and Tate's Hell State Forest; (2) Chickasawhay Ranger District of the DeSoto National Forest, and (3) Eglin Air Force Base. The Central Florida Panhandle Primary Core will harbor 1000 potential breeding groups at delisting. This recovery unit also contains three secondary core populations: (1) Conecuh/Blackwater, consisting of Conecuh National Forest and Blackwater River State Forest, (2) DeSoto Ranger District of the DeSoto National Forest, and (3) Homochitto National Forest.

Mid-Atlantic Coastal Plain Recovery Unit

The Mid-Atlantic Coastal Plain Recovery Unit (Table 8, map insert) contains two primary core populations: (1) Coastal North Carolina, consisting of Croatan National Forest, Holly Shelter Game Lands, and Marine Corps Base Camp Lejeune; and (2) Francis Marion National Forest. It also contains one essential support population: Northeast North Carolina/Southeast Virginia, consisting of Alligator River National Wildlife Refuge, Dare County Bombing Range, Palmetto-Peartree Preserve (owned by the Conservation Fund), Pocosin Lakes National Wildlife Refuge, and Piney Grove Preserve (owned by The Nature Conservancy).

Ouachita Mountains Recovery Unit

The Ouachita Mountains Recovery Unit (Table 8, map insert) contains one secondary core population, Ouachita National Forest.

Piedmont Recovery Unit

The Piedmont Recovery Unit (Table 8, map insert) contains one secondary core population: Oconee/Piedmont, consisting of Oconee National Forest and Piedmont National Wildlife Refuge.

Sandhills Recovery Unit

The Sandhills Recovery Unit (Table 8, map insert) contains two primary core populations: (1) North Carolina Sandhills East[1], consisting of Calloway Tract (owned by The Nature Conservancy), Carver's Creek Tract (owned by The Nature Conservancy), Fort Bragg, McCain Tract, and Weymouth Woods State Nature Preserve; and (2) Fort Benning. This unit contains one secondary core population: the South Carolina Sandhills, consisting of Carolina Sandhills National Wildlife Refuge and Sand Hills State Forest. This unit also contains one essential support population: North Carolina Sandhills West[11], consisting of Camp Mackall and the Sandhills Game Lands.

South Atlantic Coastal Plain Recovery Unit

The South Atlantic Coastal Plain Recovery Unit (Table 8, map insert) contains two primary core populations: (1) Fort Stewart, and (2) Osceola/Okefenokee, consisting of Osceola National Forest and Okefenokee National Wildlife Refuge. This recovery unit contains a single secondary core population, the Savannah River Site.

South/Central Florida Recovery Unit

The South/Central Florida Recovery Unit (Table 8, map insert) is one of two recovery units that do not contain a primary or secondary core population, because no

[1] Additional private properties acquired and/or managed under the provisions of the cooperative agreement between the Department of the Army and The Nature Conservancy, or protected in perpetuity through other mechanisms, will be considered as contributing to the total number of potential breeding groups in the North Carolina Sandhills East and North Carolina Sandhills West populations, as appropriate given property location.

federal properties in this unit have sufficient land base to support populations of this size. For this reason, the 1985 Recovery Plan (USFWS 1985) did not include south and central Florida in species recovery. However, maintaining populations of red-cockaded woodpeckers in south and central Florida is essential to the recovery of the species. These populations are associated with unique habitat types such as native hydric slash pine (Beever and Dryden 1992) and critically endangered sand ridge communities. South/central Florida populations contain a high degree of among-population genetic variation and at least one unique allele (Haig *et al.* 1996). In addition, south and central Florida served as the source of the longleaf pine/scrub oak community roughly 5000 to 8000 years ago (Watts 1971, Watts *et al.* 1992). The region was a refuge for red-cockaded woodpeckers during the Wisconsin Glaciation just prior to the longleaf advance, and it is likely that red-cockaded woodpeckers evolved here during a previous glacial event (Jackson 1971, Conner *et al.* 2001). Therefore, red-cockaded woodpeckers in south and central Florida are considered an essential component of the species.

All populations on state and federal lands in this unit that have the capacity to harbor 10 or more active clusters are designated essential support populations. Support populations within the South/Central Florida Recovery Unit are included in criteria for delisting (see 6). It is recognized that this recovery unit will not in itself sustain viable populations and that one or more of these populations may be lost to stochastic events. Translocation among populations within this unit is likely to be necessary for long-term maintenance of genetic variation.

Essential support populations within the South/Central Florida Recovery Unit are (1) Avon Park, consisting of Avon Park Air Force Range and Kicco Wildlife Management Area, (2) Babcock/Webb Wildlife Management Area, (3) Big Cypress National Preserve, (4) Camp Blanding Training Site, (5) Goethe State Forest, (6) Hal Scott Preserve, (7) Corbett/Dupuis, consisting of J. W. Corbett Wildlife Management Area and Dupuis Wildlife Management Area, (8) Ocala National Forest, (9) Picayune Strand State Forest, (10) St. Sebastian River State Buffer Preserve, (11) Three Lakes Wildlife Management Area, (12) Withlacoochee State Forest – Citrus Tract, and (13) Withlacoochee State Forest – Croom Tract. Currently, there are no private lands enrolled in agreements with the U.S. Fish and Wildlife Service in this recovery unit.

Upper East Gulf Coastal Plain Recovery Unit

The Upper East Gulf Coastal Plain (Table 8, map insert) contains one primary core population, Bienville National Forest, and one secondary core population, Oakmulgee Ranger District of the Talladega National Forest.

Upper West Gulf Coastal Plain Recovery Unit

The Upper West Gulf Coastal Plain (Table 8, map insert) contains one primary core population, the Sam Houston National Forest. This unit contains no secondary core populations.

West Gulf Coastal Plain Recovery Unit

The West Gulf Coastal Plain Recovery Unit (Table 8, map insert) contains two primary core populations: (1) the Angelina/Sabine National Forests and (2) Vernon/Fort Polk, consisting of the Vernon Unit of the Calcasieu Ranger District of Kisatchie National Forest, and Fort Polk. This recovery unit contains two secondary core populations: (1) Davy Crockett National Forest and (2) Catahoula Ranger District/Winn Ranger District (portion) of Kisatchie National Forest. These secondary core populations were chosen from among several federal properties that can hold populations of 250 potential breeding groups, and were selected to create a stepping-stone pattern in the hopes of enhancing natural dispersal.

Gulf Coast Prairies and Marshes Ecoregion

The Gulf Coast Prairies and Marshes ecoregion (Table 8, map insert) is not considered a recovery unit because there is only a single, small population within it and habitat for red-cockaded woodpeckers is limited. Big Branch National Wildlife Refuge is a significant support population. Because of its unusual habitat type, Big Branch National Wildlife Refuge should be conserved to the fullest extent possible.

Mississippi Alluvial Plain

The Mississippi Alluvial Plain ecoregion (Table 8, map insert) is likewise not considered a recovery unit because there is only a single, small population within it and habitat is limited. Pine City Natural Area is an important support population which, because of its unusual habitat type (pure, site-appropriate loblolly), should be conserved to the fullest extent possible.

TABLE 8. Primary core, secondary core, and essential support populations, and the properties that comprise these populations, by recovery unit. Each of these populations has a designated role in recovery. Also listed is minimum size at delisting (potential breeding groups; PBG), current size (active clusters in 2000; ACT), state, ownership type, and responsible agency. Number of active clusters is generally equal to 1.1 to 1.4 times the number of potential breeding groups. See 10 (Table 16) for key to agency abbreviations.

Recovery Unit **Population** **Property**	**Size at Delisting (PBG)**	**Current Size (ACT)**	**State**	**Type**	**Agency**
Cumberlands/Ridge and Valley					
Talladega/Shoal Creek Essential Support	100				
Shoal Creek Ranger District, Talladega NF		6	AL	Federal	USFS
Talladega Ranger District, Talladega NF		0	AL	Federal	USFS
East Gulf Coastal Plain					
Central Florida Panhandle Primary Core	1000				
Apalachicola Ranger District, Apalachicola NF		486	FL	Federal	USFS
Ochlockonee River State Park		3	FL	State	FPS
St. Mark's National Wildlife Refuge		9	FL	Federal	USFWS
Tate's Hell State Forest		29	FL	State	FDF
Wakulla Ranger District, Apalachicola NF		138	FL	Federal	USFS
Chickasawhay Primary Core	350				
Chickasawhay Ranger District, Desoto NF		15	MS	Federal	USFS
Conecuh/Blackwater Secondary Core	250				
Blackwater River State Forest		26	FL	State	FDF
Conecuh National Forest		18	AL	Federal	USFS
DeSoto Secondary Core	250				
DeSoto Ranger District, DeSoto NF		7	MS	Federal	USFS
Eglin Primary Core	350				
Eglin Air Force Base		301	FL	Federal	USAF
Homochitto Secondary Core	250				
Homochitto National Forest		51	MS	Federal	USFS
Mid-Atlantic Coastal Plain					
Coastal North Carolina Primary Core	350				
Croatan National Forest		62	NC	Federal	USFS
Holly Shelter Game Lands		38	NC	State	NCWRC
Marine Corps Base Camp Lejeune		59	NC	Federal	USMC
Francis Marion Primary Core	350				
Francis Marion National Forest		344	SC	Federal	USFS
Northeast North Carolina/Southeast Virginia Essential Support	100				
Alligator River National Wildlife Refuge		3	NC	Federal	USFWS
Dare County Bombing Range		3	NC	Federal	USAF
Palmetto-Peartree Preserve		25	NC	Private	
Piney Grove Preserve		3	NC	Private	
Pocosin Lakes National Wildlife Refuge		1	NC	Federal	USFWS

Table continued next page.

TABLE 8 (cont.). Primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Size at Delisting (PBG)	Current Size (ACT)	State	Type	Agency
Ouachita Mountains					
Ouachita Secondary Core	250				
Ouachita National Forest		21	AR	Federal	USFS
Piedmont					
Oconee/Piedmont Secondary Core	250				
Oconee National Forest		20	GA	Federal	USFS
Piedmont National Wildlife Refuge		39	GA	Federal	USFWS
Sandhills					
Fort Benning Primary Core	350				
Fort Benning		219	GA	Federal	USARMY
North Carolina Sandhills East Primary Core	350				
Calloway Tract		5	NC	Private	TNC
Carver's Creek Tract		4	NC	Private	TNC
Fort Bragg		350	NC	Federal	USARMY
McCain Tract		5	NC	Federal	NCDA
Weymouth Woods State Nature Preserve		7	NC	State	NCDENR
North Carolina Sandhills West Essential Support	100				
Camp Mackall		11	NC	Federal	USARMY
Sandhills Game Lands		134	NC	State	NCWRC
South Carolina Sandhills Secondary Core	250				
Carolina Sandhills National Wildlife Refuge		116	SC	Federal	USFWS
Sand Hills State Forest		51	SC	State	SCFC
South Atlantic Coastal Plain					
Fort Stewart Primary Core	350				
Fort Stewart		212	GA	Federal	USARMY
Osceola/Okefenokee Primary Core	350				
Okefenokee National Wildlife Refuge		37	GA	Federal	USFWS
Osceola National Forest		63	FL	Federal	USFS
Savannah River Secondary Core	250				
Savannah River Site		34	SC	Federal	DOE
South/Central Florida					
Avon Park Essential Support	40				
Avon Park Air Force Range		21	FL	Federal	USAF
Kicco Wildlife Management Area		1	FL	State	FFWCC
Babcock/Webb Essential Support	40				
Babcock/Webb Wildlife Management Area		27	FL	State	FFWCC
Big Cypress Essential Support	40				
Big Cypress National Preserve		42	FL	Federal	NPS

Table continued next page.

TABLE 8 (cont.). Primary core, secondary core, and essential support populations.

Recovery Unit Population Property	Size at Delisting (PBG)	Current Size (ACT)	State	Type	Agency
South/Central Florida (cont.)					
Camp Blanding Essential Support	25[1]				
Camp Blanding Training Site		14	FL	Federal	FDMA
Corbett/Dupuis Essential Support	40				
J. W. Corbett/Dupuis Wildlife Management Area		13	FL	State	FFWCC/ SFWMD
Goethe Essential Support	40				
Goethe State Forest		30	FL	State	FDF
Hal Scott Essential Support	15[1]				
Hal Scott Preserve		7	FL	State	SJRWMD
Ocala Essential Support	40				
Ocala National Forest		22	FL	Federal	USFS
Picayune Strand Essential Support	25[1]				
Picayune Strand State Forest		3	FL	State	FDF
St. Sebastian River Essential Support	25[1]				
St. Sebastian River State Buffer Preserve		8	FL	State	SJRWMD
Three Lakes Essential Support	40				
Three Lakes Wildlife Management Area		51	FL	State	FFWCC
Withlacoochee Citrus Tract Essential Support	40				
Withlacoochee State Forest - Citrus Tract		46	FL	State	FDF
Withlacoochee Croom Tract Essential Support	30[1]				
Withlacoochee State Forest - Croom Tract		5	FL	State	FDF
Upper East Gulf Coastal Plain					
Bienville Primary Core	350				
Bienville National Forest		104	MS	Federal	USFS
Oakmulgee Secondary Core	250				
Oakmulgee Ranger District, Talladega NF		110	AL	Federal	USFS
Upper West Gulf Coastal Plain					
Sam Houston Primary Core	350				
Sam Houston National Forest		168	TX	Federal	USFS
West Gulf Coastal Plain					
Angelina/Sabine Primary Core	350				
Angelina National Forest		29	TX	Federal	USFS
Sabine National Forest		28	TX	Federal	USFS

Table continued next page.

TABLE 8 (cont.). Primary core, secondary core, and essential support populations.

Recovery Unit **Population** **Property**	**Size at Delisting (PBG)**	**Current Size (ACT)**	**State**	**Type**	**Agency**
Catahoula Secondary Core	250				
Catahoula Ranger District, Kisatchie NF		32	LA	Federal	USFS
Winn Ranger District (portion), Kisatchie NF		5	LA	Federal	USFS
Davy Crockett Secondary Core	250				
Davy Crockett National Forest		53	TX	Federal	USFS
Vernon/Fort Polk Primary Core	350				
Fort Polk		46	LA	Federal	USARMY
Vernon Unit, Calcasieu Ranger District, Kisatchie NF		152	LA	Federal	USFS

[1]These populations each have an estimated potential size of less than 40 potential breeding groups but can contribute significantly to the delisting criterion of 250 potential breeding groups (275-350 active clusters) in the South/Central Florida Recovery Unit overall.

TABLE 9. Significant and important support populations on state and federal properties, by recovery unit. Also listed are location (state), current size (number of active clusters in 2000) and potential size (number of active clusters). Except where noted, potential size is based on an agency estimate or property goal identified in a draft or approved red-cockaded woodpecker management plan, or submitted in an Annual Report (2000). See Table 5 for significant support populations on private properties.

Recovery Unit / Property	State	Designation	Current Size	Potential Size[2]
Mid-Atlantic Coastal Plain				
Bladen Lakes State Forest	NC	Important Support	3	3[1]
Hampton Plantation State Park	SC	Important Support	1	1[1]
Jones Lake State Park	NC	Important Support	1	4
Lewis Ocean Bay Heritage Preserve	SC	Significant Support	2	10[1]
Longleaf Pine Heritage Preserve	SC	Important Support	2	4[1]
Military Ocean Terminal Sunny Point	NC	Significant Support	9	17
Sandy Island	SC	Significant Support	32	35[1]
Santee Coastal Reserve	SC	Significant Support	8	16
Singletary Lake State Park	NC	Important Support	4	6
Wedge Plantation	SC	Important Support	2	2[1]
Yawkey Wildlife Center	SC	Significant Support	8	15[1]
subtotal			72	113
Ouachita Mountains				
McCurtain County Wilderness Area	OK	Significant Support	12	44
subtotal			12	44
Piedmont				
Pee Dee National Wildlife Refuge	NC	Significant Support	1	10
Johnston Community College	NC	Important Support	1	1
subtotal			2	11
Sandhills				
Cheraw State Fish Hatchery	SC	Important Support	1	1
Cheraw State Park	SC	Significant Support	7	25
Fort Gordon	GA	Significant Support	5	25
Fort Jackson	SC	Significant Support	24	126
Manchester State Forest	SC	Important Support	3	3[1]
Poinsett Weapons Range	SC	Significant Support	6	30
subtotal			46	210
South Atlantic Coastal Plain				
Charleston Naval Weapons Station	SC	Significant Support	1	12
Persanti Island	SC	Important Support	3	3[1]
Santee State Park	SC	Important Support	1	7[1]
Webb Wildlife Center	SC	Significant Support	12	30[1]
subtotal			17	52

Table continued next page.

TABLE 9 (cont.). Significant and important populations on state and federal properties.

Recovery Unit / Property	State	Designation	Current Size	Potential Size[2]
South/Central Florida				
Central Florida Reception Center - South Unit	FL	Important Support	1	1[1]
Platt Branch Mitigation Park	FL	Important Support	4	7[1]
subtotal			5	8
Upper East Gulf Coastal Plain				
Noxubee National Wildlife Refuge	MS	Significant Support	44	88
subtotal			44	88
Upper West Gulf Coastal Plain				
D'Arbonne National Wildlife Refuge	LA	Important Support	2	5
Felsenthal National Wildlife Refuge	AR	Significant Support	15	34
Huntsville State Fish Hatchery	TX	Important Support	1	1[1]
I. D. Fairchild State Forest	TX	Important Support	4	7
Upper Ouachita National Wildlife Refuge	LA	Important Support	1	1
W. G. Jones State Forest	TX	Significant Support	14	14
subtotal			37	62
West Gulf Coastal Plain				
Alabama-Coushatta Tribe of Texas	TX	Important Support	2	2[1]
Alexander State Forest	LA	Important Support	5	5
Black Bayou National Wildlife Refuge	LA	Important Support	1	1
Evangeline Unit, Calcasieu Ranger District, Kisatchie National Forest	LA	Significant Support	72	231
Kisatchie Ranger District, Kisatchie National Forest	LA	Significant Support	29	292
Peason Ridge	LA	Significant Support	23	120
Winn Ranger District, Kisatchie National Forest	LA	Significant Support	18	263
subtotal			150	914
Outside Recovery Units:				
Pine City Natural Area	AR	Important Support	1	2[1]
Big Branch Marsh National Wildlife Refuge	LA	Significant Support	15	20
subtotal			16	22
TOTAL			**401**	**1524**

[1]Property goal based on U.S. Fish and Wildlife Service or responsible agency's estimate derived by dividing the area of currently or potentially suitable upland pine on the property by 81 ha (200 ac) per cluster.

[2] Except for those potential sizes identified as property goals in approved agency management plans, all other potential sizes are non-binding and subject to change pending approval of site-specific management plans.

8. MANAGEMENT GUIDELINES

The following management guidelines are fundamental to conservation and recovery of red-cockaded woodpeckers. We strongly encourage and recommend the application of these guidelines to the management of all woodpecker populations, including those on private lands. Managers of private lands may choose to substitute guidelines given in Appendix 5 (Private Lands Guidelines) for comparable sections below, but again are encouraged to follow the management guidelines given in this section as these have been designed specifically for population and species recovery.

A. ASSESSING PROGRESS TOWARD RECOVERY

Trends of all populations, but particularly for those identified in recovery criteria, will be monitored closely by the Red-cockaded Woodpecker Recovery Coordinator to ensure that significant progress toward recovery is being made. This assessment is a critical aspect of species conservation, management, and recovery. In this section, we define recommended rate of increase and critical rates of population decline. We identify the schedule by which assessments will be made. We also describe actions to be taken if populations are not increasing at the recommended rate or if populations are declining at a rate equal to or greater than the identified critical values. Monitoring for population size and trend is described in 3A, and population monitoring guidelines are given in 8C.

Guidelines

1. Recommended Rate and Assessment of Population Increase.

Populations are to be increasing at a rate of 5 percent per year. Population trend will be assessed by the Red-cockaded Woodpecker Recovery Coordinator annually using the U.S. Fish and Wildlife Service Annual Report. Depending on the results of annual assessments, and specifically for those populations not increasing at the recommended rate, more thorough 5-year population trend assessments and analyses will be conducted as necessary (see below).

2. Management Review for Populations Not Increasing

For those populations not increasing at the recommended rate, an investigation of which factors are restricting potential increases will be undertaken. Factors to be investigated include:

1.1.1. Condition of nesting habitat within active clusters, including number of suitable cavities and presence of hardwood midstory in clusters.

1.1.2. Condition of foraging habitat corresponding to active clusters, including age, size, and density of pines, height and density of pine and hardwood midstory, percent of canopy hardwoods, and presence of herbaceous groundcover.

1.1.3. Number of recruitment clusters available, and their placement within the landscape.

1.1.4. Condition of recruitment clusters, including condition of nesting and foraging habitat as indicated by variables listed in 1.1.1. and 1.1.2.

Once factors potentially limiting population growth have been identified, implementation of management plans will be changed accordingly. If management plans require adjustment, re-initiation of consultation with the U.S. Fish and Wildlife Service will be strongly recommended.

3. Critical Rate and Assessment of Population Decline

It is essential to conservation and recovery of red-cockaded woodpeckers that population declines be detected quickly and accurately. Population declines can occur in various forms, such as a sudden large drop or a small, slow, steady decrease in size. We therefore define critical population decline in two different ways. A population is considered declining if either of the following criteria is met:

(1) number of active clusters decreases by 10% from one year to the next.
(2) number of active clusters decreases by 10% within five years.

Captured clusters must not be included in this calculation. Each year, the Red-cockaded Woodpecker Recovery Coordinator will assess population trend for evidence of critical decline.

4. Re-initiation of Consultation for Critically Declining Populations

If populations are found to be declining at or above these critical rates, re-initiation of consultation with the US Fish and Wildlife Service will be strongly recommended. Review and adjustment of management plans and their implementation is the only appropriate response to such evidence. Declining populations are not eligible to act as a donor population for translocation (8H). Ineligibility will remain in place until populations once again meet the criteria for donor populations (8H).

Early indicators of population decline include a decreasing proportion of groups that contain potential breeding groups, increasing proportions of solitary males and/or captured clusters, and decreases in mean group size. Currently, a population exhibiting an increasing proportion of solitary males, captured clusters, or a decline in mean group size will not be formally considered critically declining populations, if number of active clusters is not declining as described above. However, this is important evidence of a population in poor health and managers are strongly encouraged to review and adjust management actions accordingly. In the future, the U.S. Fish and Wildlife Service may develop an additional definition of a critically declining population based on number of potential breeding groups, which would give an earlier indication of decline than current definitions.

5. Annual Reporting

Assessing progress toward recovery is highly dependent on conscientious reporting. Managers and researchers are required to submit an Annual Report to the Red-cockaded Woodpecker Recovery Coordinator. The Annual Report contains results of annual population monitoring and a description of management actions, including management of cavities and clusters, management and restoration of foraging habitat, and translocation if used.

TABLE 10. Worksheet to assess population trend for all primary core, secondary core, and essential support populations, sorted by recovery unit. This table presents expected population size (number of active clusters; ACT) at 5-year intervals under 5 percent annual increase through estimated time of delisting. Populations are to be increasing at this rate until the species is delisted or until the property goal is reached. Property goals are derived directly from agency or site-specific management plans, except where noted. Also listed is minimum population size required for delisting (potential breeding groups). Number of active clusters is equivalent to 1.1 – 1.4 times the number of potential breeding groups. Updates of this table will be provided on the Red-cockaded Woodpecker Recovery web page (http://rcwrecovery.fws.gov).

Recovery Unit / Population / Property	**Delisting Size (PBG)**	**Expected Size Based on Recommended Rate of Increase (ACT)**																
		2000	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**	**2065**	**2070**	**2075**	**2080**
Cumberlands/Ridge and Valley																		
Talladega/Shoal Creek	100																	
Shoal Creek RD		6	8	10	12	16	20	26	33	42	54	69	88	112	125	125	125	125
Talladega RD		0	5	6	8	10	13	17	22	28	35	45	57	73	93	110	110	110
East Gulf Coastal Plain																		
Central Florida Panhandle	1000																	
Apalachicola RD		486	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Ochlockonee River SP[1]		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
St. Mark's NWR		9	11	15	19	24	30	39	50	63	71	71	71	71	71	71	71	71
Tate's Hell SF[1]		29	37	47	60	77	98	125	160	204	261	333	400	400	400	400	400	400
Wakulla RD		138	176	225	287	366	467	506	506	506	506	506	506	506	506	506	506	506
Chickasawhay	350																	
Chickasawhay RD		15	19	24	31	40	51	65	83	106	135	172	220	280	358	456	502	502
Conecuh/Blackwater	250																	
Blackwater River SF		26	33	42	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Conecuh NF		18	23	29	37	48	61	78	99	127	162	206	263	309	309	309	309	309
DeSoto	250																	
DeSoto RD		7	9	11	15	19	24	30	39	49	63	80	102	131	167	213	272	347[2]
Eglin	350																	
Eglin Air Force Base		301	384	490	500	500	500	500	500	500	500	500	500	500	500	500	500	500

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	**Delisting Size (PBG)**	**Expected Size Based on Recommended Rate of Increase (ACT)**																
		2000	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**	**2065**	**2070**	**2075**	**2080**
East Gulf Coastal Plain (cont.)																		
Homochitto	250																	
Homochitto NF		51	65	83	106	135	173	220	254	254	254	254	254	254	254	254	254	254
Mid-Atlantic Coastal Plain																		
Coastal North Carolina	350																	
Croatan NF		62	79	101	129	165	169	169	169	169	169	169	169	169	169	169	169	169
Holly Shelter Game Lands		38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
MCB Camp Lejeune		59	75	96	123	157	173	173	173	173	173	173	173	173	173	173	173	173
Francis Marion	350																	
Francis Marion NF		344	439	453	453	453	453	453	453	453	453	453	453	453	453	453	453	453
Northeast North Carolina/ Southeast Virginia	100																	
Alligator River NWR		3	4	5	6	8	10	13	17	20	20	20	20	20	20	20	20	20
Dare Co. Bombing Range		3	4	5	6	8	10	13	17	21	17	34	44	46	46	46	46	46
Palmetto-Peartree Preserve		25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Piney Grove Preserve		3	4	5	6	8	10	10	10	10	10	10	10	10	10	10	10	10
Pocosin Lakes NWR		1	1	2	2	3	3	4	6	7	9	11	15	19	24	30	39	50
Ouachita Mountains																		
Ouachita	250																	
Ouachita NF		21	27	34	44	56	71	91	116	148	189	241	307	392	400	400	400	400

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TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
Piedmont																		
Oconee/Piedmont	250																	
Oconee NF		20	26	33	42	53	68	86	110	141	176	176	176	176	176	176	176	176
Piedmont NWR		39	50	64	81	96	96	96	96	96	96	96	96	96	96	96	96	96
Sandhills																		
Fort Benning	350																	
Fort Benning		219	280	357	450	450	450	450	450	450	450	450	450	450	450	450	450	450
North Carolina Sandhills East	350																	
Calloway Tract		5	6	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Carver's Creek Tract		4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Fort Bragg		350	436	436	436	436	436	436	436	436	436	436	436	436	436	436	436	436
McCain Tract		5	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Weymouth Woods SNP		7	9	11	13	13	13	13	13	13	13	13	13	13	13	13	13	13
North Carolina Sandhills West	100																	
Camp Mackall		11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Sandhills Game Lands		134	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
South Carolina Sandhills	250																	
Carolina Sandhills NWR		116	148	189	193	193	193	193	193	193	193	193	193	193	193	193	193	193
Sand Hills SF[1]		51	65	83	106	135	143	143	143	143	143	143	143	143	143	143	143	143
South Atlantic Coastal Plain																		
Fort Stewart	350																	
Fort Stewart		212	271	345	441	500	500	500	500	500	500	500	500	500	500	500	500	500
Osceola/Okefenokee	350																	
Okefenokee NWR		37	47	60	77	86	86	86	86	86	86	86	86	86	86	86	86	86
Osceola NF		63	80	103	131	167	213	272	348	444	462	462	462	462	462	462	462	462

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
South Atlantic Coastal Plain (cont.)																		
Savannah River	250																	
Savannah River Site		34	43	55	71	90	115	147	188	239	305	390	418	418	418	418	418	418
South/Central Florida																		
Avon Park	40																	
Avon Park Air Force Range		21	27	34	44	56	68	68	68	68	68	68	68	68	68	68	68	68
Kicco WMA[1]		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Babcock/Webb	40																	
Babcock/Webb WMA[1]		27	34	44	56	72	91	117	149	190	240	240	240	240	240	240	240	240
Big Cypress	40																	
Big Cypress NP		42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
Camp Blanding	25																	
Camp Blanding Training Site		14	18	23	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Corbett/Dupuis	40																	
J. W. Corbett/Dupuis WMA[1]		13	17	21	27	34	44	56	72	90	90	90	90	90	90	90	90	90
Goethe	40																	
Goethe SF		30	38	49	62	80	102	130	150	150	150	150	150	150	150	150	150	150
Hal Scott	15																	
Hal Scott Preserve[1]		7	9	11	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Ocala	40																	
Ocala NF		22	28	36	46	58	74	95	121	155	179	179	179	179	179	179	179	179
Picayune Strand	25																	
Picayune Strand SF[1]		3	4	5	6	8	10	13	17	21	25	25	25	25	25	25	25	25

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT) 2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
South/Central Florida (cont.)																		
St. Sebastian River	25																	
St. Sebastian River SBP		8	10	13	17	21	25	25	25	25	25	25	25	25	25	25	25	25
Three Lakes	40																	
Three Lakes WMA[1]		51	65	83	106	125	125	125	125	125	125	125	125	125	125	125	125	125
Withlacoochee – Citrus Tract	40																	
Withlacoochee – Citrus		46	59	75	96	100	100	100	100	100	100	100	100	100	100	100	100	100
Withlacoochee –Croom Tract	30																	
Withlacoochee – Croom		5	6	8	10	13	17	22	28	30	30	30	30	30	30	30	30	30
Upper East Gulf Coastal Plain																		
Bienville	350																	
Bienville NF		104	133	169	216	276	352	449	500	500	500	500	500	500	500	500	500	500
Oakmulgee	250																	
Oakmulgee RD		110	140	179	229	292	372	394	394	394	394	394	394	394	394	394	394	394
Upper West Gulf Coastal Plain																		
Sam Houston	350																	
Sam Houston NF		168	214	274	349	446	541	541	541	541	541	541	541	541	541	541	541	541
West Gulf Coastal Plain																		
Angelina/Sabine	350																	
Angelina NF		29	37	47	60	77	98	125	160	204	252	252	252	252	252	252	252	252
Sabine NF		28	36	46	58	74	95	121	154	197	252	262	262	262	262	262	262	262

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
West Gulf Coastal Plain (cont.)																		
Catahoula	250																	
Catahoula RD		32	41	52	67	85	108	138	177	225	288	317	317	317	317	317	317	317
Winn RD (portion)		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Davy Crockett	250																	
Davy Crockett NF		53	68	86	110	141	179	229	292	330	330	330	330	330	330	330	330	330
Vernon/Fort Polk	350																	
Fort Polk		46	59	75	96	122	156	179	179	179	179	179	179	179	179	179	179	179
Vernon Unit		152	194	248	302	302	302	302	302	302	302	302	302	302	302	302	302	302

[1]For these properties for which no management plan is available, property goals are non-binding estimates only and are subject to change when management plans are drafted and approved.

[2]Population goal is 386. However, 347 active clusters will provide at least the 250 potential breeding groups needed for delisting.

B. USE OF RECRUITMENT CLUSTERS

Substantial increases in population sizes are required to achieve recovery of red-cockaded woodpeckers (see 8A). Proper management of the nesting and foraging habitat of existing groups (see 8E, 8F, 8I) is a prerequisite for population increase, but recent research and experience strongly indicate that management of existing groups by itself is not sufficient to bring about the rates of increase necessary for recovery. Because population dynamics of red-cockaded woodpeckers are regulated by the number of potential breeding groups (see 2B), substantial increases in population size are best obtained through continued addition of recruitment clusters. Therefore, we have developed the following guidelines for the use of recruitment clusters in all populations being managed for increasing population size. Recruitment clusters are clusters of artificial cavities in habitat containing mature and old pines (greater than 60 years in age), with little or no hardwood midstory and a healthy grass and forb groundcover (see 2D for discussion of cluster ecology and 8F for cluster management guidelines).

Guidelines

1. Recommended Number of Recruitment Clusters: To achieve recommended rates of increase (8A), provide a constant supply of unoccupied recruitment clusters equal to 10 percent of total active clusters in the population. As recruitment clusters become occupied, establish additional recruitment clusters on an annual basis to sustain the required pool of unoccupied recruitment clusters. Do not establish more recruitment clusters than can reasonably be occupied within 1 to 3 years.

An exception to this guideline is made for recruitment clusters used in reintroductions or the development of new population segments (a set of clusters in suitable habitat somewhat removed from other groups). For these purposes, a number of recruitment clusters greater than 10 percent of active clusters may be used. These management actions will always be conducted using translocations of multiple potential pairs. Typically, for translocations of multiple potential pairs, two recruitment clusters will be established for each pair of birds being translocated.

2. Placement of Recruitment Clusters: Placement of recruitment clusters is critical to successful use. Place recruitment clusters no closer than 0.4 km (0.25 mi) to existing active clusters, to reduce the likelihood of capture by an existing group. Place recruitment clusters no farther than 3.2 km (2 mi), and preferably no farther than 1.6 km (1 mi), from existing active clusters to facilitate occupation and to develop beneficial spatial arrangements and densities within the population (see 2C).

Recruitment clusters for use in reintroduction or for developing a new segment of a population are exempt from this recommendation. Recruitment clusters for these purposes must be highly aggregated.

Recent research performed with a spatially explicit, individual based model of population dynamics (see 2C) has indicated that edges of populations are particularly vulnerable to decay from disrupted dispersal. Maintain group densities as high as possible throughout the population, and pay particular attention to population edges.

3. Recruitment Cluster Requirements:

a. Nesting and Roosting Habitat. Provision recruitment clusters with three suitable cavities and two starts, or four suitable cavities, when first installed. Once the cluster is occupied, ensure that a minimum of four suitable cavities is maintained. See 3B and 8E for further details concerning the definition of suitable cavities and recommended methods for constructing artificial cavities and starts.

b. Foraging Habitat. We anticipate that much of the foraging habitat assigned to recruitment clusters may not meet all elements of good quality foraging habitat as described under the recovery standard (8I). If the recovery standard is not met, then assign each recruitment cluster at least 49 ha (120 ac) of foraging habitat that meets elements (b, c, d, f, g, h, and i), and additionally, stands should contain no more than 70 ft^2/ac basal area in total. Within this habitat, restore habitat structure and encourage the development of old pines so that all elements of the recovery standard can be met in the future.

C. Population Monitoring

Population monitoring is an essential aspect of red-cockaded woodpecker management and recovery. Only through accurate monitoring can we determine the success and failure of our management actions, and adapt these actions accordingly. Appropriate intensity of monitoring varies with population size, role in recovery, and management objectives. In section 3A and Appendix 2 we describe basic monitoring techniques. In this section, we present guidelines for determining recommended monitoring levels for individual populations.

Guidelines

1. In primary core, secondary core, and essential support populations, monitor number of active clusters and number of potential breeding groups so that population trend and size can be determined. Follow directions for monitoring number of active clusters and potential breeding groups given in 3A. Use random sampling without replacement to select a sample of the size recommended in Table 11. For populations in which no banding is being conducted, select random samples annually. For populations in which some groups are banded, select random samples at 5-year intervals; within this five-year

period, samples remain fixed. Use stratified random sampling whenever appropriate (see 3A).

2. In critically small populations (less than 30 potential breeding groups) on federal and state lands, monitor number of active clusters, number of potential breeding groups, group size, and reproductive success. Follow directions for monitoring number of active clusters and potential breeding groups in 3A, and for group size and reproductive success given in Appendix 2. Sample the population completely. These populations are to be completely color-banded, to enable the monitoring of group size and reproductive success. In addition, this level of monitoring is required to receive translocated birds from donor populations.

3. In populations containing mitigation sites, monitor number of active clusters and number of potential breeding groups as recommended for recovery populations (see above). In addition, monitor group size and reproductive success in the neighborhood of the mitigation site both before and after the installation of mitigation sites, until successful mitigation is completed. Follow directions for monitoring number of active clusters and potential breeding groups in 3A, and for group size and reproductive success given in Appendix 2.

4. In populations serving as mitigation banks or planned as future mitigation banks, monitor number of active clusters and number of potential breeding groups as recommended for recovery populations (see above). In addition, monitor group size and reproductive success by maintaining a completely color-banded population. Follow directions for monitoring number of active clusters and potential breeding groups in 3A, and for group size and reproductive success given in Appendix 2.

5. For other populations, publicly or privately owned, we strongly recommend that the above monitoring guidelines be followed.

TABLE 11. Recommended sample sizes for monitoring number of active clusters (ACT) and potential breeding groups (PBG) in red-cockaded woodpecker populations, by population size.

	Population Size (PBG)				
Parameter	**<30**	**30 - 99**	**100 – 249**	**250 - 349**	**≥ 350 or at approved property goal**
ACT	100% of potentially active clusters per year	100% per year	100% per year	100% every 2 yrs.	consult with FWS
PBG	100% of potentially active clusters per year	100% per year	50% per year	33% per year	consult with FWS

6. For those populations and or forests that have suffered catastrophic losses of habitat and or red-cockaded woodpeckers, individualized habitat and population monitoring programs will be developed in consultation with the U.S. Fish and Wildlife Service.

D. Habitat Monitoring

The primary cause of species decline was sharp decreases in the quantity and quality of habitat (1A), and habitat limitations remain a major threat to species recovery (1B). It is therefore critical to species recovery that quantity and quality of habitat be closely monitored. We give specific guidelines for habitat monitoring in several different sections of this plan. Here we briefly summarize them and refer the reader to relevant sections.

1. Monitoring Nesting/Roosting Habitat

a. Number of Suitable Cavities per Cluster. Assess number of suitable cavities in each cluster at recommended frequencies based on population size. See 8E for sampling frequency and definition of a suitable cavity. These assessments are best conducted during cluster activity checks (March – July). If populations with a designated recovery role are not increasing at recommended rates (8A), or if they are found to be declining at or above the identified critical values of decline (8A), number of suitable cavities per cluster will be reviewed by the Red-cockaded Woodpecker Recovery Coordinator.

b. Habitat Structure within Clusters. Maintain clusters that are free of pine and hardwood midstory, as described in 8F. If populations with a designated recovery role are not increasing at recommended rates (8A), or if they are found to be declining at or above the identified critical values of decline (8A), habitat structure within clusters will be reviewed by the Red-cockaded Woodpecker Recovery Coordinator.

2. Monitoring Foraging Habitat

Assess quality and quantity of foraging habitat at a minimum frequency of once every 10 years, with the exception of midstory which is to be assessed at a minimum frequency of once every 5 years. More frequent assessments are encouraged. Evaluate foraging habitat for all habitat elements described within the recovery standard (8I), including ages of pines, pine size class distribution, presence of hardwood midstory, and percent native, site-appropriate, herbaceous groundcover. More information on monitoring these elements is given in 8I. Ensure that substantial progress toward meeting all elements put forth in the recovery standard is made. If populations with a designated recovery role are not increasing at recommended rates (8A), or if they are found to be declining at or above the identified critical values of decline (8A), quality and quantity of foraging habitat will be reviewed by the Red-cockaded Woodpecker Recovery Coordinator.

3. Documenting Prescribed Fire

Keep accurate and detailed records of all prescribed burns.

4. Reporting

Report results of all habitat monitoring and history of prescribed burns to the Red-cockaded Woodpecker Recovery Coordinator using the Annual Report.

E. Cavity Management, Artificial Cavities, and Restrictor Plates

Maintaining an adequate number of suitable cavities in each woodpecker cluster is fundamental to the recovery of the species. Loss of cavity trees was a major factor in the species' decline (see 1A), and availability of cavity trees currently limits many populations. This limitation will remain in effect until large old pines are restored throughout the lands managed for red-cockaded woodpeckers. Until large old pines become widely available, artificial cavities and restrictor plates are essential management tools that can bring about population increases, if used carefully and in suitable habitat.

Here we present guidelines for the use of artificial cavities and restrictor plates. The role of cavities in population dynamics and the cooperative breeding system of red-cockaded woodpeckers is discussed in 2B. Further information concerning nesting ecology is provided in 2D. Descriptions of artificial cavity construction techniques and their usefulness are given in 3B. Restrictor plates are also discussed in 3B, and cavity enlargement in general is described in sections 2F and 3B.

Guidelines

1. Monitor the cavity resource. Assess the number of suitable cavities in each potentially active cluster at a frequency determined by the size of the population (Table 12). Conduct these assessments in March – July. A suitable cavity has a single entrance, an entrance tunnel that is not enlarged, a cavity chamber that is not enlarged, a solid base, and is dry and free of debris. In addition, the cavity plate must not contain large amounts of dead wood. Relict, enlarged, or any suspect cavities must not be considered suitable for use by red-cockaded woodpeckers. Suitable cavities may be either naturally excavated or artificially constructed. If a restrictor is present, it must be inspected for safety during cavity suitability assessments.

To conduct this assessment, examine all unenlarged cavities internally by climbing the tree or using a video 'peeper'. An enlarged cavity is unsuitable unless a restrictor is installed and the cavity is otherwise found to be suitable by internal inspection.

TABLE 12. Frequency of cavity suitability assessment by population size and trend (see 8A for definitions of trend).

Population Size (potential breeding groups)		
< 100	**100 to 349**	**$\geq$ 350 or at approved property goal**
100% of all cavities per year	50% of all cavities if not increasing at recommended rate	50% of all cavities if decreasing by the critical rate or more

2. Maintain the recommended number of suitable cavities in each cluster.

    a. Maintain at least four suitable cavities in each active cluster, in all populations not meeting population size goals identified in delisting criteria (6) or in approved management plans. However, ensure there are sufficient cavities for all group members post-breeding season.

    b. Maintain at least four suitable cavities (or three suitable cavities and two starts) in each unoccupied recruitment cluster, in all populations not meeting population goals identified in delisting criteria (6) or in approved management plans.

    c. Do not provision excessive numbers of artificial cavities within active or recruitment clusters. Count natural suitable cavities first, then install artificial cavities as necessary to make four to six suitable cavities.

3. Use the appropriate method of cavity construction. See 3B for more information.

    a. Use the Copeyon-drilled method when heartwood is sufficient to house the cavity.

    b. Use drilled starts when heartwood is insufficient to house the cavity and cavities are not needed for a year or more. Provide more than one start for each new cavity desired.

    c. Use cavity inserts when heartwood is insufficient to house a drilled cavity and cavities are needed as soon as possible. Inserts must always be used with full restrictor plates, and all inserts must be coated with a thick layer of non-toxic sealant such as non-toxic polyurethane glue (e.g. EXCEL ONE) or wood putty. Annual maintenance of cavity inserts prolongs their suitability and minimizes potential injury or mortality to red-cockaded woodpeckers.

    d. Avoid using the modified-drilled method (see 3B).

4. Install artificial cavities as close to existing cavity trees as possible, preferably within 71 m (200 ft.).

5. If installing a cavity insert, select a tree that is greater than 45 years old but not a relict, flat-top, or very old pine.

6. Select the appropriate location on the tree. Place artificial drilled cavities as high as heartwood diameter of the recipient tree will allow. Do not place cavities above or below the range of natural cavity heights in the surrounding area. Orient entrances so that they are facing west, if possible.

7. Protect the birds from sap leakage. Ensure that no artificial cavity has resin leaking into the chamber or entrance tunnel.

a. Prior to installation, coat all inserts with a thick layer of non-toxic sealant such as non-toxic polyurethane glue or wood putty. Do not use toxic coatings or inserts without coatings.

b. Screen all drilled starts and drilled cavities with heavy wire mesh (0.64 by 0.64 cm [0.25 by 0.25 in]) for at least four weeks following installation.

c. Inspect cavity interiors when the screens are removed. If resin leaks are detected, keep the screens on and conduct additional checks. Persistent resin leaks into entrance tunnels can be treated with repeated scraping, application of wood putty, replacement of veneer, or redrilling. If severe leaks continue, block the cavity with a wooden plug at least 7.6 cm (3 in) long, and construct a replacement cavity.

d. Construct artificial cavities and starts between August and March to reduce likelihood of leaks.

e. Check all new artificial cavities and starts for resin leaks during or just prior to the first breeding season following installation, and screen or plug those found to be leaking.

f. During cavity suitability assessment (1, above), replace, screen, or plug any insert found to be dangerously faulty (i.e., containing or likely to contain resin in the interior).

8. Use cavity restrictors judiciously to control cavity enlargement.

a. Use only when necessary on active cavities. Do not restrict all cavities. Slightly enlarged cavities may be restricted but do not use to repair excessively enlarged cavities.

b. Use restrictors on a cluster-by-cluster basis to minimize potential damage to any cavity, natural or artificial, by pileated woodpeckers. Only use restrictors if there is a known problem with enlargement by pileated woodpeckers or there is a good possibility, based on past experience, that cavities may be damaged.

c. Use full restrictors on all cavity inserts and previously installed modified-drilled cavities.

d. Inspect all restrictors at least once each year and repair if loose or out of place. Do not use restrictors if annual inspections cannot be performed.

e. Do not use on unenlarged cavities for the purpose of excluding cavity kleptoparasites.

F. CLUSTERS AND CAVITY TREES

Conservation and recovery of red-cockaded woodpeckers in today's second- and third-growth forests requires skillful management of their cavity trees and clusters. Successful cluster management consists of three main programs: (1) protection of existing cavity trees, (2) development and protection of sufficient large, old pines for future cavity trees, and (3) restoration and maintenance of appropriate habitat structure, including no hardwood midstory, low densities of small pines, low to moderate densities of large pines, and abundant native grass and forb groundcovers. We recommend the removal of excessive overstory hardwoods in regions where fire suppression has resulted in the establishment of large hardwood trees. We also recommend that human disturbance within the cluster be minimized.

In this section, we provide guidelines for management of cavity trees and clusters. Information concerning nesting ecology is given in 2D. Any discussion of nesting ecology is not complete without considering fire. The role of fire in the southeastern pine ecosystem, prescribed burning as a management tool, and guidelines for the use of prescribed fire are discussed in sections 2G, 3F, and 8K, respectively.

To facilitate management and conservation, we use a management-based definition of a cluster for these guidelines. Here, the cluster is the minimum convex polygon containing all cavity trees in use by a group of red-cockaded woodpeckers *and* a 61 m (200 ft) wide buffer of continuous forest surrounding the minimum convex polygon. The cluster must contain a minimum of 4.0 ha (10 ac). Recommendations for cluster management apply to the entire cluster; that is, these guidelines apply to the buffer as well as the minimum convex polygon containing all cavity trees.

Guidelines

1. Protect existing cavity trees.

    a. Reduce risk of accidental damage or removal. Mark cavity trees for easy identification.

    b. Protect against fire damage. The application of regular, frequent fire in the clusters is the best method of protecting cavity trees against damage from fires (prescribed or wild) that are too intense. Until cavity trees are no longer a limiting resource, use one or more additional methods of protecting individual cavity trees presented in 8K.

    c. Protect cavity tree roots. Prohibit, with rare exceptions, the use of heavy machinery and vehicles within 15.25 m (50 ft) of cavity trees, and do not use at all within 15.25 m (50 ft) of cavity trees in wet areas. Do not establish plow lines within 61 m (200 ft) of cavity trees.

    d. Protect against southern pine beetle infestations. Thin dense loblolly and shortleaf pine forests regularly to maintain basal areas of less than 18.4 m^2/ha (80 ft^2/ac) or to maintain a minimum average spacing of 7.6 m (25 ft) between trees. Minimize physical disturbance to soil and roots during management operations such as thinning, midstory reduction, and prescribed burning.

    e. Reduce risk of damage from high winds. Retain a 61 m (200 ft) wide buffer of continuous forest around the minimum convex polygon containing each group's set of cavity trees, as part of the cluster. Consider retaining an additional buffer and minimize the establishment of openings adjacent to the cluster. Over time, risk of wind damage can be reduced by the development of an open habitat structure that encourages the growth of wind-resistant trees. Conversion to longleaf pine, where appropriate, also can reduce risk from winds.

2. Develop sufficient large and old pines to serve as cavity trees.

    a. Retain all potential cavity trees (pines greater than 60 years in age) within clusters, unless pine basal area is above 11.5 m^2/ha (50 ft^2/ac) and all trees are above 60 years in age.

    b. Supply trees for future cavity trees and clusters in abundance. Grow large, old pines throughout the landscape managed for red-cockaded woodpeckers (see 3E, 8J).

c. If potential cavity trees are rare, consider protecting them from fire, root damage, and other potential risks as described above for existing cavity trees.

3. Restore and maintain appropriate habitat structure.

a. Control hardwood and pine midstory. Apply prescribed fire to the entire cluster every one to five years, preferably during the growing season. This will maintain a cluster that is relatively free of midstory. If necessary, remove excessive hardwoods by hand (with chainsaws and brushhooks), mechanical means such as brush-hogging or mulching, one-time application of herbicides to live trees or stumps, or a combination of these methods. Mechanized equipment for the purpose of hardwood control will not be used within the cluster when woodpeckers are nesting. Broadcasting herbicides by hand within the cluster is permitted during nesting season. Recently abandoned clusters should be managed with the same intensity as active clusters.

b. Foster native grasses and forbs. Native grasses and forbs facilitate prescribed burning and are maintained by prescribed burning. Apply frequent growing season fire and avoid soil disturbance that negatively impacts fragile ground covers. Restrict vehicle use to existing roads and prohibit use of off-road vehicles in clusters.

c. Reduce excessive overstory hardwoods within the cluster. Overstory hardwoods within the cluster should not total more than 2.3 m^2/ha (10 ft^2/ac) in basal area. Remove all hardwoods within 50 ft. of cavity trees.

Retain natural oak inclusions of upland species, such as post, blackjack, turkey, and bluejack oak, within the cluster if they are considered a historic component of the site prior to fire suppression. The area occupied by these oaks is not counted toward the required minimum 4.0 ha (10 ac). These historic oak inclusions should be managed with prescribed fire and artificial cavities should not be installed near them. Overstory trees of mesic hardwood species such as sweetgum (*Liquidambar styraciflua*) and maples (*Acer* spp.) are generally considered undesirable components of fire suppression and are to be removed from red-cockaded woodpecker clusters.

d. Locate recruitment clusters away from stream drainages whenever possible. Although some clusters naturally occur in wetland habitats, use of upland sites as recruitment clusters whenever possible can reduce midstory encroachment associated with mesic hardwoods.

e. Retain dead and dying cavity trees and all other snags, unless they present a safety hazard.

4. Reduce human disturbance within clusters as much as possible, especially during nesting season. As a minimum, follow these guidelines:

> a. Restrict vehicle use to existing roads. Avoid construction of new roads and trails (for motorized and unmotorized use) within clusters.
>
> b. Limit pine and hardwood silvicultural and cultural operations to daylight hours; avoid these activities within at least one or two hours of dawn and dusk.
>
> c. Military training activities are restricted to those specified in installation-specific management plans approved through consultation with the U.S. Fish and Wildlife Service.
>
> d. Use of mechanized equipment in a cluster is permitted during the non-breeding season for red-cockaded woodpecker management activities only (e.g., mechanical midstory reduction).
>
> e. Habitat management activities other than prescribed burning, for example timber thinning and hardwood midstory control, are prohibited during the breeding season (April – July).

G. Predators and Cavity Kleptoparasites

Red-cockaded woodpecker populations that are healthy and of medium to large size require no predator control and few measures to combat cavity kleptoparasites. Predators and cavity kleptoparasites were not among the original causes of decline (see 1A), and their removal will not result in population increases. Occasional loss of nests to predators does not affect population size or trend in larger populations. Maintaining good quality nesting and foraging habitat, and retaining snags throughout the landscape, are the recommended management tools to control kleptoparasitism in all but the smallest populations.

Managers of critically small populations of red-cockaded woodpeckers (less than 30 potential breeding groups), especially those in shortleaf and loblolly pine habitats, may choose to use exclusion devices and other methods for predator/kleptoparasite control. A less invasive technique, bark-shaving, may be employed in any population to protect newly installed artificial cavities. However, further research into direct and indirect species interactions is necessary before the full consequences of such control are understood.

We present guidelines for the use of predator and kleptoparasite control below. Research supporting these guidelines is described in detail in 2F. The techniques themselves are described in 3C. Control of cavity enlargement through the use of restrictor plates is required in many populations regardless of population size, and is discussed in 3B and 8E.

Guidelines

1. Use methods of predator control only in small populations (less than 30 potential breeding groups).

2. If snake control measures are considered necessary, use the bark-scraping procedure or metal snake excluders and restrict this use to trees containing newly installed artificial cavities or to active trees with minimal resin that are likely to be used as nest sites. Do not use snake nets—their use is prohibited because of risk to red-cockaded woodpeckers.

3. If flying squirrel control measures are considered necessary, avoid lethal methods if possible; use flying squirrel excluder devices or removal.

4. Retain snags in clusters and throughout the landscape, and consider the protection of snags in active clusters during prescribed burns.

5. Consider using nest boxes for species other than red-cockaded woodpeckers.

H. TRANSLOCATION

Translocation is an important management tool for small or disjunct populations to be used only in conjunction with aggressive management of nesting and foraging habitat. All translocations should serve to enhance the spatial structure of the population. Potential breeding groups should be developed in locations carefully chosen to link isolated groups or population segments and increase territory density. We refer to this critical management concern as strategic recruitment. Strategic recruitment is accomplished by translocating birds from within or outside the population to (1) unoccupied recruitment clusters or (2) clusters containing solitary birds.

Translocation of birds within populations is conducted solely for the purpose of strategic recruitment. Translocation of birds from donor to recipient populations may be used for population augmentation (increasing the size of the recipient population), mitigation (see 4A), and reintroduction (establishment of a population). Again, translocation for population augmentation, mitigation, or reintroduction must also serve to create beneficial spatial arrangements of groups. See 8B for guidelines governing the use of recruitment clusters. See 3D for background information concerning translocation. Use of translocation for any purpose requires permits from the U.S. Fish and Wildlife Service as discussed in Appendix 1. Use of reintroduction requires consultation with the U.S. Fish and Wildlife Service.

Guidelines

1. Populations Eligible for Within-population Translocation.— Birds can be translocated within a population if the population meets each of the following requirements:

a. Full administrative support, including valid state and federal permits and staff well trained in the handling, banding, and transport of birds;

b. A management plan approved by the U.S. Fish and Wildlife Service that includes each of the following.

i. Population monitoring at recommended levels (3A, 8C).

ii. A prescribed burning program for both nesting and foraging habitat in place.

iii. Specific identification of objectives and locations of the proposed translocations. Objective of proposed translocations should include definitions of target areas (the area in which birds must be found for the translocation to be judged successful; see 3D).

c. Recipient clusters that are in excellent condition, with a minimum of four suitable cavities per cluster, no or very low midstory within the cluster, and suitable foraging habitat (see 8B, 8E, 8I). Generally, provide no more than two recruitment sites for each potential pair moved (but see 3B).

2. Populations Eligible for Augmentation. A population can receive birds from a donor population (augmentation) if the receiving population or a demographically isolated population segment of the receiving population contains fewer than 30 potential breeding groups, has a population goal of and current habitat capacity to support at least 10 active clusters, and meets criteria a, b, and c listed above.

Not all populations eligible for augmentation will receive birds, because available birds are limited. Whether or not a population receives birds is decided annually based on population need and importance to species recovery.

3. Populations Eligible to Donate Birds. Eligibility criteria for donor populations differ by role in recovery.

a. Populations designated as recovery populations may donate birds for translocation if one of the following conditions is met:

i. The population has reached the size required for delisting, and population trend is stable or increasing,

ii. The population is within 75 percent of its population goal (based on designated habitat), at least 50 active clusters in size, and population trend is increasing at 3 percent annually or more, or

iii. The population is at least 100 active clusters in size and population trend is stable or increasing, or

iv. The population contains multiple properties and the donor property has attained its property goal.

b. Populations not designated as recovery populations may donate birds for translocation if one of the following conditions is met:

i. The population goal (based on designated habitat) has been met, and population trend is stable or increasing,

ii. The population is within 75 percent of its goal (based on designated habitat), at least 50 active clusters in size, and population trend is increasing at 3 percent annually or more, or

iii. The population is at least 100 active clusters in size and population trend is stable or increasing.

Populations that do not meet one or more of the criteria identified above (3a, 3b) may serve as donor populations on a case-by-case basis to be evaluated through consultation with the U.S. Fish and Wildlife Service. Factors considered during the consultation process will include, but not be limited to: (1) benefit to recovery, (2) value to the recipient population, and (3) agency or landowner objectives, and (4) population size and trend.

4. Matching Recipient Populations with Appropriate Donors. Translocations will be conducted within recovery units whenever possible. This is to maintain genetic integrity and enhance translocation success by accommodating local adaptations of translocated birds, to the maximum extent possible. Translocations between non-adjacent recovery units are prohibited, except in extenuating circumstances to be determined by consultation with the U.S. Fish and Wildlife Service.

5. Recipient Clusters. Translocate birds only to clusters that are:

a. Within 3.2 km (2 mi) of an occupied cluster. This guideline applies to all translocations, whether the translocation is within a population, between populations, to an unoccupied cluster, or to a cluster containing a solitary individual. The only exception to this guideline is translocation of multiple potential pairs into the same target area, which may be unoccupied or sparsely occupied. The purpose of this guideline, and its exception, is to ensure that all translocations serve to develop a beneficial, highly aggregated spatial arrangement of groups.

b. In excellent condition prior to receiving birds, as stated above. Recipient clusters must have a minimum of four suitable cavities per cluster, no or very low midstory within the cluster, and suitable foraging habitat. Generally, provide no more than two recruitment sites for each potential pair moved (but see 3B).

6. Impacts to Donor Populations. Impacts of translocation on donor populations require further research before specific guidelines can be developed. Currently, we recommend that managers refrain from removing excessive numbers of birds. Number of individuals removed should be no more than 25 percent of potential breeding groups within the donor population or population segment. Exceptions to this may be made on a case-by-case basis through consultation with the U.S. Fish and Wildlife Service. To be considered for this exception a population must be undergoing intensive monitoring and be increasing in size. Stable populations that have met their population goals will also be considered as possible exceptions to the 25 percent guideline, pending approval by consultation. Individuals moved within a population are not counted as part of this 25 percent.

7. Birds Eligible for Translocation. Determine which birds may be removed for translocation by following these guidelines:

a. Remove only subadult males or subadult females. A subadult is less than 12 months in age.

b. Remove birds only from their natal territory.

c. Do not remove any males unless there will be at least one male helper or male fledgling remaining in the group after the individual is removed. Do not remove more than two subadult males from any group within any one year.

d. Do not remove more than two subadult females from any group.

e. Translocation of any birds not meeting these criteria (above) must be approved on a case-by-case basis through consultation with the Red-cockaded Woodpecker Recovery Coordinator.

8. When to Translocate Birds. Translocations can be performed from September 15 through January 1. Translocations in the fall may have lower success, because translocated birds will also experience winter mortality. Translocations after January 1 may have higher impacts on the donor neighborhood and donor populations,

because females that have survived the early winter have a high likelihood of becoming breeders in their native population. More research on the effects of season on translocation is required before more specific recommendations can be made. Exceptions to this time period may be made on a case-by-case basis through consultation with the Red-cockaded Woodpecker Recovery Coordinator.

9. Procedures for Capture, Transport, and Release. Procedures for the capture, transport, and release of translocated birds are provided in Appendix 3. Translocation is not to be conducted when air temperature is below 32 degrees Fahrenheit (0 degrees Celsius) or during wet weather.

10. Monitoring, Evaluation of Success, and Reporting. Adequate population monitoring, evaluation of success, and reporting are required for regulatory compliance with permits authorizing translocations. Follow these guidelines:

a. Monitor all populations in which translocation is used at recommended levels (above, 3A, 8C, Appendix 2).

b. Determine success of all translocations by presence or absence of translocated birds within target areas in the following breeding season. Management objectives (identified in management plans) dictate target areas. For example:

i. The objective of mate provisioning is successful only if the translocated bird is found in the target cluster in the following breeding season.

ii. The objective of population augmentation is successful if the translocated bird is found anywhere within the target area in the following breeding season.

c. Report all translocations and translocation attempts, both within and between populations, to the Red-cockaded Woodpecker Recovery Coordinator using the Annual Report. Include a description of the management objective, the target area, and the success of the translocation.

I. FORAGING HABITAT

Recent research has expanded our understanding of the foraging ecology of red-cockaded woodpeckers considerably (2E). We know that the structure of foraging habitat is important to fitness of red-cockaded woodpeckers as well as influencing habitat selection. Fitness increases if foraging habitat is burned regularly, has an open character and herbaceous groundcovers, and contains large old trees. Selection of habitat increases with these same characteristics. This structure constitutes good quality foraging habitat for the species. Quality of foraging habitat also affects home range size: as quality increases, the amount of foraging habitat used decreases. We base the following guidelines for the management of foraging habitat on what we now know about both habitat quality and quantity.

We provide two sets of guidelines for the management of foraging habitat: the recovery standard (below) and the standard for managed stability (Appendix 5). Under section 7(a)(1) of the Endangered Species Act, federal agencies have a responsibility to (i.e., "federal agencies shall") use their authorities to carry out programs for the conservation (i.e., recovery) of listed species. Use of the recovery standard by federal agencies will facilitate recovery. Additionally, we strongly recommend that all state properties, particularly those involved in recovery, manage under the recovery standard. We also recommend this standard for those populations on private lands that landowners wish to manage for increasing population size.

The second set of guidelines, referred to as the standard for managed stability, should be used for instances in which a landowner cannot manage to the recovery standard. If a private landowner follows the standard for managed stability, the U.S. Fish and Wildlife Service will not recommend that the landowner needs, or applies for, an incidental take permit, based on the amount of foraging habitat remaining post-project. However, other project-related impacts, for instance, disturbance in the cluster during the nesting season, may require an incidental take permit. The standard for managed stability is presented in Appendix 5, the Private Lands Guidelines. The standard for managed stability is not designed to increase population size. Additionally, its wide-scale implementation, or application, will: (1) not provide future nesting habitat or good quality foraging habitat, (2) result in population fragmentation with subsequent problems related to demographic stochasticity, and (3) based on (1) and (2) above, not maintain that population's long-term viability.

A general discussion of foraging ecology is presented in 2E, and a detailed rationale for each component of the recovery standard is given in Table 13 (below). The recovery standard includes a discussion of habitat variation. Following the recovery standard, we present guidelines on foraging habitat assessment, including general habitat monitoring. We then provide a brief description of foraging habitat partitioning. Guidelines for silvicultural methods to implement the recovery standard are given in 8J.

Guidelines

Part A. Recovery Standard

We recommend this standard for all populations on federal lands, state lands, and those populations on private lands being managed for increasing population size.

1. Area Provided by Site Productivity

a. In systems of medium to high site productivity (site index 60 or more, for the dominant pine species), provide each group of woodpeckers 49 ha (120 ac) of good quality habitat as defined below. A specific exception to this area requirement is made for longleaf and shortleaf habitat types under group selection silviculture; see below for details.

b. In systems of low site productivity (site index below 60, for the dominant pine species), provide each group of woodpeckers 80 to 120 ha (200 to 300 ac) of good quality habitat as defined below. (We recognize that some aspects of the following definition of good quality habitat may not be achievable on extremely dry or wet sites. See discussions below on geographic variation in habitat for more information.)

2. Definition of Good Quality Foraging Habitat. Good quality foraging habitat has some large old pines, low densities of small and medium pines, sparse or no hardwood midstory, and a bunchgrass and forb groundcover. Based on results of studies described in 2E and Table 13, good quality habitat has all of the following characteristics:

a. There are 45 or more stems/ha (18 or more stems/ac) of pines that are $\geq$ 60 years in age *and* $\geq$ 35 cm (14 in) dbh. Minimum basal area for these pines is 4.6 m^2/ha (20 ft^2/ac). Recommended minimum rotation ages apply to all land managed as foraging habitat.

b. Basal area of pines 25.4 – 35 cm (10 – 14 in) dbh is between 0 and 9.2 m^2/ha (0 and 40 ft^2/ac).

c. Basal area of pines < 25.4 cm (< 10 in) dbh is below 2.3 m^2/ha (10 ft^2/ac) *and* below 50 stems/ha (20 stems/ac).

d. Basal area of all pines $\geq$ 25.4 cm (10 in) dbh is at least 9.2 m^2/ha (40 ft^2/ac). That is, the minimum basal area for pines in categories (a) and (b) above is 9.2 m^2/ha (40 ft^2/ac).

e. Groundcovers of native bunchgrass and/or other native, fire-tolerant, fire-dependent herbs total 40 percent or more of ground and midstory plants and are dense enough to carry growing season fire at least once every 5 years.

f. No hardwood midstory exists, or if a hardwood midstory is present it is sparse and less than 2.1 m (7 ft) in height.

g. Canopy hardwoods are absent or less than 10 percent of the number of canopy trees in longleaf forests and less than 30 percent of the number of canopy trees in loblolly and shortleaf forests. Xeric and sub-xeric oak inclusions that are naturally existing and likely to have been present prior to fire suppression may be retained but are not counted in the total area dedicated to foraging habitat.

h. All of this habitat is within 0.8 km (0.5 mi) of the center of the cluster, and preferably, 50 percent or more is within 0.4 km (0.25 mi) of the cluster center.

i. Foraging habitat is not separated by more than 61 m (200 ft) of non-foraging areas. Non-foraging areas include (1) any predominantly hardwood forest, (2) pine stands less than 30 years in age, (3) cleared land such as agricultural lands or recently clearcut areas, (4) paved roadways, (5) utility rights of way, and (6) bodies of water.

3. Discussion of Foraging Habitat Types.

a. Longleaf Pine. Longleaf pine communities vary from highly xeric to mesic and seasonally wet (see 2E), and each of these can support red-cockaded woodpeckers if the habitat structure is suitable. Red-cockaded woodpeckers in some highly xeric sites, such as Eglin Air Force Base in Florida, have very large home ranges, sparse groundcovers, and low density of large old trees that may result from low productivity and past management practices. Thus, we recommend that between 80 to 120 ha (200 and 300 ac) of good quality foraging habitat be provided each group in such sites. Note that this number of hectares (acres) does not refer to home range size in this habitat type, but the recommended amount of good quality foraging habitat within the home range. The latter may be much larger, due to unsuitable areas and home range overlap.

Extremely dry and extremely wet longleaf habitats may be unable to support some of the characteristics identified for good quality habitat. Pine sizes, pine density, and groundcover density may be below those specified above. Failure to meet these three criteria in extremely dry and extremely wet sites is understandable, as long as habitats are burned frequently and conscientious restoration is underway. Further research will help determine the extent of the natural ability of these habitats to support longleaf pines, native groundcovers, and red-cockaded woodpeckers at higher densities.

b. Shortleaf Pine. Historically, shortleaf pine communities included those without hardwoods, those with a small hardwood component, and those dominated by hardwoods. For red-cockaded woodpeckers, some shortleaf habitats, especially those on upland areas, should be free or almost free of hardwoods. Other habitats, such as those grading into mesic sites and north facing slopes, may support more hardwood overstory (up to 20 percent) and still be important red-cockaded woodpecker foraging habitat. Overstory hardwoods should not be removed entirely from communities in which they were historically present; however, neither should they be allowed to dominate a historic pine site. Stands with an overstory hardwood component greater than 30 percent are not considered suitable foraging habitat for red-cockaded woodpeckers.

c. Loblolly Pine. Because of fire sensitivity, loblolly pine was historically much less widespread than today. Prior to fire suppression, loblolly pine was a minor component of riparian and other mesic forests in the coastal plain and a secondary component of mixed pine and pine hardwood forests in the interior uplands. Forests dominated by loblolly were rare and restricted to a part of southern Arkansas and perhaps eastern Virginia and northeastern North Carolina. Currently, because of the fire suppression of the past century, loblolly pine is the dominant pine throughout the southeast, in areas that were historically covered by longleaf pine, shortleaf pine, and shortleaf/loblolly pine forests. These off-site loblolly pine forests provide important resources for red-cockaded woodpeckers. Loblolly pine does not provide as high quality habitat as do longleaf and shortleaf pines, because it produces less resin and is more sensitive to fire, southern pine beetles, and windthrow. These characteristics also render the management of loblolly for use by red-cockaded woodpeckers somewhat more difficult. However, with care, loblolly pine can be successfully managed to provide important habitat for red-cockaded woodpeckers. Additionally, there may be opportunities to carefully restore loblolly stands to site-appropriate pines. Foraging habitat for red-cockaded woodpeckers in loblolly forests should be managed according to the recovery standard, with the additional recommendation that total stand basal area in off-site loblolly forests be kept below 18.4 m^2/ha (80 ft^2/ac).

d. South Florida Slash Pine. Foraging ecology of red-cockaded woodpeckers in native slash pine (*Pinus elliottii* var. *densa*) communities in south Florida has received little research attention. It is clear, though, that home ranges of red-cockaded woodpeckers in native slash pines are unusually large. It is also clear that hydric slash pine flatwoods do not support the size of pines, and may not support the pine density, recommended in the Recovery Standard (above). Until further information is available, we can make only intermediate provisions for these populations. Each group in south Florida slash pine habitat is to be provided at least 80 to 120 ha or more (200 to 300 ac) of good quality foraging habitat containing mature and old pines and healthy native groundcovers that are frequently burned. Again, this is not the home range size but the amount of good quality habitat to be provided. Further research will help determine the density to which south Florida slash pines can be restored, as well as the specific requirements of red-cockaded woodpeckers in this unique habitat type.

e. Slash Pine. Historically, slash pine (*Pinus elliottii* var. *elliottii*) was typically found in transitional mesic sites within longleaf pine forests, such as in narrow drainages and along pond margins. Slash pine is now much more widespread than historically, as a result of fire suppression and aggressive planting. Foraging habitat for red-cockaded woodpeckers in slash pine (var. *elliottii*) forests should be managed according to the recovery standard.

f. Pond Pine. Ecology of red-cockaded woodpeckers in pond pine communities is virtually unknown. Catastrophic natural fire regimes of these communities confound red-cockaded woodpecker management. Certainly, reintroduction of fire and restoration of an open habitat structure are important. We recognize that the above definition of good quality habitat may not apply to this habitat type but can offer no alternative at this time. Further research is necessary before more specific recommendations can be made for this habitat type.

4. Population-specific Guidelines.

Managers may formulate population-specific foraging guidelines in consultation with the U.S. Fish and Wildlife Service. Population-specific guidelines must be based on site-specific research consisting of multi-year (typically 3-5 years) data on red-cockaded woodpecker group and population health and their relationships to quantity and quality of foraging habitat. Such guidelines must still meet or exceed recommendations put forth in the recovery standard concerning these habitat elements: (1) herbaceous groundcover, (2) hardwood midstory, (3) canopy hardwoods, and (4) distance from cluster center. Site-specific guidelines may deviate from the recovery standard in these habitat elements: (1) pine basal area, (2) pine age, and (3) the size class distribution and stem density of pines. Again, deviations must be based on sound science and meet approval through consultation with the U.S. Fish and Wildlife Service.

5. Multiple Ownership.

For those situations in which more than one property is included within the foraging partition of an active cluster, each property owner shall be responsible for providing foraging habitat in proportion to the area of their property currently containing foraging habitat within the partition.

TABLE 13. Rationale for foraging guidelines based on habitat structure[1] (recovery standard).

	Recommendation	Rationale	Source
1a	49 ha (120 ac) good quality habitat	Home range/foraging habitat required decreased with habitat quality.	Walters *et al.* 2000, 2002a
		51 ha (126 ac) good quality habitat recommended.	James *et al.* 2001
		Average home range of groups with access to old growth foraging (Wade Tract, GA) was 47 ha (116 ac), including overlap.	Engstrom and Sanders 1997
1b	More foraging required for sites of low productivity	Large home ranges in Eglin Air Force Base and South/Central Florida.	DeLotelle *et al.* 1987 Beever and Dryden 1992 Hardesty *et al.* 1977
2a	$\geq$ 45 pines/ha (18/ac) that are at least 35 cm dbh (14 in) and 60 yrs in age. Minimum basal area for these pines is 4.6 m^2/ha (20 ft^2/ac).	Group size and reproduction increased with density of large pines; recommended 40 35 cm pines per ha (16 14 in pines/ac).	James *et al.* 2001
		RCWs selected stands with 50 or more pines at least 35 cm in dbh per ha (20 or more pines at least 14 in dbh/ac).	Walters *et al.* 2000, 2002a
		Group size increased with number of flat-tops per acre.	Walters *et al.* 2000, 2002a
		Pines and patches of pines selected if over 60 yrs. in age.	Zwicker and Walters 1999 Walters *et al.* 2000, 2002a

Table continued next page.

TABLE 13 (cont.). Rationale for foraging guidelines based on habitat structure[1] (recovery standard).

	Recommendation	Rationale	Source
2a (cont.)		RCWs selected large old pines in greater proportion than their availability.	Hooper and Lennartz 1981 DeLotelle *et al.* 1983, 1987 Hooper and Harlow 1986 Porter and Labisky 1986 Jones 1994 Epting *et al.* 1995 Engstrom and Sanders 1997 Hardesty *et al.* 1997 Bowman *et al.* 1998 Doster and James 1998 Zenitsky 1999 Zwicker and Walters 1999 Walters *et al.* 2000, 2002a
2b	Basal area of pines 25.4 – 35 cm (10 – 14 in) dbh is between 0 and 9.2 m^2/ha (0 and 40 ft^2/ac).	High pine density negatively affected group size and productivity.	James *et al.* 1997 Hardesty *et al.* 1997 Walters *et al.* 2000, 2002a James *et al.* 2001
2c	Basal area of pines $\geq$ 25 cm (10 in) dbh < 2.3 m^2/ha (10 ft^2/ac) *and* below 50 stems/ha (20 stems/ac).	High densities of small pines negatively affected group size and productivity.	James *et al.* 1997 James *et al.* 2001
		High densities of small pines negatively affected selection of stands for foraging.	Porter and Labisky 1986 Bradshaw 1995 Walters *et al.* 2000, 2002a
2d	Basal area of all pines $\geq$ 25.4 cm (10 in) dbh is at least 2.3 m^2/ha (40 ft^2/ac).	RCWs avoided patches with basal areas below these ranges.	Walters *et al.* 2000, 2002a
2e	Herbaceous groundcovers $\geq$ 40% of groundcovers.	Group size and reproduction increased with herbaceous groundcovers; this level recommended.	Hardesty *et al.* 1997 James *et al.* 1997 James *et al.* 2001

Table continued next page.

TABLE 13 (cont.). Rationale for foraging guidelines based on habitat structure[1] (recovery standard).

	Recommendation	Rationale	Source
2f	Hardwood midstory below 2.1 m (7 ft).	Patches with midstory below 2.1 m (7 ft) were preferred. Stand use decreased with midstory above 2.1 m (7 ft).	Walters *et al.* 2000, 2002a
		Patch and stand use decreased with midstory in general.	Hooper and Harlow 1986 Jones 1994 Epting *et al.* 1995 Bradshaw 1995 Doster and James 1998
2g	Canopy hardwoods < 10% of canopy trees in longleaf stands and < 30 % of canopy trees in loblolly and shortleaf stands.	Large hardwoods negatively affected habitat selection; Jones (1994) found a negative effect above 10%.	Jones 1994 Bradshaw 1995
2h, 2i	Within 0.8 km (0.5 mi), not separated by more than 61 m (200 ft) non-forested land.	Fragmentation of foraging habitat negatively affected RCWs.	Conner and Rudolph 1991b Rudolph and Conner 1994 Conner and Dickson 1997 Ferral 1998

[1]Foraging guidelines are based on structural components rather than total number of pines $\geq$ 10 dbh because of the evidence presented in this table and because no relationship has been found between this variable and group size or reproduction (Hooper and Lennartz 1995, Beyer *et al.* 1996, Wigley *et al.* 1999).

Part B. Assessment of Foraging Habitat

Assessment of foraging habitat is an important component of red-cockaded woodpecker conservation and recovery. Improvements in quality of foraging habitat are necessary for the recovery of the species, and progress in improving foraging habitat is to be assessed through general habitat monitoring. Also, foraging habitat assessment is required prior to executing any projects that may impact foraging habitat. Here we first discuss partitioning, which is the allocation of foraging habitat to specific woodpecker clusters. We then describe general habitat monitoring and interim guidelines for assessment of project impacts in foraging partitions (below) not meeting recommendations for foraging habitat set forth in the recovery standard.

1. Allocating Foraging Habitat

Foraging habitat is best allocated to a specific cluster by performing follows on individual groups, to ascertain which portions of forest stands a particular group is using. Acquiring such data-intensive knowledge is generally far beyond the resources of managers and researchers, but may be required for some projects.

An alternative approach has been developed using geographic information systems (GIS), based on the recommendation within previous foraging guidelines (USFWS 1985) that all foraging habitat be within 0.8 km (0.5 mi) of the center of the cluster. The technique consists of first creating 0.8 km (0.5 mi) foraging circles around the center of each cluster, then applying tabular data of stand characteristics to determine availability of foraging habitat within the newly created circular polygon. Where foraging circles overlap, the area of overlap is partitioned into equal sections and allocated accordingly. Technical resources are available to assist managers and researchers in partitioning the complex overlaps that are common in areas with high cluster densities (Lipscomb and Williams 1996, 1998). Complete and partitioned foraging circles are referred to as foraging partitions.

Revised foraging guidelines (this document) recommend that all foraging habitat be within 0.8 km (0.5 mi) of the center of the cluster, and that, preferably, 50 percent or more be within 0.4 km (0.25 mi) of the cluster center. Foraging partitions should therefore include a second, smaller circle denoting the 0.4 km (0.25 mi) radius. Because cavity tree clusters are spatially dynamic, foraging partitions should be reevaluated periodically as described below.

2. General Monitoring of Foraging Habitat

a. Monitor quality and quantity of all foraging habitat dedicated to red-cockaded woodpecker groups and recruitment clusters at a minimum frequency of 10 years, with the exception of midstory which is to be monitored at a minimum frequency of 5 years. Begin monitoring foraging habitat as soon as possible. Substantial change in habitat quality should be made during each ten-year interval until all habitat elements put forth in the recovery standard are met. Once the recovery standard is met, continued habitat monitoring will ensure that habitat quality and quantity are maintained.

b. Record, for each territory or foraging partition associated with active and recruitment clusters, the following information:

i. the number of ha (ac) of foraging habitat that meets all elements of good quality habitat identified in the recovery standard (above).

ii. the number of ha (ac) of foraging habitat that meets all elements but one, and for each forest stand, identify the missing element.

iii. the number of ha (ac) of foraging habitat that meets all elements but two, and for each forest stand, identify the missing elements.

c. Use appropriate management techniques to increase the number of ha (ac) in categories (i) and (ii) above, and to move toward meeting the standard of 49 ha (120 ac) in category (i).

d. To monitor groundcover, estimate percent native, site-appropriate herbaceous cover using as simple standard technique such as that presented by James and Shugart (1970) and proportional sampling based on the size of the stand. If necessary, more specific recommendations for groundcover monitoring will be formulated by the U.S. Fish and Wildlife Service.

e. To monitor pine size and density, use standard forestry techniques. Age of pines can be determined by coring a sample and determining the relationship between age and size for each habitat type.

3. Interim Guidelines. Here we discuss interim guidelines for assessment of project impacts in territories or foraging partitions not meeting foraging habitat recommendations. The major theme of these recommendations is that if reasonable progress toward meeting the recovery standard can be demonstrated, most projects can be implemented.

a. Demonstration of Reasonable Progress. Reasonable progress toward meeting the recovery standard is best demonstrated by increases in the area of foraging habitat that meets all of the elements of good quality habitat as set forth in the recovery standard (above). Reasonable progress can also be demonstrated by increasing habitat area that meets all elements but one, with no corresponding decrease in the habitat area meeting all elements. Finally, reasonable progress can also be demonstrated if one or more of the individual components are being moved toward the desired condition. For example, if managers can document that an area once supporting no herbaceous groundcover now supports 20 percent native herbaceous cover, reasonable progress is being made. Any of these improvements in foraging habitat have to be current (within the past 3 years) to be considered reasonable progress.

b. Guidance on Specific Projects - Cluster-level Analysis

i. If the project itself (e.g. pine thinning) will move the habitat dedicated to specific clusters toward the desired structure identified in the recovery standard, project concurrence is provided.

ii. If the project **will not** impact the best 49 ha (120 ac) dedicated to foraging habitat (or the best 80 – 120 ha (200-300 ac) in sites of low productivity), and that dedicated foraging habitat is being actively moved toward the desired structure by demonstration of reasonable progress, then project (e.g., a land use change) concurrence is provided. Here we use the term 'best' to refer to those hectares (acres) that best reflect the desired habitat structure and important habitat elements put forth in the recovery standard.

iii. If the project **will** impact some of the best 49 ha (120 ac) dedicated to foraging habitat (or the best 80 – 120 ha (200-300 ac) in sites of low productivity), and will not move the habitat directly toward the desired structure, then the project will typically require reconsideration and modification prior to concurrence. However, in some cases such as restoration of site-appropriate pine species, the project may continue at a reduced level (e.g., group selection or very small patches) so that impacts to foraging are minimized and weighed against future benefits. Such concurrence requires a case-by-case review.

c. Guidance on Specific Projects - Neighborhood-level Analysis

Foraging habitat loss or alteration can have direct effects on group size and reproduction (cluster-level analysis, above). Additionally, by affecting landscape configuration, projects may affect the health and distribution of red-cockaded groups at a neighborhood scale. Habitat fragmentation affects dispersal of individuals in adjacent or nearby groups, and the likelihood that breeding vacancies become filled. Demographic viability of groups, neighborhoods, and populations is primarily dependent on the ability of group members to disperse. If dispersal opportunities are limited or inhibited by a project, even if adequate foraging habitat remains post-project, group status, group size, and reproduction may be affected. It is important that these neighborhood effects be assessed during analysis of project impacts.

J. SILVICULTURE

Silviculture is an important tool for conservation, management, and recovery of red-cockaded woodpeckers. We describe silvicultural methods and techniques in 3E. We present general guidelines for silviculture below (Part A). These general guidelines are based on research documenting the importance of old pines and impacts of habitat fragmentation on red-cockaded woodpeckers (see 2D, 2E). We also present some approaches to satisfying foraging guidelines (8I) under various silvicultural systems currently in use. These approaches reflect our new understanding of foraging ecology (2E) and current silviculture in general; they are not based on research of the effects of these silvicultural treatments on red-cockaded woodpeckers. Experimental research into effects of specific silvicultural treatments on fitness of red-cockaded woodpeckers is a critical research need.

Guidelines

Part A. General Guidelines for Silviculture

1. Use two-aged management, uneven-aged management, or low intensity management to manage habitat for red-cockaded woodpecker populations on public lands. These guidelines are to be applied throughout the habitat managed for red-cockaded woodpeckers, unless otherwise noted.

a. If two-aged management is used, then

i. Use rotation intervals not less than 120 years for longleaf and shortleaf pines and 100 years for loblolly, slash, and pond pines. An exception to this for loblolly and shortleaf stands under high risk of mortality due to insects, disease, or other site-related problems may be given on a case-by-case basis through consultation with the U.S. Fish and Wildlife Service. These rotation intervals are considered the minimum intervals compatible with red-cockaded woodpecker conservation.

ii. Limit regeneration areas to less than 10 ha (25 ac) in populations of less than 100 potential breeding groups, and to less than 16 ha (40 ac) in populations of 100 potential breeding groups or more.

iii. Leave a minimum of 15 – 25 pines on each ha (6 – 10 pines on each ac).

iv. Retain all flat-tops, turpentine pines, and other relict pines.

b. If uneven-aged management is used, then

i. Retain 12 or more pines on each hectare (5 or more on each acre) of the oldest pines present, to establish very old pines throughout the landscape at this minimum density.

ii. Retain all flat-tops, turpentine pines, and other relict pines.

c. If low-intensity management is used, ensure that the appropriate habitat structure, as described in foraging (8I) and cluster management guidelines (8F), is maintained.

2. Use even-aged, two-aged, and/or uneven-aged management systems to restore off-site pines to native pine species. Generally, limit size of regeneration areas for restoration to 16 ha (40 ac) or less. However, regeneration areas up to 32 ha (80 ac) are acceptable for native pine restoration if such stands are at least 1.6 km (1 mi) from active or recruitment clusters.

3. Use the least invasive form of site preparation possible given habitat conditions. In most instances, prescribed burning is the preferred method.

4. Protect against infestation of southern pine beetles by practicing Integrated Pest Management, including thinning pines to maintain adequate spacing (7.6 m or 25 ft among canopy pines) and minimizing disturbance. For more specific information consult the U.S. Forest Service's Final Environmental Impact Statement for the Suppression of the Southern Pine Beetle (USFS 1987).

Part B. Silvicultural Systems and Implementation of Foraging Guidelines

Here we present a brief description of how foraging guidelines can be satisfied in forests managed under modified two-aged or uneven-aged silviculture. See 3E for more information concerning silviculture.

1. Modified Two-aged Management

a. Loblolly, Slash, and Pond Pines. Forests of these pine types are to be managed on a minimum rotation of 100 years. An exception to the minimum may be permitted in forests under high risk of infestation by southern pine beetles through consultation with the U.S. Fish and Wildlife Service. To implement foraging guidelines under a minimum rotation of 100 years, follow these recommendations:

i. Retain a minimum basal area of 4.6 m^2/ha (20 ft^2/ac) in leave trees.

ii. Do not count stands with dense, young regeneration as foraging habitat. Stands that do not meet criterion (c) in the Recovery Standard (above) cannot be counted as foraging habitat.

iii. Once regeneration reaches 25.4 cm (10 in) dbh, thin the regeneration to a maximum basal area of 9.2 m^2/ha (40 ft^2/ac) and protect or restore herbaceous groundcover. The stand should then meet the criteria of good quality habitat (above) and can be counted as foraging habitat.

b. Longleaf and Shortleaf Pines. Longleaf and shortleaf pine woodlands under modified two-aged silviculture are to be managed with a minimum rotation of 120 years. An exception to the minimum may be obtained in shortleaf forests under high risk of disease (e.g. little-leaf disease). There are at least three options for implementing the recovery standard in these woodlands. The first is to extend the rotation interval to 150 years for woodpecker groups maintained at a current or projected density of 81 ha (200 ac) per group. This would provide 49 ha (120 ac) of good quality habitat in each foraging partition. The second option is to follow the approach described above for loblolly/slash/pond pine forests under modified two-aged silviculture. However, some managers may consider leaving a minimum of 4.6 m^2/ha (20 ft^2/ac) of basal area in leave pines unrealistic in longleaf woodlands because of the shade intolerance of the species. These managers may consider a third option, which is to extend the projected density of red-cockaded woodpecker groups to 97 ha (240 ac) per group. Under this third option, regeneration areas (still requiring 15 – 25 leave pines/ha, or 6 to 10 pines/ac) are not counted as foraging habitat until the regeneration reaches at least 60 years in age and 35 cm (14 in) dbh.

2. Uneven-aged Management

Uneven-aged silviculture includes both single tree and group selection. Both silvicultural methods are compatible with management for red-cockaded woodpeckers. If single tree selection is applied appropriately, the entire forest can meet all elements of good quality foraging habitat as put forth in the recovery standard. However, when group selection is applied, small patches of regeneration (< 0.8 ha, or 2 ac) are interspersed throughout the managed forest. These individual patches of regeneration may be included within the area identified as good quality foraging habitat once the regenerating pines are at least 25.4 cm (10 in) dbh, the density of these pines is 9.2 m^2/ha (40 ft^2/ac), and the appropriate percentage of native groundcovers is present. Once the regenerating pines are 35 cm (14 in) in dbh or greater, regeneration areas should meet all elements of the recovery standard.

If red-cockaded woodpecker groups are being managed at a density of 81 ha (200 ac) per group, this approach to satisfying the recovery standard in forests under group selection will result in 40 ha (100 ac) of good quality habitat and an additional 20 ha (50 ac) of small patches that meet all elements of good quality habitat except the requirement for pines 35 cm (14 in) and larger. This is the only acceptable exception to the minimum area requirement of 49 ha (120 ac) of good quality habitat put forth in the recovery standard. This exception is considered acceptable because of the spatial distribution and size of regenerating patches (that is, regenerating patches that lack pines 35 cm (14 in) dbh and larger are small and interspersed throughout the forest).

K. Prescribed Burning

Prescribed burning is basic to the management, conservation, and recovery of red-cockaded woodpeckers. In addition, prescribed burning provides benefits for a long list of species associated with southern pine/bunchgrass ecosystems, many of which are rare, threatened, or endangered. Discussions of the integral role of fire in southern pine ecosystems and the use of prescribed fire are given in 2G and 3F. Prescribed burning should mimic natural fire regimes as closely as possible, but must be carefully planned and conducted to reduce the likelihood of damage to nesting and foraging habitat. In general, managers are to work toward a prescribed burning program of early to mid-growing season burns on a 1 to 5 year return interval. Habitat with excessive hardwood midstory is to be restored to one with an herbaceous groundcover, preferably by burning at a frequency of 1 to 3 years. Longer intervals are appropriate only for habitat that can be maintained with recommended herbaceous groundcover at those longer burn frequencies.

Guidelines

1. Planning a Prescribed Burning Program. In planning a prescribed burning program to benefit red-cockaded woodpeckers, consider the following guidelines:

a. Prioritize areas of the forest in need of burning.

i. Review the status of red-cockaded woodpeckers throughout the forest.

ii. Give first priority to maintaining active clusters that support healthy herbaceous groundcovers.

iii. Give second priority to restoring herbaceous groundcovers in active clusters with excessive hardwood midstory.

iv. Give third priority to recently inactive clusters with excessive midstory.

b. As special needs are being addressed, move to implement an effective broad-scale burning program to maintain and enhance quality of nesting and foraging habitat.

2. Burn Prescriptions. Prepare burn prescriptions for each burn unit prior to conducting prescribed burning based on habitat evaluations for individual woodpecker groups. Each prescription should include:

a. The management objective of the burn, such as habitat restoration, habitat maintenance, or fuel reduction.
b. The parameter values necessary to achieve the objective, including season of burn, fuel moisture, wind speed and direction, and relative humidity.

c. Maps indicating the location of all cavity trees within the burn unit as well as specific directions for protecting each of these cavity trees.

In light of stringent laws regulating smoke management, it is imperative that all prescribed burns comply with state and federal regulations.

3. Season of Prescribed Burning. Determine the appropriate season for prescribed burns based on management objectives. Consider the following guidelines when determining appropriate season:

a. Strive for a program of frequent early to mid-growing season burns to maintain and enhance quality of nesting and foraging habitat.

b. Apply dormant season fire prior to growing season burns when reintroducing fire to fire-suppressed habitats, but be aware that fires conducted during the late growing season and into the fall can result in increased pine mortality. Growing season burns can be used as a method of habitat restoration in some sites (see 3G and below).

c. Do not rely on dormant season fire. Once hazardous fuel accumulations have been reduced by dormant season burns, place the area on a growing season fire rotation.

d. Bear in mind geographic variation in the timing of the seasons.

e. Remember that regardless of the season, heavy fuels are very dangerous to cavity trees. During dormant season as well as growing season burns, thick duff layers surrounding pines can result in deadly smolder fires.

4. Size of Burn Units. Size of prescribed burns can vary from single clusters to over a thousand hectares (several thousand acres). In general, larger burns have a lower cost per hectare (acre) and provide the greatest benefit to the ecosystem. However, cost efficiency should not be the sole factor in determining the size of burn units. The prescribed burn should be large enough to accomplish the primary objective of the burn without reducing the burn boss's ability to maintain control of the fire's intensity.

5. Cavity Tree Protection. Protect cavity trees within and in close proximity to the burn unit, following these guidelines:

a. Ensure that all members of the burn crew have maps detailing the location and status of all cavity trees within and in close proximity to the burn unit. Information distributed to each crew member should include activity status, cavity height, and relative amount of resin present, as determined by surveys performed within one year of the burn date.

b. Determine the appropriate level of protection for cavity trees, according to the following:

i. Protect active cavity trees, inactive cavity trees, and relict pines (flat-tops, very old pines, and turpentine pines) within the burn unit if one or more of the following conditions exist: (1) the population consists of less than 30 potential breeding groups; (2) fire intensity of the prescribed burn would likely result in ignition of an unprotected tree; or (3) potential cavity trees (i.e., pines over 60 years in age, including relict pines) are limited.

ii. Protect only active cavity trees within the burn unit if all of the following conditions exist: (1) the population consists of 30 or more potential breeding groups; (2) the area proposed for burning has been burned in recent years (3 – 5 years or less) and the fuel loads have been reduced to acceptable limits; and (3) potential cavity trees are not limited.

c. Protect individual cavity trees by reducing fuels at the base of cavity trees for a minimum distance of 3 m (10 ft) from the trunk. The necessary distance varies depending on fuel types, fuel loads, amount of resin present, cavity heights, and firing technique as well as on the objective of the burn. Restoration burns require a greater distance of fuel reduction than less intense maintenance burns. Use maximum distances during the nesting season and when protecting cavity trees with turpentine scars and resin low on the bole.

d. Use one or more of the following methods of cavity tree protection:

i. Small preparation burns. Conduct preparation burns of the cluster or areas surrounding individual cavity trees before conducting the larger burn. Preparation burns can be performed immediately before or several weeks ahead of the larger burn. Carefully monitor and extinguish preparation burns to avoid damage to cavity trees or unintentional ignition of the larger burn unit. A strong advantage of this method is that it benefits groundcover plants that are harmed by other methods such as raking and mowing (below).

ii. Raking. Rake fuels far enough from the trunk to prevent cavity tree ignition. Avoid the formation of mounds or rings of concentrated fuels (such as pine straw); such piles of fuels can cause greater mortality than if no action had been taken. Remove small trees and shrubs by hand prior to raking fuels.

iii. Mowing. Mowing is effective, but heavy machinery can compact soils and damage tree roots. To reduce these negative impacts, avoid repeated mowing and use of heavy equipment, and minimize use of machinery in wet sites. Weed-whipping is a low impact alternative.

iv. Light bark scraping. Lightly scraping off the loose bark from ground to breast height can improve the effectiveness of other methods such as raking and mowing.

v. Wetting the cavity trees. A solution of water and foaming agent applied to the base of cavity trees is currently being tested as a method for cavity tree protection. This may become available for widespread use in the future. Foam may be especially effective in combination with mowing or raking.

vi. Plow lines as cavity tree protection are prohibited. Never install circular plow lines around individual cavity trees because such plow lines can cause the death of the tree.

6. Method of Ignition. Apply fire to the landscape using aerial or ground ignition. Ground ignition may require less financial resources and training. Aerial ignition increases the area burned per unit time, and improves dispersal of smoke. Either technique is suitable, and both are discussed in 3F.

If using aerial ignition, provide a greater degree of cavity tree protection than normally provided for burns ignited on the ground. Rake, mow, or burn for a distance of at least 6.1 m (20 ft) or more from the cavity trees. Even greater protection is necessary if the area has not been burned frequently and the habitat requires restoration. If restoration is required, we recommend a prescribed burn of the cluster ignited on the ground prior to igniting the larger burning unit from the air.

7. Restoration Burning. Restoration burning and the reintroduction of fire can be used to reduce or remove dense hardwood midstories. When applying restoration burns, have fire suppression equipment on site in case the fire crosses control lines. Clusters on deep, sandy soils, with a dense hardwood midstory and a sparse accumulation of ground fuels, can be effectively treated with a restoration burn during the growing season.

Key to success of this management action is a thorough understanding of fire behavior in those fuel types under a variety of weather conditions. The use of fire for restoration purposes often requires burning under very specific weather conditions, which may include moderate winds, low relative humidity, and low fuel moistures. Use of prescribed burns under these conditions requires extensive experience in the application of growing season fire and must be conducted only by qualified burners. Again, it is imperative that all prescribed burns comply with state and federal regulations.

8. Consider the use of wildland fire to accomplish management objectives in appropriate areas. Protect public safety and property if implementing this policy. Protect cavity trees from ignition, and ensure that emergency fire suppression personnel are familiar with cavity protection methods and the need to protect cavity tree roots from plow lines and other firebreaks.

9. RECOVERY TASKS

The following recovery tasks are presented as a stepdown outline, a format required by the U.S. Fish and Wildlife Service's recovery planning guidelines. Ecology and management techniques relevant to these tasks are described in the Introduction. Management guidelines are given in detail in previous sections of Recovery. Specific guidelines relevant to tasks are referred to in parentheses.

1. Increase existing populations on all federal lands, and on those state lands identified in recovery criteria, until population objectives are reached.

1.1. Protect existing active clusters.

1.1.1. Apply prescribed burns every 1 to 5 years, preferably during the growing season (included in task 1.7., see 8K).

1.1.2. Provide and maintain four suitable cavities per cluster, if necessary using artificial cavities and/or restrictor plates (8E).

1.1.3. Control midstory and overstory hardwoods using means other than prescribed fire as necessary, but minimize disturbance to soil and native herbaceous groundcovers (8F, 8K).

1.1.4. Retain and protect active and inactive cavity trees and potential cavity trees (8F, 8K).

1.1.5. Practice integrated pest management to limit risk of damage by southern pine beetles.

1.2. Provide and maintain a sufficient number of recruitment clusters to achieve an annual average rate of population increase between 5 and 10 percent (8A).

1.2.1. Choose strategic locations for recruitment clusters, to facilitate occupation and develop beneficial spatial arrangements of groups (8B).

1.2.2. Restore suitable habitat structure prior to the installation of artificial cavities in recruitment clusters, using prescribed fire and other means as necessary to remove midstory and overstory hardwoods. Conduct pine thinning if densities are too high. Minimize disturbance to soils and native herbaceous groundcovers (8B, 8E, 8F, 8K).

1.2.3. Provision a number of recruitment clusters equal to 10 percent of potential breeding groups (or number of active clusters, if potential breeding groups is unknown). For each recruitment cluster, provide 3 artificial cavities and two drilled starts, or four artificial cavities (8A, 8B).

1.2.4. Apply prescribed burns to unoccupied recruitment clusters every 1 to 5 years, preferably during the growing season (8K).

1.2.5. When occupied, manage recruitment clusters as in 1.1 above.

1.3. Provide suitable quality and quantity of foraging habitat for each active and recruitment cluster, following the recovery standard (8I).

1.3.1. Apply prescribed fire to foraging habitat every 1 to 5 years, preferably during the growing season, to protect and restore native herbaceous groundcovers and control densities of midstory hardwoods and pines (8I, 8K).

1.3.2. Use means other than prescribed fire, if necessary, to control densities of midstory and overstory hardwoods and small and medium-sized pines (8I, 8K).

1.3.3. Protect and/or develop an old growth or mature pine component within the foraging habitat, at recommended densities (8I, 8J).

1.3.4. Provide suitable quantity of good quality foraging habitat (8I).

1.3.5. Practice integrated pest management to limit risk of damage by southern pine beetles.

1.4. Combat effects of fragmentation on demography and genetic resources.

1.4.1. Locate newly developed recruitment clusters of artificial cavities in strategic locations to enhance natural dispersal (same as task 1.2.1).

1.4.2. Use within-population translocation when appropriate to stabilize and increase isolated sub-populations (8H).

1.4.3. Consider population augmentation if your population is less than 30 potential breeding groups, through enrolling in a regional translocation program (8H). Provide high quality nesting and foraging habitat prior to translocation (8B, 8E, 8F, 8I).

1.4.4. Avoid further fragmentation of forests managed for red-cockaded woodpeckers (8J).

1.5. Provide additional habitat for population growth to achieve population objectives.

1.5.1. Use appropriate silvicultural techniques to produce suitable foraging and nesting habitat for future population expansion (8J).

1.5.2. Restore historic vegetation type (e.g., longleaf and shortleaf pine communities) where appropriate (8J).

1.6. Monitor woodpecker populations using recommended monitoring intensity (8C).

1.7. Apply prescribed fire to all habitat managed for red-cockaded woodpeckers at least every 1 to 5 years (tasks 1.1.1, 1.2.4, and 1.3.1).

2. Maintain and/or increase populations on state lands not identified in recovery criteria.

2.1. Provide regulatory and economic incentives for state managers to participate in recovery efforts.

2.2. Enlist managers in statewide and regional recovery programs and partnerships.

2.3. Protect existing active clusters and encourage population increase (see tasks 1.1-1.7).

3. Maintain and/or increase populations on private lands, and establish new populations.

3.1. Provide regulatory and economic incentives for private landowners to participate in recovery efforts.

3.2. Enroll private landowners in management, conservation, and recovery programs, including Safe Harbor, Habitat Conservation Plans, and Memoranda of Agreement.

3.3. Provide awards to private landowners, both citizens and corporations, for exemplary conservation efforts.

3.4. Protect existing active clusters and encourage population increase (see tasks 1.1-1.7.).

4. Increase awareness of stakeholders and the general public.

4.1. Increase awareness of red-cockaded woodpecker ecology, status, and recovery.

4.2. Increase awareness of the role of fire in southeastern ecosystems and the need for prescribed burning.

4.3. Increase awareness of the need to restore an old growth pine component to federal, state, and private lands of the south.

5. Conduct research to further our understanding of woodpecker ecology, management, and recovery.

5.1. Explore and evaluate best management practices to increase populations at a rate appropriate for the recovery potential and habitat availability of individual populations.

5.2. Expand current understanding of relationships between condition of foraging habitat (structure, age, and species composition) and measures of group fitness and population health, for various habitat types such as mesic and xeric longleaf pine, south Florida slash pine, pond pine, off-site and site-appropriate loblolly, and shortleaf pine systems.

5.3. Expand current understanding of the relationships between condition of nesting habitat (density of pines, age of cavity trees, and groundcover composition) and measures of group fitness and population health.

5.4. Research conditions and factors that promote territorial budding and pioneering.

5.5. Further evaluate genetic threats.

5.6. Gain a better understanding of effects of cavity kleptoparasitism and predation on population dynamics, for various population sizes and habitat conditions.

5.7. Further research juvenile dispersal, especially factors promoting movements between populations.

5.8. Identify the thresholds at which quantity and quality of foraging habitat affect population trends, to better evaluate management of woodpeckers on private lands.

5.9. Further evaluate the relative benefits and drawbacks of artificial cavity installation methods.

5.10. Further assess the value of translocation as a management tool, including research on impacts to donor populations, benefits to receiving populations, and best techniques to increase success. Determine if translocation among recovery populations is warranted for genetic conservation (informed by results of tasks 5.5 and 5.7) or if drawbacks outweigh potential benefits of this action.

5.11. Further research the relationships among bark beetles, red-cockaded woodpeckers, and habitat management, including the extent and cause of elevated mortality of cavity trees infested with bark beetles, effects of habitat management on risk of infestation, and reasons why cavity trees attract bark beetles. Develop measures to prevent or reduce beetle-induced mortality of cavity trees.

5.12. Research the impacts of exotic species such as melaleuca and fire ants on red-cockaded woodpeckers.

6. Explore costs, benefits, and feasibility of moving from management based on single clusters to landscape level management.

6.1. On federal lands.

6.2. On state lands.

6.3. On private lands.

6.4. On tribal lands.

10. IMPLEMENTATION SCHEDULE AND ESTIMATED COSTS

We present several tables in this section. First are tables of estimated time to delisting (Table 14) and downlisting (Table 15), as calculated by projecting a 5 percent annual increase. Next is the implementation schedule and estimated costs for each recovery task (Table 16). These costs are given per unit (e.g., per active cluster, or per unit area). Finally, there are tables that illustrate estimated costs, by recovery population and responsible agency, for three recovery tasks: cavity maintenance (Table 17), cavity installation in recruitment clusters (Table 18), and frequent prescribed burning of all woodpecker habitat (Table 19).

TABLE 14. Estimated time (years, to the nearest 5 years) for each recovery population to meet size specified in delisting criteria, by recovery unit. Also listed is current size (number of active clusters in 2000, ACT) and minimum size required at delisting (potential breeding groups, PBG). Each estimated time is calculated based on a recommended 5% annual growth rate and a ratio of 1.4 active clusters per potential breeding group. Estimated time to delisting is 75 years, the maximum time in this table.

Recovery Unit	**Population**	**Current Size (ACT)**	**Size at Delisting (PBG)**	**Time to Required Size (yrs)**
Cumberlands/Ridge and Valley	Talladega/Shoal Creek	6	100	55
East Gulf Coastal Plain	Central Florida Panhandle	665	1000	50
	Chickasawhay	15	350	75
	Conecuh/Blackwater	44	250	60
	DeSoto	7	250	75
	Eglin	301	350	10
	Homochitto	51	250	35
Mid-Atlantic Coastal Plain	Coastal North Carolina	159	350	25
	Francis Marion	344	350	10
	Northeast North Carolina/Southeast Virginia	35	100	50
Ouachita Mountains	Ouachita	21	250	60
Piedmont	Oconee/Piedmont	59	250	45
Sandhills	Fort Benning	219	350	15
	North Carolina Sandhills East	371	350	15
	North Carolina Sandhills West	145	100	0
	South Carolina Sandhills	167	250	25
South Atlantic Coastal Plain	Fort Stewart	212	350	20
	Osceola/Okefenokee	100	350	40
	Savannah River	34	250	50
South/Central Florida	Avon Park	21	40	20
	Babcock/Webb	27	40	15
	Big Cypress	42	40	5
	Camp Blanding	14	25[1]	15
	Corbett/Dupuis	13	40	30
	Goethe	30	40	15
	Hal Scott	7	15[1]	15
	Ocala	22	40	20
	Picayune Strand	3	25[1]	45
	St. Sebastian River	8	25[1]	30
	Three Lakes	51	40	5
	Withlacoochee - Citrus Tract	46	40	5
	Withlacoochee - Croom Tract	5	30[1]	40
Upper East Gulf Coastal Plain	Bienville	104	350	35
	Oakmulgee	110	250	25
Upper West Gulf Coastal Plain	Sam Houston	168	350	25

Table continued next page.

TABLE 14 (cont.). Estimated time for each recovery population to meet size specified in delisting criteria.

Recovery Unit	**Population**	**Current Size (ACT)**	**Size at Delisting (PBG)**	**Time to Required Size (yrs)**
West Gulf Coastal Plain	Angelina/Sabine	57	350	45
	Catahoula	37	250	55
	Davy Crockett	53	250	40
	Vernon/Fort Polk	198	350	15

[1]These populations each have an estimated potential size of less than 40 potential breeding groups but can contribute significantly to the delisting criterion of 250 potential breeding groups (275-350 active clusters) in the South/Central Florida Recovery Unit overall.

TABLE 15. Estimated minimum time (years, to the nearest 5 years) for each recovery unit to meet downlisting criteria, assuming the currently largest populations within each recovery unit fulfill downlisting criteria first. Estimated time is calculated based on a recommended 5% annual growth rate and a ratio of 1.4 active clusters per potential breeding group. Estimated time to downlisting is 50 years.

Recovery Unit	**Time to Meet Downlisting Criteria (yrs)**
Cumberlands/Ridge and Valley	50
East Gulf Coastal Plain	0
Mid-Atlantic Coastal Plain	25
Ouachita Mountains	30
Piedmont	15
Sandhills	0
South Atlantic Coastal Plain	15
South/Central Florida	15
Upper East Gulf Coastal Plain	25
Upper West Gulf Coastal Plain	20
West Gulf Coastal Plain	15

TABLE 16. Implementation schedule and estimated costs by recovery task. See key below for explanation of abbreviations and cost estimates. For more information on costs and implementation schedule for select recovery tasks, see Tables 17, 18, and 19. See key (below) for explanation of column headings and abbreviations.

Task	Task No.	P	D	Responsible Parties	Cost Estimates ($1) FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Increase All Federal and Specific State Populations														
Nesting Habitat, Active Clusters														
Prescribed burning	1.1.1	1	C	AGENCY	50/ha[1]	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Cavity installation and restriction (see Table 17)	1.1.2	1	D	AGENCY	200/ACT[2]	200/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT
Other hardwood control	1.1.3	1	C	AGENCY	0-250/ha[3]	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha
Protect cavity trees	1.1.4	1	C	AGENCY	*Included in prescribed burning costs above*									
Practice IPM	1.1.5	1	C	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Nesting Habitat, Recruitment Clusters														
Strategic locations	1.2.1	1	D	AGENCY	0	0	0	0	0	0	0	0	0	0
Initial habitat restoration	1.2.2	1	D	AGENCY	0-250/ha[3]	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha
Cavity installation (see Table 18)	1.2.3	1	D	AGENCY	800/RC[4]	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC
Maintenance burning	1.2.4	1	D	AGENCY	50/ha[1]	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Appropriate management when occupied (task 1.1)	1.2.5	1	C	AGENCY	*Included in task 1.1*									
Foraging Habitat														
Prescribed burning	1.3.1	1	C	AGENCY	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Other hardwood or pine control	1.3.2	1	C	AGENCY	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha
Develop mature pines	1.3.3	1	C	AGENCY	0	0	0	0	0	0	0	0	0	0
Provide suitable quantity	1.3.4	1	C	AGENCY	0	0	0	0	0	0	0	0	0	0
Practice IPM	1.3.5	1	C	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Table continued next page.

TABLE 16 (cont.). Implementation schedule and estimated costs by recovery task.

Task	Task No.	P	D	Responsible Parties	Cost Estimates ($1) FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Increase All Federal and Specific State Populations (cont.)														
Combat Fragmentation				AGENCY										
Strategically locate recruitment clusters (1.2.1)	1.4.1	1	D	AGENCY	0	0	0	0	0	0	0	0	0	0
Within-pop. translocation	1.4.2	2	D	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Population augmentation, pops. < 30 PBG only	1.4.3	1	D	AGENCY	3000-9000 /new PBG[5]	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG
Avoid fragmentation	1.4.4	1	C	AGENCY	0	0	0	0	0	0	0	0	0	0
Develop Additional Habitat														
Silviculture	1.5.1	1	D	AGENCY	0	0	0	0	0	0	0	0	0	0
Habitat restoration	1.5.2	1	D	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Monitor Populations	1.6	1	C	AGENCY	750/ACT[6]	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT
Burn All Habitat in HMA at least every 1-5 yrs. (1.1.1, 1.2.4, 1.3.1; see Table 19)	1.7	1	C	AGENCY	50/ha[1]	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Maintain and/or increase all other state populations														
Provide incentives	2.1	2	C	STATES &USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Enlist in programs	2.2	2	D	STATES & USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Protect existing clusters, encourage increases	2.3	2	C	STATES & USFWS	*See tasks 1.1 – 1.7*									
Maintain and/or increase populations on private lands														
Provide incentives	3.1	2	C	STATES & USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Enlist in programs	3.2	2	D	STATES & USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Provide awards	3.3	2	D	USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Protect existing clusters, encourage increases	3.4	2	C	STATES & USFWS	*See tasks 1.1 – 1.7*									
Increase public awareness														
Ecology, status, recovery	4.1	2	C	ALL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Importance of fire	4.2	2	C	ALL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Importance of old pines	4.3	2	C	ALL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Table continued next page.

TABLE 16 (cont.). Implementation schedule and estimated cost by recovery task.

Task	Task No.	P	D	Resp. Parties	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
					Cost Estimates ($1*1000)									
Research needs														
Best management to increase populations	5.1	1	TBD	PI	200	200	200	200	200	200	200	200	200	200
Foraging habitat & fitness, in various habitat types	5.2	1	TBD	PI	200	200	200	200	200	200	100	100	100	100
Nesting habitat & fitness	5.3	1	TBD	PI	100	100	100	100	100	100	0	0	0	0
Budding & pioneering	5.4	2	TBD	PI	100	100	100	100	0	0	0	0	0	0
Genetic threats	5.5	2	TBD	PI	50	50	50	50	50	50	0	0	0	0
Cavity kleptoparasitism & predation	5.6	3	TBD	PI	30	30	30	30	0	0	0	0	0	0
Dispersal	5.7	2	TBD	PI	100	100	100	100	100	100	0	0	0	0
Foraging & private lands	5.8	2	TBD	PI	200	200	200	200	0	0	0	0	0	0
Cavity installation methods	5.9	3	TBD	PI	30	30	30	30	30	30	30	30	0	0
Translocation	5.10	2	TBD	PI	50	50	50	50	50	50	0	0	0	0
Bark Beetles	5.11	1	TBD	PI	100	100	100	100	100	100	0	0	0	0
Threats from exotic species	5.12	3	TBD	PI	30	30	30	30	0	0	0	0	0	0

Key to Column Headings and Abbreviations:

Task: Recovery task from stepdown outline, section 9. See section 8 for guidelines.
Task No.: Task number identified in stepdown outline (see 9).
P: Priority assigned to recovery task, including (1) tasks that must be completed to meet delisting criteria; (2) tasks that should be done to help meet recovery objective; and (3) tasks that should be done to enhance management of the species.
D: Duration of recovery task. Two levels are identified here: (C) continuous, up to and after delisting; and (D) until delisting.
Resp. Parties: Agencies and other parties responsible for the completion of recovery task. Abbreviations are as follows:

AGENCY **-** all agencies responsible for properties identified in delisting criteria, i.e. the following:
Florida Department of Military Affairs (FDMA)
Florida Division of Forestry (FDF)
Florida Fish and Wildlife Conservation Commission (FFWCC)
Florida Park Service (FPS)
National Park Service (NPS)
North Carolina Department of Agriculture (NCDA)
North Carolina Department of Environment and Natural Resources (NCDENR)
North Carolina Wildlife Resources Commission (NCWRC)

Key to Column Headings and Abbreviations (cont.):

South Carolina Forestry Commission (SCFC)
South Florida Water Management District (SFWMD)
Saint John's River Water Management District (Florida; SJRWMD)
U.S. Air Force (USAF)
U.S. Army (USARMY)
U.S. Department of Energy (USDOE)
U.S. Forest Service (USFS)
U.S. Fish and Wildlife Service (USFWS)
U.S. Marine Corps (USMC)
U.S. Navy (USNAVY)

PI	Principal investigators
STATES	All state agencies with occupied properties
ALL	All federal and state agencies with occupied properties and principal investigators

Cost Estimates: The figures in this column represent the estimated annual cost of each task. Further information is given in the following notes and in Tables 17, 18, and 19.

[1]Estimate for prescribed burning is a well-known figure in the field.
[2]Estimate for artificial cavity installation includes salary, equipment, overhead, and associated costs.
[3]Estimate for chemical and mechanical control varies within this range, well-known in the field.
[4]Estimate for cavity installation in recruitment clusters is four times the cost per cavity (4 x $200).
[5]Estimate for translocation for population augmentation is based on price per bird ($1500), success rate (varies between 25 and 50%), and movement of one or two birds; it does not include costs of constructing recruitment clusters.
[6]Estimate for monitoring is based on survey of federal properties' annual expenditures.

Abbreviations under Cost Estimates:

ACT	active cluster
FY	fiscal year
PBG	potential breeding group
RC	recruitment cluster
TBD	to be determined

TABLE 17. Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*) by responsible agency, for all federal properties and those state properties identified in recovery criteria. See key to Table 16 for agency abbreviations. Annual estimated cost = $200 x number of active clusters for the first 2 years, then $100 x number of active clusters for the remaining time period[1]. Estimated cost per artificial cavity = $200. Number of active clusters (ACT, 2000) is projected over 10 years with an annual population increase of 5 percent[1] until property goal is met. Properties that reach their goal are considered to require the same level of cavity maintenance over these ten years, with the exception of the Apalachicola Ranger District. Properties will require cavity maintenance until the average age of potential cavity trees is at least 80 and 100 years for loblolly and longleaf pine, respectively.

Responsible		**ACT**	**Property**	**Estimated Annual Cost ($1) for Cavity Maintenance**									
Agency	**Property**	**2000**	**Goal[2]**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
FDF	Blackwater River SF	26	45	5600	5800	3100	3200	3400	3500	3700	3900	4100	4300
	Goethe SF	30	150	6400	6800	3500	3700	3900	4100	4300	4500	4700	4900
	Picayune Strand SF	3	25	800	800	400	400	400	500	500	500	500	500
	Tate's Hell SF	29	400	6200	6400	3400	3600	3800	3900	4100	4300	4500	4800
	Withlacoochee - Citrus Tract	46	100	9800	10200	5400	5600	5900	6200	6500	6800	7200	7500
	Withlacoochee - Croom Tract	5	30	1200	1200	600	700	700	700	800	800	800	900
	subtotal	139	750	30000	31200	16400	17200	18100	18900	19900	20800	21800	22900
FDMA	Camp Blanding Training Site	14	25	3000	3200	1700	1800	1800	1900	2000	2100	2200	2300
	subtotal	14	25	3000	3200	1700	1800	1800	1900	2000	2100	2200	2300
FFWCC	Babcock/Webb WMA	27	240	5800	6000	3200	3300	3500	3700	3800	4000	4200	4400
	J.W. Corbett/Dupuis WMA[3]	13	90	2800	3000	1600	1600	1700	1800	1900	2000	2100	2200
	Three Lakes WMA	51	125	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
	subtotal	91	455	19400	20400	10800	11100	11800	12400	12900	13600	14300	15000
FPS	Ochlockonee River SP	3	3	600	600	300	300	300	300	300	300	300	300
	subtotal	3	3	600	600	300	300	300	300	300	300	300	300
NCDA	McCain Tract	5	7	1200	1200	600	700	700	700	700	700	700	700
	subtotal	5	7	1200	1200	600	700	700	700	700	700	700	700

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
				Estimated Annual Cost ($1) for Cavity Maintenance									
NCDENR	Weymouth Woods State NP	7	13	1600	1600	900	900	900	1000	1000	1100	1100	1200
	subtotal	7	13	1600	1600	900	900	900	1000	1000	1100	1100	1200
NCWRC	Holly Shelter Game Lands	38	38	7600	7600	3800	3800	3800	3800	3800	3800	3800	3800
	Sandhills Game Lands	134	160	28200	29600	15600	16300	17200	18000	18900	19800	20800	21900
	subtotal	172	198	35800	37200	19400	20100	21000	21800	22700	23600	24600	25700
NPS	Big Cypress NP	42	42	8400	8400	4200	4200	4200	4200	4200	4200	4200	4200
	subtotal	42	42	8400	8400	4200	4200	4200	4200	4200	4200	4200	4200
SCFC	Sand Hills SF	51	143	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
	subtotal	51	143	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
SFWMD	Kicco WMA	1	1	200	200	100	100	100	100	100	100	100	100
	St. Sebastian River SBP	8	25	1800	1800	1000	1000	1100	1100	1200	1200	1300	1400
	subtotal	9	26	2000	2000	1100	1100	1200	1200	1300	1300	1400	1500
SJRWMD	Hal Scott Preserve	7	15	1600	1600	900	900	900	1000	1000	1100	1100	1200
	subtotal	7	15	1600	1600	900	900	900	1000	1000	1100	1100	1200
USAF	Avon Park AFR	21	68	4600	4800	2500	2600	2700	2900	3000	3200	3300	3500
	Dare County Bombing Range	3	46	800	800	400	400	400	500	500	500	500	500
	Eglin AFB	301	500	63400	66400	34900	36600	38500	40400	42400	44500	46700	49100
	Poinsett Weapons Range	6	30	1400	1400	700	800	800	900	900	900	1000	1000
	subtotal	331	644	70200	73400	38500	40400	42400	44700	46800	49100	51500	54100

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
				Estimated Annual Cost ($1) for Cavity Maintenance									
USARMY	Camp Mackall	11	11	2200	2200	1100	1100	1100	1100	1100	1100	1100	1100
	Fort Benning	219	450	46000	48400	25400	26700	28000	29400	30900	32400	34000	35700
	Fort Bragg	350	436	73600	77200	40600	42600	43600	43600	43600	43600	43600	43600
	Fort Gordon	5	25	1200	1200	600	700	700	700	800	800	800	900
	Fort Jackson	24	126	5200	5400	2800	3000	3100	3300	3400	3600	3800	4000
	Fort Polk	46	179	9800	10200	5400	5600	5900	6200	6500	6800	7200	7500
	Fort Stewart	212	500	44600	46800	24600	25800	27100	28500	29900	31400	32900	34600
	MOT Sunny Point	9	17	2000	2000	1100	1100	1200	1300	1300	1400	1400	1500
	Peason Ridge	23	120	5000	5200	2700	2800	3000	3100	3300	3400	3600	3800
	subtotal	899	1864	189600	198600	104300	109400	113700	117200	120800	124500	128400	132700
USDOE	Savannah River Site	34	418	7200	7600	4000	4200	4400	4600	4800	5100	5300	5600
	subtotal	34	418	7200	7600	4000	4200	4400	4600	4800	5100	5300	5600
USFS	Angelina NF	29	252	6200	6400	3400	3600	3800	3900	4100	4300	4500	4800
	Apalachicola RD	486	500	0	0	0	0	0	0	0	0	0	0
	Bienville NF	104	500	22000	23000	12100	12700	13300	14000	14700	15400	16200	17000
	Catahoula RD	32	317	6800	7200	3800	3900	4100	4300	4600	4800	5000	5300
	Chickasawhay RD	15	502	3200	3400	1800	1900	2000	2100	2200	2300	2400	2500
	Conecuh NF	18	309	3800	4000	2100	2200	2300	2500	2600	2700	2800	3000
	Croatan NF	62	169	13200	13800	7200	7600	8000	8400	8800	9200	9700	10100
	Davy Crockett NF	53	330	11200	11800	6200	6500	6800	7200	7500	7900	8300	8700
	DeSoto NF	7	368	1600	1600	900	900	900	1000	1000	1100	1100	1200
	Evangeline RD	72	231	15200	16000	8400	8800	9200	9700	10200	10700	11200	11800
	Francis Marion NF	344	453	72400	76000	39900	41900	44000	45300	45300	45300	45300	45300

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	Estimated Annual Cost ($1) for Cavity Maintenance 2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
USFS (cont.)	Homochitto NF	51	254	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
	Kisatchie RD	29	292	6200	6400	3400	3600	3800	3900	4100	4300	4500	4800
	Oakmulgee RD	110	394	23200	24400	12800	13400	14100	14800	15500	16300	17100	18000
	Ocala NF	22	179	4800	5000	2600	2700	2900	3000	3100	3300	3500	3600
	Oconee NF	20	176	4200	4600	2400	2500	2600	2700	2900	3000	3200	3300
	Osceola NF	63	462	13400	14000	7300	7700	8100	8500	8900	9400	9800	10300
	Ouachita NF	21	400	4600	4800	2500	2600	2700	2900	3000	3200	3300	3500
	Sabine NF	28	262	6000	6200	3300	3500	3600	3800	4000	4200	4400	4600
	Sam Houston NF	168	541	35400	37200	19500	20500	21500	22600	23700	24900	26100	27400
	Shoal Creek RD	6	125	1400	1400	700	800	800	900	900	900	1000	1000
	Talladega RD	0	110	200	400	300	400	500	600	600	600	700	700
	Vernon Unit	152	302	32000	33600	17600	18500	19400	20400	21400	22500	23600	24800
	Wakulla RD	138	506	29000	30600	16000	16800	17700	18500	19500	20400	21500	22500
	Winn RD	18	263	3800	4000	2100	2200	2300	2500	2600	2700	2800	3000
	subtotal	2048	8197	330600	347200	182300	191400	201000	210400	218400	227000	236000	245600
USFWS	Alligator River NWR	3	20	800	800	400	400	400	500	500	500	500	500
	Big Branch Marsh NWR	15	20	3200	3400	1800	1900	2000	2000	2000	2000	2000	2000
	Black Bayou NWR	1	1	200	200	100	100	100	100	100	100	100	100
	Carolina Sandhills NWR	116	193	24400	25600	13500	14100	14900	15600	16400	17200	18000	18900
	D'Arbonne NWR	2	5	600	600	300	300	300	300	300	300	400	400
	Felsenthal NWR	15	34	3200	3400	1800	1900	2000	2100	2200	2300	2400	2500
	Noxubee NWR	44	88	9400	9800	5100	5400	5700	5900	6200	6600	6900	7200
	Okefenokee NWR	37	86	7800	8200	4300	4500	4800	5000	5300	5500	5800	6100
	Pee Dee NWR	1	10	400	400	200	200	200	200	200	200	200	200

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	**Property**	**ACT Property 2000**	**Goal[2]**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
				Estimated Annual Cost ($1) for Cavity Maintenance									
USFWS	Piedmont NWR	39	96	8200	8600	4600	4800	5000	5300	5500	5800	6100	6400
(cont.)	Pocosin Lakes NWR	1	50	400	400	200	200	200	200	200	200	200	200
	St. Marks NWR	9	71	2000	2000	1100	1100	1200	1300	1300	1400	1400	1500
	Upper Ouachita NWR	1	1	200	200	100	100	100	100	100	100	100	100
	subtotal	284	675	60800	63600	33500	35000	36900	38600	40300	42200	44100	46100
USMC	MCB Camp Lejeune	59	173	12400	13200	6900	7200	7600	8000	8400	8800	9200	9700
	subtotal	59	173	12400	13200	6900	7200	7600	8000	8400	8800	9200	9700
USNAVY	Charleston Naval Weapons Station	1	12	400	400	200	200	200	200	200	200	200	200
	subtotal	1	12	400	400	200	200	200	200	200	200	200	200
	TOTAL	**4196**	**13660**	**785600**	**822800**	**432000**	**452300**	**473700**	**494000**	**512900**	**533300**	**554400**	**577400**

[1]Methods of rounding can substantially affect estimates of future population sizes and costs. Here, number of active clusters was not rounded in projections of future population size but future population size was then rounded up for cost estimates. For example, estimated population size in 2001 for Charleston Naval Weapons Station was 1.05 in 2001, rounded up to 2, and the cost estimate was thus $400 for that year. Cost estimate for Upper Ouachita NWR, as a second example, remained at $100/year throughout 2003-2010 because the property has reached its goal of 1 active cluster.

[2]Some property goals are non-binding estimates; see notes for Tables 6 and 9 for further information.

[3]Dupuis WMA is managed by SFWMD.

TABLE 18. Estimated annual cost for implementation of recovery task 1.2.3 (*provision recruitment clusters equal to 10 percent of population, 4 artificial cavities each*), for all federal properties and those state properties identified in recovery criteria. See key (Table 16) for agency abbreviations. Annual estimated cost = $800 x (0.1 x number of active clusters). Number of recruitment clusters to be provisioned annually is adjusted at 5-year intervals, based on a population size increasing at 5 percent annually[1]. Populations at or above property goal[2] require no more recruitment clusters. This estimate does not include habitat restoration (see Tables 16 and 19).

Responsible Agency	Property	ACT 2000	Property Goal[2]	Recruitment Clusters/Yr 2001-2006	Cost/Yr ($1) 2001-2006	Recruitment Clusters/Yr 2006-2010	Cost/Yr ($1) 2006-2010
FDF	Blackwater River SF	26	45	3	2400	4	3200
	Goethe SF	30	150	3	2400	5	4000
	Picayune Strand SF	3	25	1	800	1	800
	Tate's Hell SF	29	400	3	2400	4	3200
	Withlacoochee - Citrus Tract	46	100	5	4000	7	5600
	Withlacoochee - Croom Tract	5	30	1	800	1	800
	subtotal	139	750	16	12800	22	17600
FDMA	Camp Blanding Training Site	14	25	2	1600	2	1600
	subtotal	14	25	2	1600	2	1600
FFWCC	Babcock/Webb WMA	27	240	3	2400	4	3200
	J. W. Corbett/Dupuis WMA[3]	13	90	2	1600	2	1600
	Three Lakes WMA	51	125	6	4800	7	5600
	subtotal	91	455	11	8800	13	10400
FPS	Ochlockonee River SP	1	3	0	0	0	0
	subtotal	1	3	0	0	0	0
NCDA	McCain Tract	5	7	1	800	1	800
	subtotal	5	7	1	800	1	800
NCDENR	Weymouth Woods State NP	7	13	1	800	1	800
	subtotal	7	13	1	800	1	800
NCWRC	Holly Shelter Game Lands	38	38	0	0	0	0
	Sandhills Game Lands	134	160	14	11200	0	0
	subtotal	172	198	14	11200	0	0
NPS	Big Cypress NP	42	42	0	0	0	0
	subtotal	42	42	0	0	0	0
SCFC	Sand Hills SF	51	143	6	4800	7	5600
	subtotal	51	143	6	4800	7	5600

Table continued next page.

TABLE 18 (cont.). Estimated annual cost for implementation of recovery task 1.2.3 (*provision recruitment clusters equal to 10 percent of population, 4 artificial cavities each*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	Recruitment Clusters/Yr 2001-2006	Cost/Yr ($1) 2001-2006	Recruitment Clusters/Yr 2006-2010	Cost/Yr ($1) 2006-2010
SFWMD	Kicco WMA	1	1	0	0	0	0
	St. Sebastian River SBP	8	25	1	800	2	1600
	subtotal	9	26	1	800	2	1600
SJRWMD	Hal Scott Preserve	7	15	1	800	1	800
	subtotal	7	15	1	800	1	800
USAF	Avon Park AFR	21	68	3	2400	3	2400
	Dare County Bombing Range	3	46	1	800	1	800
	Eglin AFB	301	500	31	24800	41	32800
	Poinsett Weapons Range	6	30	1	800	1	800
	subtotal	331	644	36	28800	46	36800
USARMY	Camp Mackall	11	11	0	0	0	0
	Fort Benning	219	450	22	17600	30	24000
	Fort Bragg	350	436	35	28000	0	0
	Fort Gordon	5	25	1	800	1	800
	Fort Jackson	24	126	3	2400	4	3200
	Fort Polk	46	179	5	4000	7	5600
	Fort Stewart	212	500	22	17600	29	23200
	MOT Sunny Point	9	17	1	800	2	1600
	Peason Ridge	23	120	3	2400	4	3200
	subtotal	899	1864	92	73600	77	61600
USDOE	Savannah River Site	34	418	4	3200	5	4000
	subtotal	34	418	4	3200	5	4000
USFS	Angelina NF	29	252	3	2400	4	3200
	Apalachicola RD	486	500	49	39200	0	0
	Bienville NF	104	500	11	8800	14	11200
	Catahoula RD	32	317	4	3200	5	4000
	Chickasawhay RD	15	502	2	1600	3	2400
	Conecuh NF	18	309	2	1600	3	2400
	Croatan NF	62	169	7	5600	9	7200
	Davy Crockett NF	53	330	6	4800	8	6400
	DeSoto NF	7	368	1	800	1	800
	Evangeline RD	72	231	8	6400	10	8000
	Francis Marion NF	344	453	35	28000	0	0
	Homochitto NF	51	254	6	4800	7	5600

Table continued next page.

TABLE 18 (cont.). Estimated annual cost for implementation of recovery task 1.2.3 (*provision recruitment clusters equal to 10 percent of population, 4 artificial cavities each*).

Responsible Agency	**Property**	**ACT 2000**	**Property Goal**[2]	**Recruitment Clusters/Yr 2001-2006**	**Cost/Yr ($1) 2001-2006**	**Recruitment Clusters/Yr 2006-2010**	**Cost/Yr ($1) 2006-2010**
USFS (cont.)	Kisatchie RD	29	292	3	2400	4	3200
	Oakmulgee RD	110	394	11	8800	15	12000
	Ocala NF	22	179	3	2400	3	2400
	Oconee NF	20	176	2	1600	3	2400
	Osceola NF	63	462	7	5600	9	7200
	Ouachita NF	21	400	3	2400	3	2400
	Sabine NF	28	262	3	2400	4	3200
	Sam Houston NF	168	541	17	13600	23	18400
	Shoal Creek RD	6	125	1	800	1	800
	Talladega RD	0	110	8	6400	8	6400
	Vernon Unit	152	302	16	12800	21	16800
	Wakulla RD	138	506	14	11200	19	15200
	Winn RD	18	263	2	1600	3	2400
	subtotal	2048	8197	224	179200	180	144000
USFWS	Alligator River NWR	3	20	1	800	1	800
	Big Branch Marsh NWR	15	20	2	1600	0	0
	Black Bayou NWR	1	1	0	0	0	0
	Carolina Sandhills NWR	116	193	12	9600	16	12800
	D'Arbonne NWR	2	5	1	800	1	800
	Felsenthal NWR	15	34	2	1600	3	2400
	Noxubee NWR	44	88	5	4000	6	4800
	Okefenokee NWR	37	86	4	3200	5	4000
	Pee Dee NWR	1	10	1	800	1	800
	Piedmont NWR	39	96	4	3200	6	4800
	Pocosin Lakes NWR	1	50	1	800	1	800
	St. Marks NWR	9	71	1	800	2	1600
	Upper Ouachita NWR	1	1	0	0	0	0
	subtotal	284	675	34	27200	42	33600
USMC	MCB Camp Lejeune	59	173	6	4800	8	6400
	subtotal	59	173	6	4800	8	6400
USNAVY	Charleston Naval Weapons Station	1	12	1	800	1	800
	subtotal	1	12	1	800	1	800
	TOTAL	**4194**	**13660**	**448**	**358400**	**405**	**324000**

[1]Population size was not rounded for size projections but was rounded up to calculate recruitment clusters.

[2]Some property goals are non-binding estimates; see notes for Table 6 for further information.

[3]Dupuis WMA is managed by SFWMD.

TABLE 19. Estimated annual cost for implementation of recovery task 1.7 (*burn entire area managed for red-cockaded woodpeckers at least once every 1 to 5 years*), for all federal properties and those state properties identified in recovery criteria. See key (Table 16) for agency abbreviations. Annual estimated cost = $49.4 x (1/3 total ha), or $20 x (1/3 total ac), assuming all habitat is burned once every 3 years. Estimated available habitat is based on property goal; see notes in Table 6 for further information on property goals.

Responsible Agency	**Property**		**Estimated Available Habitat [ha (ac)]**		**Estimated Annual Cost ($1)**
FDF	Blackwater River SF		3640	(9000)	60000
	Goethe SF		12140	(30000)	200000
	Picayune Strand SF		2020	(5000)	3330
	Tate's Hell SF		32380	(80000)	533330
	Withlacoochee - Citrus Tract		8090	(20000)	133330
	Withlacoochee - Croom Tract		2430	(6000)	40000
		subtotal	60700	(150000)	999990
FDMA	Camp Blanding Training Site		2020	(5000)	33330
		subtotal	2020	(5000)	33330
FFWCC	Babcock/Webb WMA		19420	(48000)	320000
	J. W. Corbett/Dupuis WMA[1]		7280	(18000)	120000
	Three Lakes WMA		10120	(25000)	166670
		subtotal	36820	(91000)	606670
FPS	Ochlockonee River SP		240	(600)	4000
		subtotal	240	(600)	4000
NCDA	McCain Tract		570	(1400)	9330
		subtotal	570	(1400)	9330
NCDENR	Weymouth Woods State NP		1050	(2600)	17330
		subtotal	1050	(2600)	17330
NCWRC	Holly Shelter Game Lands		3080	(7600)	50670
	Sandhills Game Lands		12950	(32000)	213330
		subtotal	16030	(39600)	264000
NPS	Big Cypress NP		3400	(8400)	56000
		subtotal	3400	(8400)	56000
SCFC	Sand Hills SF		11570	(28600)	190670
		subtotal	11570	(28600)	190670

Table continued next page.

TABLE 19 (cont.). Estimated annual cost for implementation of recovery task 1.7 (burn entire area managed for red-cockaded woodpeckers at least once every 1 to 5 years).

Responsible Agency	Property		Estimated Available Habitat [ha	(ac)]	Estimated Annual Cost ($1)
SFWMD	Kicco WMA		80	(200)	13330
	St. Sebastian River SBP		2020	(5000)	33330
		subtotal	2100	(5200)	46660
SJRWMD	Hal Scott Preserve		1210	(3000)	20000
		subtotal	1210	(3000)	20000
USAF	Avon Park AFR		5500	(13600)	90670
	Dare County Bombing Range		3720	(9200)	61330
	Eglin AFB		40470	(100000)	666670
	Poinsett Weapons Range		2430	(6000)	40000
		subtotal	52120	(128800)	858670
USARMY	Camp Mackall		890	(2200)	14670
	Fort Gordon		2020	(5000)	33330
	Fort Bragg		35290	(87200)	581330
	Fort Jackson		10200	(25200)	168000
	Fort Stewart		40470	(100000)	666670
	Fort Benning		36420	(90000)	600000
	Fort Polk		14490	(35800)	238670
	MOT Sunny Point		1380	(3400)	22670
	Peason Ridge		9710	(24000)	160000
		subtotal	150870	(372800)	2485330
USDOE	Savannah River Site		33830	(83600)	557330
		subtotal	33830	(83600)	557330
USFS	Angelina NF		20400	(50400)	336000
	Apalachicola RD		40470	(100000)	666670
	Bienville NF		40470	(100000)	666670
	Catahoula RD		25660	(63400)	422670
	Chickasawhay RD		40630	(100400)	669330
	Conecuh NF		25010	(61800)	412000
	Croatan NF		13680	(33800)	225330
	Davy Crockett NF		26710	(66000)	440000
	DeSoto NF		29790	(73600)	490670
	Evangeline RD		18700	(46200)	308000
	Francis Marion NF		36670	(90600)	604000
	Homochitto NF		20560	(50800)	338670
	Kisatchie RD		23630	(58400)	389330

Table continued next page.

TABLE 19 (cont.). Estimated annual cost for implementation of recovery task 1.7 (*burn entire area managed for red-cockaded woodpeckers at least once every 1 to 5 years*).

Responsible Agency	**Property**		**Estimated Available Habitat [ha (ac)]**		**Estimated Annual Cost ($1)**
USFS (cont.)	Oakmulgee RD		31890	(78800)	525330
	Ocala NF		14490	(35800)	238670
	Oconee NF		14250	(35200)	234670
	Osceola NF		37390	(92400)	616000
	Ouachita NF		32380	(80000)	533330
	Sabine NF		21210	(52400)	349330
	Sam Houston NF		43790	(108200)	721330
	Shoal Creek RD		10120	(25000)	166670
	Talladega RD		8900	(22000)	146670
	Vernon Unit		24440	(60400)	402670
	Wakulla RD		40960	(101200)	674670
	Winn RD		21290	(52600)	350670
		subtotal	645200	(1594200)	10628010
USFWS	Alligator River NWR		1620	(4000)	26670
	Big Branch Marsh NWR		1620	(4000)	26670
	Black Bayou NWR		80	(200)	1330
	Carolina Sandhills NWR		15620	(38600)	257330
	D'Arbonne NWR		400	(1000)	6670
	Felsenthal NWR		2750	(6800)	45330
	Noxubee NWR		7120	(17600)	117330
	Okefenokee NWR		6960	(17200)	114670
	Pee Dee NWR		810	(2000)	13330
	Piedmont NWR		7770	(19200)	128000
	Pocosin Lakes NWR		4050	(10000)	66670
	St. Marks NWR		5750	(14200)	94670
	Upper Ouachita NWR		80	(200)	1330
		subtotal	54630	(135000)	900000
USMC	MCB Camp Lejeune		14000	(34600)	230670
		subtotal	14000	(34600)	230670
USNAVY	Charleston Naval Weapons Station		970	(2400)	16000
		subtotal	970	(2400)	16000
		TOTAL	**1005860**	**(2500000)**	**16569330**

[1] Dupuis WMA is managed by SFWMD.

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GLOSSARY OF TERMS

Active cavity	A completed cavity or start exhibiting fresh pine resin associated with cavity maintenance, cavity construction, or resin well excavation by red-cockaded woodpeckers.
Active cavity tree	Any tree containing one or more active cavities.
Active cluster	A cluster containing one or more active cavity trees.
Adaptive management	The process of implementing flexible management and policy that is responsive to results of continuous biological monitoring and scientific experimentation.
Allozyme	An enzyme that has different forms, resulting from different alleles at the locus encoding the enzyme.
Augmentation	Increasing the size of a population by translocating individuals between populations.
Basal area	The area of a horizontal cross section of a tree's stem, generally measured at breast height.
Breeding dispersal	Movement of individuals between consecutive breeding locations.
Budding	One of two processes of new group formation in red-cockaded woodpeckers (see also pioneering), referring to the splitting of one territory into two.
Canopy	The uppermost layer of foliage in a forest or forest stand.
Captured cluster	A cluster that does not support its own group of red-cockaded woodpeckers, but contains active cavity trees in use or kept active by birds from a neighboring cluster.
Catastrophe	A random environmental event of great consequence.
Clayhills	Pine communities on clay soils, especially in northwestern Florida, eastern Alabama, and southwestern Georgia.
Clearcut	An area in which all trees have been removed in one cutting.
Cluster	The aggregation of cavity trees previously and currently used and defended by a group of woodpeckers, or this same aggregation of cavity trees *and* a 61 m (200 ft) wide buffer of continuous forest. Here, the second definition is used. For management purposes, the minimum area encompassing the cluster is 4 ha (10 ac). Use of the term cluster is preferred over colony because colony implies more than one nest (as in colonial breeder).
Cluster, active	See active cluster.
Cluster, captured	See captured cluster.

Coadapted gene complexes	Genes, having evolved together, that as a unit confer higher fitness than the sum of the individual genes' contributions. A coadapted gene's fitness effect depends on the genetic environment (the presence of other genes).
Coastal plain	In the United States, an ecoregion or physiographic province located near the Atlantic Ocean or Gulf of Mexico.
Cooperative breeding	A breeding system in which one or more adults assist a breeding pair in rearing of young. These extra adults, called helpers, delay their own dispersal and reproduction and are generally related to the offspring of the breeding pair.
Critical rate of decline	Critical rate of population decline identified in this recovery plan is 10% decrease in number of active cluster clusters from one year to the next, or within 5 years.
Decreasing population trend	See critical rate of decline.
Demographic stochasticity	Randomly occurring events affecting individuals.
Demography	Vital rates, including birth, death, and dispersal rates, and the analysis of population size and trend.
Dispersal	Movement of individuals from natal to first breeding location (natal dispersal), or between consecutive breeding locations (breeding dispersal).
Ecoregion	A system of classification based on physiography.
Effective population size	The size of the ideal, hypothetical population in which all individuals mate randomly and all contribute equally to reproduction. Variation in reproductive success and other processes in a real population affect how many genes are conserved in subsequent generations. The concept of effective population size is used to control for the effects of such processes when discussing genetic conservation.
Environmental stochasticity	Random changes in environmental conditions and their effects on populations.
Even-aged management	A silvicultural method designed primarily for timber production, in which all trees in a stand are of one age/size class. The forest is regulated by developing equal areas in each age/size class.
Extirpation	Loss of a population or all populations within a specified region.
Flatwoods	Mesic pine communities on the Gulf and Atlantic coastal plains with a well-developed woody shrub or midstory layer.
Floater	An adult bird not associated with a breeding group.
Forb	A herbaceous plant that has broad leaves, not a grass.
Fragmentation	Habitat loss that results in isolated patches of remaining habitat.
Gene flow	The movement of genetic material among populations or within a population.

Genetic drift	Random sampling of genetic resources within a population from one generation to the next. In populations of finite size, this sampling will always result in loss of variation. In populations of large size, such loss may be offset by new variation arising through mutation.
Genetic stochasticity	Random changes in gene frequencies.
Group	The social unit in red-cockaded woodpeckers, consisting of a breeding pair with one or more helpers, a breeding pair without helpers, or a solitary male.
Habitat selection	Use of a resource above what is expected based on the availability of that resource.
Heartwood	The inner, inactive core of a tree.
Helper	An adult that delays its own reproduction to assist in the rearing of another breeding pair's young. Typically, helpers are related to the breeding pairs that they assist.
Herbs	Grasses and forbs.
Herbaceous	Non-woody.
Heterozygosity	Genetic diversity within an individual or population, as measured by the proportion of loci containing two different alleles.
Home range	The area supporting the daily activities of an animal, generally throughout the year.
Homozygosity	Genetic similarity within an individual or population, as measured by the proportion of loci containing two identical alleles.
Immigration	Movement of one or more individuals into a population.
Inbreeding	Mating between relatives.
Inbreeding depression	Loss of fitness due to the increase in homozygosity that results from inbreeding.
Increasing population trend, recommended rate of	Five percent increase in active clusters from one year to the next.
Kleptoparasitism	Theft by one species of resources procured by another species, resulting in positive effects for the parasite and negative effects for the species being parasitized. Generally this term is applied to theft of food, but has recently been expanded to include theft of spatial resources.
Local adaptation	Traits conferring higher fitness in a local environment.
Metapopulation	A set of interacting populations.
Midstory	A layer of foliage intermediate in height between canopy and groundcover, litter layer, or soil surface.

Mitigation	Reduction of negative impacts.
Mutation	A heritable change in a DNA molecule.
Natal dispersal	Movement of individuals from their place of birth to their first breeding location.
Pioneering	One of two processes of new group formation in red-cockaded woodpeckers (see also budding), by which a group colonizes previously unoccupied areas. Because of the difficulty of cavity excavation, this process occurs at very low frequencies.
Plate	On a cavity tree, the area surrounding the cavity entrance with bark removed by red-cockaded woodpeckers. Newly formed cavities may not exhibit a well-developed plate.
Pocosin	A wetland dominated by a dense cover of evergreen and deciduous shrubs.
Population	A group of individuals of the same species occupying a given area. Methods of specifying such an area may differ according to purpose. A common specification is the area within which gene flow is sufficient to avoid genetic differentiation.
Population augmentation	Translocation between populations to increase population size.
Population dynamics	Properties of a population such as trend and regulation of population size.
Population trend	See increasing population trend, decreasing population trend, and stable population trend.
Potential breeding group	An adult female and adult male that occupy the same cluster, whether or not they are accompanied by a helper, attempt to nest, or successfully fledge young.
Predation	The acquisition of food by killing and eating another organism.
Prescribed burning	Fire applied to the landscape to meet specific management objectives.
Primary cavity nester	Species that nest in cavities they created.
Primary core population	A population identified in recovery criteria that will hold at least 350 potential breeding groups at the time of and after delisting. Defined by biological boundaries.
RAPD	Randomly amplified polymorphic DNA; used as a genetic marker.
Recovery	Species viability.
Recovery population	One of a set of populations designated necessary to the recovery of the species.
Recovery unit	One of a set of geographical areas, delineated according to ecoregions, that likely represent broad-scale geographic and genetic

	variation in red-cockaded woodpeckers. Viable populations in each recovery unit, to the fullest extent that available habitat allows, are considered essential to the recovery of the species.
Recruitment	The addition of individuals into a breeding population through reproduction and/or immigration and attainment of a breeding position.
Recruitment cluster	A cluster of artificial cavities in suitable nesting habitat, located close to existing groups.
Regeneration	A silvicultural method of simultaneously harvesting, and establishing reproduction in, a stand of trees.
Regulation	A process of implementing silvicultural techniques to establish equal areas of tree size classes, to sustain a given level of timber production over time.
Reintroduction	Translocation of individuals from a captive or wild population to previously occupied but currently unoccupied habitat.
Resinosis	A process through which injured sapwood in a pine tree becomes saturated with hardened resin, reducing and eventually preventing loss of resin.
Resin well	A wound in a pine tree's cambium, created and maintained by red-cockaded woodpeckers, for the purpose of resin production.
Restrictors	Metal plates used to prevent or repair enlargement of cavity entrances.
Rotation	In even-aged management of forests, the number of years between regeneration events.
Sandhills	Xeric and sub-xeric longleaf pine communities on deep sandy soils. Also, the ecoregion encompassing the fall-line sandhills communities, between the mid- and south-Atlantic coastal plains and Piedmont.
Sapwood	The outer, active layer of tissue in a tree, lying just inside the cambium.
Savannah	A mesic and seasonally wet pine community, often transitional between xeric pine systems and wetlands, characterized by diverse grass and forb groundcovers.
Secondary cavity nester	Species that inhabit cavities they did not create.
Secondary core population	A population identified in recovery criteria that will hold at least 250 potential breeding groups at the time of and after delisting. Defined by biological boundaries.
Seed-tree	A method of timber regeneration in which most trees in a site are cut, and tree seedlings become established under remnant large trees. Remnant large trees are retained at lower densities than under the shelterwood method.

Selection cutting	A method of timber regeneration in which single trees or patches of trees (0.8 ha or less, 2 ac or less) are cut.
Shelterwood	A method of timber regeneration in which many but not all trees in a site are cut, and tree seedlings become established under remnant large trees. Remnant large trees are retained at higher densities than under the seed-tree method.
Silviculture	The theory and practice of controlling the establishment, composition, structure, and growth of forests to achieve management objectives. Silviculture was developed primarily for the purpose of timber production, but can be used for other purposes including biological conservation.
Snag	A standing, dead tree.
SNEDs	Snake excluder devices.
Solitary male	An unpaired male that is the sole resident of a cluster.
SQEDs	Squirrel excluder devices.
Stable population	A population that exhibits neither an increasing or decreasing population trend.
Stand	A silvicultural term for an area of trees that is or has been treated as a single management unit.
Start	An incomplete cavity.
Strategic recruitment	Placement of recruitment clusters in locations strategically chosen to enhance the spatial arrangement of breeding groups. Breeding groups aggregated in space rather than isolated are beneficial to population dynamics and viability.
Stochasticity	Random events.
Support population	All known populations not designated a primary or secondary core are designated support populations. Support populations (other than essential supports) are defined by ownership rather than biological boundaries. There are three classifications for support populations: 1. Essential support populations are those populations, identified in recovery criteria, that represent unique or important habitat types that cannot support a larger, core population. They are located on federal and state lands and two private properties. 2. Significant support populations are populations, not identified in recovery criteria, that contain and/or have a population goal of 10 or more active clusters. They are located on federal and state lands and on private lands enrolled in agreements with the U.S. Fish and Wildlife Service. 3. Important support populations are populations, not identified in recovery criteria, that contain and have a population goal of less than 10 active clusters. They are located on federal and state lands and on

	private lands enrolled in agreements with the U.S. Fish and Wildlife Service.
Take	As defined by the Endangered Species Act, take means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (Section 3.18 of the Act). Habitat destruction and alteration are considered forms of take, following a Supreme Court ruling on this issue (Sweet Home vs. Babbitt).
Taxonomy	Hierarchical classification system for all life forms.
Territory	A region within an animal's home range that is defended from conspecifics.
Thinning	A silvicultural treatment removing some trees in a stand to reduce tree density.
Translocation	The artificial movement of wild organisms between or within populations to achieve management objectives. Originally, translocation referred to the movement of animals from captive to wild populations, but the term has been expanded to include movements (by artificial means) within and between wild populations.
Two-aged management	A silvicultural method designed primarily for timber production, in which trees of two age/size classes are present in the same stand. The forest is regulated by developing equal areas in each age/size class.
Uneven-aged management	A silvicultural method designed primarily for timber production, in which trees of at least three age classes are present in the same stand. Stands are regulated by size class structure or volume.
Viability	The ability of a population or species to persist over time.

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APPENDIX 1. PERMITS, TRAINING, AND COMPLIANCE REQUIREMENTS

The objectives of the permitting and compliance program are to: (1) identify, standardize, and, as needed, modify training/certification procedures to ensure the safety of and minimize death and injury to red-cockaded woodpeckers; (2) standardize permit reporting requirements; (3) ensure compliance with all permit requirements, including reporting; (4) ensure that a coordinated specimen disposal program exists, and (5) facilitate distribution of research findings resulting from permit activities. The permit process is an important component of adaptive management. Permitted activities may be modified or eliminated based on research findings and/or an evaluation of their biological costs versus conservation benefits. The primary objective of establishing certification procedures, including "hands-on" protocols, is to minimize the potential for injury or death. Ultimately, it is our responsibility as individuals and as federal and state agency regulators to ensure that biological and ethical protocols are established and followed when conducting activities that have the potential to harm or harass red-cockaded woodpeckers.

The following activities associated with the monitoring and management of red-cockaded woodpeckers require an exemption from the prohibitions of Section 9 of the Endangered Species Act. This exemption is usually authorized via a Section 10(a)(1)(A) permit. The U.S. Fish and Wildlife Service considers that these activities have the potential to harass or result in death or injury to an individual red-cockaded woodpecker or to raise concern about possession of endangered wildlife contrary to laws and regulations.

1. installation and/or modification of artificial nesting cavities.
2. installation of cavity restrictors.
3. manipulation (removal or modification) of red-cockaded woodpecker cavities or cavity trees, including installation of SNEDs, SQEDs, cameras, etc.
4. capturing and handling (for any purpose, including banding or color marking) nestling and adult birds.
5. placing radiotelemetry devices on red-cockaded woodpeckers.
6. visual examination of active cavities with a mirror and droplight or a video probe (“peeper”).
7. salvage of addled eggs, and/or determining viability of eggs.
8. collection and retention of red-cockaded woodpecker specimens or their body parts (including eggs, blood or feathers) for scientific and other purposes consistent with the species' conservation strategy.
9. interstate commerce of dead or living birds or their body parts, including sale or bartering for financial gain.
10. translocation and/or temporary confinement of adults, fledglings, chicks, or eggs.
11. any other activity or practice that may be construed to harm or harass red-cockaded woodpeckers during any life stage.

In addition, the following activities involving red-cockaded woodpeckers are likely to require a Section 10(a)(1)(A) permit unless you are an employee or agent of the

U.S. Fish and Wildlife Service, any other federal land management agency, or a state conservation agency who is designated by his agency for the following purposes:

1. aid to a sick, injured, or orphaned specimen.
2. disposal of a dead specimen.
3. salvage of a dead specimen which may be useful for scientific study.

(Federal or state employees and agents must notify the U.S. Fish and Wildlife Service, Division of Law Enforcement within 5 days of undertaking these activities and must receive concurrence from the U.S. Fish and Wildlife Service on the disposition of these specimens.)

Those individuals placing aluminum bands and/or auxiliary markers (including colored leg bands) on red-cockaded woodpeckers, require a permit (in addition to a U.S. Fish and Wildlife Service Section 10(a)(1)(A) permit) for each of those activities from the U.S. Geological Survey, Biological Resources Division's National Bird Banding Lab, Route 197, Laurel, Maryland 20708; telephone: (301) 498-0428. Most, if not all, states harboring red-cockaded woodpeckers also require permits for some of the activities listed above, including translocating birds from and to their state. Contact state wildlife agencies for endangered/threatened species permit requirements. Each permit has a specific purpose and provides important information to the agency legally responsible for issuing the permit.

Reporting Requirements

Every Section 10(a)(1)(A) permit requires an annual report to the U.S. Fish and Wildlife Service. The Annual Report fulfills this requirement, and must be completed and submitted to the Recovery Coordinator (original) and the U.S. Fish and Wildlife Service’s Regional Office (copy) annually by January 31st. Agencies or individuals not submitting completed reports will not have their permits re-authorized. This reporting system ensures that this critical recovery program is evaluated annually for its conservation value, and is modified as needed in response to new information.

Training

Prior to issuing any Section 10(a)(1)(A) permit, the U.S. Fish and Wildlife Service must meet several criteria, including the determination of the applicant’s ability to successfully accomplish the authorized activities. Because of the potential for direct injury or death to red-cockaded woodpeckers from the above activities, all individuals involved in any of these activities must be trained and certified for each activity prior to receiving a permit or sub-permit under someone else's permit. Potential applicants must be trained by an individual who has the proper permits for and extensive experience in the activity in question. Several federal and state biologists, consultants, and researchers are considered "trainers" or "certifiers" by the U.S. Fish and Wildlife Service for one or more of the above activities. Upon satisfactory completion of training (as determined by the trainer and the Service), the trainer certifies in writing to the Service that the individual is competent and qualified to perform the activity or activities in question. Contact the Red-cockaded Woodpecker Recovery Coordinator to arrange training with certified trainers.

Training for Installation of Artificial Cavities and Restrictors

Training prior to installation of artificial cavities and restrictors is considered adequate if the following criteria are met:

a. A period of apprenticeship is completed under the direction of a person that has held appropriate permits for at least three years and has been involved in the activities in question throughout that time.

b. The apprentice has installed at least 10 restrictors, 10 drilled cavities, 10 starts, and 10 inserts under direct supervision of the permit holder.

c. The apprentice has learned the maintenance and inspection procedures for cavities and restrictors.

d. The permit holder has certified in writing to the U.S. Fish and Wildlife Service Regional Permits Coordinator and the Red-cockaded Woodpecker Recovery Coordinator that the apprentice completed the required training. If the permit holder determines that additional training of the apprentice is necessary or that the apprentice should not be issued a permit, he or she should certify such in writing to the apprentice and the coordinators listed above.

Training for Monitoring, Capture, Banding, Etc.

Safe and accurate monitoring of red-cockaded woodpeckers requires skill, normally acquired through years of experience with red-cockaded woodpeckers and their habitat. Apprenticeship training by a recognized expert in the biology of red-cockaded woodpeckers can accelerate the acquisition of appropriate monitoring skills. The Red-cockaded Woodpecker Recovery Coordinator maintains a list of recognized experts who are willing to serve as trainers. Persons seeking the endangered species and bird banding permits necessary for red-cockaded woodpecker monitoring will document their *need* in writing to the Red-cockaded Woodpecker Recovery Coordinator and the Regional Permits Coordinator. If both Coordinators concur that the monitoring need is legitimate and that the permit applicant is the appropriate entity to conduct the monitoring, the applicant will be referred to the list of qualified trainers. In reaching the referral decision the Recovery Coordinator or Permits Coordinator may conduct background inquiries as they deem necessary.

The applicant will select a red-cockaded woodpecker trainer from the provided list, contact that person, and arrange for training to occur. The cost of training will be borne by the applicant. The red-cockaded woodpecker expert will personally supervise the training of the applicant. The training period will be at the discretion of the trainer, but will not be less than:

a. 50 cavities correctly assessed for stage and activity,

b. 15 cavity trees climbed and cavity contents checked,

c. 10 adult red-cockaded woodpeckers captured and banded (with appropriate data taken) without injury to the birds,

d. 20 nestlings captured, aged and banded (with appropriate data taken) without injury to the birds,

e. 20 free ranging red-cockaded woodpeckers correctly identified by color-bands,

f. 10 sub-adults translocated without injury or mortality (including all associated activities such as feeding during transport, etc.), and

g. 10 red-cockaded woodpeckers treated for any other handling technique (such as bleeding, etc.).

Once at least the minimum amount of training, as described above or as otherwise dictated by the Recovery Coordinator, is accomplished to the satisfaction of the trainer, he or she will certify such in writing to the Recovery Coordinator and the Regional Permits Coordinator. The trainer will only conduct training and certification in areas of expertise in which he or she is certified. The trainer is under no obligation to certify anyone if in his or her opinion the applicant has not completed training adequately. If such is the case, the trainer will document the deficiencies in writing to the applicant, the Recovery Coordinator and the Regional Permits Coordinator, and recommend either more training or permit denial. Certification may be issued for some techniques and withheld for others. A person receiving certification cannot in turn train and certify other individuals until he or she has at least 3 years of experience in the certified techniques, has all required permits in good order and has been placed on the Recovery Coordinator's list of red-cockaded woodpecker trainers.

APPENDIX 2. PROTOCOL FOR MONITORING REPRODUCTIVE SUCCESS, GROUP SIZE, AND GROUP COMPOSITION (COLOR-BANDING)

Monitoring reproductive success and group size is accomplished by periodic visits to the nest, color-banding all nestlings and unbanded adults, conducting fledgling checks and/or late-nestling checks, and identifying all banded adults throughout the breeding season. This appendix provides information on: (1) nest checks, (2) aging nestlings according to Ligon age characteristics, (3) capturing and color-banding nestlings, (4) capturing and color-banding adults, (5) fledgling or late nestling checks, (6) color-band observation, (7) determining group composition, and (8) data management.

1. Nest Checks

Nest checks consist of repeated visits to the cluster on a 7 to 11 day cycle until a nest is found. More frequent nest checks subject the birds to unnecessary disturbance for little additional information. Less frequent nest checks greatly increase the likelihood that nestlings will be too old to band when found, and nest failures may go undetected.

Each active cavity tree in the cluster is a potential nest site, although nests are typically found in the most active cavity tree and often in the most recently completed cavity. Locate nests by observing adult behavior (e.g., flushing from a cavity during the day, tending nestlings) and/or inspecting contents of active cavities using Swedish ladders or a video probe. Once a nest is located, observe and record contents, including number of eggs or nestlings and nestling age (see below), as well as other relevant information such as date, time, and cavity, cavity tree, and cluster identification numbers. Schedule the following nest visit by optimal banding age (see below). If a discovered nest contains eggs, return to the cluster in 7 to 11 days. After nestlings are banded, it is not necessary to return to the site until the late/nestling check or fledgling check, whichever is used (see below).

If a nest fails before nestlings have fledged, return the cluster to the nest check cycle to detect renesting. If no nest is observed within a cluster, conduct a morning follow of group members (3A) and survey for new cavity trees within suitable habitat in and near the cluster (3A).

During nest checks, identify all adults present by color-band observation and record their color-band combination and activity (e.g., incubating, feeding nestlings, conflicting with other adults). This information is important to determining group composition (see below).

2. Aging Nestlings

Nestlings are aged according to descriptive characteristics set out by Ligon (1970; Table 20). Aging of nestlings is done with extreme care and attention to detail.

TABLE 20. Nestling characteristics indicative of nestling age, in number of days.

Nestling Age	Character	Description
DAY 0	SKIN	Loose and pink
	BILL	Mandible roughly 2mm longer that maxilla; diamond-shaped egg-tooth on maxilla
	WINGS	Permanently extended and used to remain upright
	RETRICES	Bumps
	FEET	Heel pad greatly enlarged
	SIZE	Appears small enough to fit back into egg
DAY 1	SIZE	Appears that the body would fit back into shell, but not the head
DAY 3	REMIGES	Dots visible
DAY 4	SKIN	Tail darkening
	BILL	Turning black except for egg tooth
	TRACTS	Back, wing, and scapular tracks visible
DAY 5	SKIN	Skin darkening
	TRACTS	Crown, lower neck, and most of spinal, femoral, and ventral tracks visible
DAY 6	BILL	Maxilla almost as long as mandible
	EARS	Open
	RETRICES	Bristles visible
DAY 7	TRACTS	Crural tracts visible
	FEET	Increasing in size
DAY 8	SKIN	Darker
	BILL	Maxilla and mandible are about equal in length
	RETRICES	Protruding
	REMIGES	Quills protruding from skin
	FEET	Darkening
DAY 9	EYE	Opening
	RETRICES	Exposed short distance
	FEET	Extended toes 34 mm
DAY 10	REMIGES	Quills showing
	TRACTS	Well developed; feather tips exposed at tail, rump, slightly on breast, and on lower abdominal tract. Quills of middle and lesser coverts, humeral tract, and spinal tract showing.
	FEET	Feet and tarsi dark, heel pads light, losing knobs and tubercles
DAY 11	BILL	Maxilla slightly longer than mandible, culmen 11 – 12 mm
	REMIGES	1^{st} secondary 8mm, 2^{nd} primary 7 mm
	TRACTS	Feather tips of spinal, scapulars, anterior ventral and crural tracts showing
	BEHAVIOR	Call changes to more adult-like
DAY 13	RETRICES	Quills 6.5 – 7.5 mm
	REMIGES	Outer primary quills about 25 mm; longest primary 18 – 25 mm

Table continued next page.

TABLE 20 (cont.). Nestling characteristics indicative of nestling age, in number of days.

Nestling Age	Character	Description
DAY 15	RETRICES	Quills 16 – 18 mm
	TRACTS	Feathers still largely sheathed
DAY 16	BILL	Culmen 14 mm
	REMIGES	Longest primary 27 mm (sheath 20 mm)
	TRACTS	Erupted feathers covering much of body surface
DAY 17	TRACTS	Feather sheaths on pileum of males broken away except for those of red crown patch
DAY 19	RETRICES	Longest feather 29 mm and quills beginning to break away
	REMIGES	Longest primary 45 mm and quills beginning to break away
	TRACTS	Body covered with feathers except for abdomen and flanks
	BEHAVIOR	Active and pecking at observer’s hand

3. Capturing and Color-banding Nestlings

Nestlings are banded between the ages of 5 to 10 days old. Banding nestlings older than 10 days in age is prohibited because of greatly increased risk of injury and mortality. Banding nestlings younger than 5 days old is not possible because they cannot accommodate three color-bands on one leg. In southerly parts of the range, nestling 5 or 6 days in age may not be large enough to wear three color-bands. In these regions, narrow the window of banding opportunity to 7 to 10 days in age.

Nestlings are captured and carefully removed from the nest cavity using a soft noose liberally lubricated with cornstarch (Jackson 1982). Nestlings must be kept warm and dry, and out of direct sunlight, while out of the nest.

Each individual is banded with a unique combination of color-bands (size XB) and a U.S. Geological Survey aluminum band (size 1A). Nestlings and adults (see below) are banded with three color-bands on one leg and the aluminum band, with or without an additional color-band, on the other leg. Birds are not to be banded with one or two color-bands alone on a leg, because color-bands that move excessively can cause injury to toes. Birds are not to be banded with more than a single color-band on the leg carrying the aluminum band. Therefore, we recommend that both legs be banded. If only one leg is banded, color-band combinations are reduced to a single color-band and the aluminum band.

Once nestlings are banded, check the accuracy of the band combination several times. Record necessary data on banding sheets. Return nestlings to the cavity.

4. Capturing and Banding Adults

Adults are captured for banding or color-band replacement following the breeding season, or at any time other than the breeding season, unless the bird in question cannot be caught except during breeding (e.g., a female without a roost cavity). Aluminum bands are never replaced, and are only removed if the band is causing injury. Color-bands may sometimes need replacement, but capture of adults should be minimized to the fullest possible extent.

Adults are typically captured at the roost cavity at dawn or dusk with a net attached to a telescoping pole. Adults will not be caught at night, except those captured for translocation that evening and for specific research needs with appropriate permits. Adults will also not be caught during wet weather; handling wet birds can kill them. Adults are banded in the same way as nestlings: three color-bands on one leg, and the aluminum band with or without an additional color-band on the other leg.

5. Fledgling or Late Nestling Checks

Fledgling checks or late nestling checks are performed to determine how many nestlings survived to fledging, and the sex of those individuals. Fledgling checks are preferable to late nestling checks because the accuracy of survival estimates are improved and because fledgling checks are an important time to identify adult members of the group. However, late nestling checks may be substituted if time and personnel are constrained.

Conduct fledgling checks for each banded nest between 2 and 14 days after the projected fledging date (26 days after estimated hatching date). Fledgling checks last a minimum of one hour or until all nestlings banded are seen as fledglings. Record number of fledglings, their color band combinations, and their sex. Determine sex by unobstructed views of the fledgling's entire crown: females have a black crown and males have a red crown patch. If a banded nestling is not detected as a fledgling during the one-hour fledgling check, conduct a second check within ten days. If no fledglings are detected in these two checks, examine active cavity trees for an additional nest attempt.

Conduct late nestling checks before the 21^{st} day after estimated hatching date. If nestlings are disturbed at age 21 days or older, they may fledge prematurely. During a late nestling check, identify, count, and sex all nestlings and record these data.

6. Color-band Observation

Using spotting scopes, identify and count adults whenever they are encountered. Most observations are made during nest and fledgling checks. Do not count birds by sound alone. Record color-band combinations, cluster, date, and behavioral data such as tending young or conflicting with other adults present. Verify unexpected color-band combinations.

7. Determining Group Composition

Group composition is determined using color-band observations described above. Breeding male status can be assigned to a male if any one of the following criteria are met: (1) he is the only male in the group, (2) he is the oldest male in the group, (3) he roosts in the nest cavity, or (4) he was the breeding male in the previous year. Once the breeding male has been determined, other adult males present are assigned helper status if they are on their natal territory or if they were seen incubating, tending young, or interacting peacefully with other adult members of the group. Breeding female status is assigned to a female if (1) she is the only female, (2) she is the oldest female in the group, or (3) she was the breeding female in that group in the previous year. Other adult females are assigned helper status only if they are on their natal territory.

Birds that are observed in conflict with group members are intruders from a nearby group or non-breeding adults without a group (floaters). Extra adult females that peacefully interact with a group, but are not on their natal territory, sometimes occur. The role of these auxiliary females deserves further research.

In cases where group composition or individual status remains uncertain, conduct a morning follow (3A) or roost check. This will enable determination of which bird roosts in the nest cavity as well as locate breeders or helpers not seen previously. Old breeding males, for example, may be especially hard to observe during nest and fledgling checks. If it appears that an old breeding male is no longer present, a morning follow or roost check is recommended to verify his disappearance.

8. Data Management

We recommend that data be stored using database management software rather than spreadsheets or other software types. Of course, data management will vary according to research and species management needs.

However, for monitoring reproductive success and group size, it is useful to keep at least these two separate data sets: (1) the first containing one record for each individual in each breeding season, and including information such as color-band combination, age or minimum age, status (e.g. helper or breeder), cluster, and year; and (2) the second containing one record per group per year, including information such as the number of eggs, nestlings, and fledglings produced, whether or not a nest was attempted, and group size. Group size should not include fledglings. Managers may consider creating a third data set that contains one record for every time a bird was observed, although this is time-consuming. Other data sets can be created as needed.

APPENDIX 3. PROTOCOL FOR TRANSLOCATION EVENTS

This appendix describes general protocol for confirmation of cluster status and the capture, transport, and release of birds for the purposes of translocation. Translocation guidelines (8H) must be followed for all translocation events. If a bird is being translocated to a cluster containing a solitary bird (mate provisioning), solitary status in the recipient cluster is to be confirmed by a morning follow (i.e., morning roost check, see 3A) just prior to the translocation event.

Part A. Confirmation of Cluster Status

1. Confirm status of the recipient cluster one to three days before the translocation event, by a morning follow (i.e., morning roost check; see 3A). This is conducted in all clusters receiving birds, to determine:

a. if the cluster is inactive, for translocations of potential pairs;
b. if the cluster contains a solitary bird, for translocations of potential mates;
c. if the cluster contains a potential breeding group, contrary to expectations;
d. the suitability of cavities and cluster habitat structure.

If the intended recipient cluster contains a potential breeding group, or does not have suitable cavities and habitat structure, cancel the translocation. If cluster status is confirmed as expected and the translocation can proceed, ensure that the cluster and target cavity trees are easily found at night and flag a route if necessary.

2. Confirm status of potential donor clusters one to three days before the translocation event, by a morning follow (3A). Ensure, for all clusters donating birds, that the birds intended for translocation are actually available. Follow guidelines for bird availability given in 8H. Have several potential donor clusters for every one bird to be translocated, in case a bird cannot be captured or bird availability status has changed.

Part B. Capture, Transport, and Release of Individuals

1. Plan the capture of the birds based on transport time.

1. Observe roosting of the birds to be translocated. Capture the birds that night or the following morning with a net and telescoping pole. Birds should be trapped at night if transport time is not expected to exceed 5 or 6 hours, and in the new cavity by midnight; if not, morning captures are used. Double-check the aluminum band numbers to ensure that the correct birds were captured.

2. Transport the birds in covered, well-ventilated cages placed in the interior of unheated and quiet vehicles. Never transport more than one bird in each cage. Be certain that you

always know the location of each captured bird, but keep disturbance to an absolute minimum. Feed crickets and mealworms to birds every 45 to 60 minutes if transported during daytime.

3. Put the birds safely, quickly, and quietly into recipient cavities. Screen cavity entrances with ½ in hardware cloth tacked firmly but lightly so that the screen can be easily removed in the morning. Drop a string from the screen to the ground so that the screen can be removed without climbing. If the cluster contains a solitary bird prior to translocation, take care not to flush it.

4. Arrive at the cluster at first light. If a solitary male roosts in the cluster, release the translocated potential mate when the resident male exits his cavity. If a potential pair has been moved, wait until both are pecking at the screen, and release them simultaneously. Have ladders present in case the tree has to be climbed to remove the screen.

5. A cassette of red-cockaded woodpecker calls played just after release may help increase the likelihood that birds encounter each other.

6. Once the birds are released, wait at least one week before returning to the cluster for any follow-up check. Follow-up checks are not necessary; no further observations are required until the next breeding season. During the next breeding season, the cluster and surrounding clusters should be monitored to determine the presence of potential breeding groups and the location of translocated birds. In populations undergoing translocation for the purpose of population augmentation (i.e., receiving birds from donor populations), all clusters are monitored for group size and reproductive success (Appendix 2).

Part C. Other Methods of Translocation

Other techniques for the translocation of individuals may prove more successful than current methods (e.g. Wallace and Buchholz 2001), but are not approved for general use at this time.

APPENDIX 4. SURVEY PROTOCOL

Guidelines for Surveys to Assess Potential Project Impacts to Red-cockaded Woodpecker Nesting and/or Foraging Habitat

Surveys are used to determine whether the nesting and/or foraging habitat of a red-cockaded woodpecker group will be adversely impacted by a proposed project, such as a timber sale or development activity, on a particular tract of land. This is an important part of the conservation and management of this endangered species, and therefore the Fish and Wildlife Service has developed standard survey and analysis procedures for such determinations. These determinations must be undertaken prior to the initiation of any project within the southeastern United States that calls for removal of pine trees 30 years or older; typically such trees will be at least 25.4 cm (10 in) dbh or larger. The procedure is also used following new land acquisition by state and federal agencies in the southeast or any other circumstance in which the presence or absence of red-cockaded woodpeckers is to be assessed.

The first step in the survey procedure is to determine if suitable nesting or foraging habitat exists within the area to be impacted by the project. If no suitable nesting or foraging habitat is present within the project impact area, further assessment is unnecessary and a "no effect" determination is appropriate. If no suitable nesting habitat is present within the project impact area, but suitable foraging habitat is present and will be impacted, potential use of this foraging habitat by groups outside the project boundaries must be determined. This is accomplished by identifying any potential nesting habitat within 0.8 km (0.5 mi) of the suitable foraging habitat that would be impacted by the project. Any potential nesting habitat is then surveyed for cavity trees. This procedure is described in greater detail below. If no active clusters are found, then a "no effect" determination is appropriate. If one or more active clusters are found, a foraging habitat analysis is conducted (see 8I) to determine whether sufficient amounts of foraging habitat will remain for each group post-project.

For nesting and foraging habitat surveys within project impact areas and within 0.8 km (0.5 mi) of the project site, potential habitat is assessed at the level of the stand. A stand is a term often used to refer to a wooded area receiving past or current silvicultural treatment as a single management unit. Here we expand the term to include any subset of a tract of wooded land, divided by biological community type, management history, or any other reasonable approach. A small tract of land may be considered a single stand.

Identification of Suitable Foraging Habitat

For the purpose of surveying, suitable foraging habitat consists of a pine or pine/hardwood stand of forest, woodland, or savannah in which 50 percent or more of the dominant trees are pines and the dominant pine trees are generally 30 years in age or older. These characteristics do not necessarily describe good quality foraging habitat (see 2E, 8I); rather, this is a conservative description of potentially suitable habitat.

Identification of pine and pine/hardwood stands can be made using cover maps that identify pine and pine/hardwood stands, aerial photographs interpreted by standard techniques, or a field survey conducted by an experienced forester or biologist. Age of stands can be determined by aging representative dominant pines in the stands using an increment-borer and counting annual growth rings. Stand data describing size classes may be substituted for age if the average size of 30 year-old pines is known, i.e., at least 25.4 cm (10 in) dbh or larger, for the local area and habitat type.

If no suitable foraging habitat is present within the project area (that is, no pines 30 years or older will be impacted), then further evaluation is unnecessary and red-cockaded woodpeckers are considered absent. If the project area contains any suitable foraging habitat that will be impacted by the project, that habitat, if it contains any 60 year old trees or older, and all other suitable nesting habitat within 0.8 km (0.5 mi) of the project site, regardless of ownership, must be surveyed for the presence of red-cockaded woodpeckers.

Identification of Suitable Nesting Habitat

For the purpose of surveying, suitable nesting habitat consists of pine, pine/hardwood, and hardwood/pine stands that contain pines 60 years in age or older and that are within 0.8 km (0.5 mi) of the suitable foraging habitat to be impacted at the project site (see above). Additionally, pines 60 years in age or older may be scattered or clumped within younger stands; these older trees within younger stands must also be examined for the presence of red-cockaded woodpecker cavities. These characteristics do not necessarily describe good quality nesting habitat (see 2D, 8E, 8F); rather, this is a conservative description of potential nesting habitat.

Determination of suitable nesting habitat may be based on existing stand data, aerial photo interpretation, and/or field reconnaissance. All stands meeting the above description, regardless of ownership, are surveyed for cavity trees.

Surveying for Red-cockaded Woodpecker Cavity Trees

Once suitable nesting habitat is identified (above), it must be surveyed for cavity trees of red-cockaded woodpeckers by personnel experienced in management and/or monitoring of the species. Potential nesting habitat is surveyed by running line transects through stands and visually inspecting all medium-sized and large pines for evidence of cavity excavation by red-cockaded woodpeckers. Transects must be spaced so that all trees are inspected. Necessary spacing will vary with habitat structure and season from a maximum of 91 m (100 yards) between transects in very open pine stands to 46 m (50 yards) or less in areas with dense midstory. Transects are run north-south, because many cavity entrances are oriented in a westerly direction, and can be set using a hand compass.

When cavity trees are found, their location is recorded in the field using a Global Positioning System (GPS) unit, aerial photograph, and/or field map. Activity status, cavity stage (start, advanced start, or complete cavity), and any entrance enlargement are assessed and recorded at this time. Again, it is extremely important to have all surveys and cavity tree assessments performed by experienced personnel.

If cavity trees are found, more intense surveying within 457 m (1500 ft) of each cavity tree is conducted to locate all cavity trees in the area. Cavity trees are later assigned into clusters based on observations of red-cockaded woodpeckers as described in 3A. Any cavity trees or other evidence of red-cockaded woodpecker activity is reported to the Fish and Wildlife Service, at either a local office or the Clemson Field Office, Clemson, South Carolina.

APPENDIX 5. PRIVATE LANDS GUIDELINES

Private landowners have different responsibilities than do public land managers for endangered species conservation under the Endangered Species Act. Because of this, we provide specific guidance here for private landowners to follow on lands occupied by red-cockaded woodpeckers. However, private landowners are strongly encouraged to follow general guidelines for red-cockaded woodpecker management given in section 8 of this document.

Here, we first list activities that have the potential for harass and/or harm under the definition of "take" in the Act. These activities cannot be conducted within clusters and foraging habitat of red-cockaded woodpeckers without concurrence and/or a permit (see 4A) from the U.S. Fish and Wildlife Service. We then present guidelines for the management of foraging habitat on private lands. Finally, we give guidance on monitoring the activity status of red-cockaded woodpecker clusters specific to private landowners.

Potentially Harmful Activities

Because of the potential for harass and/or harm under the definition of 'take' in the Endangered Species Act, the following activities require concurrence and/or a permit from the U.S. Fish and Wildlife Service.

1. Removing any red-cockaded woodpecker cavity tree, through cutting, bulldozing, or any other activity.

2. Damaging an active cavity tree which results in the death of that tree. Damage includes, but is not limited to, injury to the bole or root system (generally due to heavy equipment use), exposure to herbicides, and fire scorch to the crown due to inadequate protective measures during prescribed burning. Pines are best protected from damage by intense fires through frequent low-intensity prescribed burns (see 8K).

3. Using insecticides on any standing pine tree. Prevention and control of disease and insect infestations is encouraged. Infestations of insects such as southern pine beetles are best prevented by maintaining open structure and adequate spacing between pines (see 8J). Control of active infestations often includes the cutting of infested trees. If such control will result in losses of trees below recommended foraging guidelines (below), or in the removal of cavity trees, the U.S. Fish and Wildlife Service must be contacted prior to the action.

4. Constructing roads and utility rights-of-way within a cluster. Use of existing roads, improved or unimproved, generally does not adversely affect red-cockaded woodpeckers and therefore is permitted. If, in the landowner’s opinion, there is no reasonable alternative to construction of new roads, either improved or unimproved, or if there is no reasonable alternative to placing a utility right-of-way within the cluster, the U.S. Fish

and Wildlife Service must be contacted before construction or clearing activities are initiated.

5. Construction of facilities including, but not limited to, buildings, campgrounds, recreational developments, residential dwellings, and industrial or business complexes. If, in the landowner's opinion, extenuating circumstances require a facility to be constructed in an active cluster, the U.S. Fish and Wildlife Service must be contacted during the planning phase and prior to any construction activity.

6. Planting of shrubs and/or ornamental plants that will exceed 2.1 m (7 ft) in height within 15.24 m (50 ft) of active and inactive cavity trees. If cavities are 3.05 m (10 ft) or less in height, planting any shrubs within 15.24 m (50 ft) of cavity trees may adversely affect red-cockaded woodpeckers. Construction equipment and construction material cannot be stored within 61 m (200 ft) of cavity trees. Landscaping within clusters should be accomplished with hand tools or lightweight power equipment rather than tractor-mounted equipment.

Foraging Habitat

We present two sets of guidelines for the management of foraging habitat. The first, named the recovery standard, is presented in 8I, and scientific reasoning underlying these guidelines is explained in 2E. However, because of differing responsibilities of private landowners and public land managers under the Endangered Species Act, it may be unreasonable to expect that private landowners manage their foraging habitat at the same level of quality at which public land managers are expected to manage their lands. Populations on public lands are required to be increasing, whereas many populations on private lands are managed for stability. For those private landowners that wish to increase the size of their population, we strongly encourage that the recovery standard be followed. However, we present an alternative set of foraging guidelines for groups in populations on private lands managed to maintain existing population size. Because our understanding of foraging requirements is not yet sufficient to identify the specific level of foraging resources at which a population changes from stable to increasing (see recovery task 5.8.), these guidelines are based on existing minimum amounts of foraging resources of groups known to be surviving and reproducing over at least short time periods.

Red-cockaded woodpeckers can benefit by the establishment of lower guidelines for populations in which only stability rather than increasing trends is required, because lower guidelines can encourage private landowners to enroll in conservation agreements and participate in active management. Flexibility in guidelines, within appropriate boundaries, is an important component of successful conservation on private lands because it fosters cooperation rather than resentment (see 4A). But, these guidelines are presented with a caveat: stability of small populations cannot be attained without additional management (such as use of artificial cavities and/or translocation; see 3B, 3D, 8E, 8H). Additionally, the standard for managed stability is not designed to increase population size nor is its wide-scale implementation within a population adequate to maintain that population's viability over the long-term. It does not provide future nesting habitat or suitable, i.e., good quality, foraging habitat over the long-term. Its wide-scale implementation will result in population fragmentation with subsequent problems related to demographic stochasticity and perhaps genetic variability. Again, private landowners are strongly encouraged to manage at or toward the recovery standard, and should provide at least the standard for managed stability. The standard for managed stability is as follows:

1. Provide each group of red-cockaded woodpeckers a minimum of 689 m^2 (3000 ft^2) of pine basal area, including only pines $\geq$ 25.4 cm (10 in) dbh.

2. Provide the above pine basal area on a minimum of 30.4 ha (75 ac).

3. Count only those pine stands in suitable habitat that, for this standard only, has each of the following characteristics:

   a. Stands that are at least 30 years old and older.

   b. An average pine basal area of pines $\geq$ 25.4 cm (10 in) between 9.2 and 16.1 m^2/ha (40 and 70 ft^2/ac).

   c. An average pine basal area of pines < 25.4 cm (10 in) less than 4.6 m^2/ha (20 ft^2/ac).

   d. No hardwood midstory or if a hardwood midstory is present, it is sparse and less than 2.1 m (7 ft) in height.

   e. Total stand basal area, including overstory hardwoods, less than 23.0 m^2/ha (80 ft^2/ac).

   f. We recommend that all land counted as foraging habitat be within 0.4 km (0.25 mi) of the cluster, and that any stand counted as foraging habitat be within 61 m (200 ft) of another foraging stand or the cluster itself.

   g. Frequent prescribed burning of foraging habitat, especially during the growing season, is strongly recommended. Development and protection of herbaceous groundcovers facilitates prescribed burning and benefits red-cockaded woodpeckers.

As stated above, the standard for managed stability can benefit red-cockaded woodpeckers on ownerships not legally required to recover the species, because it encourages cooperation between landowners and the U.S. Fish and Wildlife Service. Previous guidelines for privately owned lands facilitated the development of successful

Safe Harbor Agreements and Memoranda of Agreement (see 4A). Again, research to date does not adequately support the designation of foraging habitat that will result in stable vs. increasing populations, so these guidelines have been developed using minimum observed values for successfully reproducing groups. For the most part, the standard for managed stability reflects previous guidelines for private lands. Changes include requirements of slightly more minimum acreage, lower maximum pine densities, and higher minimum pine densities. These modifications were made based on results of recent research described in detail in 2E.

We stress the importance of adequate stand structure. Stands cannot be considered suitable as foraging habitat unless they have an "open" character. A pine stand that is 30 years in age and has an average tree diameter of 25.4 cm (10 in) or more does not necessarily qualify as suitable foraging habitat. If such a stand has not been prescribed burned (or otherwise treated to control hardwood midstory) and has not been thinned to a basal area of 16.1 m^2/ha (70 ft^2/ac) or less, it will not satisfy the "open" condition criterion. Dense stands of young pine and pine/hardwood are typical of unmanaged plantations and natural regeneration areas (particularly loblolly seedtree harvests) that have not been thinned or frequently burned. Such stands cannot be considered suitable foraging habitat simply because they have the required total and stand basal area and average stem diameter. Stand quality, as measured by an open structure, is a critical factor determining suitability and use of foraging habitat and must be considered when acceptable foraging habitat is identified.

Development, with concurrence from the U.S. Fish and Wildlife Service, can occur within the 0.8 km (0.5 mi) radius surrounding the cluster. However, the level of development cannot reduce the available foraging substrate below the required standard of managed stability. Although residential and commercial facilities and their associated infrastructures (roads, right-of-way, parking areas, recreational complexes, etc.) are permitted, all reasonable measures will be taken to minimize the impact of these developments on the foraging habitat available to the red-cockaded woodpecker. In other words, developments will strive to minimize clearing for rights-of-way, road widths, residential dwellings, and commercial and/or industrial complexes. If development would result in foraging habitat losses below the recommended guidelines, a permit (see 4A) is required. Landscaping, whenever possible, should use existing natural vegetation and will not involve extensive hardwood tree plantings.

Monitoring Activity Status of Clusters

Private landowners are encouraged to monitor the number of active clusters on their property and report this information annually to the Red-cockaded Woodpecker Recovery Coordinator. A description of monitoring number of active clusters, and further information concerning the Annual Report, is given in 3A. Private landowners are not responsible for the protection and maintenance of inactive or abandoned clusters, but must adequately document that a cluster is no longer active. This section defines inactive and abandoned clusters and explains how to adequately document cluster activity status.

For the purposes of these private lands guidelines, an abandoned cluster is one that has not shown any evidence of activity by red-cockaded woodpeckers for three years or more. An inactive cluster is one that is not currently supporting any red-cockaded woodpeckers and shows no evidence of red-cockaded woodpecker activity.

Declaring a cluster inactive or abandoned requires the expertise of a knowledgeable biologist or other individual familiar with the identification, life history, and ecology of red-cockaded woodpeckers. The individual must have ample experience with red-cockaded woodpeckers to recognize, and interpret, the sometimes confusing and subtle differences associated with cavity status. One visit is not sufficient to determine activity status, because of several of the species' life history traits. Therefore a cluster-specific monitoring program must be established for at least each cluster in question, and preferably for all clusters on the property.

The objective is to determine whether any red-cockaded woodpeckers are using any cavities within the cluster. Clusters are monitored for red-cockaded woodpecker activity during early morning and/or early evening hours. The number of monitoring days and/or periods (morning/evening) required to document the use or non-use of the cluster by red-cockaded woodpeckers will depend on several factors.

These factors include, but are not limited to,

1. The existing number and condition of cavities. If at least one cavity tree has fresh resin, the cluster is active. If all cavity trees appear as if abandoned for several years, one additional visit at dawn or dusk is generally sufficient to verify the absence of red-cockaded woodpeckers. In contrast, if the cluster appears possibly active, or active within the last few months, several visits may be necessary to document the presence or absence of birds.

2. Distance from, and numbers of, other known active clusters. Active clusters nearby (within a few km, or mi) increase the probability that the cluster in question is active. The number of visits to the cluster should be increased if there are active clusters nearby.

3. Time of year that cluster status is determined. Red-cockaded woodpeckers may not spend as much time in the fall and winter on cavity and resin well maintenance; additionally, resin flow is not as vigorous during the non-growing season. Both of these factors should be considered if cluster status is being determined during the fall/winter period.

Ultimately, a significant amount of professional judgment is required when deciding upon an acceptable monitoring strategy. In general, the monitoring program should be designed to meet individual needs, to the degree necessary, to accurately determine whether or not red-cockaded woodpeckers are using the cluster. Landowners are encouraged to obtain the assistance of red-cockaded woodpecker biologists, consultants, and other qualified individuals to help them certify the status of their particular cluster(s).

As general guidance, when it is not obvious that the cluster has been abandoned for a long time (several to many years), monitoring for either: (1) an extended period of consecutive days, with a mix of morning and evening periods or (2) a series of randomly selected days, spread over several weeks or months, will be necessary to determine the cluster's status. If new evidence, such as a change in appearance of cavities or resin wells, arises during the monitoring period, even though red-cockaded woodpeckers were not observed, the existing monitoring strategy must be revised to include additional visits to the cluster.

Because of the variability and uncertainties associated with individual red-cockaded woodpecker behavior, no single monitoring strategy can be designed for all situations. Strategies will be developed on a case-by-case basis and discussed with the Red-cockaded Woodpecker Recovery Coordinator for adequacy and acceptability. Flexibility in design and implementation of red-cockaded woodpecker cluster status monitoring programs is important and will be emphasized with each landowner.

Appendix C-5: West Indian Manatee Recovery Plan

Florida Manatee Recovery Plan

(*Trichechus manatus latirostris*)
Third Revision

U.S. Fish and Wildlife Service
Southeast Region

FLORIDA MANATEE RECOVERY PLAN

(Trichechus manatus latirostris)

THIRD REVISION

Original Approval: April 15, 1980
First revision approved: July 24, 1989
Second revision approved: January 29, 1996

Southeast Region
U.S. Fish and Wildlife Service
Atlanta, Georgia

Approved: Sam D. Hamilton

Sam D. Hamilton, Regional Director, Southeast Region,
U.S. Fish and Wildlife Service

Date: 10/30/01

DISCLAIMER

Recovery plans delineate reasonable actions believed to be required to recover and/or protect listed species. Plans published by the U.S. Fish and Wildlife Service (FWS), are sometimes prepared with the assistance of recovery teams, contractors, state agencies, and other affected and interested parties. Recovery teams serve as independent advisors to FWS. Plans are reviewed by the public and submitted to additional peer review before they are adopted by FWS. Objectives of the plan will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific tasks and may not represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than FWS. They represent the official position of FWS only after they have been signed by the Regional Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

By approving this document, the Regional Director will certify that the data used in its development represent the best scientific and commercial data available at the time it was written. Copies of all documents reviewed in development of the plan are available in the administrative record located at U.S. Fish and Wildlife Service, 6620 Southpoint Drive, South, Suite 310, Jacksonville, Florida 32216. (904) 232-2580.

LITERATURE CITATION SHOULD READ AS FOLLOWS:

U.S. Fish and Wildlife Service. 2001. Florida Manatee Recovery Plan, (*Trichechus manatus latirostris*), Third Revision. U.S. Fish and Wildlife Service. Atlanta, Georgia. 144 pp. + appendices.

ADDITIONAL COPIES MAY BE OBTAINED FROM:

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814
(301) 492-6403 or 1-800-582-3421

Fees for plans vary depending upon the number of pages.

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***Appointed Recovery Team members have an asterisk by their name.**

EXECUTIVE SUMMARY

CURRENT SPECIES STATUS

Endangered. The near and long term threats from human-related activities are the reasons for which the Florida manatee currently necessitates protection under the Endangered Species Act. The focus of recovery is not on how many manatees exist, but instead the focus is on implementing, monitoring and addressing the effectiveness of conservation measures to reduce or remove threats which will lead to a healthy and self-sustaining population. The Florida manatee could be considered for reclassification from endangered to threatened provided that threats can be reduced or removed, and that the population trend is stable or increasing for a sufficient time period.

HABITAT REQUIREMENTS AND LIMITING FACTORS

The Florida manatee lives in freshwater, brackish and marine habitats. Submerged, emergent, and floating vegetation are their preferred food. During the winter, cold temperatures keep the population concentrated in peninsular Florida and many manatees rely on the warm water from natural springs and power plant outfalls. During the summer they expand their range and on rare occasions are seen as far north as Rhode Island on the Atlantic coast and as far west as Texas on the Gulf coast.

The most significant problem presently faced by manatees in Florida is death or injury from boat strikes. The long-term availability of warm-water refuges for manatees is uncertain if minimum flows and levels are not established for the natural springs on which many manatees depend, and as deregulation of the power industry in Florida occurs. Their survival will depend on maintaining the integrity of ecosystems and habitat sufficient to support a viable manatee population.

RECOVERY GOAL

The goal of this revised recovery plan is to assure the long-term viability of the Florida manatee in the wild, allowing initially for reclassification to threatened status and, ultimately, removal from the List of Endangered and Threatened Wildlife.

RECOVERY CRITERIA

This plan sets forth criteria, which when met, will ensure a healthy, self-sustaining population of manatees in Florida by reducing or removing threats to the species' existence.

The following criteria must be met prior to **reclassification of the Florida manatee from endangered to threatened (downlisting)**:

1. Reduce threats to manatee habitat or range, as well as threats from natural and manmade factors by:
   - identifying minimum spring flows;
   - protecting selected warm-water refuge sites;
   - identifying for protection foraging habitat associated with the warm-water refuge sites;
   - identifying for protection other important manatee areas; and
   - reducing unauthorized human caused "take."

2. Achieve the following population benchmarks in each of the four regions over the most recent 10 year period of time:
   - statistical confidence that the average annual rate of adult survival is 90% or greater;
   - statistical confidence that the average annual percentage of adult female manatees accompanied by first or second year calves in winter is at least 40%; and
   - statistical confidence that the average annual rate of population growth is equal to or greater than zero.

The following criteria must be met prior to **removal of the Florida manatee from the List of Endangered and Threatened Wildlife (delisting)**:

1. Reduce or remove threats to manatee habitat or range, as well as threats from natural and manmade factors by enacting and implementing federal, state or local regulations that:
   - adopt and maintain minimum spring flows;
   - protect warm-water refuge sites;
   - protect foraging habitat associated with select warm-water refuge sites;
   - protect other important manatee areas; and
   - reduce or remove unauthorized human caused "take."

2. Achieve the following population benchmarks in each of the four regions for an additional 10 years after reclassification:
   - statistical confidence that the average annual rate of adult survival is 90% or greater;
   - statistical confidence that average annual percentage of adult female manatees accompanied by first or second year calves in winter is at least 40%; and
   - statistical confidence that average annual rate of population growth is equal to or greater than zero.

ACTIONS NEEDED

1. Minimize causes of manatee disturbance, harassment, injury and mortality.
2. Determine and monitor the status of the manatee population.
3. Protect, identify, evaluate, and monitor manatee habitats.
4. Facilitate manatee recovery through public awareness and education.

DATE OF RECOVERY

Currently, in some regions of the state, there are only reliable population data for the past 6 years. Therefore, full recovery may not be possible for at least another 14 years in order to meet the standard of assessing the population over the most recent 10 years of data for reclassification from endangered to threatened status and for an additional 10 years after reclassification for removal from the List of Endangered and Threatened Wildlife. Time is also needed to establish and implement management initiatives to reduce or remove the threats.

TOTAL ESTIMATED COST OF RECOVERY

Based on information provided by our recovery partners, current annual estimated budget expenditures for recovery approach $10,000,000.

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LIST OF ACRONYMS AND ABBREVIATIONS

The following standard abbreviations for units of measurements and other scientific/technical acronyms and terms are found throughout this document:

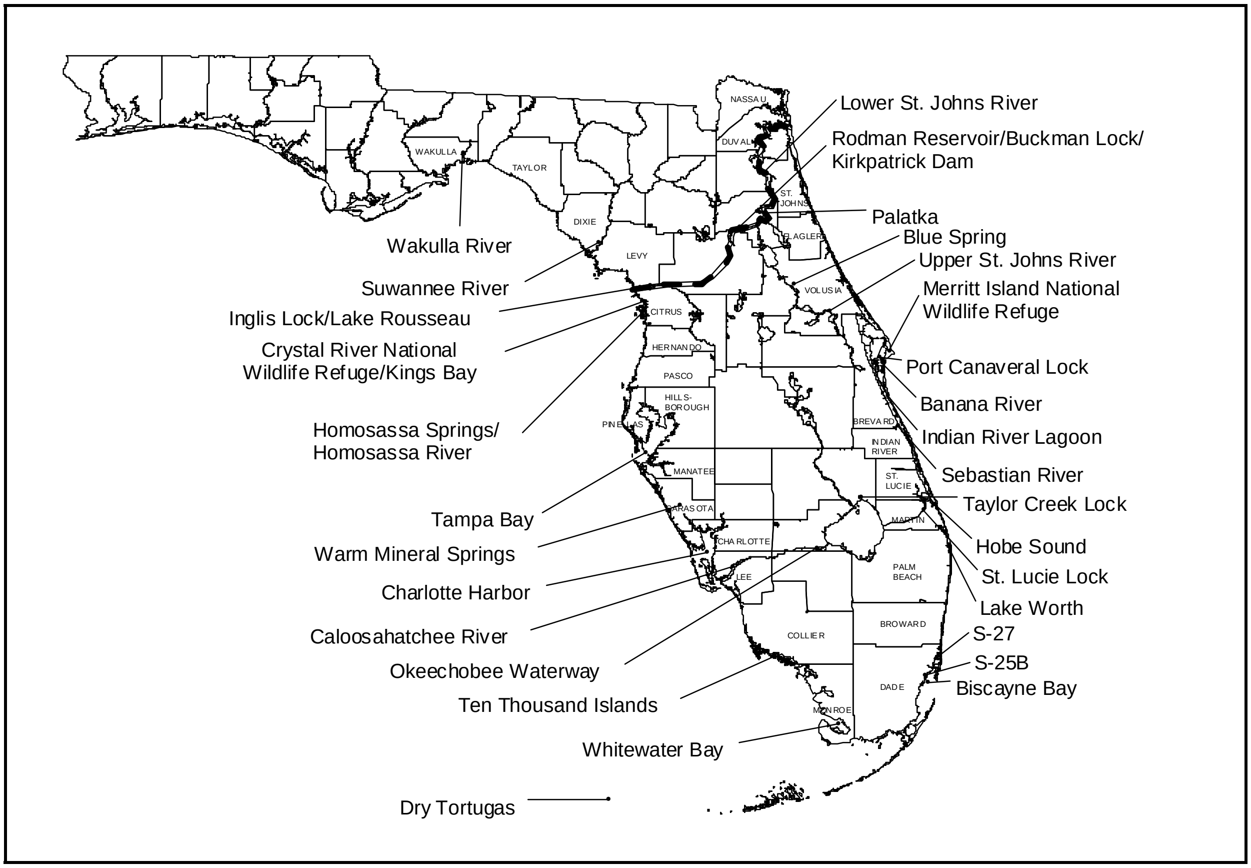
BPSM	Florida Fish and Wildlife Conservation Commission, Bureau of Protected Species Management
CERP	Comprehensive Everglades Restoration Plan
CFR	Code of Federal Regulations
COE	U.S. Army Corps of Engineers
CZS	Chicago Zoological Society
DERM	Miami-Dade Department of Environmental Resources Management
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act of 1973, as amended
FDEP	Florida Department of Environmental Protection
FDNR	Florida Department of Natural Resources
FIND	Florida Inland Navigation District
FMRI	Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute
FPL	Florida Power and Light Company
FR	Federal Register
FWC	Florida Fish and Wildlife Conservation Commission
FWC-DLE	Florida Fish and Wildlife Conservation Commission Division of Law Enforcement
FWS	U.S. Fish and Wildlife Service
GDNR	Georgia Department of Natural Resources
GIS	Geographic Information System
GPS	Global Positioning System
HBOI	Harbor Branch Oceanographic Institute
HWG	Habitat Working Group
IOWG	Interagency Oceanaria Working Group

LOA	Letter of Authorization
LE	Law Enforcement
MIPS	Manatee Individual Photo-Identification System
MML	Mote Marine Laboratory
MMPA	Marine Mammal Protection Act of 1972, as amended
MMPL	Marine Mammal Pathology Lab
MNPL	Maximum net productivity level
MPP	Manatee Protection Plan
MPS	Manatee protection system
MPSWG	Manatee Population Status Working Group
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPS	National Park Service
NSAV	Native submerged aquatic vegetation
NWR	National Wildlife Refuge
OC	The Ocean Conservancy (formerly the Center for Marine Conservation)
OSP	Optimum Sustainable Population
PIT	Passive Integrated Transponder
SAV	Submerged aquatic vegetation
SMC	Save the Manatee Club
USCG	U.S. Coast Guard
USGS-Sirenia	U.S. Geological Survey, Sirenia Project
USN	U.S. Navy
VHF	Very high frequency
WMD's	Water Management Districts

C Fish Industry	Commercial Fishing Industry
Local Gov'ts	Local Governments
M Industry	Marine Industries
Oceanaria	Cincinnati Zoo, Columbus Zoo, Homosassa Springs State Wildlife Park, Living Seas, Lowry Park Zoo, Miami Seaquarium, Mote Marine Laboratory, Sea World Florida and California, South Florida Museum
Photo-ID	Photo-identification
P Industry	Power Industries
R Fish Industry	Recreational Fishing Industry

C	Centigrade
cm	centimeters
ft	feet
hrs	hours
K	carrying capacity
kg	kilograms
km	kilometers
lbs	pounds
m	meters
mi	miles
min	minutes
ppm	parts per million
%	percent
≤	less than or equal to
°	degrees

Florida Coastal Counties and Other Sites Referenced in the Florida Manatee Recovery Plan



PREFACE

This Florida Manatee Recovery Plan revision adds new and refines existing recovery program activities for the next five years. The Recovery Plan is composed of four major sections:

1. Introduction: This section acquaints the reader with the Florida manatee, its status, the threats it faces, and past and ongoing conservation efforts. It also serves as a review of the biological literature for this subspecies.

2. Recovery: This section describes the goal of the plan; outlines an upcoming status review; presents reclassification and delisting criteria based upon the five listing/recovery factors and population benchmarks to assist in evaluating the status; objectives, strategy and actions or tasks needed to achieve recovery. These recovery tasks are presented in step-down outline format for quick reference and in a narrative outline, organized by four major objectives: (1) minimize causes of manatee disturbance, harassment, injury and mortality; (2) determine and monitor the status of the manatee population; (3) protect, identify, evaluate, and monitor manatee habitats; and (4) facilitate manatee recovery through public awareness and education.

3. Implementation Schedule: This section presents the recovery tasks from the step down outline in table format; assigns priorities to the tasks; estimates the time necessary to complete the tasks; identifies parties with authority, responsibility, or expressed interest in implementation of the tasks; and estimates the cost of the tasks and recovery program.

4. Appendices: This section presents additional information utilized by the FWS and Recovery Team to draft this revision.

PART I. INTRODUCTION

The Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.) (ESA), establishes policies and procedures for identifying, listing and protecting species of wildlife that are endangered or threatened with extinction. The ESA defines an “endangered species” as “any species which is in danger of extinction throughout all or a significant portion of its range.” A “threatened species” is defined as “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.”

The West Indian manatee, *Trichechus manatus*, was listed as endangered throughout its range for both the Florida and Antillean subspecies (*T. manatus latirostris* and *T. manatus manatus*) in 1967 (32 FR 4061) and received federal protection with the passage of the ESA in 1973. It should be noted that since the manatee was designated as an endangered species prior to enactment of the ESA, there was no formal listing package identifying threats to the species, as required by Section 4(a)(1) of the ESA. Critical habitat was designated in 1976 for the Florida subspecies, *Trichechus manatus latirostris* (50 CFR Part 17.95(a)). This was one of the first ESA designations of critical habitat for an endangered species and the first for an endangered marine mammal.

The Secretary of the Interior is responsible for administering the ESA’s provisions as they apply to this species. Day-to-day management authority for endangered and threatened species under the Department’s jurisdiction has been delegated to the U.S. Fish and Wildlife Service (FWS). To help identify and guide species recovery needs, section 4(f) of the ESA directs the Secretary to develop and implement recovery plans for listed species or populations. Such plans are to include: (1) a description of site-specific management actions necessary to conserve the species or population; (2) objective measurable criteria which, when met, will allow the species or populations to be removed from the List; and (3) estimates of the time and funding required to achieve the plan’s goals and intermediate steps. Section 4 of the ESA and regulations (50 CFR Part 424) promulgated to implement its listing provisions, also set forth the procedures for reclassifying and delisting species on the federal lists. A species can be delisted if the Secretary of the Interior determines that the species no longer meets the endangered or threatened status based upon these five factors listed in Section 4(a)(1) of the ESA:

(1) the present or threatened destruction, modification, or curtailment of its habitat or range;
(2) overutilization for commercial, recreational, scientific, or educational purposes;
(3) disease or predation;
(4) the inadequacy of existing regulatory mechanisms; and
(5) other natural or manmade factors affecting its continued existence.

Further, a species may be delisted, according to 50 CFR Part 424.11(d), if the best scientific and commercial data available substantiate that the species or population is neither endangered nor threatened for one of the following reasons: (1) extinction; (2) recovery; or (3) original data for classification of the species were in error.

West Indian manatees also are protected under the Marine Mammal Protection Act (MMPA) of 1972, as amended (16 U.S.C. 1461 *et seq*.). The MMPA establishes, as national policy, maintenance of the health and stability of marine ecosystems, and whenever consistent with this primary objective, obtaining and maintaining optimum sustainable populations of marine mammals. It also establishes a moratorium on the taking of marine mammals, which includes harassing, hunting, capturing, killing, or attempting to harass, hunt, capture, or kill any marine mammal. Section 101(a)(5)(A) of the MMPA allows FWS, upon request, to authorize by specific regulation the incidental, unintentional take of marine mammals by persons engaged in identified activities within specific geographic areas, if FWS determines that such taking would have a negligible impact on the species or stock. Since the West Indian manatee, which is comprised of the Florida and Antillean manatee stocks, is currently listed as "endangered" under ESA, they are thus considered "depleted" under the MMPA. Section 115(b) of the MMPA requires that conservation plans be developed for marine mammals considered "depleted." Such plans are to be modeled after recovery plans required under section 4(f) of the ESA, as described above. The purpose of a conservation plan is to identify actions needed to restore species or stocks to optimum sustainable population levels as defined under the MMPA. Thus, in the case of the Florida manatee, this plan addresses conservation planning under MMPA and recovery planning under the ESA.

FWS developed the initial recovery plan for the West Indian manatee in 1980. This initial plan focused primarily on manatees in Florida, but included Antillean manatees in Puerto Rico and the United States Virgin Islands. In 1986, FWS adopted a separate recovery plan for manatees in Puerto Rico. To reflect new information and planning needs for manatees in Florida, FWS revised the original plan in 1989 and focused exclusively on the Florida manatee. This first revision covered a 5-year planning period ending in 1994. FWS revised and updated the plan again in 1996, which again covered a 5-year planning period ending in 2000. In 1999, FWS initiated the process to revise the plan for a third time. A 18-member recovery team (see Acknowledgment Section), consisting of representatives of the public, agencies, and groups that have an interest in manatee recovery and/or could be affected by proposed recovery actions, was established to draft this revision.

In the 20 years since approval of the original recovery plan, a tremendous amount of knowledge of manatee biology and ecology has been obtained, and significant protection programs have been implemented, through the guidance provided by the recovery planning process. This third revision of the Florida Manatee Recovery

Plan reflects many of those accomplishments, addresses current threats and needs, and specifically addresses the planning requirements of both the ESA and MMPA through 2006. This plan was developed with the assistance of the Florida Manatee Recovery Team. Henceforth in this document, unless otherwise specified, the term "manatee" refers to *Trichechus manatus latirostris*, the Florida manatee subspecies of the West Indian manatee.

OVERVIEW

In the southeastern United States, manatees occur primarily in Florida and southeastern Georgia, but individuals can range as far north as Rhode Island on the Atlantic coast (Reid 1996), and probably as far west as Texas on the Gulf coast. This population appears to be divided into at least two somewhat isolated areas, one on the Atlantic coast and the other on the Gulf of Mexico coast of Florida and into two regional groups on each coast: Northwest, Southwest, Atlantic, and Upper St. Johns River (Fig. 1).

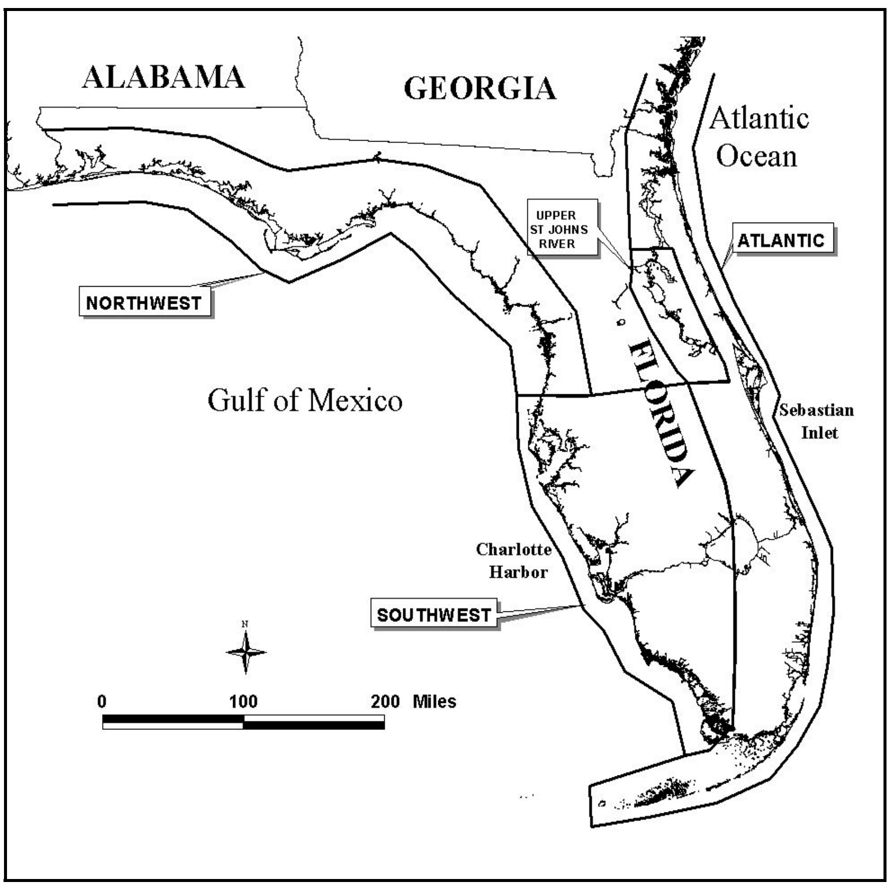


Figure 1. Florida manatee generalized regions: Northwest, Southwest, Upper St. Johns River and Atlantic coast.

Florida manatees have a low level of genetic diversity (Garcia-Rodriguez *et al*. 1998). Historical accounts and archeological evidence of manatees prior to the first half of the 20th century are poor and often contradictory (Domning *et al*. 1982; O'Shea 1988). The record indicates that manatees probably are almost as geographically widespread today as they were historically; however, they appear to be less abundant in many regions (Lefebvre et al. 2001). They were hunted by pre-Columbian societies, but the extent to which they were taken is unclear. After Spanish occupation, Florida's human population increased, and manatees probably were taken in greater numbers. Commercial and subsistence hunting, particularly in the 1800s, probably reduced the population significantly. In 1893, the State of Florida passed legislation prohibiting the killing of manatees.

The major threats faced by manatees today are many fold. Collisions with watercraft account for an average of 24 percent (%) of known manatee deaths in Florida annually (1976-2000), with 30% in 1999 and 29% in 2000. Deaths attributed to water control structures and navigational locks represents 4% of known deaths. The future of the current system of warm-water refuges for manatees is uncertain as deregulation of the power industry in Florida occurs, and if minimum flows and levels are not established and maintained for the natural springs on which many manatees depend. There are also threats to habitat caused by coastal development throughout much of the manatee's Florida range. Florida's human population has grown by 130% since 1970 (6.8 to 15.7 million) and is expected to exceed 18 million by 2010 and 20 million by the year 2015 (Florida Office of Economic and Demographic Research 2000). It is also projected that by 2010, 13.7 million people will reside in the 35 coastal counties (Florida Office of Economic and Demographic Research 2000). There are also threats from natural events such as red tide and cold events. The challenge for managers has increasingly become how to modify human, not manatee, behavior (Reynolds 1999). Yet, since the first Manatee Recovery Plan in 1980, well-coordinated interagency and non-governmental efforts to recover the Florida manatee have been extraordinary, making recovery an achievable goal (Domning 1999).

Based on the highest minimum count of the southeastern United States manatee population (Table 1), Florida manatees constitute the largest known group of West Indian manatees anywhere in the species' range. Outside the United States, manatees occur in the Greater Antilles, on the east coast of Mexico and Central America, along the North and Northeastern coast of South America, and in Trinidad (Lefebvre *et al*. 2001). In most of these areas, remaining populations are believed to be much smaller than the United States population and are subject to poaching for food, incidental take in gillnets, and habitat loss. Manatee protection programs in many countries are not well organized or supported and, in this context, protection of the Florida population takes on international significance.

Table 1. Estimates of manatee life history traits and related statistics. Except as noted, information was obtained from O'Shea *et al*. 1995.

Life-history trait		**Data**
Maximum determined age		59 years
Gestation		11-14 months
Litter size		1
% twins	Blue Spring	1.79%
	Crystal River	1.40%
Sex ratio at birth		1:1
Calf survival	Blue Spring	60%
	Crystal River	67%
Annual adult survival	Atlantic coast	90%
	Blue Spring	96%
	Crystal River	96%
Age of first pregnancy (female)		3-4 years
Mean age at first reproduction (female)		5 years
Age of spermatogenesis (male)		2-3 years
Proportion pregnant	Salvaged carcasses	33%
	Blue Spring (photo-ID)	41%
Proportion nursing - 1st-year calves during winter	Mean	36%
	Blue Spring	30%
	Crystal River	36%
	Atlantic coast	38%
Calf dependency		1.2 years
Interbirth interval		2.5 years
Highest number of births		May-September
Highest frequency in mating herds		February-July
No. verified carcasses in Florida[a]		4,043 (1974-2000)
No. documented in ID catalog		>1,200 (1975-2000)
Highest minimum count (aerial surveys)[a]		3,276 in Jan 5-6, 2001

[a] Data provided by the Florida Marine Research Institute, FWC.

A. TAXONOMY

The West Indian manatee, *Trichechus manatus* Linnaeus, 1758, is one of four living species of the mammalian Order Sirenia. The other three sirenians are the West African manatee (*T. senegalensis*), the Amazonian manatee (*T. inunguis*), and the dugong (*Dugong dugon*). All four species are aquatic herbivores listed as endangered or threatened throughout their ranges by FWS. A fifth species, Steller's sea cow (*Hydrodamalis gigas*), existed in sub-Arctic waters of the Bering Sea. Hunted to extinction within 27 years of its discovery in 1741, Steller's sea cow was a toothless sirenian that fed on kelp and reached lengths of up to 8 m (26 ft) (Reynolds and Odell 1991).

Two subspecies of West Indian manatee are now recognized: the Florida manatee, *T. manatus latirostris*, which occurs in the southeastern United States, and the Antillean manatee, *T. manatus manatus*, found throughout the remainder of the species' range. The Florida manatee was first described by Harlan (1824) as a separate species, *Manatus latirostris*. Later, Hatt (1934) recognized Florida manatees as a subspecies of *T. manatus* Linnaeus. Although subsequent researchers (Moore 1951; Lowery 1974) questioned the validity of the subspecies status, Domning and Hayek (1986) carefully examined morphological characteristics and concluded that the distinction was warranted. The historical ranges of the two subspecies may overlap on the coast of Texas, where the origin of occasional strays (from Florida or Mexico) is uncertain.

B. SPECIES DESCRIPTION

West Indian manatees are massive fusiform-shaped animals with skin that is uniformly dark grey, wrinkled, sparsely haired, and rubber-like. Manatees possess paddle-like forelimbs, no hind limbs, and a spatulate, horizontally flattened tail. Females have two axillary mammae, one at the posterior base of each forelimb (Fig. 2). Their bones are massive and heavy with no marrow cavities in the ribs or long bones of the forearms (Odell 1982). Adults average about 3.0 m (9.8 ft) in length and 1,000 kg (2,200 lbs) in weight, but may reach lengths of up to 4.6 m (15 ft) (Gunter 1941) and weigh as much as 1,620 kg (3,570 lbs) (Rathbun *et al*. 1990). Newborns average 1.2 to 1.4 m (4 to 4.5 ft) in length and about 30 kg (66 lbs) (Odell 1981). The nostrils, located on the upper snout, open and close by means of muscular valves as the animals surface and dive (Husar 1977; Hartman 1979). A muscular flexible upper lip is used with the forelimbs to manipulate food into the mouth (Odell 1982). Bristles are located on the upper and lower lip pads. Molars designed to crush vegetation form continuously at the back of the jaw and move forward as older ones wear down (Domning and Hayek 1986). The eyes are very small, close with sphincter action, and are equipped with inner membranes that can be drawn across the eyeball for protection. Externally, the ears are minute with no pinnae. Internally, the ear structure suggests that they can hear sound within a relatively narrow low frequency range, that their hearing is not acute, and that they have difficulty in localizing sound (Ketten *et al*. 1992). This indirect "structured" evidence is not entirely concordant with actual electro physiological measurements. Gerstein (1995) suggested that manatees may have a greater low-frequency sensitivity than the other marine mammal species that have been tested.

Figure 2. Mother manatee nursing a calf. (*Photograph by G. Rathbun*)

C. POPULATION BIOLOGY

Information on manatee population biology was reviewed during a technical workshop held in February 1992 (O'Shea *et al.* 1992). The objectives of the workshop were to synthesize existing information, evaluate the strengths and weaknesses of current data sets and research methods, and make recommendations for future research, particularly for constructing new population models (O'Shea *et al*. 1995). The population and life history information published in the workshop proceedings suggests that the potential long-term viability of the Florida manatee population is good, provided that strong efforts are continued to curtail mortality, ensure warm-water refuges are protected, maintain and improve habitat quality, and offset potential catastrophes (Lefebvre and O'Shea 1995).

The value of maintaining long-term databases was emphasized in the 1992 workshop. The collection of manatee reproduction, sighting history, life history, carcass salvage, and aerial survey data has continued, and improved techniques for estimating trends in important population characteristics have been developed.

Such measures include estimation of adult manatee survival (probabilities based on photo-identification) (Langtimm *et al*. 1998), determination of population trends from aerial survey data (Craig *et al*. 1997; Eberhardt *et al*. 1999), and development of population models (Eberhardt and O'Shea 1995). Population modeling will be an ongoing process that evolves as databases and modeling tools improve.

POPULATION SIZE Despite considerable effort in the early 1980s, scientists have been unable to develop a useful means of estimating or monitoring trends in the size of the overall manatee population in the southeastern United States (O'Shea 1988; O'Shea *et al*. 1992; Lefebvre *et al.* 1995). Even though many manatees aggregate at warm-water refuges in winter (Fig. 3) and most if not all such refuges are known, direct counting methods (i.e., by aerial and ground surveys) have been unable to account for uncertainty in the number of animals that may be away from these refuges at any given time, the number of animals which are not seen because of turbid water, and other factors. The use of mark-resighting techniques to estimate manatee population size based on known animals in the manatee photo identification database also has been impractical, as the proportion of unmarked manatees cannot be estimated.

Figure 3. Manatee aggregated during a winter cold front at a power plant warm-water outfall in Titusville, Florida. (*Photograph by B. Bonde*)

The only data on population size have been uncalibrated indices based on maximum counts of animals at winter refuges made within one or two days of each other. Based on such information in the late 1980s, the total number of manatees throughout Florida was known to be at least 1,200 animals (Reynolds and Wilcox 1987). Because aerial and ground counts at winter refuges are highly variable depending on the weather, water clarity, manatee behavior, and other factors (Packard *et al.* 1985; Lefebvre *et al*. 1995), interpretation of analyses for temporal trends is difficult (Packard and Mulholland 1983; Garrott *et al*. 1994). Strip-transect aerial surveys are used routinely to estimate dugong population size and trends (Marsh and Sinclair 1989); however, they are difficult to adapt to manatees because of the species' much more linear (coastal and riverine) distribution. This survey method was tested in the Banana River, Brevard County, and recommended for use in that area to monitor manatee population trends (Miller *et al*. 1998). This approach may also have utility in the Ten Thousand Islands-Everglades area.

Beginning in 1991, the former Florida Department of Natural Resources (FDNR) initiated a statewide aerial survey program to count manatees in potential winter habitat during periods of severe cold weather (Ackerman 1995). These surveys are much more comprehensive than those used to estimate a minimum population during the 1980s. The highest two-day minimum count of manatees from these winter synoptic aerial surveys and ground counts is 3,276 manatees in January 2001 (Fig. 4); the highest east coast of Florida count is 1,756 and highest on the west coast is 1,520, both in 2001. It remains unknown what proportions of the total manatee population were counted in these surveys. No statewide surveys were done during the winters of 1992-93 or 1993-94 because of the lack of strong mid-winter cold fronts. These uncorrected counts do not provide a basis for assessing population trends. However, trend analyses of temperature-adjusted aerial survey counts show promise for providing insight to general patterns of population growth in some regions (Garrott *et al*. 1994, 1995; Craig *et al.* 1997; Eberhardt *et al.* 1999).

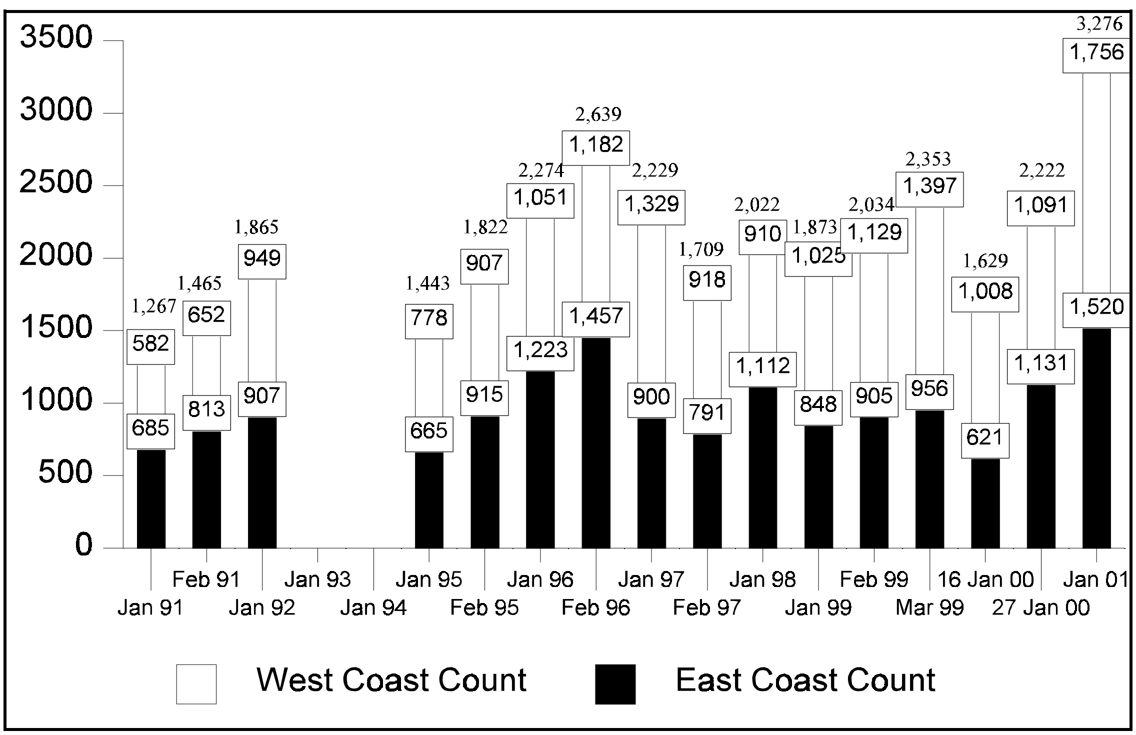


Figure 4. Manatee synoptic survey total, West coast, and East coast counts, 1991-2001 (FWC, unpublished data).

On a more limited basis, it has been possible to monitor the number of manatees using the Blue Spring and Crystal River warm-water refuges. At Blue Spring, with its unique combination of clear water and a confined spring area, it has been possible to count the number of resident animals by identifying individual manatees from scar patterns. The data indicate that this group of animals has increased steadily since the early 1970s when it was first studied. During the 1970s the number of manatees using the spring increased from 11 to 25 (Bengtson 1981). In the mid-1980s about 50 manatees used the spring (Beeler and O'Shea 1988), and in the winter of 1999-2000, the number increased to 147 (Hartley 2001).

On the west coast of Florida, the clear, shallow waters of Kings Bay have made it possible to monitor the number of manatees using the warm-water refuge in Kings Bay at the head of the Crystal River. Large aggregations of manatees apparently did not exist there until recent times (Beeler and O'Shea 1988). The first careful counts were made in the late 1960s. Since then manatee numbers have increased significantly. In 1967 to 1968, Hartman (1979) counted 38 animals in Kings Bay. By 1981 to 1982, the maximum winter count increased to 114 manatees (Powell and Rathbun 1984) and in December 1997, the maximum count was 284 (Buckingham *et al.* 1999). Both births and immigration of animals from other areas have contributed to the increases in manatee numbers at Crystal River and Blue Spring. Three manatee sanctuaries in Kings Bay were established in 1980, an additional three were added in 1994, and a seventh in 1998. The increases in counts at Blue Spring and Crystal River are accompanied by estimates of adult survival and population growth that are higher than those determined for the Atlantic coast (Eberhardt and O'Shea 1995; Langtimm *et al.* 1998; Eberhardt *et al.* 1999).

OPTIMUM SUSTAINABLE POPULATION The MMPA defines the term "optimum sustainable population" (OSP) for any population stock to mean "the number of animals which will result in the maximum productivity of the population or species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element." By regulation (50 CFR 216.3), the OSP is further defined as a range of population sizes between the maximum net productivity level (MNPL) and the carrying capacity (K) of the environment, under conditions of no harvest. The MNPL is defined as the population level producing "the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality."

Pursuant to the MMPA, stocks are to be maintained within their OSP ranges. Just as we are uncertain of the Florida manatee's population size and trend, we are uncertain whether the population is currently below or within its OSP level. Even in the regions where population growth has been documented (Northwest and Upper St. Johns River), we do not know if maximum productivity has yet been achieved.

The MNPL has been estimated only for a few marine mammal species, and is generally treated as a percentage of carrying capacity. Carrying capacity varies over time and space, and is likely to be artificially reduced by a growing human population. Loss of artificial and natural warm-water refuges, for example, could greatly reduce the winter carrying capacity of habitats north of the Sebastian River on the Atlantic coast and the Caloosahatchee River on the Gulf coast. The Recovery Team recognizes the importance of conserving important manatee habitat, and emphasizes the need for sufficient quantity and quality of habitat within each region of the Florida manatee's range to permit sustained manatee population growth from current population levels. Key habitat types include those that are used for the following essential manatee activities: (1) thermoregulation at warm-water refuges; (2) feeding, reproduction and shelter; and (3) travel and migration.

DETERMINATION OF POPULATION STATUS The quality of the long-term database of scarred manatees "captured" by photography (Fig. 5) at winter-aggregation sites, combined with advances in mark-recapture (resighting) statistical models and computer programs, has allowed statistically valid estimates of adult manatee survival rates (Pollock *et al.* 1990; Lebreton *et al.* 1992; Pradel and Lebreton 1993, cited in Langtimm *et al*. 1998; Langtimm *et al.* 1998; White and Burnham 1999). Additional models have been developed that will allow estimation of the proportion of females with calves (Nichols *et al.* 1994). These statistical techniques allow the examination of vital rate variation over time or in association with specific environmental factors. They provide "Goodness-of-Fit" tests of the data to the models to assess bias in the estimates, and provide confidence intervals to assess the precision of the estimates. The application of these techniques to the manatee photo-identification (photo-ID) data provides statistical robustness (Langtimm *et al.* 1998) that has not yet been achieved with trend analyses of aerial survey data (Lefebvre *et al.* 1995; Eberhardt *et al.* 1999) or carcass recovery data (Ackerman *et al.* 1995). Furthermore, population size changes only after there has been a change in survival and/or reproductive rates (or emigration/immigration). Thus, directly monitoring survival and reproduction rates can provide immediate information on probable trends in abundance and gives managers specific information that can help them design realistic plans to achieve species recovery, reclassification, and eventual removal from the List of Endangered and Threatened Wildlife.

The previous recovery plan (FWS 1996) identified the need for a population status working group to assess manatee population size and trends. The first meeting of the Manatee Population Status Working Group (MPSWG), a subcommittee of the Recovery Team, was held in March 1998. The goals of the MPSWG are to: (1) assess the status of the Florida manatee population; (2) advise FWS on population recovery criteria for determining when recovery has been achieved (see Appendix A); (3) provide interpretation of available information on manatee population biology to managers; (4) make recommendations concerning needed research directions and methods; and (5) obtain rigorous external review of manatee population data, conclusions, and research methods by independent researchers with expertise in population biology. The Manatee Population Ecology and Management Workshop, scheduled for April 2002, is a forum that will address these goals and will specifically include a panel of independent experts to review research progress and to make recommendations on how to improve integration of population models with management.

Figure 5. Catalogued female Florida manatee SB 79 was first documented on May 1, 1993 with a large calf (not shown on left). Documented with her third calf (right) on August 15, 1997. These photographs illustrate how injuries/scars appear to change as they heal or as they are altered by new features. This individual uses the Ft. Myers/Charlotte Harbor area during the winter and Sarasota Bay during the warmer months. Estimated to be at least 13 years old, she has given birth to calves in 1992, 1994, 1997, and 2000. (*Photographs by J. Koelsch*)

In order to develop quantitative recovery criteria, the MPSWG reviewed the best available published information on manatee population trends, and determined that analysis of status and trends by region would be appropriate. Based on the highest minimum winter counts for each region between 1996 and 1999 (Fig. 4 and Fig. 6), the number of manatees on the east and west coasts of Florida appears to be approximately equal. Within both the east and west coast segments of the Florida manatee population, documented movements suggest that at least some loosely formed subpopulations exist, which may constitute useful management units. Four subgroups were identified, which tend to return to the same warm-water refuge(s) each winter (Fig. 1) and have similar non-winter distribution patterns. For example, on the east coast, a core group of more than 100 manatees use the Blue Spring warm-water refuge in the upper St. Johns River. Radio-tracking studies (Bengtson 1981) and other information (Beeler and O'Shea 1988; Marine Mammal Commission 1988) suggest that most manatees wintering at Blue Spring tend to remain in the area identified as the **Upper St. Johns River Region** (Fig. 1). The lower St. Johns River, the east coast, and the Florida Keys are considered to represent the **Atlantic Region** (Fig. 1), based on the results of long-term radio tracking and photo-ID studies (Beck and Reid 1995; Reid *et al.* 1995; Deutsch *et al.* 1998).

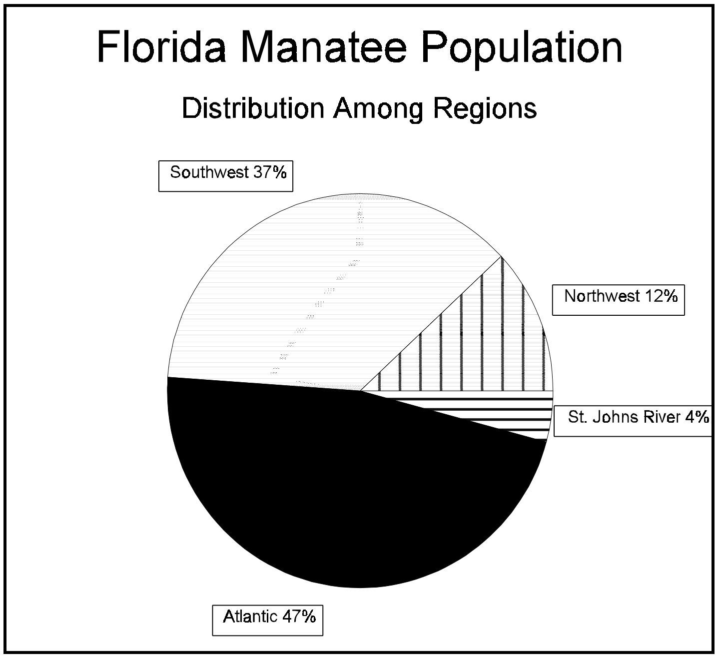


Figure 6. Florida manatee population distribution among regions. Percentage estimates are based upon highest minimum winter counts for each region between 1996 and 2000 (FWC, unpublished data).

On the west coast, Rathbun *et al.* (1995) reported that of 269 recognizable manatees identified at the Kings Bay and Homosassa River warm-water refuges in northwest Florida between 1978 and 1991, 93% of the females and 87% of the males returned to the same refuge each year. Radio-tracking results suggest that many animals wintering at Crystal River disperse north in warm seasons to rivers along the Big Bend coast, particularly the Suwannee River (Rathbun *et al.* 1990). This area is designated as the **Northwest Region** (Fig. 1). The existence of more or less distinct subgroups in the southwestern half of Florida (i.e., from Tampa Bay south) is debatable. It is possible that manatees using warm-water refuges in Tampa Bay, the Caloosahatchee River, and Collier County may be somewhat discrete groups; however, given available data, the Recovery Team chose to identify them as one group, the **Southwest Region** (Fig. 1).

Determination of manatee population status is based upon research described in Objective 2 and Appendix B. Table 2 provides regional status summaries and includes an overview of current status, habitat concerns, carcass recovery and cause of death data, and reproduction, survival, and population growth estimates for each region, if available. Cause of death data are summarized for each region in Appendix C to provide an overview on causes of death for: (1) all age classes; and (2) for adults only. Modeling has shown that manatee population trends are most sensitive to changes in adult survival rates (Eberhardt and O'Shea 1995; Marmontel *et al.* 1997; Langtimm *et al.* 1998).

Table 2. Florida manatee population status summaries by region. Data from the Northwest, Upper St. Johns River and Atlantic Regions were based upon survival rates from Langtimm et al. (1998) and population growth estimates from Eberhardt and O'Shea (1995).

		Northwest Primarily NW peninsular FL	**Southwest** Tampa Bay to Whitewater Bay	**Upper St. Johns** Upstream, South of Palatka	**Atlantic** GA - Miami & lower St. Johns
Photo-identification-based estimates	Adult Survival (% per year)	96.5 (95.1-97.5)	Survival, reproductive and population growth rate estimates based on resightings of known individuals are not currently available.	96.1 (90.0-98.5)	90.7 (88.7-92.6)
	Population Growth Rate (% per year)	7.4		5.7 (3-8)	1.0
	Reproduction: Percent adult females with calf	43% ± 9%		41%	42%
	Percent adult females with 1st year calf	36% ± 6%		30%	39%
	Mean interbirth interval	2.5 ± 0.77		2.6 ± 0.81 winter seasons	2.6 ± 0.64 winter seasons
	Mean calf dependency period	1.2 ± 0.42		1.3 ± 0.48 winter seasons	1.2 ± 0.42 winter seasons
	Mean age females at first reproduction	5.1 ± 1.21 years		5.4 ± 0.98 years	- - -
Causes of death based on carcass recovery	1980 - 1999 Overview	• Total of 153 carcasses • All causes, increasing 5.5% per year • Watercraft-related, increasing 10.8% per year	• Total of 1,358 carcasses • All causes increasing 4.8% per year • Watercraft-related, increasing 7.1% per year	• Total of 79 carcasses • All causes, increasing 2.6% per year • Watercraft-related, increasing 1.6% per year	• Total of 1,659 carcasses • All causes, increasing 6.9% per year • Watercraft-related, increasing 5.5% per year
	1989 - 1999 More recent trends	• Average of 8.9 per year (range = 6-12) • Human related cause of death 30% (adults 40%)	• Average of 85.5 per year (range = 57-134) • 281 in 1996 (including 145 red tide related deaths) • Human related cause of death 30% (adults 48%)	• Average of 4.5 per year (range = 2-7) • Human related cause of death 43% (adults 62%)	• Average of 107 per year (range = 70-135) • 206 in 1990 (46 cold-related) • Human related cause of death 34% (adults 57%)
Habitat Related Concerns		• Spring flow rates • Water quality and SAV • Storm-related salinity fluctuations, resulting in vegetation declines • Storm-related impacts on adult survival • Human disturbance at warm-water springs • Potential conflict between weed control and manatee food supply • Papilloma virus implications unknown	• Manatee dependence on power plants as thermal refuges • Increasing boat traffic • Periodic red tide-related deaths • Moderate level of water control structure deaths • Water quality and SAV • Salinity fluctuations, resulting in vegetation declines • Storm-related impacts on adult survival • Human disturbance	• Spring flow rates • Increasing boat traffic • Water quality and SAV • Low to moderate level of water control structure deaths • Potential conflict between weed control and manatee food supply	• Manatee dependence on power plants as thermal refuges • Increasing boat traffic • ICW shared manatee-human travel corridor • High level of water control structure deaths, especially in SE • Water quality and SAV • Salinity fluctuations, resulting in vegetation declines • Storm-related impacts on adult survival • Human disturbance
Current Status		• Exceeds survival, reproduction, and population growth criteria • Although overall deaths are relatively low, watercraft-related deaths are increasing rapidly	• Estimates of survival and population growth not yet available; reproduction criterion has been exceeded for group that summers in Sarasota Bay • Overall deaths are high, watercraft-related deaths are increasing rapidly	• Meets or exceeds survival, reproduction, and population growth criteria • Overall deaths are moderate, watercraft-related deaths increasing slowly	• Meets reproduction criterion; may meet survival and population growth criteria • Overall deaths are high, watercraft-related deaths increasing moderately

CURRENT STATUS Two goals of the MPSWG are to assess the status of the Florida manatee population and provide interpretation of available information on manatee population biology to managers. The MPSWG developed a status statement (Appendix D) for these purposes, and through Recovery Task 2.1 will update this statement annually.

The **Northwest** and **Upper St. Johns River Regions** have survival and reproduction rates that are adequate to sustain population growth (Eberhardt and O'Shea 1995). The adult survival rates are estimated at 96.5% and 96.1% respectively (Table 2). These two regions represent only 16% of the manatees documented in the last three years (Fig. 6). Collection of comparable life history data for the **Southwest Region** only began in 1995 and was not adequate for these survival estimates. This region represents 37% of the population. The health of the population in the **Atlantic Region**, which represents almost one-half of the entire population, is less certain, and the confidence interval surrounding a 90.7% adult survival rate suggests a cause for concern as it drops below 90.0% (Langtimm *et al*. 1998). These statements about the regions are based on data collected from 1977 to 1993 and thus may not reflect the current status of the population. Additionally, the recent increase in the percentage of watercraft-related deaths as a proportion of the total mortality and the effects this will have on adult survival rates is uncertain. Regional demographic estimates are currently being updated for the Manatee Population Ecology and Management Workshop in April 2002.

The near and long term threats from human-related activities are the reasons for which the Florida manatee currently necessitates protection under the ESA. The focus of recovery is not on how many manatees exist, but instead the focus is on implementing, monitoring and addressing the effectiveness of conservation measures to reduce or remove threats which will lead to a healthy and self-sustaining population. The Florida manatee could be considered for reclassification from endangered to threatened provided that threats can be reduced or removed, and that the population trend is stable or increasing for a sufficient time period.

D. DISTRIBUTION AND HABITAT USE PATTERNS

Based on telemetry, aerial surveys, photo identification sighting records, and other studies over the past 20 years, manatee distribution in the southeastern United States is now well known (Marine Mammal Commission 1984, 1986; Beeler and O'Shea 1988; O'Shea 1988; Lefebvre *et al.* 2001). In general, the data show that manatees exhibit opportunistic, as well as predictable patterns in their distribution and movement. They are able to undertake extensive north-south migrations with seasonal distribution determined by water temperature.

When ambient water temperatures drop below 20° C (68°F) in autumn and winter, manatees aggregate within the confines of natural and artificial warm-water refuges (Fig. 7, Lefebvre *et al.* 2001) or move to the southern tip of Florida (Snow 1991). Most artificial refuges are created by warm-water outfalls from power plants or paper mills. The largest winter aggregations (maximum count of 100 or more animals) are at refuges in Central and Southern Florida (Fig. 7). The northernmost natural warm-water refuge used regularly on the west coast is at Crystal River and at Blue Springs in the St. Johns River on the east coast. Most manatees return to the same warm-water refuges each year; however, some use different refuges in different years and others use two or more refuges in the same winter (Reid and Rathbun 1984, 1986; Rathbun *et al.* 1990; Reid *et al.* 1991; Reid *et al.* 1995). Many lesser known, minor aggregation sites are used as temporary thermal refuges. Most of these refuges are canals or boat basins where warmer water temperatures persist as temperatures in adjacent bays and rivers decline.

During mild winter periods, manatees at thermal refuges move to nearby grassbeds to feed, or even return to a more distant warm season range (Deutsch *et al.* 2000). For example, manatees using the Riviera Power Plant feed in adjacent Lake Worth and in Jupiter and Hobe Sounds, 19 to 24 km (12 to 15 mi) to the north (Packard 1981); animals using the Port Everglades power plant feed in grass beds in Biscayne Bay 24 to 32 km (15 to 20 mi) to the south (Marine Mammal Commission 1988); animals in Kings Bay feed on submerged aquatic vegetation along the mouth of the Crystal River (Rathbun *et al.* 1990); animals at Blue Spring leave the spring run to feed on freshwater aquatic plants along the St. Johns River and associated waters near the spring (Bengtson 1981; Marine Mammal Commission 1986).

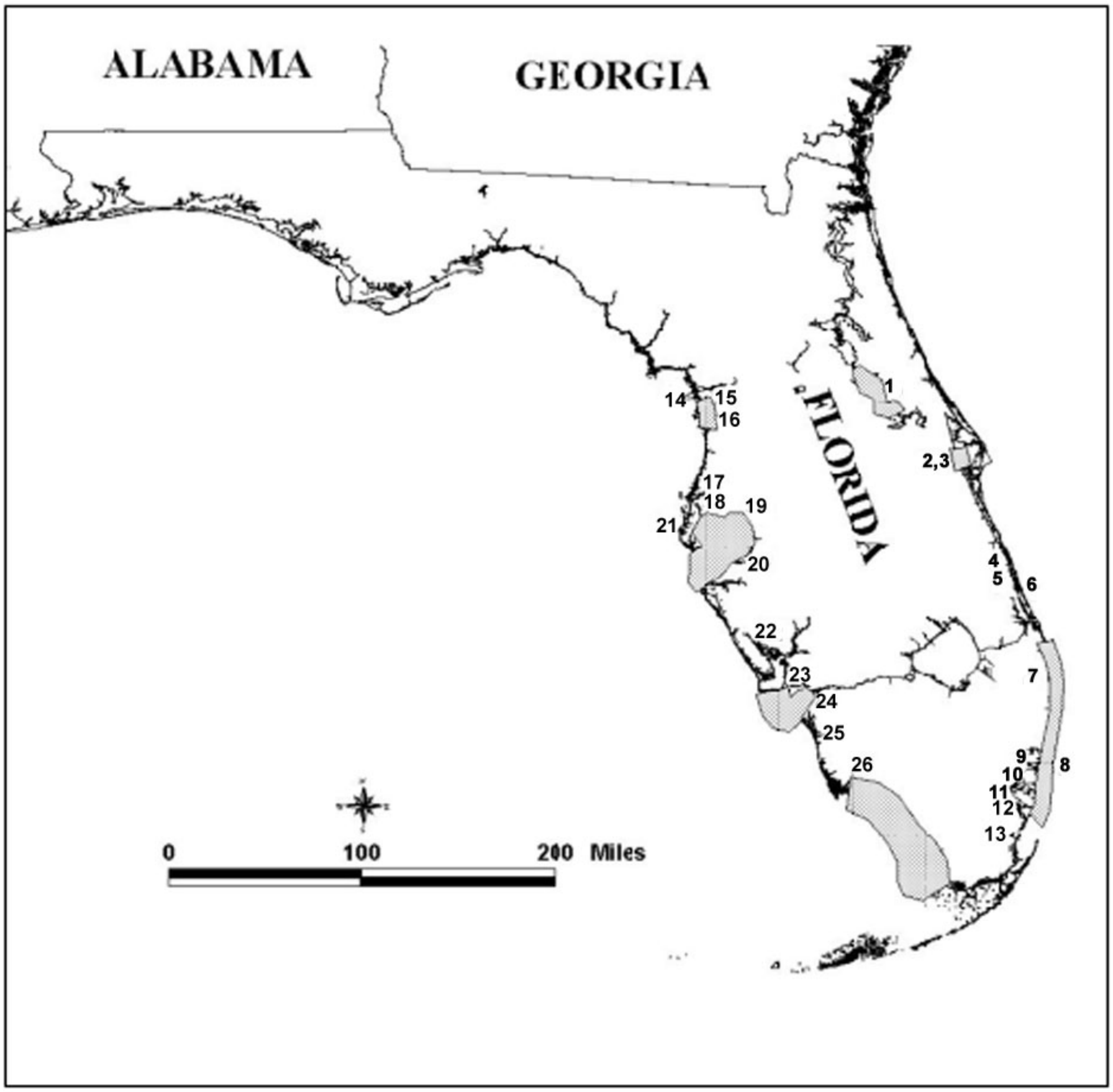


Figure 7. General winter distribution and warm-water manatee aggregation sites in the southeastern United States. Key with name of location and status of refuge is on the following page.

Key to Figure 7. Winter Aggregation Sites (based on Table 1, FWS 1996)

	❶ =	commonly have aggregations of 100 or more manatees
	❷ =	commonly have aggregations of 25 to 100 manatees
	❸ =	aggregations of less than 25 manatees
EAST COAST	(1)	❶Blue Spring (Volusia County, FL)
	(2)	❶Reliant Energy Power Plant (Brevard County, FL)
	(3)	❶FPL Canaveral Power Plant (Brevard County, FL)
	(4)	❷Sebastian River (Brevard County, FL)
	(5)	❷Vero Beach Power Plant (Indian River County, FL)
	(6)	❷Henry D. King Electric Station (St. Lucie County, FL)
	(7)	❶FPL Riviera Beach Power Plant (Palm Beach County, FL)
	(8)	❶FPL Port Everglades Power Plant (Broward County, FL)
	(9)	❶FPL Fort Lauderdale Power Plant (Broward County, FL)
	(10)	❷Little River (Dade County, FL)
	(11)	❷Coral Gables Waterway (Dade County, FL)
	(12)	❷ Palmer Lake (Dade County, FL)
	(13)	❸Black Creek Canal (Dade County, FL)
WEST COAST	(14)	❷FPC Crystal River Power Plant (Citrus County, FL)
	(15)	❶Crystal River (Citrus County, FL)
	(16)	❶Homosassa River (Citrus County, FL)
	(17)	❸Weeki Watchee/Mud/Jenkins Creek Springs (Hernando County, FL)
	(18)	❸FPC Anclote Plant (Pasco County, FL)
	(19)	❷TECO Port Sutton Plant (Hillsborough County, FL)
	(20)	❶TECO Big Bend Power Plant (Hillsborough County, FL)
	(21)	❷FPC Bartow Power Plant (Pinellas County, FL)
	(22)	❷Warm Mineral Springs (Sarasota County, FL)
	(23)	❷Matlacha Isles (Lee County, FL)
	(24)	❶FPL Fort Myers Power Plant (Lee County, FL)
	(25)	❷Ten Mile Canal Borrow Pit (Lee County, FL)
	(26)	❶Port of the Islands (Collier County, FL)
Abbreviations:	FPC	Florida Power Corporation
	FPL	Florida Power & Light Company
	TECO	Tampa Electric Company

As water temperatures rise manatees disperse from winter aggregation areas. While some remain near their winter refuges, others undertake extensive travels along the coast and far up rivers and canals. On the east coast, summer sightings drop off rapidly north of Georgia (Lefebvre *et al.* 2001) and are rare north of Cape Hatteras (Rathbun *et al.* 1982; Schwartz 1995); the northernmost sighting is from Rhode Island (Reid 1996). On the west coast, sightings drop off sharply west of the Suwannee River in Florida (Marine Mammal Commission 1986), although a small number of animals, about 12 to 15 manatees, are seen each summer in the Wakulla River at the base of the Florida Panhandle. Rare sightings also have been made in the Dry Tortugas (Reynolds and Ferguson 1984) and the Bahamas (Lefebvre *et al*. 2001; Odell *et al.* 1978).

In recent years, the most important spring habitat along the east coast of Florida has been the northern Banana River and Indian River Lagoon and their associated waters in Brevard County; more than 300 to 500 manatees have been counted in this area shortly before dispersing in late spring (Provancha and Provancha 1988; FWC, unpublished data). A comparable spring aggregation area does not appear to exist on the west coast, although Charlotte Harbor was visited in the spring by almost half of the 35 manatees radio-tagged at the Fort Myers power plant in Lee County (Lefebvre and Frohlich 1986). During summer, manatees may be commonly found almost anywhere in Florida where water depths and access channels are greater than 1 to 2 m (3.3 to 6.6 ft) (O'Shea 1988). Manatees can be found in very shallow water. Hartman (1979) observed manatees utilizing waters as shallow as 0.4 m with their backs out of the water. In warm seasons they usually occur alone or in pairs, although interacting groups of five to ten animals are not unusual.

Shallow grass beds with ready access to deep channels are preferred feeding areas in coastal and riverine habitats. Manatees often use secluded canals, creeks, embayments, and lagoons, particularly near the mouths of coastal rivers and sloughs, for feeding, resting, cavorting, mating, and calving (Marine Mammal Commission 1986, 1988). In estuarine and brackish areas, natural and artificial fresh water sources are sought by manatees. As in winter, manatees often use the same summer habitats year after year (Reid *et al.* 1991; Koelsch 1997).

E. BEHAVIOR AND PHYSIOLOGY

The first comprehensive study of manatee behavior was conducted in the late 1960s at Crystal River by Hartman (1979). This study attempted, among other things, to develop an ethogram for the species, and despite a number of additional studies that have been done since, Hartman's work stands today as the best source of information on certain aspects of manatee behavior, such as locomotion, breathing, resting, and socializing.

Other aspects of manatee behavioral ecology have been clarified during the last 20 years of manatee research. Migration corridors and responses by individual animals have been elaborated by long-term telemetry studies initiated by scientists at U.S. Geological Survey, Sirenia Lab (USGS-Sirenia) and the Florida Fish and Wildlife Conservation Commission (FWC) Florida Marine Research Institute (FMRI). Scientists have demonstrated site-fidelity in manatees, but have also noted that individual animals adjust their behaviors to take advantage of protected areas or changes in availability of resources. For example, Buckingham *et al.* (1999) confirmed increased manatee use of selected sanctuary areas during times when surrounding disturbance by boats was high. Reynolds and Wilcox (1994) continued to document the extent that manatees seek warm water at power plant discharges in winter (Fig. 8), taking advantage of the tendency by the manatees to aggregate around warm-water refuges in winter. Packard (1981, 1984), Lefebvre and Powell (1990), Rathbun *et al.* (1990) and Zoodsma (1991) described feeding and feeding ecology of manatees aggregated at natural or artificial warm-water refuges in winter, and additional studies further elaborated aspects of feeding behavior and ecological consequences thereof. Studies of foraging ecology were complemented by analyses of gut contents (e.g., Ledder 1986) and assessments of the functional morphology of the gastrointestinal tract (Reynolds and Rommel 1996).

Figure 8. Manatee aggregation at power plant warm-water outfall in Titusville, Florida. (*Photograph by T. O'Shea*)

Descriptions of behaviors have been followed or paralleled by studies that address how and why questions. Perhaps the most obvious questions center around why manatees need to seek warm-water refuges in winter. Gallivan and Best (1980) and Irvine (1983) documented the surprisingly low metabolism of manatees, and scientists suggested that water temperatures below 19° C triggered manatee behavioral changes, such as movements to warm-water sources. Recent research suggests that the temperature eliciting metabolic and behavioral changes in manatees is closer to 17° C, but upper and lower critical temperatures for manatees (the points at which they become metabolically stressed) remain unclear (Worthy *et al.* 1999). It is also unclear, but vital to understand, how manatees would react physiologically and behaviorally to reductions, cessations, or other changes in availability of warm water in winter.

Scientists have noted that manatees seek freshwater sources to drink. Hill and Reynolds (1989) suggested that the structure of the manatee kidney should permit the animals to survive well without regular access to freshwater. In other words, fresh water may be an attractant, without being required for survival, by manatees. Although manatees can tolerate a wide range of salinities (Ortiz *et al.* 1998), they prefer habitats where osmotic stress is minimal or where fresh water is periodically available (O'Shea and Kochman 1990). Ortiz *et al*. (1998) report that "manatees may be susceptible to dehydration after an extended period if freshwater is not available."

A number of research projects have considered manatee sensory capabilities, in part to attempt to comprehend how manatees perceive their environment, including aspects of the environment that are harmful to manatees, such as high-speed watercraft. Behavioral observation studies (e.g., Hartman 1979; Wells *et al*. 1999), and anatomical studies (e.g., Ketten *et al*. 1992) and psychoacoustic research that produced an audiogram for the manatee (Gerstein *et al.* 1999) have all addressed manatee hearing capabilities and the watercraft/manatee issue. These studies have not produced a complete understanding of manatee acoustics.

Other studies that have assessed other sensory capabilities, neuroanatomy, or fine motor coordination include: (1) Cohen *et al.* 1982 (photo receptors and retinal function); (2) Griebel and Schmid 1996 (color vision); (3) Griebel and Schmid 1997 (brightness discrimination); (4) Marshall *et al.*1998a (use of perioral bristles in feeding); (5) Marshall *et al.* 1998b (presence of a muscular hydrostat to facilitate bristle use); (6) Marshall and Reep 1995 (structure of the cerebral cortex); (7) Mass *et al.* 1997 (ganglion layer topography and retinal resolution); (8) O'Shea and Reep 1990 (extent of encephalization); (9) Reep *et al.* 1998 (distribution and innervation of facial bristles and hairs)and (10) Bowles *et al.* 2001(studies of response to novelty). Questions still remain regarding chemosensory ability of manatees, and clarification is needed regarding acoustics and the functional morphology of non-cerebral cortex regions of the brain.

The outcome of research into behavior, general physiology and sensory biology is that these aspects of manatee biology are better understood than is the case for most marine mammals. Due to long-term and diverse research efforts, scientists understand a great deal and continue to learn more about manatee habitat utilization, general behavior patterns, and life history attributes. Science and management would benefit from a carefully structured approach to answering, or providing higher resolution answers to questions associated with thermoregulation and thermal requirements of manatees and aspects of psychoacoustics and perceptual psychology (e.g., what they hear and how they respond to high levels of anthropogenic noise).

A comprehensive description of manatee behavior appears in Wells *et al.* (1999). This chapter provides synopses of the following topics: diving behavior, predation, foraging, thermoregulation and thermally-induced movements, resource aggregations, mating, rearing patterns, communication, and social organization. Sensory and general physiology of manatees are reviewed by Wartzok and Ketten (1999) and Elsner (1999), respectively. Reynolds and Powell (in press) provide a brief overview of manatee biology and conservation, including synopses of behavioral and physiological attributes.

F. FEEDING ECOLOGY

Manatees are herbivores that feed opportunistically on a wide variety of submerged, floating, and emergent vegetation. Because of their broad distribution and migratory patterns, Florida manatees utilize a wider diversity of food items and are possibly less specialized in their feeding strategies than manatees in tropical regions (Lefebvre *et al.* 2000).

Feeding rates and food preferences depend, in part, on the season and available plant species. Bengtson (1981, 1983) reported that the time manatees spent feeding in the upper St. Johns River was greatest (6 to 7 hrs/day) before winter (August to November), least (3 to 4 hrs/day) in spring and summer (April to July), and intermediate (about 5 hrs/day) in winter (January to March). He estimated annual mean consumption rates at 33.2 kg/day/manatee or about 4 to 9% of their body weight per day depending on season (Bengtson 1983). At Crystal River, Etheridge *et al.* (1985) reported cumulative daily winter feeding times from 0 to 6 hrs. 10 min. based on observations of three radio-tagged animals over seven 24-hour periods. The estimated daily consumption rates by adults, juveniles, and calves eating hydrilla (*Hydrilla verticillata*) were 7.1, 9.6, and 15.7% of body weight per day, respectively.

Seagrasses appear to be a staple of the manatee diet in coastal areas (Ledder 1986; Provancha and Hall 1991; Kadel and Patton 1992; Koelsch 1997; Lefebvre *et al.* 2000). Packard (1984) noted two feeding methods in coastal seagrass beds: (1) rooting, where virtually the entire plant is consumed; and (2) grazing, where exposed grass blades are eaten without disturbing the roots or sediment. Manatees may return to specific seagrass beds to graze on new growth (Koelsch 1997; Lefebvre *et al.* 2000).

In the upper Banana River, Provancha and Hall (1991) found spring concentrations of manatees grazing in beds dominated by manatee grass (*Syringodium filiforme*). They also reported an apparent preference for manatee grass and shoalgrass (*Halodule wrightii*) over the macroalga *Caulerpa* spp. Along the Florida-Georgia border, manatees feed in salt marshes on smooth cordgrass (*Spartina alterniflora*) by timing feeding periods with high tide (Baugh *et al*. 1989; Zoodsma 1991).

G. REPRODUCTION

Breeding takes place when one or more males (ranging from 5 to 22) are attracted to an estrous female to form an ephemeral mating herd (Rathbun *et al*. 1995). Mating herds can last up to 4 weeks, with different males joining and leaving the herd daily (Hartman 1979; Bengtson 1981; Rathbun *et al*. 1995. Cited in Rathbun 1999). Permanent bonds between males and females do not form. During peak activity, the males in mating herds compete intensely for access to the female (Fig. 9; Hartman 1979). Successive copulations involving different males have been reported. Some observations suggest that larger, presumably older, males dominate access to females early in the formation of mating herds and are responsible for most pregnancies (Rathbun *et al.* 1995), but males as young as three years old are spermatogenic (Hernandez *et al.* 1995). Although breeding has been reported in all seasons, Hernandez *et al.* (1995) reported that histological studies of reproductive organs from carcasses of males found evidence of sperm production in 94% of adult males recovered from March through November. Only 20% of adult males recovered from December through February showed similar production.

Figure 9. Mating herd in Plummers Cove, St. Johns River, Jacksonville, Florida. (*Photograph by B. Brooks*)

Females appear to reach sexual maturity by about age five but have given birth as early as four (Marmontel 1995; Odell *et al.* 1995; O'Shea and Hartley 1995; Rathbun *et al.* 1995), and males may reach sexual maturity at 3 to 4 years of age (Hernandez *et al.* 1995). Manatees may live in excess of 50 years (Marmontel 1995), and evidence for reproductive senescence is unclear (Marmontel 1995; Rathbun *et al.* 1995). Catalogued Florida manatee CR 28, a wild manatee that overwinters in Crystal River, was last documented with a calf in 1998, at which time she was estimated to be at least 34 years of age (USGS-Sirenia, unpublished data). A captive animal, MSTm-5801, gave birth to a calf in 1990, at which time she was estimated to be 43 to 48 years of age (FWS, unpublished data). The length of the gestation period is uncertain but is thought to be between 11 and 14 months (Odell *et al.* 1995; Rathbun *et al.* 1995; Reid *et al.* 1995). The normal litter size is one, with twins reported rarely (Marmontel 1995; Odell *et al.* 1995; O'Shea and Hartley 1995; Rathbun *et al.* 1995).

Calf dependency usually lasts one to two years after birth (Hartman 1979; O'Shea and Hartley 1995; Rathbun *et al.* 1995; Reid *et al.* 1995). Calving intervals vary greatly among individuals. They are probably often less than 2 to 2.5 years, but may be considerably longer depending on age and perhaps other factors (Marmontel 1995; Odell *et al.* 1995; Rathbun *et al.* 1995; Reid *et al.* 1995). Females that abort or lose a calf due to perinatal death may become pregnant again within a few months (Odell *et al.* 1995), or even weeks (Hartman 1979).

H. THREATS TO THE SPECIES

The most significant problem presently faced by manatees in Florida is death or serious injury from boat strikes. The availability of warm-water refuges for manatees is uncertain if minimum flows and levels are not established for the natural springs on which many manatees depend, and as deregulation of the power industry in Florida occurs. Consequences of an increasing human population and intensive coastal development are long-term threats to the Florida manatee. Their survival will depend on maintaining the integrity of ecosystems and habitat sufficient to support a viable manatee population.

CAUSES OF DEATH (A summary of Cause of Death by region can be found in Appendix C). Data on manatee deaths in the southeastern United States have been collected since 1974 (O'Shea *et al.* 1985; Ackerman *et al.* 1995; FWC, unpublished data). Data since 1976 were used in the following summary (Table 3), as carcass collection efforts were more consistent following that year. They indicate a clear increase in manatee deaths over the last 25 years (Fig. 10, 6.0 % per year exponential regression between 1976 and 2000; Ackerman *et al.* 1995; FWC, unpublished data). Most of the increase can be attributed to increases in watercraft-related and perinatal deaths (Marine Mammal Commission 1993). However, it is unclear whether this represents a proportional increase relative to the overall population of manatees.

Natural causes of death include disease, parasitism, reproductive complications, and other non-human-related injuries, as well as occasional exposure to cold and red tide (O'Shea *et al.* 1985; Ackerman *et al.* 1995). These natural causes of death accounted for 17% of all deaths between 1976 and 2000 (FWC, unpublished data). Perinatal deaths accounted for 21% of all deaths in the same period. Human-related causes of death include watercraft collisions, manatees crushed in water control structures and navigational locks, and a variety of less-common causes. Human-related causes of death accounted for at least 31% of deaths between 1976 and 2000. Cause of death of some carcasses could not be determined, because they were too decomposed, the cause was medically difficult to determine, or the carcass was verified but not recovered. The cause of death for these carcasses was classified as undetermined (30% of deaths between 1976 and 2000).

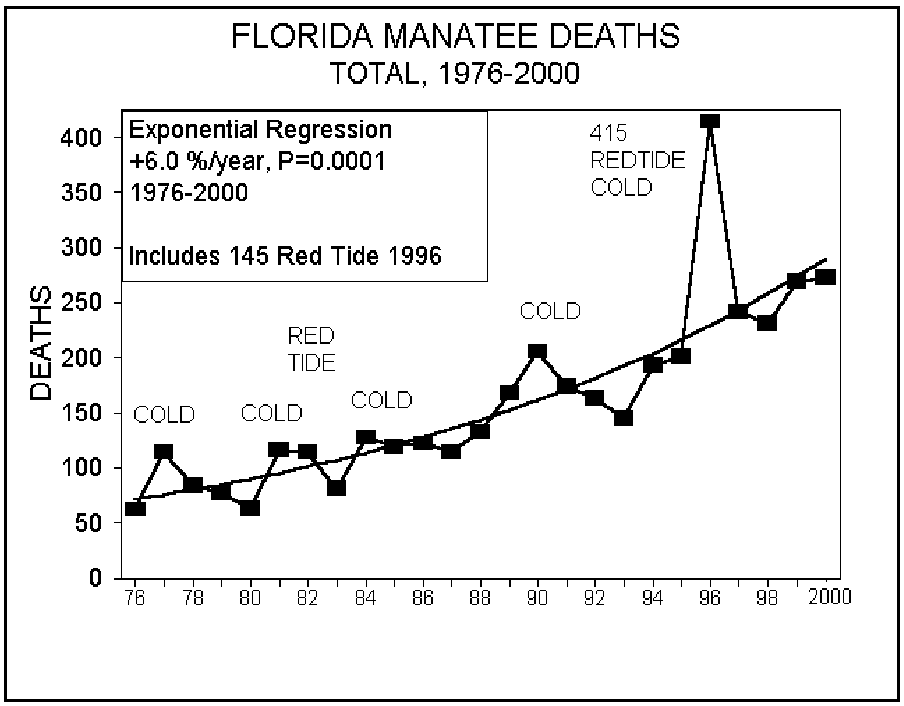


Figure 10. Florida manatee deaths from 1976 to 2000 with an exponential regression of +6.0% per year (FWC, unpublished data).

A prominent natural cause of death in some years is exposure to cold. Following a severe winter cold spell at the end of 1989, at least 46 manatee carcasses were recovered in 1990; cause of death for each was attributed to cold stress. Exposure to cold is believed to have caused many deaths in the winters of 1977, 1981, 1984, 1990, 1996, 2001 and have been documented as early as the 19th century (Ackerman *et al*. 1995; O'Shea *et al.* 1985; FWC, unpublished data).

In 1982, a large number of manatees also died coincidentally with a red tide dinoflagellate (*Gymnodinium breve*) outbreak between February and March in Lee County, Florida (O'Shea *et al.* 1991). At least 37 manatees died, perhaps in part due to incidental ingestion of filter-feeding tunicates that had accumulated the neurotoxin-producing dinoflagellates responsible for causing the red tide. In 1996, from March to May, at least 145 manatees died in a red tide epizootic over a larger area of southwest Florida (Fig. 11; Bossart *et al.* 1998; Landsberg and Steidinger 1998). Although the exact mechanism of manatee exposure to the red tide brevetoxin is unknown in the 1982 and 1996 outbreaks, ingestion, inhalation, or both are suspected (Bossart *et al.* 1998). The critical circumstances contributing to high red tide-related deaths are concentration and distribution of the red tide, timing and scale of manatee aggregations, salinity, and timing and persistence of the bloom (Landsberg and Steidinger 1998). It is difficult to manage for these rare but catastrophic causes of mortality.

Figure 11. Several of the 145 manatees that died during the red tide mortality event, Southwest Florida, 1996. (*Photographs by T. Pitchford*)

Perinatal deaths are carcasses of very small manatees (≤150 cm in length, O'Shea *et al.* 1995). Some are aborted fetuses; others are stillborn or die of natural causes within a few days of birth. Some may die from disease, reproductive complications, and/or congenital abnormalities. The cause of many perinatal deaths is difficult to determine, because these carcasses are generally in an advanced state of decomposition at the time they are retrieved. Most perinatal deaths appear to be due to natural causes; however, watercraft-related injuries or disturbance, or other human-related factors affecting pregnant and nursing mothers also may be responsible for a significant number of perinatal deaths. It has also been suggested that some may die from harassment by adult males (O'Shea and Hartley 1995). Between 1976 and 1999, perinatal deaths increased at an average of 8.8 % per year, increasing from 14% of all deaths between 1976 and 1980 to 22% between 1992 and 2000 (Ackerman *et al.* 1995; FWC, unpublished data).

The largest known cause of manatee deaths is collisions with the hulls and/or propellers of boats and ships. Between 1976 and 2000, watercraft-related deaths accounted for 24% of the total mortality and increased at an average of 7.2% per year: increasing from 21% of all deaths between 1976 and 1980; to 29% between 1986 and 1991; and 24% between 1992 and 2000 (Ackerman *et al.* 1995; FWC, unpublished data). Watercraft-related deaths were much lower in 1992 and 1993, but increased thereafter. From 1996 to 2000, the watercraft-related deaths have been the highest on record.

The next largest human-related cause of manatee deaths is entrapment or crushing in water control structures and navigational locks and accounts for 4% of the total mortality between 1976 and 2000 (Ackerman *et al.* 1995; FWC, unpublished data). These deaths were first recognized in the 1970s (Odell and Reynolds 1979), and steps have been taken to eliminate this source of death. Beginning in the early 1980s gate-opening procedures were modified; annual numbers of deaths initially decreased after this modification. However, the number of deaths subsequently increased, and in 1994, a record 16 deaths were documented. An ad hoc interagency task force was established in the early 1990s and now includes representatives from the South Florida Water Management District (WMD), U.S. Army Corps of Engineers (COE), FWS, Miami-Dade Department of Environmental Research Management (DERM), FWC and Florida Department of Environmental Protection (FDEP). This group meets several times a year to discuss recent manatee deaths and develop measures to protect manatees at water control structures and navigational locks. The overall goal is to eliminate completely structure-related deaths.

Other known causes of human-related manatee deaths include poaching and vandalism, entanglement in shrimp nets, monofilament line (and other fishing gear), entrapment in culverts and pipes, and ingestion of debris. These account for 3% of the total mortality from 1976 to 2000. Together, deaths attributable to these causes have remained constant and have accounted for a low percentage of total known deaths, i.e., about 4% between 1976 and 1980, 3% between 1981 and 1985, 2% between 1986 and 1991, and 2% between 1992 and 2000 (Ackerman *et al*. 1995; FWC, unpublished data). Entrapment in shrimp nets has been the largest component of this catch-all category. Eleven deaths were probably related to shrimping activities from 1976 to 1998 (7 in Florida, 4 in other states; Nill 1998). These deaths have become less common since regulations on inshore shrimping, the 1995 Florida Net Ban regulations, and education efforts about protecting manatees were implemented.

These data on causes of manatee deaths, and particularly the increasing number of watercraft-related deaths, should be viewed in the context of Florida's growing human population, which increased by 130% since 1970, 6.8 to 15.7 million (Florida Office of Economic and Demographic Research, 2001). The rise in manatee deaths during this period is attributable, in part, to the increasing number of people and boats sharing the same waterways. It should be noted that the increasing number of deaths could, in part, also be due to increasing numbers of manatees.

Table 3. Known manatee mortality in the southeastern United States reported through the manatee salvage and necropsy program, 1976 to 2000 (FWC, unpublished data).

Age Class	Adult/Subadult					Perinatal (≤150 cm)				Total
Cause Year	Water-craft	Lock Gate	Other Human	Natural	Undeter-mined	Water-craft	Lock Gate	Other Human	Natural/ Undeter-mined	
1976	10	3	0	1	32	0	1	0	15	62
1977	13	6	5	1	79	0	0	1	10	115
1978	21	9	1	3	40	0	0	0	10	84
1979	22	8	8	4	24	2	0	1	9	78
1980	15	8	2	6	19	1	0	0	14	65
1981	23	2	4	9	65	1	0	0	13	117
1982	19	3	2	40	37	1	0	0	15	117
1983	15	7	5	6	30	0	0	0	18	81
1984	33	3	1	24	41	1	0	0	27	130
1985	35	3	3	20	39	0	0	0	23	123
1986	31	3	1	13	47	2	0	0	28	125
1987	37	5	3	15	23	2	0	1	31	117
1988	43	7	3	22	25	0	0	1	33	134
1989	50	3	4	32	45	1	0	1	40	176
1990	49	3	4	71	41	0	0	0	46	214
1991	52	9	6	15	39	1	0	0	53	175
1992	38	5	6	21	49	0	0	0	48	167
1993	35	5	7	24	36	1	0	0	39	147
1994	50	16	5	37	40	0	0	0	46	194
1995	43	8	5	35	55	0	0	0	57	203
1996	59	10	1	118	164	1	0	0	63	416
1997	52	8	8	46	67	3	0	1	61	246
1998	66	9	6	23	85	1	0	0	53	243
1999	83	15	7	43	69	0	0	1	56	274
2000	79	8	8	51	75	0	0	0	58	279
Total	973	166	105	680	1,266	18	1	7	866	4,082

THREATS TO HABITAT

WARM WATER One of the greatest threats to the continued existence of the Florida manatee is the stability and longevity of warm-water refuges. Historically, the sub-tropical manatee relied on the warm temperate waters of south Florida and on natural warm-water springs scattered throughout their range as buffers to the lethal effects of cold winter temperatures. With the advent of industrial plants and their associated warm-water discharges, manatees have expanded their winter range to include these sites as refuges from the cold. In the absence of these sources of warm water, manatees are vulnerable to cold temperatures and can die from both hypothermia and prolonged exposure to cold. Based upon recent synoptic survey data, just under two-thirds of the population of Florida manatees rely on industrial sites, which are now made up almost entirely of power plants (FWC unpublished data).

Overall, industrial warm-water refuges have been a benefit to manatees inasmuch as they have: (1) reduced the frequency of cold-related deaths by providing reliable sources of warm water during the winter; (2) reduced the incidence of juvenile, cold-weather related mortality in south Florida; and (3) provided additional winter refuges and foraging sites which supplant heavily-stressed wintering sites in south Florida. While these sites have clearly benefitted the species, they also pose a significant risk. During periods of extreme cold, some plants are unable to provide water warm enough to meet the manatees' physiological needs. Plants are also vulnerable to winter shutdowns due to equipment failures and needed maintenance and, in the long-term, have a limited life span. Older plants are less cost-effective to operate, and market economics will increasingly play a more significant role in the plants' operating schedules (FWS 2000).

In addition, natural wintering sites also have been affected by human activities (FWS 2000). Winter habitat in south Florida has been altered (e.g., shoreline areas have been rip-rapped and bulkheaded, sources of warm water have been diverted and/or capped, foraging and resting sites have been eliminated, etc.). Important springs in the northern area of the species' range have also been altered; demands for water for residential, industrial, and agricultural purposes from the aquifer have diminished spring flows, as have paving and water diversion projects in spring recharge areas. Nutrient loading (e.g., nitrates) from residential and agricultural sources has promoted the growth of alga and clouded water columns, thus reducing available winter forage in these refuges.

Alterations to both natural and industrial warm-water refuges will significantly affect the manatee's ability to tolerate and withstand the cold. In the absence of stable, long term sources of warm water and winter habitat, large numbers of manatees may succumb to the cold. Given the magnitude of the problem, the outright loss of these numbers of animals could significantly affect recovery efforts. The power industry and wildlife managers and researchers are currently working together to secure the manatee's winter habitat.

OTHER HABITAT As discussed earlier in this document, Florida manatees are found in fresh, brackish, and marine environments in the southeastern United States. These areas include many habitat types (including vegetated freshwater bottoms, salt marshes, sea grass meadows, and many others) where manatees ably exploit the many resources found in these areas. As herbivores, manatees feed on the wide range of forage that these habitats provide. In addition, manatees utilize many other resources found in these areas, including: (1) springs and deep water areas for warmth; (2) springs and freshwater runoff sites for drinking water; (3) quiet, secluded tributaries and feeder creeks for resting, calving, and nurturing their young, (4) open waterways and channels as travel corridors, etc.

These habitats are affected by human activities. Dredge and fill activities, polluted runoff, propeller scarring, and other actions have resulted in the loss of vegetated areas and springs. Quiet backwaters have been made more accessible to human activities, and increasing levels of vessel traffic have made manatees increasingly vulnerable to boat collisions in travel corridors. Manatees seem to have adapted to some of these changes. For example, industrial warm-water discharges and deep-dredged areas are now used as wintering sites, stormwater pipes and freshwater discharges in marinas provide manatees with drinking water, and the imported exotic plant, hydrilla (which has replaced native aquatic species), has become an important food source at wintering sites.

While manatees may adapt to some changes, some activities clearly can have an adverse effect on the species. The loss of industrial warm-water discharges can result in the deaths of individuals using these sites. Dozens of manatees die each year due to collisions with watercraft. Other activities may also affect manatees, albeit on a much more subtle level. Harassment by boats and swimmers may drive animals away from preferred sites; the loss of vegetation in certain areas (e.g., as seen in winter foraging areas) requires manatees to travel greater distances to feed. Adequate feeding habitat associated with warm-water refuge sites is important to the overall recovery of the Florida manatee, however, it does not appear that warm season foraging habitat is limiting.

Efforts are in place and are being made to protect, enhance, and restore the manatee’s aquatic environment. There are many existing federal, state, and local government regulations in place to minimize the effect of human activities on manatees and their habitat (e.g., Clean Water Act, Rivers and Harbors Act, ESA, Fish and Wildlife Coordination Act, Coastal Zone Management Act, etc.), and significant efforts are being made to improve this environment and to maintain those resources that are vital to the manatee. Also refer to the discussion in section I, **HABITAT PROTECTION**.

CONTAMINANTS AND POLLUTION EFFECTS The reliance of manatees on inshore habitats and their attraction to industrial and municipal outfalls have the potential to expose them to relatively high levels of contaminants. Despite this relationship, there have been few studies of contaminant levels and their effects on manatees. Available information suggests that direct effects are not significant at a population level. O'Shea *et al.* (1984) investigated levels of pesticides, polychlorinated biphenyls, mercury, lead, cadmium, copper, iron, and selenium in manatee tissues collected in the late 1970s and early 1980s. Of these, only copper levels in the liver were found to be notably high. The highest copper levels (1,200 ppm dry weight) were found in animals from areas of high herbicidal copper usage and exceeded all previously reported concentrations in livers of wild mammals. Despite these findings, there were no field reports of copper poisoning and no evidence of deleterious effects to individual animals. Ames and Van Vleet (1996) analyzed a small number of tissue samples for chlorinated hydrocarbons and petroleum hydrocarbons. None of the latter were found; however, pesticides (o,p-DDT, o,p-DDD, hexachlorobenzene, and lindane) were found in some of the liver, kidney, and blubber samples, but at very low concentrations and at a lower frequency of occurrence than in earlier studies. Contaminants, siltation and modified deliveries of fresh water to the estuary can indirectly impact manatees by causing a decline in submerged aquatic vegetation on which manatees depend.

Manatees ingest various debris incidental to feeding. Beck and Barros (1991) found monofilament fishing line, plastic bags, string, rope, fish hooks, wire, rubber bands, and other debris in the stomachs of 14.4% of 439 manatees recovered between 1978 and 1986. Monofilament line was the most common item found. In most cases, ingested items do not appear to affect animals. However, ingested monofilament line has resulted in death due to blockage of the digestive system (Forrester *et al.* 1975; Buergelt *et al.* 1984). A few deaths were caused by ingesting wire, which perforated the stomach lining, and plastic sheeting, which blocked the digestive tract (Laist 1987). Discarded monofilament line and rope were found wrapped around flippers, sometimes leading to serious injury or death (Beck and Barros 1991). Records of scarred or mutilated flippers on free-ranging manatees known from the photo-ID catalog and rescue events suggest that female manatees are more vulnerable than males to entanglement in fishing gear (Beck and Lefebvre 1995).

I. PAST AND ONGOING CONSERVATION EFFORTS

Under the guidance of previous manatee recovery plans, federal agencies, state agencies, local agencies and private organizations have initiated cooperative actions to address the important conservation needs, which this plan builds upon. Some of the major initiatives are reviewed below.

EFFORTS TO REDUCE WATERCRAFT-RELATED INJURIES AND DEATHS The largest identified cause of manatee death is collisions with watercraft. Many living manatees also bear scars or wounds from vessel strikes. An analysis of injuries to 406 manatees killed by watercraft and recovered between 1979 and 1991 found that 55% were killed by impact, 39% were killed by propeller cuts, 4% had both types of injuries, either of which could have been fatal, and 2% with unidentified specifics (Wright *et al.* 1995). Between 1976 and 2000, the total number of carcasses (i.e., deaths due to all causes) collected has increased at a rate of 6.0 percent per year, while deaths caused by watercraft strikes increased by 7.2 percent per year (Fig. 12). Because watercraft operators cannot reliably detect and avoid hitting manatees, federal and state managers have sought to limit watercraft speed in areas where manatees are most likely to occur to afford both manatees and boaters time to avoid collisions.

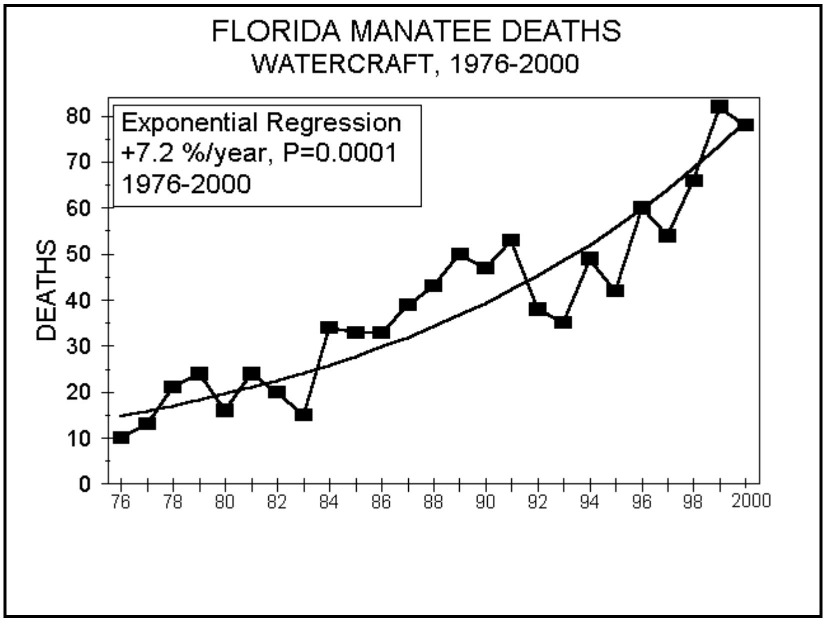


Figure 12. Florida manatee watercraft deaths from 1976 to 2000 with an exponential regression increase of 7.2% per year (FWC, unpublished data).

In 1989, the Florida Governor and Cabinet approved a series of recommendations by the former FDNR to improve protection of manatees in 13 key counties. For the next ten years, state and local governments cooperated in the creation and implementation of four county Manatee Protection Plans and 12 county-wide manatee protection speed zone rules. In 1999, Florida's manatee research and management programs were transferred to the newly created FWC. FWC approved comprehensive manatee protection rules in Lee County, completing the speed zone component of the initiative started in 1989. As the State of Florida's initiative to establish manatee protection zones in the 13 key counties is completed, attention is now focused on the development and approval of key county manatee protection plans.

Two types of manatee protection areas also have been developed by FWS: (1) manatee sanctuaries; and (2) manatee refuges. Manatee sanctuaries are areas in which all waterborne activities are prohibited, and manatee refuges are areas where certain waterborne activities are restricted or prohibited (designation of refuges or sanctuaries, however, will not eliminate waterway property owner access rights). To date, FWS has established seven winter sanctuaries to protect manatees in association with the Crystal River National Wildlife Refuge (NWR). The most recent was a one-quarter-acre sanctuary established in 1997 at Three Sisters Spring run (Fig. 13).

Figure 13. Three Sisters Spring Manatee Sanctuary, Crystal River, Florida. Manatees within the sanctuary and tour boats (left) and snorklers (right) along the outer sanctuary boundary edge. (*Photographs by J. Kleen and C. Shaw*)

FWS and FWC continue to evaluate needs for additional protection areas that may be necessary to achieve recovery. The goal is to consider the needs of the manatee at an ecosystem level and to establish regulations to ensure that adequate protected areas are available throughout Florida to satisfy habitat requirements of the Florida manatee population with a view toward recovery. In addition, through the NWR System Administration Act, access rules for boats have been established by FWS to protect manatees within Merritt Island NWR.

In recent years, both the FWS and FWC have been using targeted enforcement strategies in an attempt to increase boater compliance with speed zones and ultimately reduce manatee injuries and death. FWS strategy has been to allocate significant enforcement manpower to specific areas on designated weekends. These enforcement teams travel to various locations around the state, with particular emphasis given to those zones within counties where there is a history of high watercraft-caused manatee deaths. FWC has increased its emphasis on enforcement and compliance with manatee speed zones by adding new officers, conducting law enforcement task force initiatives, increasing overtime, and increasing the proportion of law enforcement time devoted to manatee conservation.

In addition to manatee protection plans, manatee protection areas, and other efforts, managers, researchers, and the boating industry have investigated the use of various devices to aid in the reduction of watercraft-related manatee deaths. For example, the State of Florida funded an evaluation of propeller guards (Milligan and Tennant 1998). The state's evaluation concluded that these devices would reduce cutting damage associated with propellers when boats were operating at low speeds. However, when boats (including boats equipped with propeller guards) operate at high speeds, guards would be of little benefit because animals would continue to be killed by blunt trauma associated with impacts from boat hulls, lower units, and other gear. The U.S. Coast Guard (USCG) identified additional concerns, stating that propeller guards on small recreational vessels "may create more problems than they solve" and does not support their use on recreational vessels at this time (Carmichael 2001). There are propeller guard applications, however, that appear to work for certain large, commercial vessels; for example, the use of guards on C-tractor tugs has eliminated this specific source of manatee mortality at the Kings Bay Naval Submarine Base in St. Marys, Georgia. To prevent injuries to manatees, propeller guards are used on some rental and sight-seeing boats at Blue Spring and Crystal River.

Researchers have also begun to investigate the manatees' acoustic environment to better evaluate the animal's response to vessel traffic. This line of research needs to be thoroughly assessed for its potential as another management tool to minimize collisions between manatees and boats. Results from Gerstein (1999) indicate that manatees hear in the range from 500 Hz to 38 kHz and that inadequate hearing sensitivity at low frequencies may be a contributing factor to the manatees' ability to effectively detect boat noise to avoid collisions. One technology often discussed is an acoustic deterrence device mounted on a boat. Conceptually, this technological approach may sound like an answer to the manatee/watercraft issue. A number of problems have been defined with the use of acoustic deterrents. No alarm/warning device has yet been demonstrated to adequately protect wildlife or marine mammals. Additionally, concern has also been stated regarding the increase in background noise that these deterrents would add to an already noisy marine environment. It has not been determined what negative impacts this device would have on marine life and what effects it would have on animals that use acoustic cues for a variety of purposes. For these reasons, this technology needs to be thoroughly researched and assessed and managers need to evaluate the MMPA and ESA "take" issues related to implementing such technology.

Current research into the sensory capabilities of manatees is being supported at both the state and federal levels. The FWC contracted Mote Marine Laboratory to further test manatee sensory capabilities. One contract assessed the effects of boat noise in a more controlled environment. This study recorded the physical and acoustic reaction of a manatee to a pre-determined acoustical level. This study design will allow the development of a relationship between acoustic dosage and behavioral responses (vocal and visual displays; movements). Another contract study looked at acoustical propagation over various types of marine topography. In cooperation with Mote Marine Laboratory and the Woods Hole Oceanographic Institution, the FWC is also examining manatee behavioral response to watercraft using new technology, the DTAG, a digital acoustic tag which records acoustic attributes of the environment and detailed manatee movement simultaneously. A FWS contracted study to assess manatee behaviors in the presence of fishing gear and their response to novelty and the potential for reducing gear interactions has an acoustic component. The FWC also received funding to support the development and implementation of technological solutions for reducing the risks that watercraft pose to manatees. They recently issued a Request for Proposals (RFP) to specifically address manatee avoidance technology.

Currently, priority actions in manatee conservation and protection include boater education, enforcement, maintenance of signs and buoys, compliance assessment, and periodic re-evaluation of the effectiveness of the rules. Such work requires close cooperation between FWC Bureau of Protected Species Management (BPSM), FWC's Division of Law Enforcement (DLE), county officials, the Inland Navigation Districts, FWS, USCG, and, of course, boaters.

EFFORTS TO REDUCE FLOOD GATE AND NAVIGATION LOCK DEATHS Entrapment in water-control structures and navigational locks is the second largest cause of human-related manatee deaths. In some cases, manatees appear to have been crushed in closing gates; in others, they may have been drowned after being pinned against narrow gate openings by water currents rushing through openings. Water-control structures implicated in manatee deaths in Dade and Broward counties are operated by the South Florida WMD. From 1976 through 2000, 166 manatees have been killed in water control structures in Dade County alone, accounting for 33% of all manatee deaths in this county.

The COE operates five water-control structures in conjunction with navigational locks along the Okeechobee Waterway and also operates the Port Canaveral Lock, located in Brevard County. FDEP operates locks and water-control structures associated with the Cross Florida Greenway.

In the early 1980s, steps were taken to modify gate-opening procedures to ensure openings were wide enough to allow a manatee to pass through unharmed. Steps were also initiated to fence off openings and cavities in gate structures where manatees might become trapped. Manatee deaths subsequently declined and remained low for much of the 1980s (Table 2). Since the 1996 Recovery Plan, much progress has been made toward identifying, testing, and installing manatee protection devices at water control structures. The COE Section 1135 Study, "Project Modification on Manatee Protection at Select Navigation and Water Control Structures, Part I," has been completed and the technology developed and successfully tested. Consequently, since 1996, pressure sensor devices have been installed at the five water control structures. Three recent deaths at two of the modified South Florida Water Management District water control structures suggests that these type of protective measures will continue to need on-going maintenance, review and refinement. The COE has also installed removable barriers on the upstream side of the Ortona and St. Lucie Lock spillway structures. The large difference in the up and downstream water levels at these structures compromises the effectiveness and use of pressure sensor devices. Such barriers will be considered for other structures where appropriate. A task force, established in 1991, comprised of representatives from the South Florida WMD, COE, FWC, FDEP, DERM, and FWS, continues to monitor, examine and make recommendations to protect manatees at water control structures and navigational locks.

The COE completed the "Section 1135 Project Modification Report on Manatee Protection at Select Navigation and Water Control Structures, Part II," which investigated several alternatives to protect manatees at locks. The COE contracted with the Harbor Branch Oceanographic Institute (HBOI) to develop and install a prototype acoustic array for manatee protection at lock gates. HBOI completed system design, and during 1999 the St. Lucie Lock was equipped with this manatee protection system (Fig. 14). This system consists of a device that is installed on the lock gates and detects the presence of manatees through acoustic signals. When a manatee is detected near the gate during the last 52 inches of closure, an alarm sounds; the gate stops closing and is then re-opened back to 52 inches. An upgraded version of this same type of system also has been installed at Port Canaveral Lock. Future plans are to install protective systems at the following locks: Moore Haven, Ortona, and Port Mayaca.

Figure 14. Water control structure retrofitted with pressure sensitive technology (left). Retrofitting of St. Lucie Lock with acoustic sensors (right) to protect manatees from being crushed as the gates close. (*Photographs by FWS and B. Brooks*)

FDEP currently is designing and preparing to install barriers at the Kirkpatrick Dam (Putnam County), and on the tainter valve culvert pipes at Buckman Lock (Putnam County) and downstream side of Inglis Lock (Levy County); work is anticipated to be completed during 2001. FDEP also has contracted with HBOI to install an acoustic array system at Buckman Lock, similar to arrays installed at the COE's Port Canaveral and St. Lucie Locks. Upon completion of the manatee protection systems at the Rodman Reservoir (Putnam County), FDEP plans to reopen Buckman Lock for operation. Currently the FDEP's Inglis Lock at Lake Rouseau/Withlacoochee River is not operating; long-term plans are to replace Inglis Lock with a smaller one with a manatee protection system installed.

HABITAT PROTECTION Intensive coastal development throughout Florida poses a long-term threat to the Florida manatee. There are three major approaches to address this problem. First, FWS, FWC, Georgia Department of Natural Resources (GDNR), and other recovery partners review and comment on applications for federal and state permits for construction projects in manatee habitat areas and to minimize their impacts. Under section 7 of the ESA, FWS annually reviews hundreds of permit applications to the COE for construction projects in waters and wetlands that include or are adjacent to important manatee habitat. FWC and GDNR provide similar reviews to their respective state's environmental permitting programs.

A second approach is the development of county manatee protection plans. The provisions of these plans are anticipated to be implemented through amendments to local growth management plans under the Florida's Local Government Comprehensive Planning and Land Development Regulation Act of 1985. In addition to boat speed rules, manatee protection plans are to include boat facility siting policies and other measures to protect manatees and their habitat. To date, five counties (Citrus, Collier, Dade, Duval, and Indian River counties) have completed manatee protection plans, which the State of Florida has approved, and other counties' plans are in varying stages of development. Of the five completed plans, FWS has approved only two, those of Citrus and Dade.

A third approach to habitat protection is land acquisition. Both FWS and the State of Florida have taken steps to acquire and add new areas containing important manatee habitat to federal and state protected area systems. The State of Florida has acquired important areas through several programs, most notably the Florida Forever Program (formerly the Conservation and Recreational Lands Program). In Florida, the Governor and Cabinet have included special consideration for purchase of lands that can be of benefit to manatees and their habitat. Over $500 million has been spent to acquire 250,000 acres, whose importance included, but was by no means limited to, protection of manatee habitat. Particularly important purchases have been made along and near the Crystal River, at Rookery Bay, the Sebastian River, and near Blue Spring. FWS has also acquired and now manages thousands of acres of land important to manatees and many other species in the NWR System. In addition to these efforts, FWS's initiative to propose new manatee refuges and sanctuaries factors into habitat protection. Both the State of Florida and FWS are continuing cooperative efforts with a view towards establishing a network of important manatee habitats throughout Florida.

MANATEE RESCUE, REHABILITATION AND RELEASE Thousands of reports of distressed manatees purportedly in need of assistance have been made to the state wildlife enforcement offices and other resource protection agencies by a concerned public. While most of the manatees do not require assistance, dozens of manatees are rescued and treated each year. A network of state and local agencies and private organizations (Fig. 15), coordinated by FWS, has been rescuing and treating these animals for well over twenty years.

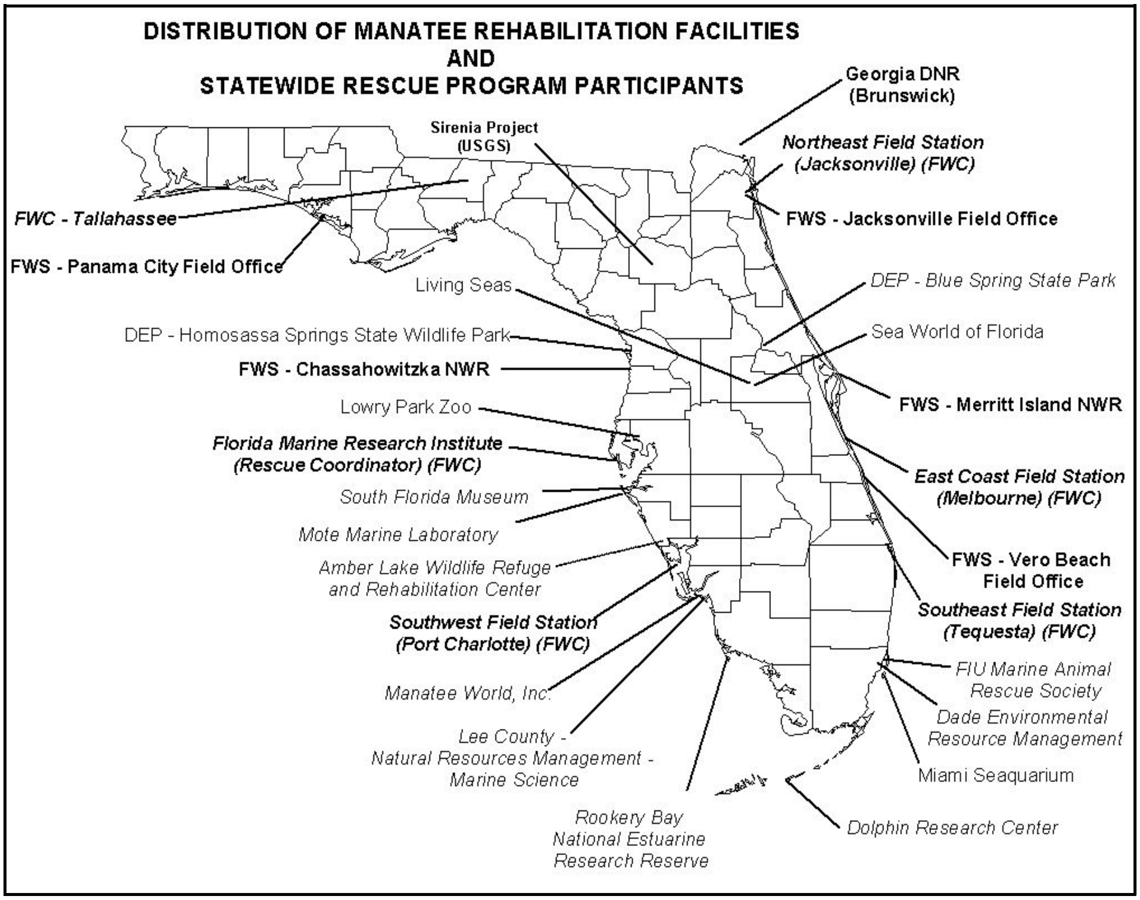


Figure 15. Locations of participants in the manatee rescue, rehabilitation, and release program.

Manatees are brought into captivity when stressed by cold weather, when struck and injured by watercraft, when injured because of entanglements in crab traps and monofilament fishing line, when orphaned, and when compromised by other natural and man-made factors. Program veterinarians and staff have developed treatments and protocols for these animals and have been remarkably successful in their efforts to rehabilitate compromised individuals (Fig. 16). Since 1973, over 180 manatees have been treated and returned to the wild (FWS unpublished data).

Treatments and protocols developed for these distressed animals have provided notable insights into the physiology and behavior of manatees. In certain settings, captive manatees are used in research; captive studies have provided a wealth of information on sensory capacities, digestion, reproduction, etc. Information obtained through treatments and research, in addition to the number of animals released back into the wild each year, contributes significantly to efforts to reduce mortality and further the recovery of the species.

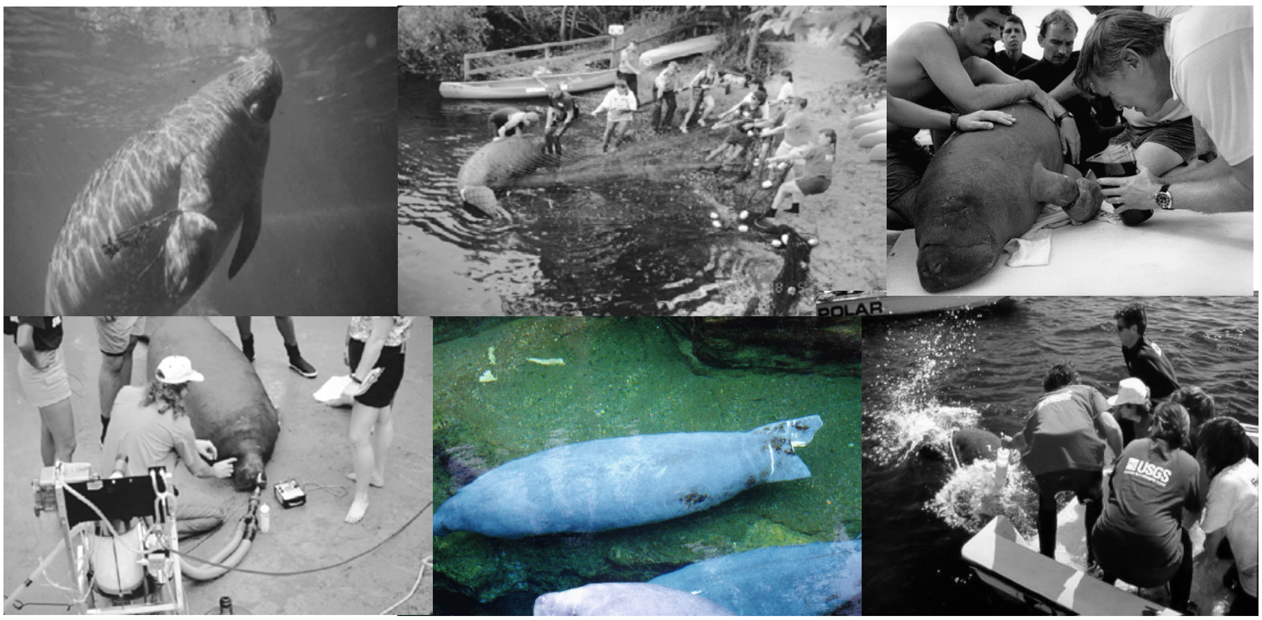


Figure 16. Manatee rescue, rehabilitation, and release program. (*Photographs by G. Rathbun, C. Shaw, J. Reid, Miami Seaquarium, J. Pennington, and J. Reid*)

Media coverage of manatee rescues, treatments, and releases helps to educate millions of people about manatees, the life-threatening problems that they face, and actions that can be taken to minimize the effect of anthropogenic activities on this species. In addition, more than eighteen million visitors a year see manatees at rehabilitation facilities and participate in manatee education programs sponsored by several parks. The publicity and outreach inherent in this program provide significant support to efforts to recover the manatee.

PUBLIC EDUCATION, AWARENESS, AND SUPPORT Government agencies, industries, oceanaria and environmental groups have all contributed to manatee public awareness and education efforts that were initiated in the 1970s. These efforts have expanded in scope and increased in quantity since that time. Some key counties in Florida also have started the education component of their manatee protection plans.

These public awareness and education efforts encourage informed public participation in regulatory and other management decision-making processes and provide constructive avenues for private funding of state manatee recovery programs, research, and land acquisition efforts through programs such as the specialty automobile license tag for manatees. This particular funding source has resulted in substantial savings in federal and state tax revenues and has permitted important work to proceed which likely would not have been possible in their absence.

The public has been made aware of new information on the biology and status of manatees, urgent conservation issues, and the regulations and measures required to assure their protection through the production of brochures, posters, films and videos, press releases, public service announcements and advertisements, and other media-oriented materials. Outdoor signs have been produced that provide general manatee information and highlight the problems associated with feeding manatees.

Manatee viewing opportunities have also been made available to the public. In addition, volunteers from several organizations annually give presentations to schools and other groups and distribute educational materials at festivals and events. Such efforts are essential for obtaining public compliance with conservation measures to protect manatees and their habitats.

Many public awareness materials have been developed specifically focusing on boater education. Public awareness waterway signs are produced and distributed alerting boaters to the presence of manatees. Brochures, boat decals, boater's guides, and other materials with manatee protection tips and boating safety information have been produced and are distributed by law enforcement groups, through marinas, and boating safety classes. Educational kiosks have been designed and installed at marinas, boat ramps, and other waterfront locations. Fishing line collection sites and cleanup efforts are being established. In addition, the Manatee Awareness Coalition of Tampa Bay and Crystal River NWR have initiated programs for on-water manatee public awareness.

Several agencies and organizations provide educator's guides, posters, and coloring and activity books to teachers in Florida and across the United States. In addition, Save The Manatee Club (SMC) and FWC Advisory Council on Environmental Education have produced a video for distribution to schools throughout Florida and the United States. SMC and FWC also provide free manatee education packets to students and staff interviews for students. Agencies and organizations help to educate law enforcement personnel about manatees and inform them about available outreach materials that can be distributed to user groups.

Public interest in manatee conservation also has grown internationally. Manatee education and public awareness materials are distributed in Central and South America and the wider Caribbean, as well as to numerous other countries around the world.

PART II. RECOVERY

The goal of this revised recovery plan is to assure the long-term viability of the Florida manatee in the wild, allowing initially for reclassification from endangered to threatened status (downlisting) and ultimately removal from the List of Endangered and Threatened Wildlife (delisting).

This section of the Recovery Plan presents: (A) details on an upcoming status review; (B) objective and measurable recovery criteria; (C and D) site-specific management actions to monitor and reduce or remove threats to the Florida manatee; and (E) Literature Cited. The steps for reclassification and removal from the list are consistent with provisions specified under sections 4(a)(1), 4(b), 4(c)(2)(B), and 4(f)(1) of the ESA. The FWS must, to the maximum extent practicable, incorporate into each recovery plan objective, measurable recovery criteria which, when met, would result in a determination that the species be removed from the List of Endangered and Threatened Wildlife. In designing these criteria, the FWS has addressed the five statutory listing/recovery factors (section 4(a)(1) of the ESA, (see page 1) to the current extent practicable.

A. STATUS REVIEW

The 1967 Federal Register Notice (32FR406) designating the West Indian manatee and several other species as "endangered" did not provide a detailed explanation for the listing. Since the manatee was designated as an endangered species prior to enactment of the ESA (1973), there was no formal listing package identifying threats to the species, as required by Section 4(a)(1). Under section 4(c)(2) of the ESA, the FWS is charged with periodically reviewing the the status of species included in the List of Endangered and Threatened Wildlife to determine whether any species should change in status from a threatened species to an endangered species, change in status from an endangered species to a threatened species, or be removed from the List.

During the 20 years since approval of the first manatee recovery plan, a tremendous amount of knowledge has been gained about manatee biology and ecology and significant protection programs have been implemented. The knowledge and the results of these protection programs are reflected in this recovery plan. The Manatee Population Ecology and Management Workshop scheduled for April 2002 will update and review the science and population ecology of manatees, including an assessment of the recovery criteria presented in this plan. The FWS has determined that the year following this workshop is an appropriate time to conduct a thorough status review of the Florida manatee and anticipates this review to take place in 2003.

The review will include:

(1) a detailed evaluation of the population status using the most up to date demographic data and other biological indices available (The FWS anticipates that much of this data will come from the April 2002 Manatee Population Ecology and Management Workshop);
(2) an evaluation of the status of manatee habitat as it relates to recovery;
(3) an evaluation of the existing threats to the species and the effectiveness of existing mechanisms to reduce or remove those threats (e.g., adequate protection areas, signage, enforcement, education and compliance have resulted in a reduction or minimization of watercraft deaths) as prescribed in this recovery plan;
(4) recommendations, if any, regarding reclassification of the Florida manatee; and
(5) if necessary, recommendations to update or modify recovery criteria.

B. RECOVERY CRITERIA

RECLASSIFICATION FROM ENDANGERED TO THREATENED (DOWNLISTING)

The near and long term threats from human-related activities are the reasons for which the Florida manatee currently necessitates protection under the ESA. The focus of recovery is not on how many manatees exist, but instead the focus is on implementing, monitoring and addressing the effectiveness of conservation measures to reduce or remove threats which will lead to a healthy and self-sustaining population. The Florida manatee could be considered for reclassification from endangered to threatened status if the following listing/recovery and demographic criteria are met:

LISTING/RECOVERY FACTOR CRITERIA: Tasks listed with each criterion are examples of actions that may reduce or remove the identified threats and were developed from recovery team discussions.

Listing/Recovery Factor A: The Present or Threatened Destruction, Modification, or Curtailment of a Species Habitat or Range (Habitat Working Group and Warm-water Task Force identified in other portions of this plan are tasked to further refine and improve these criteria.) In order to ensure the long-term recovery needs of the manatee and provide adequate assurance of population stability (i.e., achieving the demographic criteria), threats to the manatee's habitat or range must be reduced or removed. This can be accomplished through federal, state or local regulations (identified in Factor D below) to establish minimum spring flows and protect the following areas of important manatee habitat:

a. Minimum flow levels to support manatees at the Crystal River Spring Complex, Homosassa Springs, Blue Springs, Warm Mineral Spring, and other spring systems as appropriate, in terms of quality (including thermal) and quantity have been identified by the WMDs or other organizations.(Task 3.2.4.3)
b. A network of the level 1 and 2 warm-water refuge sites identified in Figure 7 are protected as either manatee sanctuaries, refuges or safe havens. (Task 1.2.3, 1.3, 3.2.2, 3.2.3, 3.2.4, 3.3.1)
c. Feeding habitat sites (extent, quantity and quality) associated with the network of warm-water refuge sites above in (b) have been identified by the HWG for protection. (Task 3.1(3), 3.3.8).
d. A network of migratory corridors, feeding areas, calving and nursing areas are identified by the HWG to be protected as manatee sanctuaries, refuges and/or safe havens in the following Florida counties: Duval (including portions of Clay and St. Johns in the St. Johns River), Volusia, Brevard, Indian River, Martin, Palm Beach, Broward, Dade and Monroe on the Florida Atlantic Coast; Citrus, Pinellas, Hillsborough, Manatee, Sarasota, Charlotte, Lee and Collier on the Florida Gulf Coast; and Glades County on the Okeechobee Waterway. (Task 1.3, 3.3.1)

Listing/Recovery Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes "Take" in the form of harassment, is currently occurring at some of the winter refuge sites and other locations. This "take" is presently not authorized under the MMPA or ESA. However, there are no data at this time to indicate that this issue is limiting the recovery of the Florida manatee. The actions in this plan that address harassment are recommended in order to achieve compliance with the MMPA and ESA and as a conservation benefit to the species. Statutory mechanisms outlined in Factor D to protect and enact protection regulations for important manatee habitats identified in Factor A and enact regulations to address unauthorized "take" identified in Factor E, will also assist to reduce or remove these threats.

Recovery actions and their subtasks specifically addressing this issue are 1.1, 1.11, 4.4 and those tasks identified in Factors A, D and E.

Listing/Recovery Factor C: Disease or Predation At this time, there are no data indicating that this is a limiting factor, thus no reclassification (downlisting) criteria are necessary.

Listing/Recovery Factor D: The Inadequacy of Existing Regulatory Mechanisms The current legal framework outlined below allows federal and state government agencies to take both broad scale and highly protective action for the conservation of the manatee and its habitat. The FWS believes these regulatory mechanisms are adequate for recovery. However, additional specific actions under these laws such as those listed pursuant to Factor A and E must be accomplished (as well as meeting the demographic criteria) before the FWS will consider this species for reclassification.

Factor A (a) Establish Minimum Flows (Task 3.2.4.3)

STATE Florida Water Resources Act of 1972, Chapter 373, F.S. (specifically Minimum Flows and Levels, Sect. 370.42, F.S. and Establishment and Implementation of Minimum Flows and Levels, Sect. 370.421, F.S.)

Factor A (b)(c) and (d) Protect Important Manatee Habitats (Task 1.2, 1.3.1, 1.3.2, 1.4, 3.2.2, 3.2.3, 3.2.4, 3.3.1, 3.3.8)

FEDERAL Endangered Species Act; Marine Mammal Protection Act; Clean Water Act, Sect. 401, 402 and 404; Rivers and Harbors Act, Sect. 10; National Environmental Policy Act; and Coastal Zone Management Act;

STATE Florida Manatee Sanctuary Act, Sect. 370.12(2), F.S.; Florida Water Resources Act of 1972, Chapter 373, F.S.; Florida Air and Water Pollution Control Act, Chapter 403, F.S.; State Lands, Chapter 253, F.S.; and State Parks and Preserves, Chapter 258, F.S.; and

LOCAL Florida Manatee Sanctuary Act, Sect. 370.12(o), F.S. which allows local governments to regulate by ordinance, motorboat speed and operations to protect manatees.

Factor E (a)(b)(c) Reduce or Remove Unauthorized "take" (Task 1.1, 1.2, 1.3.1, 1.3.2, 1.4, 1.6, 1.7, 3.3.1)

FEDERAL Marine Mammal Protection Act; and Endangered Species Act; and

STATE Florida Manatee Sanctuary Act, 370.12(2), F.S.

Listing/Recovery Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence The most predictable and controllable threat to manatee recovery remains human-related mortality. In order to ensure the long-term recovery needs of the manatee and provide adequate assurance of population stability (i.e., achieving the demographic criteria), natural and manmade threats to manatees need to be reduced or removed. This can be accomplished through establishing the following federal, state or local regulations, tasks and guidelines to reduce or remove human caused "take" of manatees:

a. State safe havens and/or federal manatee refuges have been established by regulation and are being adequately enforced to reduce unauthorized watercraft-related “take” in the following Florida counties: Duval (including portions of Clay and St. Johns in the St. Johns River), Volusia, Brevard, Indian River, Martin, Palm Beach, Broward, Dade and Monroe on the Florida Atlantic Coast; Citrus, Pinellas, Hillsborough, Manatee, Sarasota, Charlotte, Lee and Collier on the Florida Gulf Coast; and Glades County on the Okeechobee Waterway. (Task 1.3, 1.4, 1.5, 3.3.1)

b. One half of the water control structures and navigational locks listed as needing devices to prevent mortality have been retrofitted. (Task 1.6)

c. Guidelines have been drafted to reduce or remove threats of injury or mortality from fishery entanglements and entrapment in storm water pipes and structures. (Task 1.7, 1.6.3)

DEMOGRAPHIC CRITERIA: The annual synoptic surveys have too many weaknesses to reliably guage the health of the population (see discussion of Population Size in the Introduction and in Appendix D). Therefore, the FWS has established population related benchmarks for certain aspects of manatee demographics (based upon mark/recapture studies and population modeling) that it will use to help determine the success of manatee conservation efforts. These are derived from the MPSWG’s Recommendation for Population Benchmarks To Help Measure Recovery (Appendix A). While these benchmarks are dependent on the amount and statistical reliability of the data available, we believe these “vital signs” are currently the best scientific indicators of the overall health of the manatee population. If future scientific studies indicate that other survival, reproduction, or population growth rates or other population indices are more appropriate for demographic recovery criteria, the FWS will modify these benchmarks.

The current benchmarks are as follows:

a. statistical confidence that the average annual rate of adult manatee survival is 90 % or greater;

b. statistical confidence that the average annual percentage of adult female manatees accompanied by first or second year calves in winter is 40% or greater; and

c. statistical confidence that the average annual rate of population growth is equal to or greater than zero.

These population benchmarks should be achieved with a 95% level of statistical confidence. When they are achieved in each of the four regions for the most recent ten year period of time (approximately one manatee generation), we may conclude that the manatee is not in danger of extinction throughout all or significant portion of its range and reclassify to threatened, provided the listing/recovery factor criteria (outlined above) are also met.

REMOVAL FROM THE LIST OF ENDANGERED AND THREATENED WILDLIFE (DELISTING)
The Florida manatee could be considered for removal from the List of Endangered and Threatened Wildlife if the following listing/recovery and demographic criteria are met:

LISTING/RECOVERY FACTOR CRITERIA: Tasks listed with each criterion are examples of actions that may reduce or remove the identified threats.

Listing/Recovery Factor A: The Present or Threatened Destruction, Modification, or Curtailment of a Species Habitat or Range (The Warm-water Task Force and Habitat Working Group identified in other portions of this plan are tasked to further refine and improve these criteria.) In order to ensure the long-term recovery needs of the manatee and provide adequate assurance of population stability (i.e., achieving the demographic criteria), threats to the manatee's habitat or range must be reduced or removed. This can be accomplished through federal, state or local regulations to establish and maintain minimum spring flows and protect the following areas of important manatee habitat:

a. Minimum flow levels to support manatees at the Crystal River Spring Complex, Homosassa Springs, Blue Springs, Warm Mineral Spring, and other spring systems as appropriate, in terms of quality (including thermal) and quantity have been adopted by regulation and are being maintained.(Task 3.2.4.3)
b. A network of level 1, 2 and 3 warm-water refuge sites identified in Figure 7 have been protected as either manatee sanctuaries, refuges or safe havens. (Task 1.2.3, 1.3, 3.2.2, 3.2.3, 3.2.4, 3.3.1)
c. Adequate feeding habitat sites (extent, quantity and quality) associated with the network warm-water refuge sites identified by the HWG and are protected. (Task 3.1(3), 3.3.8).
d. The network of migratory corridors, feeding areas, calving and nursing areas identified by the HWG are protected as manatee sanctuaries, refuges or safe havens. (Task 1.3, 3.3.1)

Listing/Recovery Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes "Take" in the form of harassment, is currently occurring at some of the winter refuge sites and other locations. This "take" is presently not authorized under the MMPA or ESA. However, there are no data at this time to indicate that this issue is limiting the recovery of the Florida manatee. The actions in this plan that address harassment are recommended in order to achieve compliance with the MMPA and ESA and as a conservation benefit to the species. Statutory mechanisms outlined in Factor D to protect and enact protection regulations for important manatee habitats identified in Factor A and enact regulations to address unauthorized "take" identified in Factor E, will also assist to reduce or remove these threats.

Recovery actions and their subtasks specifically addressing this issue are 1.1, 1.11, 4.4 and those tasks identified in Factors A, D and E.

Listing/Recovery Factor C: Disease or Predation At this time, there are no data indicating that this is a limiting factor, thus no delisting criteria are necessary.

Listing/Recovery Factor D: The Inadequacy of Existing Regulatory Mechanisms The current legal framework outlined below allows federal and state government agencies to take both broad scale and highly protective action for the conservation of the manatee and its habitat. The FWS believes these regulatory mechanisms are adequate for recovery. However, additional specific actions under these laws such as those listed pursuant to Factor A and E must be accomplished (as well as meeting the demographic criteria) before the FWS will consider this species for removal from the List of Endangered and Threatened Wildlife.

Factor A (a) Establish Minimum Flows (Task 3.2.4.3)

STATE Florida Water Resources Act of 1972, Chapter 373, F.S. (specifically Minimum Flows and Levels, Sect. 370.42, F.S. and Establishment and Implementation of Minimum Flows and Levels, Sect. 370.421, F.S.)

Factor A (b)(c) and (d) Protect Important Manatee Habitats (Task 1.2, 1.3.1, 1.3.2, 1.4, 3.2.2, 3.2.3, 3.2.4, 3.3.1, 3.3.8)

FEDERAL Marine Mammal Protection Act; Clean Water Act, Sect. 401, 402 and 404; Rivers and Harbors Act, Sect. 10; National Environmental Policy Act; and Coastal Zone Management Act;

STATE Florida Manatee Sanctuary Act, Sect. 370.12(2), F.S.; Florida Water Resources Act of 1972, Chapter 373, F.S.; Florida Air and Water Pollution Control Act, Chapter 403, F.S.; State Lands, Chapter 253, F.S.; and State Parks and Preserves, Chapter 258, F.S.; and

LOCAL Florida Manatee Sanctuary Act, Sect. 370.12(o), F.S. which allows local governments to regulate by ordinance, motorboat speed and operations to protect manatees.

Factor E (a)(b)(c) Reduce or Remove Unauthorized "take" (Task 1.1, 1.2, 1.3.1, 1.3.2, 1.4, 1.6, 1.7, 3.3.1)

FEDERAL Marine Mammal Protection Act; and

STATE Florida Manatee Sanctuary Act, 370.12(2), F.S.

Listing/Recovery Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence The most predictable and controllable threat to manatee recovery remains human-related mortality. In order to ensure the long-term recovery needs of the manatee and provide adequate assurance of population stability (i.e., achieving the demographic criteria), natural and manmade threats to manatees need to be removed or removed. This can be accomplished through establishing the following federal, state or local regulations, tasks and guidelines to reduce or remove human caused "take" of manatees:

a. State, federal and local government manatee conservation measures (such as, but not limited to speed zones, refuges, sanctuaries, safe havens, enforcement, education programs, county MPPs etc.) have been adopted and implemented to reduce or remove unauthorized watercraft-related "take" in the following Florida counties: Duval (including portions of Clay and St. Johns in the St. Johns River), Volusia, Brevard, Indian River, Martin, Palm Beach, Broward, Dade and Monroe on the Florida Atlantic Coast; Citrus, Pinellas, Hillsborough, Manatee, Sarasota, Charlotte, Lee and Collier on the Florida Gulf Coast; and Glades County on the Okeechobee Waterway. These measures are not only necessary to achieve recovery, but may ultimately help to comply with the MMPA. (Task 1.3, 1.4, 1.5, 3.3.1).

   Stable or positive population benchmarks as outlined in the demographic criteria provide measurable population parameters that will assist in measuring the stabilization, reduction, or minimization of watercraft related "take." Two other indices (weight of evidence) will assist in measuring success include: (1) watercraft-related deaths as a proportion of the total known mortality; and (2) watercraft-related deaths as a proportion of a corrected estimated population. These and other indices should be monitored.

b. All water control structures and navigational locks listed as needing devices to prevent mortality have been retrofitted. (Task 1.6)
c. Guidelines have been established and are being implemented to reduce or remove threats of injury or mortality from fishery entanglements and entrapment in storm water pipes and structures. (Task 1.7, 1.6.3)

DEMOGRAPHIC CRITERIA: The ESA requires that the FWS, to the maximum extent practicable, incorporate into each recovery plan objective, measurable recovery criteria which, when met, would result in a determination that the species be removed from the List of Endangered and Threatened Wildlife. The MPSWG thus far has not proposed delisting criteria to the FWS "as specific, quantitative habitat criteria have yet to be developed" (Appendix A). In lieu of criteria from the MPSWG, the FWS will use the population benchmarks for reclassification (downlisting) to help determine the long-term success of manatee conservation efforts and recovery. While these benchmarks are dependent on the amount and statistical reliability of the data available, we believe these "vital signs" are currently the best scientific indicators of the overall health of the manatee population. If future scientific studies indicate that other survival, reproduction, or population growth rates or other population indices are more appropriate for demographic recovery criteria, the FWS will modify these benchmarks.

Those benchmarks are as follows:

a. statistical confidence that the average annual rate of adult manatee survival is 90 % or greater;
b. statistical confidence that the average annual percentage of adult female manatees accompanied by first or second year calves in winter is 40% or greater; and
c. statistical confidence that the average annual rate of population growth is equal to or greater than zero.

These benchmarks should be achieved with a 95% level of statistical confidence. When they are achieved in each of the four regions for an additional 10 years after reclassification (an additional manatee generation), we may conclude that the population is healthy and will sustain itself such that the Florida manatee could be removed from the List of Endangered and Threatened Wildlife provided the listing/recovery factor criteria (outlined above) are also met.

C. OUTLINE OF RECOVERY ACTIONS ADDRESSING THREATS

D. NARRATIVE OUTLINE OF RECOVERY ACTIONS

OBJECTIVE 1: Minimize causes of manatee disturbance, harassment, injury, and mortality. Manatees are killed and injured as a result of interactions with boats, water control structures, navigational locks, stormwater pipes, marine debris, and fishing gear. In rare cases, manatees are killed by vandals and poachers. Additional mortalities from natural causes, such as severe cold weather or red tide, may also significantly affect the status of the manatee population. To permit maintenance and/or growth of the manatee population to attain recovery, such causes of mortality, injury, harassment and disturbance must be minimized. This section of the recovery plan identifies activities needed to minimize sources of disturbance, harassment, injury, and mortality.

1.1 **Promulgate special regulations for incidental take under the MMPA for specific activities.** FWS will evaluate its programs related to watercraft operation and watercraft access facilities and promulgate incidental take regulations under the MMPA for FWS activities (e.g., operation of vessels, managing surface waters and recreation on NWRs, and funding of boat ramps through Federal Aid). The process will lead to appropriate modification to FWS activities to ensure that such activities are minimized to the maximum extent practicable and ensure that these activities will have no more than a negligible impact on the manatee. FWS believes that programs of other federal and state agencies would benefit from a similar review and rule promulgation process.

1.2 **Continue state and federal review of permitted activities to minimize impacts to manatees and their habitat.** There are three separate processes where state and federal agencies provide biological review in order to minimize impacts to manatees and their habitat. These are: (1) review of permits for development activities (such as marinas, boat ramps, and other boat-related facilities) and dredge and fill activities; (2) review of permits for marine events (boat races and regattas); and (3) review of permits for power plants and other industrial outfalls (authorization to discharge warm water through the NPDES permit). FWS , FWC and GDNR should continue to participate in all of these review processes.

1.2.1 **Continue to review coastal construction permits to minimize impacts.** Dredge and fill activities and coastal construction of facilities such as marinas or large docks require permits from the COE, environmental resource permits from FDEP or the WMDs, and, in some cases, submerged land leases from Florida’s Board of Trustees, and in Georgia from the GDNR Coastal Resources Division. There are several aspects of these development projects that must be considered. First, the construction process itself should be conducted in a way to minimize the direct risk to manatees. Second, the permanent effect of the facility once it is built must be considered. For example, facilities should be designed to minimize shading of submerged aquatic plants. Third, the intended use or indirect effects of the project must also be considered. Marinas, boat ramps, and docking facilities can alter boat traffic patterns and increase boat traffic in specific areas, thus potentially increasing the possibility that manatees will be injured or killed. The effects of that traffic should be considered in the permit evaluation. Finally, the cumulative effect of multiple projects must be taken into account. While the impacts of a small single project may be negligible, multiple small projects may have a cumulative effect as great or greater than single large projects.

FWC will continue to provide assessments and recommendations on permit and submerged land lease applications to FDEP or appropriate WMD. GDNR Wildlife Resources Division will continue to provide assessments and recommendations on permit applications to the Coastal Resources Division. These permitting agencies have specific state statutory obligations to protect listed species and should use the recommendations provided by FWC and GDNR in meeting those obligations. In addition, FWC and GDNR will actively coordinate on an annual basis with the permitting agencies to ensure that the best data are available, that communication remains unimpeded, and that the review process is efficient and effective. FWS will continue to provide consultations, pursuant to section 7 of the ESA and other federal laws to the COE, USCG, and other federal agencies on permit applications where it has been determined that the activity may affect manatees or any other listed species and/or their habitat. This formal review process is a fundamental part of the manatee recovery program and must be continued. (Also refer to Task 3.3.5 regarding regulatory recommendations supporting habitat conservation.)

1.2.2 Minimize the effect of organized marine events on manatees. Marine sport events may also affect manatees, and many of these events require permits from the USCG. Under section 7 of the ESA and other federal laws, the FWS reviews and comments on permit applications where it has been determined that the activity may affect manatees or any other listed species. In order to provide guidance to the USCG regarding the types of events and the locations where manatee conditions are needed, standard draft guidelines were prepared. These are also intended to assist event planners involved in the planning process for boat races, fishing tournaments, water ski events, boat parades, and other organized boating events. The guidelines and standard conditions pertaining to when, where, and under what conditions such events could be held consistent with manatee protection objectives, should be updated and agreed upon by FWS and FWC. These guidelines should be distributed to the USCG groups in Florida. The USCG, in following those guidelines, should consult with FWS on appropriate events. FWC should provide technical expertise and data where needed to assist FWS in the review.

1.2.3 Continue to review NPDES permits to minimize impacts. The NPDES has been approved by the Environmental Protection Agency (EPA) to be implemented by FDEP and GDNR. Power plants and other industries that discharge into state waters are required to obtain a NPDES permit. In Florida, power plants that have the potential to affect manatees because of the attraction of a warm-water discharge are required to have a power plant manatee protection plan (MPP) as part of the permit. FWC works directly with the utilities in the development of the plan. FWC provides a recommendation to FDEP whether to accept, modify, or reject the MPP. FWS also reviews the plan and provides an assessment. This program ensures that issuance of the NPDES permit for discharge of warm water into ambient waters of the State of Florida by powerplants includes FWS- and FWC-approved plans. GDNR Nongame and Endangered Wildlife Program provides an assessment and recommendations to the GDNR Environmental Protection Division on NPDES permits in Georgia. This permit review process should be continued. (Task 3.2.2 provides further discussion of NPDES permits.)

1.2.4 Pursue regulatory changes, if necessary, to address activities that are "exempt," generally authorized, or not covered by state or federal regulations. FWS should look at non-regulated coastal construction projects or projects authorized under general permits to assess their cumulative impact on manatees. FWS should propose changes to existing regulatory programs as appropriate to minimize such impacts.

1.3 Minimize collisions between manatees and watercraft. Significant work is needed to monitor, review, assess needs to update existing protection zones (Task 2.7.2), develop new zones warranted in other areas, and make vessel operators aware of those zones. FWC has the responsibility for developing and amending state waterway speed and access rules to protect manatees. These rules aim to reduce the risk of collisions between manatees and watercraft by considering both manatee use patterns and the needs of the boating public. Further, under the authority of the ESA and MMPA and their implementing regulations at 50 CFR 17, FWS may designate certain waters as manatee protection areas, within which certain waterborne activities will be restricted or prohibited for the purpose of preventing the taking of manatees. Actions to address these needs are discussed below. In addition to these methods, alternative strategies minimizing collisions between manatees and watercraft should be investigated (Tasks 1.5.1, 1.5.2, 2.8.12, and 2.8.16).

1.3.1 **Develop and refine state waterway speed and access rules.** FWC is responsible for developing and amending state waterway speed and access rules to protect manatees under the State of Florida Manatee Sanctuary Act. FWC will monitor and review the effectiveness of existing zones and make appropriate modifications as needed. FWC will establish additional zones, as needed, to protect manatees throughout the state and implement where appropriate.

1.3.2 **Develop and refine federal waterway speed and access rules.** As necessary and appropriate, federal rules should be promulgated and existing rules should be modified in cooperation with the State of Florida and other concerned parties to protect the manatee. Particularly, waterways in or adjacent to NWRs, National Parks, and other federally-managed areas within manatee habitat should be protected as warranted. Under the authority of the ESA and MMPA and their implementing regulations at 50 CFR 17, FWS may establish boating speed and access rules in conjunction with efforts to designate certain waters as manatee sanctuaries (areas where all waterborne activities are prohibited), no entry areas or manatee refuges (areas where certain waterborne activities such as boat speeds may be regulated) (Task 3.3.1).

1.3.3 **Post and maintain regulatory signs.** The effective use of regulatory and informational signs is essential in providing the public with on-site information on manatee protection measures. Sign messages, to the greatest extent possible, should be uniform, understandable, and concise. Sign design and placement should provide for uniformity, rapid identification as a regulatory sign, and should be located at a site where it is readily observable to the target audience. Regulated areas should be posted by the appropriate agency. Of critical need is the continued effort to inspect and repair/replace signs as needed in an expedient manner. A task force, which includes the USCG, FWC, FWS, the navigation districts, and those counties with sign-posting responsibilities needs to be established. This task force should focus on improving the sign-posting and maintenance process and will explore innovative sign designs that would contribute to better compliance and enforcement.

1.4 **Enforce manatee protection regulations.** Enforcement is one the highest priorities for manatee recovery. Compliance with manatee protection regulations will reduce human-caused manatee mortality, particularly that caused by watercraft collisions. Effective enforcement of these regulations is needed to maximize protection efforts and to minimize manatee injuries and deaths.

(Also refer to Task 1.11 and its related tasks regarding enforcement of regulations prohibiting harassment).

1.4.1 Coordinate law enforcement efforts. Enforcement of manatee protection rules is provided by officers of FWS and FWC-DLE, USCG, and local law enforcement agencies, as well as the courts. To ensure compliance with the waterway speed and access rules and with manatee harassment provisions, enforcement capabilities must be expanded and coordinated. Although efforts have increased significantly during the past two years, manatee enforcement operations still must be expanded in both geographic scope and frequency. To meet these needs, federal and state enforcement agencies should take all possible steps to increase funding and heighten agency priority for manatee-related law enforcement activities. Those activities should be maintained at levels commensurate with those of vessel traffic, watercraft-related manatee deaths, and added enforcement responsibilities. To carry out enforcement activities as efficiently and cost-effectively as possible, involved agencies are encouraged to coordinate enforcement efforts. In addition, enforcement agencies should review and assist as possible with the development of new manatee protection statutes and regulations, the posting of manatee regulatory signs, enforcement training seminars, studies to monitor regulatory compliance, and actions by the judiciary to prosecute violations.

1.4.2 Provide law enforcement officer training. Law enforcement officers responsible for enforcing manatee regulations need to receive training in order to acquire knowledge and skills to enhance their abilities. Officers should be given training on manatee regulations during appropriate agency training courses. Refresher training should be conducted annually at appropriate opportunities.

1.4.3 Ensure judicial coordination. Designated personnel will meet periodically with members of the judiciary to ensure their knowledge of present manatee protection regulations or changes thereto, as well as to provide a forum for information exchange.

1.4.4 Evaluate compliance with manatee protection regulations. Compliance with manatee protection regulations is paramount to their subsequent success. FWS, FWC, and local governments should evaluate compliance with manatee protection regulations through research, surveys and other methods to ensure effectiveness and to identify needed improvements (Task 2.7.2.2.).

1.4.5 **Educate boaters about manatees and boater responsibility.** State-wide speed limits, boat operator licenses, and mandatory boater education will enhance efforts to reduce watercraft-related manatee deaths by offering opportunities to educate boaters about rules to protect manatees and to reduce boat speeds in other areas where manatees may occur. New proposals to establish state-wide boating safety measures should be encouraged. Particular efforts should be made to integrate manatee protection concerns into any new boater education programs (Tasks 4.1 through 4.3.). A website should be developed to allow the public and boating community easy access to manatee protection zone information (Task 4.2.2).

1.4.6 **Evaluate effectiveness of enforcement initiatives.** In recent years, both federal and state agencies have been using targeted enforcement strategies in an attempt to increase boater compliance with speed zones and ultimately reduce manatee injuries and death. FWS strategy has been to allocate significant enforcement manpower to specific areas on designated weekends. These enforcement teams travel to various locations around the state, with particular emphasis given to those zones within counties where there is a history of high watercraft-caused manatee deaths. FWC has increased its emphasis on enforcement and compliance with manatee speed zones by adding new officers, conducting law enforcement task force initiatives, increasing overtime, and increasing the proportion of law enforcement time devoted to manatee conservation. FWS and FWC should evaluate the effectiveness of these and other enforcement efforts and make adjustments, as appropriate. The research should evaluate if there are significant changes in boater compliance as a result of additional enforcement, and determine the residual effect of the enforcement efforts, if any.

1.4.7 **Provide updates of enforcement activities to managers.** It is important for managers to have a good understanding of enforcement activities and special initiatives in order to determine if the desired outcomes (reduction of manatee injury/death and enhanced public awareness and compliance) are achieved. In addition, up-to-date information on enforcement activities is needed for outreach and media contacts. As part of a new manatee enforcement initiative, FWC provides updates of manatee-related enforcement every other week to FWC managers. Such data summary and distribution should continue. Other law enforcement agencies also should provide similar updates of their special enforcement details. Information provided in the updates should be standardized across agencies so that a law enforcement database can be developed to provide information on effort, number of citations and/or other contacts, vessel registration, size, type, disposition of the case, and other pertinent information.

1.5 **Assess and minimize mortality caused by large vessels.** Large vessels (e.g., tugs and cargo vessels) and large displacement hull vessels are known to kill manatees. Some animals appear to be pulled into propeller blades by the sheer power of generated water currents, while others are crushed between the bottom and the hull of deep draft ships. When moored, large vessels also can crush manatees between their hulls and adjacent wharves or ships.

1.5.1 **Determine means to minimize large vessel-related manatee deaths.** Studies should be undertaken to: (1) further review mortality data for evidence of deaths attributable to large vessels; (2) examine barge, tug, and other large vessel traffic patterns relative to manatee distribution; (3) assess the feasibility and cost of installing propeller guards or shrouds on large displacement hull vessels or tugs routinely plying waterways used by manatees; (4) evaluate ways to educate harbor pilots about threats large vessels pose to manatees; and (5) identify other possible mitigation measures to minimize these threats. Actions to implement appropriate measures should be taken based on study findings.

1.5.2 **Provide guidance to minimize large vessel-related manatee deaths.** FWS and FWC will promote use of devices such as fenders to maintain minimum stand-off distances of four feet at maximum compression between moored vessels and between vessels and wharves to minimize manatee deaths. If studies support actions to address the threat of large vessel propeller-related incidences to manatees, it is recommended that propellers of large displacement hull vessels, particularly tugs that tend to remain in harbors or rivers, be retrofitted with a propeller guard or shroud to reduce these types of mortalities.

1.6 **Eliminate manatee deaths in water control structures, navigational locks, and drainage structures.** The second largest source of human-related manatee death is due to entrapment in water control structures and navigational locks. These structures are owned and operated by the WMDs, COE, and FDEP and are primarily located in South Florida. They have been responsible for an average of 10 manatee deaths per year since 1995 and a total of 167 deaths since 1976. An ad hoc interagency task force was established in 1991 (current members include South Florida WMD, COE, FWS, DERM, FWC, and FDEP) to examine steps to prevent such deaths. This group meets at least twice a year to discuss recent manatee deaths and measures to protect manatees from structure-related mortality. The overall goal is to eliminate completely structure-related deaths.

In addition to causing crushing deaths, manatees may become trapped in the extensive canal systems of south Florida. Manatees passing through open structures become trapped once the structures close, due to changing water conditions. Manatees trapped in the shallow canal systems are vulnerable to cold stress during the winter. An evaluation and mapping of manatee-accessible canals is needed, and actions should be taken to prevent manatee entry into these areas.

FWS also should assess the need for manatee protection technology and help to update standard operating procedures at the lock systems at Lake Moultrie, South Carolina and Lake Seminole, Florida/Georgia.

Entrapment in drainage structures such as pipes, culverts and ditches also lead to injury and death of manatees. Installation of barriers or guards on such structures can prevent future entrapments.

1.6.1 Install and maintain protection technology at water control structures where manatees are at risk and monitor success. Pressure sensor devices have been installed at the five water control structures in south Florida through a South Florida WMD/COE cooperative project. Although the success of these devices generally has been encouraging, two structures equipped with the device have failed to eliminate all manatee deaths at them. An investigation at S-25B, after two deaths in December 1999, revealed that modifications to the sensitivity were required to provide the needed protection for manatees; after a manatee death at S-27 in January 2000, the South Florida WMD moved the manatee sensor strips in an attempt to get them closer to the actual gate. Thus, while it has been demonstrated that manatees can be successfully protected through the installation of pressure devices at water control structures, it is possible that as more devices are installed and operated, occasional failures will occur until all site-specific maintenance and installation needs are identified and resolved.

Twenty identified water control structures should be equipped with a manatee protection system (MPS) (pressure devices or removable barriers) by the year 2004. Removable barriers should be installed at structures where the pressure sensor devices are not feasible or appropriate. Standard operating procedures to protect manatees also have been developed for periods when the barriers are removed for high flow or cleaning the debris off the barriers. MPSs will be installed at additional water control structures in the Central and South Florida Project on a case-by-case basis as part of the Comprehensive Everglades Restoration Plan (CERP), and standard operating procedures and the need for a MPS should be assessed and installed as needed for other structures in manatee habitat.

The FDEP is designing and preparing to install barriers at the Kirkpatrick Dam, the tainter valve culvert pipes at Buckman Lock, and the downstream side of Inglis Lock. FDEP anticipates to complete this work during the summer of 2001.

1.6.2 **Install and maintain protection technology at navigational locks where manatees are at risk and monitor success.** Manatee protection devices have been installed at the St. Lucie, Port Canaveral, and Taylor Creek Locks. The long-term plan is to continue installing these protective devices on the remaining locks in order of their potential to harm manatees until all such structures are equipped with manatee protection devices. The COE should continue to partner with local sponsors to accomplish this retrofitting as quickly as possible. The COE should prepare an annual report assessing the performance of the manatee protection devices and evaluating the needs for modification and improvement.

FDEP has contracted with HBOI to install an acoustic array system at Buckman Lock similar to arrays installed at the COE's Canaveral and St. Lucie Locks. FDEP plans to reopen Buckman Lock for operation once the manatee protection systems are installed on both the Buckman Lock and Kirkpatrick Dam. It is anticipated that these projects will be completed during the summer of 2001 (the State of Florida has also budgeted $800,000 to begin restoring the Oklawaha River). Currently FDEP's Inglis Lock at Lake Rouseau/Withlacoochee River is not operating; long-term plans are to replace the existing lock with a smaller one which includes manatee protection equipment.

1.6.3 **Minimize injuries and deaths attributable to entrapment in drainage structures.** Sites where manatees have been rescued or died due to entrapment in drainage structures should be identified and, as warranted, steps taken to install barriers or guards which prevent such entrapment at these culverts or drainage structures. Additionally, stormwater outfalls or similar drainage structures in aggregation areas should be retrofitted with appropriate barriers to prevent manatee entrapment. Federal, state, and local permits should require that new drainage structures (greater than 18 but less than 84 inches in diameter) in manatee habitat be grated or otherwise made inaccessible to manatees.

1.6.4 **Assess risk at existing and future water control structures and canals in South Florida.** Using existing data bases and/or field inspections, categorize all structures as to whether manatees could pass through the structure, and what level of risk the structure poses. Similarly, characterize all canals (including minor irrigation ditches and storm water connector canals) as to whether manatees have access. Based on interagency recommendations, some canals may be designated as off-limits to manatees. The South Florida WMD should establish manatee-safe barriers to prevent access to designated areas. The CERP will dramatically alter the water delivery system in south Florida. New canals and water retention areas will be created, and existing canals will be modified or eliminated. It is critical that the COE and South Florida WMD coordinate closely with FWS and FWC and consider impacts to manatees from this long-range restoration project. Only manatee-safe structures should be installed, and manatee access to newly-created areas should be evaluated by the interagency task force.

1.7 Minimize manatee injuries and deaths caused by fisheries and entanglement. Due to the dynamic nature of commercial and recreational fishing and gear, information on interactions with fishing techniques and gear should be kept under review by FWS, GDNR, and FWC, and measures to reduce or avoid such interactions should be taken. This review should also assess the impacts of the mariculture industry and develop recommendations to minimize impacts to manatees and habitat. To minimize adverse entanglement interactions, the following steps are needed. A working group, which was established in 1999 to address fishery and marine debris and to make recommendations to minimize impacts, should continue to meet regularly.

1.7.1 Minimize injuries and deaths attributed to crab pot fishery. With the recent increasing trend of manatee rescues from crab trap buoy lines, information on interactions with buoy lines should be kept under review by FWC and FWS, and steps should be taken to improve reporting and documentation of such incidents. Steps to identify and implement measures which would reduce or avoid such interactions should be taken, including research regarding gear interactions and ways to avoid them, outreach, and promulgation of regulations (e.g., gear modification) if necessary.

1.7.2 Minimize injuries and deaths attributed to commercial and recreational fisheries, gear, and marine debris. Sites where interactions with recreational and/or commercial fishing gear occur should be identified and, as warranted, steps should be taken to assess and implement actions to prevent potentially threatening interactions with fishing gear. Strategies to reduce monofilament entanglements also need to focus on educating the fishing community on properly discarding monofilament and provide an avenue for recycling it. Strategies also should encourage underwater and drift line debris clean-up of monofilament and other debris in popular fishing areas used by manatees (Task 2.7.4).

1.8 **Investigate and prosecute all incidents of malicious vandalism and poaching.** Poaching, shooting, butchering, and other malicious vandalism against manatees are rare occurrences. All reports and evidence regarding such incidents should be turned over to FWS law enforcement agents for investigation and prosecution to the fullest extent of the law.

1.9 **Update and implement catastrophic plan.** FWS and FWC Contingency Plans for Catastrophic Rescue and Mortality Events for the Florida Manatee should be reviewed annually and updated as needed by those who would be involved in the response. Additionally, guidance and notification procedures between FWC and FWS should be developed and updated as needed for events that do not reach unusual or catastrophic levels in order for such events to be documented.

1.10 **Rescue and rehabilitate distressed manatees and release back into the wild.** Thousands of reports have been provided by the public regarding sick, injured, orphaned, entrapped, and wayward manatees that appear to be in need of assistance. While many clearly do not require intervention, 30 to 40 manatees are rescued every year. Some are assisted and immediately released, while others are taken to one of three critical-care facilities for supportive treatment. Animals successfully treated are released, and to the extent possible, their progress is monitored through tagging and tracking studies. Publicity surrounding distressed manatees, their rescues, treatment, and outcome help to educate millions of people every year about manatees and the problems that they face. The number of manatees successfully treated and released back into the wild provides an important safeguard to the wild population of manatees.

1.10.1 **Maintain rescue network.** FWS is responsible for the rescue and rehabilitation network and coordinates this program through an endangered species/marine mammal enhancement permit. Participants are authorized to participate in the program through Letters of Authorization (LOAs) under the permit held by FWS Jacksonville Field Office. Letter holders: (1) verify the status of manatees reportedly in distress; (2) rescue and/or transport rescued manatees; and (3) treat and maintain distressed manatees. The terms and conditions of the LOA describe the letter holders' level of participation and responsibilities in the program, based on their level of experience and resources. FWS must retain a current permit to authorize these activities and must maintain, update, and modify participant LOAs. As needs and circumstances dictate, letter holders may be added or removed from the program.

To ensure prompt, effective responses to distressed manatees, a rescue coordinator is needed to coordinate and mobilize rescue network teams. FWC 's FMRI maintains a network of field stations to conduct manatee research throughout the state. Field station activities are coordinated through the FMRI's Marine Mammal Pathobiology Laboratory's manager, who acts as the rescue coordinator. FMRI's existing network of staff, resources, and contacts with local law enforcement officials (and others likely to receive reports of distressed manatees) provides the necessary infrastructure for the program. Reports of distressed animals are directed to the rescue coordinator and his/her staff, who in turn contact authorized participants to respond. FWS is notified of ongoing rescues and unusual or significant events, as appropriate. GDNR maintains similar capabilities through its Nongame and Endangered Wildlife Program in their Brunswick, Georgia office.

1.10.2 Maintain rehabilitation capabilities. Adequate facilities are needed to place and treat injured animals. Every year, there are approximately 50 manatees in captivity at any given time, including manatees receiving critical and long-term care treatment. In 2000, there were three critical-care and six long-term care facilities treating manatees, including three out-of-state facilities. In order to maintain our ability to treat distressed manatees, critical care space must be available for these animals. While every effort is made to release treated manatees in a timely manner, some animals are not immediately releasable. Manatees that cannot be released quickly may be transferred to long-term care facilities to make room for critical-care cases. When necessary, existing facilities may expand their holding areas, or additional facilities may be authorized to create room for long-term care cases. Critical-care facilities provide the resources needed to conduct these activities; some costs are statutorily defrayed throughout the State of Florida.

1.10.3 Release captive manatees. As manatees complete the rehabilitation process, their medical status is reviewed by respective facility veterinarians in anticipation of their release. Following this review of physical and behavioral parameters, facility veterinarians recommend that the animal is either ready for release or should be retained for further supportive care. If an animal is deemed healthy, FWS (with input from the Interagency Oceanaria Working Group (IOWG)) evaluates the status of the animal in the context of captive release guidelines and determines whether or not the animal should be released. When an animal is deemed releasable, a release site and release date are identified, and appropriate follow-up monitoring plans are selected. The animals are then transported to the selected site and released. Follow-ups are then conducted, relying on either active monitoring (in which the animals are tagged with satellite, very high frequency (VHF), and/or sonic tags and tracked via satellite and in the field) or passive monitoring (which relies on marking the animals with PIT tags and freeze-brands or by their unique, distinctive markings). These animals are then monitored opportunistically in the field during field studies and/or through the carcass salvage program. Methods identified during a 1998 captive release workshop should be implemented to improve survival rates for released captives. Behavioral parameters need to be evaluated to assess their value in the captive release process.

1.10.4 Coordinate program activities. In addition to authorizing network participants, FWS coordinates many of the day-to-day needs of the program. All transfers and releases, research proposals, and follow-up monitoring plans, program concerns, etc., are evaluated and acted upon by FWS. Many of these are discussed and resolved through the IOWG, which meets twice a year to coordinate rescue, rehabilitation, and release activities and to manage captive program activities to meet manatee recovery objectives. Inherent in this are reviews on the status of rescue and rehabilitation activities, record keeping, development and review of rescue, transport, rehabilitation, maintenance, and release methods, informational exchanges, etc. A product of these meetings will include the development of an annual work plan describing projected releases and monitoring activities.

1.10.5 Provide assistance to international sirenian rehabilitators. Manatee rescue and rehabilitation activities in the United States and Puerto Rico are characterized by more than 30 years of experience and expertise. Rescue and transport techniques, medical practices, and release protocols have been successfully developed and are models for similar efforts. These experiences and expertise should be shared with other countries developing manatee and dugong rescue and rehabilitation programs.

1.10.6 Provide rescue report. An annual report summarizing each year's rescue and rehabilitation activities will be prepared consistent with the requirements of FWS's endangered species/marine mammal enhancement permit. In the interim, monthly updates will be made available to program participants through FWS's internet website.

1.11 Implement strategies to eliminate or minimize harassment due to other human activities. In some cases, human activities (e.g., fishing, swimming, snorkeling, scuba diving, manatee observation, and provisioning) may also disturb, alter behavior or harass manatees. Such disturbance could be life-threatening to manatees, for example, if it occurs in warm-water refuges and animals subsequently move into colder waters. Areas of such conflict should be identified and management actions implemented in order to reduce negative impacts on manatees. Harassment of manatees is considered a form of take as defined in both the ESA and MMPA. Any activity that results in a change of natural behavior which could create harm to the animal is considered take. Most waterborne activities, as well as some upland activities, have the potential to disturb and harass manatees. The following efforts are needed to minimize the impact of these activities.

1.11.1 Enforce regulations prohibiting harassment. Where clear and convincing evidence of harassment is occurring, enforcement of regulations controlling such activities is needed.

1.11.2 Improve the definition of "harassment" within the regulations promulgated under the ESA and MMPA. The current definition of harassment is very vague, making it difficult to enforce. Regulatory definitions need to be amended to specify, to the greatest extent practicable, what actions and activities constitute manatee harassment.

OBJECTIVE 2: Determine and monitor the status of manatee populations. The success of efforts to develop and implement measures to minimize manatee injury and mortality depends upon the accuracy and completeness of data on manatee life history and population status. Population data are needed to identify and define problems, make informed judgments on appropriate management alternatives, provide a sound basis for establishing and updating recovery criteria and management plans, and to determine whether or not actions taken are achieving management objectives. The tasks outlined below are essential to a complete understanding of manatee population status and trends. For all tasks, publication of peer-reviewed results is the preferred method of information dissemination. A detailed research plan is presented in Appendix D and includes informative background information and more detail than is presented here in the narratives.

2.1 Continue the MPSWG. The interagency MPSWG was established in March 1998 as a subcommittee of the recovery team. The group's primary tasks are to: (1) assess manatee population trends; (2) advise FWS on population criteria to determine when species recovery has been achieved; and (3) provide managers with interpretation of available information on manatee population biology. The group also has formulated strategies to seek peer review of their activities. The MPSWG should continue to hold regular meetings, refine recovery criteria, annually update regional and statewide manatee status statements, convene a population biology workshop early in 2002, analogous to the one held in 1992, and publish the results of the workshop.

2.2 Conduct status review. After the Population Status Workshop referenced in Task 2.1 is held, FWS will conduct a status review of the Florida manatee. The review will include: (1) a detailed evaluation of the population status using the benchmark data obtained from the 2002 Population Biology Workshop; (2) an evaluation of the status of manatee habitat as it relates to recovery-based information obtained from the HWG; (3) an evaluation of existing threats to the species and the effectiveness of existing mechanisms to control those threats; (4) recommendations, if any, regarding reclassification of the Florida manatee from endangered to threatened; and (5) objective, measurable criteria for delisting.

2.3 Determine life history parameters, population structure, distribution patterns, and population trends. Population research and data are needed to determine the status of the Florida manatee population. Data collection should be focused so that information on manatee sightings, movement patterns, site use and fidelity, and reproductive histories all can be utilized for further analyses of manatee survival and reproductive rates. Tools which should be continued as a means of gathering these data include: (1) the Manatee Individual Photo-identification System (MIPS); (2) the carcass salvage program; (3) PIT-tagging; (4) telemetry studies; and (5) aerial survey. It is particularly important to utilize these tools at important wintering sites, areas of high use, and poorly-studied regions.

2.3.1 Continue and increase efforts to collect and analyze mark/recapture data to determine survivorship, population structure, reproduction, and distribution patterns. Photographs using standardized protocols for data collection and coding should be collected annually and documented in the field, especially at the winter aggregation sites; these efforts should be expanded, particularly in Southwest Florida. In addition, PIT tags should be inserted under the skin of all manatees that are captured during the course of ongoing research or rescue/rehabilitation. All manatees captured, recaptured, rescued, or salvaged should be checked for PIT tags and other identifying information, because these data provide an additional source of life history information (changes in manatee size, reproductive status, and general condition between time of tagging and recovery). Methods for reliably checking for PIT tags on free-swimming manatees should be developed and tested, and plans should be developed for re-examining the utility of PIT-tagging manatees of certain age classes (juveniles and subadults) or in specific areas where photo-ID is not a feasible way to re-identify individuals.

Analyses using mark-recapture modeling procedures to estimate annual survival rates should be updated annually, utilizing data in MIPS and comparing results to analyses of PIT tag data. To enhance the accuracy and precision of survival estimates, dead manatees previously identified by photographic documentation must be noted in the MIPS database before mark-recapture analyses are undertaken. This research should include estimates of sample sizes required to determine population traits, such as survival and reproductive rates.

Additionally, emphasis should be placed on estimating variance and 95% confidence intervals.

Concurrently with data collection and monitoring, it is important to conduct long-term studies of reproductive traits and life histories of individual females. Such studies would provide information on: (1) age at first reproduction; (2) age-specific birth rates; (3) calving interval; (4) litter size; and (5) success in calf-rearing. The relative success of severely- and lightly-scarred females in bearing and rearing calves also should be determined.

2.3.2 Continue collection and analysis of genetic samples to determine population structure and pedigree. Collection of tissue samples from salvage specimens and from living manatees at winter aggregation sites, captured during research, or rescued for rehabilitation should continue. Continued genetic analysis through collaborations with state and federal genetics laboratories may reveal greater population structure than has been demonstrated thus far (i.e., a significant difference between east and west coasts, but not within coasts). Such research will improve our ability to define regional populations and management units. Stock and individual identity for forensic purposes ultimately will be possible. Analytical techniques recently developed for identifying the structure of other marine stocks should be investigated.

Paternity cannot be established in wild manatees without the ability to determine family pedigrees. This information is needed to determine if successful reproduction is limited to a small proportion of adult males, which has important implications for the genetic diversity of the Florida manatee population. By continuing the development of nuclear DNA markers, pedigree analysis can be applied to the growing collection of manatee tissue samples. Pedigree analysis also would improve greatly our knowledge of matrilineal relationships and female reproductive success. Identification of factors associated with successful breeding by males is important in assessing reproductive potential in the wild and in captivity.

2.3.3 Continue carcass salvage data analysis to determine reproductive status and population structure. Information and tissue samples collected from all carcasses recovered in the salvage program to determine reproductive status should be continued. Resulting estimates of reproductive parameters complement information obtained from long-term data on living manatees and will help to determine trends and possible regional differences in reproductive rates. The salvage program yields important information on the manatee population sex ratio and proportion of age classes (adult, subadult, juvenile, and perinatal) within each cause-of-death category. Annual changes in these proportions may indicate increases or decreases in certain types of mortality, and thus should be considered as part of the weight of evidence that supports (or rejects) a reclassification decision. Ear bone growth-layer-group analysis should be continued to determine more precise ages of dead manatees, particularly those that have a known history through the MIPS database, telemetry studies, or PIT tag data. Although the age structure of the carcass sample is biased toward younger animals, opportunities may occur to document better the natural age structure within specific regions because of age-independent mortality events.

2.3.4 Continue and improve aerial surveys and analyze data to evaluate fecundity data and to determine distribution patterns, population trends, and population size. Aerial surveys provide limited information on the proportion of calves to adults, which may provide insights on reproductive trends when a long time-series of surveys have been conducted by one or relatively few individuals in the same geographic regions. Calf counts from such surveys should be continued and should be compared to those obtained by photo-ID methods.

As appropriate and possible, local and regional aerial surveys should be undertaken or continued to improve information on habitat use patterns and changes in distribution. Documentation of changes in distribution at power plants will be particularly important when changes in warm water availability occur.

Methods to correct for various types of visibility bias in surveys should be developed. Standard procedures for survey teams involved in annual statewide surveys need to be developed and implemented. Where appropriate, strip transect aerial surveys should be used, as it is possible to use this type of survey data to detect regional population trends. Specifically, strip transect surveys should be continued on an annual basis in the Banana River, and their feasibility should be investigated in remote coastal areas of Southwest Florida. To the extent possible, all aerial surveys should be designed to estimate accurately a minimum population number.

2.3.5 Continue collection and analysis of telemetry data to determine movements, distribution, habitat use patterns, and population structure. Multi-year telemetry studies have been completed for the Atlantic coast and Southwest Florida from Tampa Bay through Lee County, and research findings have been summarized in manuscripts currently undergoing peer review. Radio-tracking has provided substantial documentation of seasonal migrations, other long-distance movements, and local movements that reveal patterns of site fidelity and habitat use. Such information is needed from each region, particularly Southwestern Florida and the Everglades and areas where anticipated changes are likely to impact manatees, in order to develop management strategies for all significant subgroups within the regional population, however transitory they may be.

Steps should be undertaken to incorporate geographic positioning system (GPS) technology into telemetry studies to improve the accuracy of manatee location data. Such improvements will be helpful in studying precise habitat-use patterns (e.g., the extent to which manatees use marked boat channels verses waterway margins for travel) and the location of preferred foraging sites, especially around warm-water refuge sites.

2.3.6 Continue to develop, evaluate, and improve population modeling efforts and parameter estimates and variances to determine population trend and link to habitat models and carrying capacity. Uncorrected aerial survey data do not permit statistically valid population estimation or trend analysis. Models to correct for the inherent bias and uncertainty have been developed, and these efforts need to be continued.

It also is important to utilize models such as that developed by Eberhart and O'Shea (1995). The underlying assumptions of a population model, the importance of parameters used in the model, the accuracy and uncertainty of the parameter estimates, the relationships of the parameters, and the appropriateness of the mathematics implemented in the model need to be critically evaluated and updated. Also, comparisons need to be made between predicted outcomes of a model and estimates or indices of population trend from other modeling efforts or other data sets. Steps should be taken to improve and to develop more complex models incorporating additional life history information and which better reflect our understanding of the processes involved in population dynamics.

Where estimates of model parameters need to be developed or improved, other relevant tasks should be modified or strengthened. Because parameters can vary over space and time and such variation affects population growth rates, emphasis should be placed on estimating variance and 95% confidence intervals along with developing best estimates of particular population parameters.

It is important for those developing manatee population models to coordinate their activities and to interact directly with research biologists who have collected manatee life history data or who are very familiar with manatee ecology. Interaction with management also is needed to help focus the questions addressed by present and future modeling efforts. Estimates of the number of manatee deaths that can be sustained per region, while still allowing population stability or growth to be achieved are needed. Coordination is needed to develop better models that meet the needs of manatee biologists, policy makers, and managers. The MPSWG is best positioned to track research developments, link important players, and provide one level of peer review and evaluation. Additional peer review from other internal and external sources also is essential.

As manatee habitat requirements are documented and recovery criteria are identified (based on habitat needs) (Task 3.1.1), it will become possible to link regional population and habitat models and estimate optimum sustainable populations for regions. Integration of population and habitat information is essential to understand the implications of habitat change before negative impacts on manatee population trends can occur. The MPSWG and Geographic Information System (GIS) Working Group should meet jointly on an annual basis to coordinate their activities and progress. Summary reports of these meetings should be distributed to all agencies and interested parties involved in manatee recovery efforts.

2.3.7 Conduct a PVA to help assess population parameters as related to the ESA and MMPA. The FWS should conduct a PVA and/or other modeling exercises to: determine minimum viable population(s); model effects of various scenarios of stochastic events; determine consequences of losses of industrial warm-water refuge sites; further test and refine demographic recovery criteria; and assist in determination of negligible impacts under the MMPA.

2.4 Evaluate and monitor causes of mortality and injury. The manatee salvage/necropsy program is fundamental to identifying causes of manatee mortality and injury and should be continued. The program is responsible for collecting and examining virtually all manatee carcasses reported in the Southeastern United States, determining the causes of death, monitoring mortality trends, and disseminating mortality information. Program data are used to identify, direct, and support essential management actions (e.g., promulgating watercraft speed rules, establishing sanctuaries, and reviewing permits for construction in manatee habitat).

The current manatee salvage and necropsy program components are: (1) receiving manatee carcass reports from the field; (2) coordinating the retrieval and transport of manatee carcasses and conducting gross and histological examinations to determine cause of death; (3) maintaining accurate mortality records; and (4) carrying out special studies to improve understanding of mortality causes, rates, and trends. The carcass salvage program should continue to: (1) describe functional morphology of manatees; (2) assess certain life history parameters of the population; and (3) collect data on survival of known individuals.

To improve the program, FWC should continue to hold manatee mortality workshops to review critically its salvage and necropsy procedures and methods. These workshops: (1) establish and improve "state-of-the-art" forensic techniques, specimen/data collection, and analyses; (2) identify and create projects focusing on death categories that are unresolved; (3) prepare for and assist with epizootics; (4) generate reference data on manatee health; and (5) generate suggestions for attainment of a "healthy" manatee population.

To implement the salvage and rescue program in Florida, FWC maintains a central necropsy facility called the Marine Mammal Pathobiology Laboratory (MMPL) which is located in St. Petersburg. FWC also has three field stations on the east coast situated in Jacksonville, Melbourne, and Tequesta, and one field station on the west coast at Port Charlotte. The GDNR, South Carolina Department of Natural Resources, Louisiana Department of Wildlife and Fisheries, Texas Marine Mammal Stranding Network, University of North Carolina at Wilmington, and others help to coordinate carcass salvages and rescues in other Atlantic and Gulf coast states. FWS and FWC should provide assistance to these manatee salvage and rescue programs through workshops, providing equipment and assistance when possible. The MMPL will maintain and curate the Southeast U.S. Manatee Mortality Database to facilitate management and enhance communication among state agencies and reinforce timely reporting.

2.4.1 Maintain and improve carcass detection, retrieval, and analysis. To the extent possible, the historic mortality database should be reviewed and updated to reflect the cause of death categories currently in used. To estimate the number of unreported manatee carcasses, studies should be done on carcass detection and reporting rates. Studies focusing on carcass drift, rate of decomposition, and how decomposition affects necropsy results should be conducted. Periodic peer reviews should be conducted of necropsy methods, data recording and analysis, and documentation of tissues collected. Selected representative samples should be archived with appropriate national tissue banks. Workshops such as FWC Manatee Mortality Workshop should continue to be conducted to strengthen collaborative research and information sharing. Partnerships with other agencies and process analysis of carcass retrieval protocols should be ongoing to improve efficiency.

2.4.2 **Improve evaluation and understanding of injuries and deaths caused by watercraft.** Longitudinal studies should be established to examine the effect of boats and boating activity on population growth and reproductive success. Investigations of the characteristics of lethal compared to non-lethal injuries and causes should be developed using data from carcasses and photo-ID records. Another important data set would be that characterizing healing in rescued injured animals; under-reporting of watercraft mortality may occur as individuals die from complications resulting from injuries sustained by boats. Lethal and non-lethal injuries should be investigated to characterize size of vessels, relative direction of movement of vessel, and propeller vs. blunt trauma statistics. Research on mechanical characteristics of skin and bones should be developed to obtain a better understanding of the effects of watercraft-related impacts. Regional studies are needed to characterize boating intensity, types of boats, boating behavior, and boating hot spots in relation to manatee watercraft-related mortality.

2.4.3 **Improve the evaluation and understanding of injuries and deaths caused by other anthropogenic causes.** Research is needed to continue to assess manatee behavior leading to vulnerability around the water control structures and navigational locks, as well as operational or structural changes that can prevent serious injury or death of manatees. MMPL should continue to associate forensic observations obtained at necropsy with specific characteristics of the particular structure that caused the death.

Commercial fishing is not a major culprit involved in manatee mortality, unlike the case with most other marine mammals. However, manatees have been killed by shrimp trawls and hoop nets, and in recent years injuries and death from monofilament entanglement, hook and line ingestion, and crab pot/rope entanglement have been more prevalent. There is a need to improve the evaluation and understanding of injuries and deaths of manatees caused by commercial and recreational fisheries. To reduce the increasing numbers of fishing gear entanglements, a multi-agency Manatee Entanglement Task Force has been established and should continue to focus on creating changes in data collection protocols, potential technique/gear modifications, innovative tag designs, entanglement research, gear recovery/clean-up, and education/outreach efforts. Research on rates of entanglement, types of gear, and geographical and temporal changes in rates and types of entanglements should be developed. Studies on behavioral characteristics of manatees contributing to entanglement should be pursued. Research on the amount of marine debris in inshore waters should be conducted, particularly where there are high levels of manatee entanglement. Programs to remove marine debris and recycle monofilament line also should be encouraged and continued (Task 1.7.2).

Although no known death or pathology has been associated with toxicants, some concentrations of contaminants have caused concern. Over time, concentrations of chemicals found in manatees from early studies have changed, possibly as a result of the regulation of chemical use. Such changes highlight the need to monitor tissues for chemical residue and also can provide insight into the presence of different or new compounds in the environment. While a broad range of tests have been conducted, there needs to be a greater focus on endocrine disruptor compounds. These compounds can alter reproductive success and have a dramatic effect on population growth.

2.4.4 Improve the evaluation and understanding of naturally-caused mortality and unusual mortality events. By definition, natural causes of mortality are not directly anthropogenic and thus not easily targeted by management strategies. However, some aspects of natural mortality may be influenced by human activities. These activities include but are not limited to: (1) sources of artificial warm water; (2) nutrient loading; and (3) habitat modification.

Cold stress can be a cause or contributing factor to manatee deaths during the winter. Acute cold-related mortality is related to hypothermia and metabolic changes which occur as a consequence to exposure to cold. Research should continue to focus on critical cold air and water temperatures affecting manatee physiology (particularly as it pertains to acute cold- and cold stress-related mortality). To provide important clues as to how manatees deal with cold temperature, future research should study behavioral adjustments to cold (e.g., directed movement to warm-water refuges, time budget during cold periods, and surface resting intervals during warm spells). Research identifying the manatee's anatomical and physiological mechanisms for heat exchange are an important step to understanding the biological limitation of the species. Ancillary research should include identification of natural warm-water sites, because a growing population of manatees may be seasonally-limited by overcrowding at the larger well-known warm-water refuges.

Research is needed to improve our ability to detect brevetoxin in manatee tissues, stomach contents, urine, and blood. At the same time, environmental detection of red tides, their strengths, and the development of retardants are necessary. More advanced immunological research utilizing manatee cell cultures may result in the development of better treatment of manatees exposed to brevetoxin.

Improved methods are needed to subdivide the perinatal category into categories of: (1) clearly fetal; (2) at or near the time of birth; and (3) clearly born. Once these categories are well-defined, analysis can ascertain the life stage subject to the greatest impact, thus allowing for the future development of appropriate management policies. Field research focusing on factors affecting calf survival should be conducted (e.g., age of mother at reproduction, behavior, characteristics of calving areas, and human disturbance).

The FWS and FWC have created complementary manatee die-off contingency plans (Geraci and Lounsbury 1997; FWS 1998) that have been merged into one comprehensive document (FDEP *et al.* 1998). The document contains information and guidance from the two plans together with advice and provisions outlined in the executive summary from Wilkinson (1996). Research and investigations should follow the protocols and recommendations found in the Contingency Plans. In addition, there should be ongoing collection and storage of tissues and samples from healthy and non-mortality event manatees to establish a baseline and to aid interpretation of test results obtained during a catastrophic event and for retrospective studies. Investigators should contact and work closely with other research projects monitoring and evaluating harmful algal blooms. FWC mortality workshops should continue and help to facilitate and develop cooperative arrangements among investigators and institutions.

2.5 **Define factors that affect health, well-being, physiology, and ecology.** Relatively little attention has been paid to the health and well-being of individual manatees, although factors affecting individuals ultimately influence the overall status of the population. There is a need to determine the relatively constant internal state in which factors such as temperature and chemical conditions remain stable and therefore within a range of values that permit the body to function well, despite changing environmental conditions. Stress is part of existence, and not all stress is bad for an individual. However, a stressor can affect homeostasis and health, and thereby precipitate a chain of events that can compromise the survival of an individual. There also is a need to understand the factors that underlie large-scale trends. For example, individual manatees compromised by severe injury or disease may not be able to reproduce successfully. Similarly, sublethal effects of toxicants and even the effects of nutritional, noise-related, and disturbance-related stresses can impair immune function and potentially reduce the ability of individuals to reproduce. Study plans and protocols should be developed, collaborators identified, and results published.

2.5.1 Develop a better understanding of manatee anatomy, physiology, and health factors. Efforts should be made to develop and publish a synthesis of: (1) current knowledge of manatee serology; (2) ranges of values associated with manatees in various demographic groups; (3) anomalies identified in manatees via serum analyses; and (4) any remaining unanswered questions. Major organs and organ systems have been examined by a variety of scientists over the years. Those systems or organs which have been ignored are important to assessing manatee health and should be studied; these include: (1) the lymphatic system; (2) most parts of the endocrine system; and (3) non-cerebral parts of the brain. In addition, potential changes in reproductive tracts routinely should be assessed as part of ongoing life history assessments. Manatee histology (microscopic anatomy) has been relatively unstudied, compared to gross anatomy. It is of no less importance in understanding normal organ or tissue functions, as well as abnormalities thereof; therefore, responsible agencies should respond to this important deficiency.

Anatomical and experimental studies have indicated that manatees osmoregulate well in either fresh or salt water; however, it is unclear whether or not manatees physiologically require fresh water to drink, and it is unknown what stresses may be created when fresh water is not available. Research should be continued, and managers attempting to protect resources sought by, if not required by, manatees should bear in mind that fresh water is a desirable and possibly necessary resource for healthy manatees.

Body indices research at FMRI has initiated certain measurements documenting the body condition of manatees. Maintenance of this work, and refinements/extensions thereof, should be continued to gain a better understanding of physiology and health of individuals and the population.

Continuous long-term monitoring of individual manatees allows for documentation of an animal's health. Information should be gathered on: (1) the acquisition and severity of new wounds to facilitate research on the length of time required for injuries to heal; and (2) any effects of injuries on behavior or reproduction. Natural factors affecting the health of the population also should be monitored during the course of photo-ID studies on wild individuals (e.g., cold-related skin damage, scars caused by fungal infections, and papilloma lesions).

As discussed earlier, brevetoxin has been implicated or suspected in major and minor mortality events for manatees for decades. Tests now exist to allow pathologists to assess, even retrospectively, manatee tissues for signs of brevetoxicosis. The important questions include: (1) how many manatee deaths can be truly attributed to exposure to brevetoxin over the years; (2) if red tides are a natural occurrence, how can effects of red tides on manatees be reduced or mitigated; (3) would changes in human activities (i.e., creation of warm-water refuges which lead to aggregations of manatees) appreciably change vulnerability of the animals; and (4) have human activities contributed to increased prevalence and virulence of red tides.

Inasmuch as a single epizootic event can cause 2 to 3 times as many manatee deaths as watercraft causes annually, gaining a better understanding of the issue is vital and urgent. Development of cell lines and testing of manatee tissues would represent an extremely useful approach. In particular, preliminary results indicate that exposure to brevetoxin reduces manatee immune system function. Further study of the immune system will define levels of concern and will help to identify when rehabilitated manatees are ready for release into the wild. Other natural toxins have affected marine mammals (e.g., saxitoxin) and may represent another potential problem for manatees. Exposure of cultured cells of manatees to saxitoxin and assessment of the responses of those cells, would be useful.

Toxicant studies demonstrate that a few metals occur in high concentrations in manatee tissues. Testing for toxicants can be extremely expensive, thus a carefully-constructed study plan should be developed first to address the most critical uncertainties and to make the assessments as cost-effective as possible. Sediment chemistry/toxicity testing could be used as an indicator to direct toxicant studies in important habitats known to contain sediments that are contaminated.

A disease involves an illness, sickness, an interruption, cessation, or disorder of body functions, systems, and organs. As noted at the outset of this section, scientists need to learn the boundaries of normal structure and function before they can diagnose what is normal or diseased. This process has occurred to some degree through the necropsy program, but it needs considerable refinement. Over the years, cause of death for about 1/3 of all manatee carcasses has been undetermined; this percentage would doubtless drop considerably with better information about and diagnosis of manatee disease states. Planned workshops by the FMRI will attempt to bring scientists conducting necropsies on manatees together with pathologists and forensic scientists working with humans and other species. This effort should be very useful as a first step in an ongoing process of refinement.

Nutritional characteristics of manatee food plants and the importance of different food sources for different manatee age and sex classes in various regions are needed to help assure that adequate food resources are protected in different areas of the population's range. Ongoing studies should be completed to identify manatee food habits and the nutritional value of different aquatic plants important to manatees. In addition, seasonal patterns of food availability in areas of high manatee use need to be documented. Research should also address manatee foraging behavior, emphasizing ways that manatees are able to locate and utilize optimal food resources.

Since degrees of parasitic infestation may be associated with the changes in the health of manatees, assessments of changes in prevalence of parasites over time should be undertaken. Inasmuch as parasite loads are assessed, at least qualitatively, during necropsies, this should be easy to accomplish, relatively speaking.

2.5.2 Develop a better understanding of thermoregulation. Although work has been ongoing to assess effects of environmental temperatures on metabolism of manatees, the relationship among temperature change, metabolic stress, onset of chronic or acute disease symptoms, and even mortality of manatees is not perfectly understood. As noted above, the relationships among manatee reproductive status, body condition, thermal stress levels, and metabolic responses to such stress remain unclear. Answers are needed as the specter of decreased availability of both natural and artificial warm-water sources looms. The research should focus not only on lower critical temperatures (the cold temperatures where metabolic stress occurs), but also on the upper critical temperature.

2.5.3 Develop a better understanding of sensory systems. Vision in manatees has been well studied and tactile ability and acoustics also have been assessed. Conclusions reached as a result of acoustic studies are somewhat inconsistent and controversial, especially in terms of the extent that manatees may hear approaching watercraft. Since the auditory sense of manatees appears to be vital to their ability to communicate and to avoid injury, further studies are warranted. In addition, although chemoreception has been suggested as a mechanism by which male manatees locate estrous females, chemosensory ability of manatees is virtually unknown and should be studied.

2.5.4 Develop a better understanding of orientation and navigation. It is clear from various lines of evidence that manatees show site fidelity, especially in terms of their seasonal use of warm-water refuges, but also in their use of summer habitat. To some extent, calves learn locations of resources from their mothers. However, the way that manatees perceive their environment, cues they use to navigate, and the hierarchy of factors they use to select a particular spot or travel corridor are all unknown. As humans continue to modify coastal environments (physically, acoustically, visually, and chemically), it would be useful to understand better how such changes may interfere with the manatee's ability to orient and to locate or select optimal habitat.

2.5.5 Develop a better understanding of foraging behavior during winter. Research should address manatee winter foraging behavior, emphasizing ways that manatees are able to locate and utilize optimal food resources. Research should address food availability near winter aggregation areas and determine if they are a limiting resource. Therefore, food resources near winter aggregation sites in each region need to be assessed to ensure that food resources are adequate and protected.

2.5.6 Develop baseline behavior information. Both field studies and controlled experiments at captive facilities are needed to document basic behaviors. This documentation will allow detection and understanding of changes in behavior that occur through changes in allocation of essential resources, such as vegetation and warm water. Telemetry, photo-ID, and aerial videography have been useful tools for behavioral research. New innovative approaches are needed, particularly in habitats where visibility is poor.

2.5.7 Develop a better understanding of disturbance. Stress caused by disturbance will be difficult to document, but if manatees move away from critically important resources (e.g., warm water in winter) to avoid being disturbed, this movement could place the animals in immediate and acute jeopardy. Sources and level of activities eliciting disturbance responses need to be characterized further.

2.5.7.1 Continue to investigate how a vessel's sound affects manatees. In order to understand the nature of watercraft/manatee interactions, the primary reasons for collisions must be identified. Manatees, particularly mothers and calves, communicate vocally. Often, while vessels are still outside of visual range, manatees initiate movements as boats approach, suggesting that they respond on the basis of hearing the boats. Noise from boats or other sources may interfere with communications or provide a source of stress. Hearing capabilities have been examined through studies involving two individuals in captivity (Gerstein 1995, 1999).

There is a need for further research on hearing capabilities and the effects of noise on manatees potentially to provide another management tool to minimize collisions between manatees and boats. In particular, it is important to determine: (1) the sensitivity of manatee hearing to the different kinds of vessels to which they are exposed; (2) the range of frequencies of importance to manatee communication; (3) the abilities of manatees to localize sound sources; and (4) the role that habitat features may play in altering sound characteristics. The levels and characteristics of vessel sounds leading to behavioral changes, including potentially vacating an area, need to be determined. Development of manatee avoidance technology needs to be thoroughly researched and assessed and managers need to evaluate the MMPA and ESA “take” issues related to implementing such technology.

2.5.7.2 Investigate, determine, monitor, and evaluate how vessel presence, activity, and traffic patterns affect manatee behavior and distribution. More effective diagnosis of watercraft-related injuries and mortalities is important for describing the extent and nature of the threat posed by watercraft. Mortality workshops are intended to improve our ability to diagnose watercraft-related mortalities more effectively on both fresh and decomposed carcasses. Prevention of such injuries and mortalities is the goal. Research is needed to address the causes of watercraft mortality and the effectiveness of management actions. Importantly, such research also should investigate the effects of sublethal injuries and stress occurring as a result of boating activity. Injuries and stress may: (1) lead to reductions in animal condition and reproductive success; (2) cause animals to abandon habitat important for foraging, reproduction, or thermal regulation; or (3) impair immune system function thereby increasing the vulnerability of animals to disease, pollutants, or toxins. Thus, indirect or secondary effects of boating activity also may impede population recovery in ways that have not yet been assessed.

MML, FWC, and others are investigating reactions of manatees to boats. Preliminary information indicates that manatees perceive boats, but may, under certain circumstances, react in ways that place the animals in the path of, rather than away from, the boats. Additional studies of manatee responses to boats and vessel acoustics are needed (Task 2.5.7.1). Indirect deleterious effects of shallow-draft or jet boats that can disturb manatees and cause them to move to boating channels or interrupt normal behaviors need to be studied. An evaluation of spatial and temporal factors associated with risk to manatees (i.e., proportion of time manatees are exposed to vessels relative to depth, habitat, and manatee activity) should be conducted. Additional factors to be investigated include: (1) types and frequency of approaches; (2) numbers of boats; (3) distance of nearest approach; (4) individual variations in manatee responses to boats; (5) influences on diurnal activity patterns and habitat use; and (6) effects on mothers and young.

2.5.7.3 **Assess boating activity and boater compliance.** Studies that characterize the intensity and types of boating activities should be conducted at selected locations around the state, with emphasis on areas where boat-related mortality of manatees is highest. Studies are underway and should be expanded to additional areas to identify and evaluate adherence to manatee speed zone restrictions through statewide boater compliance studies. The following studies should be continued and assessed: (1) the frequency of boater compliance with posted manatee speed zone restrictions; (2) the degree of boater compliance with posted manatee speed zone restrictions; (3) the levels of compliance among boat classes, seasonally, and temporally; (4) changes in compliance resulting from different enforcement regimes; and (5) changes in compliance resulting from different signage. Underlying sociological factors affecting compliance also should be investigated (Task 1.4.4). New methods for monitoring compliance, such as remote video systems, should be assessed.

2.5.7.4 **Evaluate the impacts of human swimmers and the effectiveness of sanctuaries.** Specific circumstances or characteristics of human swimming, snorkeling, or SCUBA diving that may result in changes in manatee behavior, including vacating an area, remain to be determined. Factors to be investigated include: (1) types and frequency of approaches; (2) numbers of swimmers; (3) distance of nearest acceptable approach; (4) occurrence of contact; (5) individual variations in manatee responses to humans; (6) influences on diurnal activity patterns and habitat use; and (7) effects on mothers and young.

2.5.7.5 **Evaluate the impacts of viewing by the public.** The relative benefits of burgeoning human attention as compared to potential adverse impacts on the animals have not been evaluated properly to determine the desirability of increasing or decreasing control over manatee viewing activities. Studies relating marketing and overall levels of human viewing activities to changes in manatee behavior, including vacating an area, need to be conducted. Conversely, benefits accrued to the manatees from increased viewing by the public also should be evaluated for comparison.

2.5.7.6 Evaluate the impacts of provisioning. In many parts of the species' range, people provide food or water to manatees, in spite of regulations prohibiting such activities. A systematic evaluation should be conducted to determine if these activities potentially adversely affect manatees in terms of changing their behavior, placing them at greater risk from other human activities, or encouraging them to use inappropriate habitat.

OBJECTIVE 3: Protect, identify, evaluate, and monitor manatee habitats. Manatee population recovery and growth depend on maintaining the availability of habitat suitable to support a larger manatee population. Manatee habitat needs include: (1) ample food sources (including submerged, floating, and emergent vegetation); (2) warm-water refuges during cold winter periods; (3) quiet, secluded areas for calving and nursing; (4) mating and resting areas; (5) safe travel corridors connecting such areas; and (6) possibly fresh drinking water. These resources are affected by development in coastal and riverine areas and by human activities in waterways used by manatees. Managers must protect the quality and quantity of essential manatee habitats and provide for human needs.

Many important manatee areas in Florida are protected through the state's Florida Manatee Sanctuary Act, which protects manatees and their habitat through designated manatee protection zones and sanctuaries; manatee areas also are protected under the ESA and MMPA manatee sanctuaries and refuges provisions. These Acts provide a means to minimize the direct and indirect effects of coastal development on manatees. Existing protection areas should be evaluated and properly-managed, and other important unprotected areas should be identified and afforded necessary protection. Resource agencies, through these authorities, are able to address and minimize the effects of development through comments to state and federal permitting agencies. County MPPs are important guidance documents for agencies and developers. Plans should be developed for those counties lacking state- and federally-approved plans. All plans should be reviewed periodically.

In order to protect adequate quantities of essential habitat in the quality necessary to recover the manatee, information is needed to identify habitats, assess their condition, and understand the factors affecting them.

Methods and means should be improved/developed to understand better and monitor the interactions that take place between manatees, manatee habitat, and humans. A HWG should be convened to assess needs and to identify the tools needed to identify, monitor, and evaluate manatee habitats and better define manatee ecology.

3.1 Convene a Habitat Working Group. A HWG (established as a subcommittee of the recovery team), that includes resource managers, manatee biologists, and experts familiar with the many features of the manatees' aquatic environment will meet on a regular basis. This group will: (1) assist managers responsible for protecting habitat; (2) help identify information needs; (3) ensure the implementation of tasks needed to identify, monitor, and evaluate habitat; and (4) refine and improve the recovery criteria that address threats to manatee habitat by October 2002.

3.2 Protect, identify, evaluate, and monitor existing natural and industrial warm-water refuges and investigate alternatives. One of the greatest threats to the continued existence of the Florida manatee is the stability and longevity of warm-water habitat. Manatees have learned to rely on natural and industrial warm-water refuges during periods of cold weather. This reliance has made it extremely important for managers and researchers to understand the role played by warm-water refuges in overall manatee survival. Protection, enhancement and/or replacement, identification, and characterization of these sites are essential to the continued recovery of the manatee population.

3.2.1 Continue the Warm-Water Task Force. A task force consisting of governmental agencies, power industry representatives, and non-government organizations has been convened to develop and implement strategies to ensure safe and dependable warm-water refuges for manatees. In developing these strategies, the task force should: (1) develop a conceptual plan for a long-term network of warm-water refuges; (2) determine the optimal northern extent of industrial warm-water refuges; (3) develop a plan to reduce the potential loss of manatees in the event that a power plant goes off-line, either permanently or for an extended period of time; (4) explore whether new sources of artificial warm water are an avenue that should be considered and, if so, identify potential new sources that could be exploited to produce consistent, dependable, and inexpensive warm water. The task force also should examine the potential effects of deregulation of the Florida power industry.

3.2.2 Develop and implement an industrial warm-water strategy. Short- and long-term strategies should be developed for industrial warm-water refuges. Efforts to address short-term concerns currently are accomplished through the state-adopted NPDES permitting program, which includes power plant-specific MPPs. These plans ensure a safe, consistent, and dependable network of warm-water refuges. A long-term plan, addressing concerns identified in Task 3.2.1, should be developed with the creation of an effective network of warm-water refuges as its goal. The development of this plan will require that all industrial sites used by wintering manatees be identified, described, and monitored. These assessments should contain the location and physical description of each plant, expected life span of each plant, and history of manatee use at each plant. Habitat attributes associated with each plant also should be addressed. These attributes should include: (1) availability and location of forage and freshwater; and (2) an assessment of human disturbance levels over the next 5, 10, and 20 years. As more information regarding each plant is collected, BPSM and FWS should recommend modifications to existing power plant-specific MPPs to insure protection of manatees at these facilities.

3.2.2.1 Obtain information necessary to manage industrial warm-water refuges. Research efforts should focus on collating and analyzing existing data related to manatees and industrial warm-water refuges. New research initiatives should focus on filling in data gaps concerning manatees, warm water requirements, and associated behaviors. These research efforts should include: (1) determining the tolerance of manatees to low ambient air and water temperatures; and (2) investigating manatee use of warm-water refuges and nearby habitats in relation to water temperature. Existing research efforts such as aerial monitoring of manatee use at power plants and identifying trends in the abundance of manatees at each plant should be continued. Carrying capacity and factors influencing the number of manatees which can and/or should be using each individual plant should be assessed for each facility. Building partnerships with the industry is imperative in finding resources and answers to a multitude of questions related to this issue.

3.2.2.2 Define manatee response to changes in industrial operations that affect warm-water discharges. Current power plant operations involve activities that affect their respective warm-water discharges. For example, in the absence of demand for electricity, power companies cut back on the amount of electricity produced by certain power plants. These cut-backs may result in temporary or long-term loss of warm water or diminished flows of warm water, thereby reducing their attractiveness to wintering manatees. These operational changes and the effects they have on wintering manatees should be monitored. Understanding the response of manatees to these changes will provide important information for managers seeking to improve short- and long-term management strategies.

3.2.3 Protect, enhance, and investigate other non-industrial warm-water refuges. Non-industrial warm-water refuges include areas such as dredged basins which provide warm water because of their configurations and other features. For example, deep dredged basins with few inputs from adjoining ambient waters may create solar-heated, manatee-accessible systems with water temperatures several degrees above ambient. Dredged areas accessible to manatees also may penetrate sources of groundwater. When tapped into, these warm-water seeps elevate ambient water temperatures and are attractive to manatees in need of refuge from the cold. Due to the uncertainty of some of the power plant discharges being available in the future for manatees, alternatives to these discharges should be identified and developed, if needed. New environmentally-sensitive, non-industry-dependent warm-water refuges should be considered. Sites should be identified and technologies tested while existing refuges remain available.

3.2.4 Protect and enhance natural warm-water refuges. The continued functioning of the natural springs, rivers, and creeks used by manatees is essential to their recovery. Of greatest immediate importance are the spring systems at Blue Spring, Kings Bay, Homosassa Springs, and Warm Mineral Springs. These springs are used as cold season warm-water refuges by at least 20% of the manatee population during winter cold fronts (FWC, unpublished data). Critical to the continued functioning of natural warm-water sites is the maintenance of minimum spring flows and levels, maintenance or improvement of water quality, and protection of adequate foraging habitat within and adjacent to these sites.

3.2.4.1 Develop and maintain a database of warm-water refuge sites. BPSM and FMRI staff should identify and maintain an active database of all natural and non-industrial warm-water refuge sites. When new sites are discovered, these should be added to the database. Manatee use and changes in system function these sites should be monitored over time. Sites should be prioritized based on extent of manatee use and regional importance to cold season populations. FWS and FWC staff also should identify potential natural refuge sites near industrial warm-water facilities used by manatees and assess whether enhancement of these sites should be pursued.

3.2.4.2 **Develop comprehensive plans for the enhancement of natural warm-water sites.** If the strategy for a site includes enhancement, then a comprehensive plan should be developed addressing: (1) agency responsibilities; (2) permitting requirements; (3) funding sources; and (4) physical modifications. Existing and additional needed protection measures for each site should be identified and assessed for effectiveness. To provide for maximum protection of these warm-water sites, protection strategies also should include land acquisition, use of regulatory mechanisms, and outreach.

3.2.4.3 **Establish and maintain minimum spring flows and levels at natural springs.** Water demands from the aquifer for residential and agricultural purposes have diminished spring flows at important manatee wintering areas. Additionally, paving and water diversion projects in spring recharge areas can reduce water levels at springs.

A database of priority springs and flowing systems accessible to manatees should be developed and maintained by FWC staff. The database should include baseline information on water availability and quality so that adverse changes can promptly be identified and impacts mitigated. FWC and FWS should coordinate with the WMDs to prioritize establishing minimum spring flows for high manatee use systems, such as King, Homosassa and Blue Springs. Agency staff should advocate maintaining spring flow rates above the minimum levels necessary to support manatees. FWS and FWC should develop a coordinated review program with FDEP and WMDs' permitting programs on applications requesting ground water withdrawal from applicable spring systems. In addition, FWC and FWS should participate in FDEP and/or WMD springs task force efforts where manatee warm-water refuge protection issues are involved. State legislation protecting spring flow should be sought. Other recovery partners should advocate the establishment of minimum flows and levels as appropriate.

3.2.5 **Assess changes in historical distribution due to habitat alteration.** Summarize what is known about historical distribution in order to clarify how and to what extent artificial warm-water refuge sites and flood control canals have altered distribution and habitat use patterns.

3.3 **Establish, acquire, manage, and monitor regional protected area networks and manatee habitat.** The establishment of manatee sanctuaries, refuges, and protected areas, along with the federal, state, local and private acquisition of coastal areas and essential manatee habitat has created regional networks of protected areas crucial for the long-term survival of the manatee population. Management of these refuges, sanctuaries, reserves, preserves, and parks in Florida offers assurance that habitat (e.g., warm-water springs, grassbeds, and quiet secluded waterways) important to manatees are protected. These efforts need to continue as well as efforts to manage key protected areas in ways that enhance achievement of the recovery objectives.

In addition, work should be undertaken to better understand and monitor the complex interactions among manatees, humans, and manatee habitat. Information from such a program will identify future threats to manatee populations and help to explain observed manatee population trends. Presently, there is no systematic approach to monitoring the condition of important manatee habitats. To provide a means of detecting potential problems in areas supporting manatee populations, essential manatee habitat features should be monitored and evaluated. This information also will assist in determining areas which may need some additional level of protection (i.e., sanctuaries or refuges).

3.3.1 **Establish manatee sanctuaries, refuges, and protected areas.** Under authority of the ESA and its implementing regulations at 50 CFR 17, FWS may designate certain waters as manatee sanctuaries (areas where all waterborne activities are prohibited) or manatee refuges (areas where certain waterborne activities may be regulated). In the 1980s and 1990s, FWS designated six manatee sanctuaries in Kings Bay, Citrus County. In addition, under the NWR System Administration Act, the FWS established a 24-square-km (15-square-mi) zone, in the upper Banana River south of the NASA Causeway, in which motorboats are prohibited. Any such established areas must be posted and enforced.

In 2000, FWS initiated an effort to assess and propose new manatee refuges and sanctuaries throughout peninsular Florida. The goal is to consider the needs of the manatee at an ecosystem level and to use this rule-making provision to ensure that adequately protected areas are available to satisfy the life requisites of the species, with a view toward recovery. The FWS will periodically assess the need for additional or fewer manatee refuges and sanctuaries.

The establishment of No Entry, Limited Entry and No Motorboat zones by state and local regulations function similarly to FWS manatee sanctuaries. These protection areas were established to prevent human disturbance. Examples of these types of zones include: (1) Winter No Entry Zones around power plant warm-water outfalls that attract manatees; (2) Winter No Entry Zone at Blue Spring in Volusia County; (3) Year-round No Entry at Pansy Bayou in Sarasota County; and (4) the Virginia Key and Black Creek Year-round No Entry Zones in Dade County.

3.3.2 Identify and prioritize new land acquisition projects. Manatee-related land acquisition, which helps to expand regional networks of essential manatee habitat, is particularly important. In this regard, identification of priority areas must consider regional manatee habitat requirements and relationships among essential manatee habitats. To promote and guide these efforts, the HWG will establish a subcommittee, to include individuals from FWS, FWC, USGS-Sirenia, and others, to convene an annual meeting regarding acquisition projects. The subcommittee will act as a clearinghouse on the status of manatee acquisition projects and otherwise help coordinate efforts for relevant land acquisition projects by federal and state agencies, The Nature Conservancy, and others. As new information on manatee habitat use patterns and essential habitats become available, new areas for acquisition should be identified as warranted. Recent examples of local, state and federal manatee-related acquisition efforts are at Weeki Wachi Spring, Blue Waters and Three Sisters Spring in Citrus County, Warm Mineral Spring Run in Charlotte County, and Munyon and Little Munyon Islands in Palm Beach County.

3.3.3 Acquire land adjacent to important manatee habitats. Several NWRs managed by FWS contain essential manatee habitat and are adjacent to other essential non-protected manatee habitat areas. Expanding these areas and establishing new refuges would significantly improve protection not only for manatees, but also for many other species. State land acquisition programs administered by the five regional WMDs, FDEP, FWC, and DCA have acquired many areas that will further manatee habitat protection and have many important acquisition projects in varying stages of development. Local and private land acquisition efforts also enhance manatee habitat protection. Particularly important areas utilized as warm-water refuges, such as Three Sisters Spring in Citrus County and Warm Mineral Spring in Sarasota County, should be considered. As possible, FWS and state land acquisition programs cooperatively should pursue expanding publically-owned lands to incorporate manatee habitat.

3.3.4 Establish and evaluate manatee management programs at protected areas. After essential manatee habitats are acquired as identified in Task 3.3.5, the agencies responsible for administering those areas should incorporate manatee protection and public awareness measures into these unit administration programs. Such management measures, depending on local conditions and human activity patterns, may be needed to ensure that activities and development projects within or adjacent to protected areas or affecting state-owned submerged lands do not adversely affect manatees or their habitat. Such measures should be updated as appropriate.

3.3.5 Support and pursue other habitat conservation options. Manatee habitat conservation can be achieved through existing regulatory means (Task 1.2 and its subtasks) and through coordination with private foundations with an interest in environmental protection. Federal and state regulatory programs can provide for additional protection of water quality and aquatic resource protection through establishment of conservation easements and mitigation. Private foundations should be approached to procure sensitive lands around important manatee habitat areas. Purchased lands can be managed with the purpose of maintaining water quality (and quantity in the case of springs) by existing local, state or federal programs or through the foundation itself. It is also possible to foster protection of privately held lands important to manatee habitat protection through government tax incentives and focused outreach efforts.

3.3.6 Assist local governments in development of county MPPs. Local governments in Florida are encouraged to develop comprehensive, multi-faceted MPPs with technical and financial assistance from FWS , FWC, FDEP, COE, special interest groups, and the general public. Each plan should be designed to ensure manatee protection by addressing a variety of recovery elements or components including: (1) regulating boat facility siting; (2) protecting manatee habitat; (3) providing for public outreach and education; and (4) ensuring appropriate levels of law enforcement. Each plan also should reflect manatee protection zones established by state and federal agencies (sanctuaries, refuges, boat speed zones) and consider if other locally-approved zones are needed. These comprehensive plans will assist in planning future development in a manner compatible with manatee protection, and will ensure local government involvement in manatee protection efforts. All efforts should be made to achieve concurrence among state and federal agencies regarding the approval of county plans.

If local governments are not willing or able to develop comprehensive plans, then FWS and FWC will offer assistance in the development of individual components which would aid in manatee recovery and form the basis for future comprehensive planning efforts. For example, such a component might outline local government's public outreach and education efforts and set forth funding needs and sources as well as an implementation schedule. While not as valuable as a comprehensive plan, these individual components would still be helpful in achieving recovery of the manatee.

In the absence of approved MPPs, or components thereof, case-by-case decision-making on permit applications by state and federal regulatory agencies will consider the best available scientific and commercial data in order to render their decisions. It is likely that some permits will be denied or required to undergo significant modifications because of uncertainties resulting in the absence of comprehensive planning. While plans or components do not have official status as state or federal laws, certain elements, such as boat facility-siting, can be adopted as local ordinances, and the implementation of these elements can strongly influence and streamline state and federal permitting systems.

Florida's Governor Jeb Bush convened a special manatee summit in October 2000, to examine improvements which might be made to achieve better manatee protection. A special panel, including representatives from marine-related industries, environmental organizations, local governments, and state and federal agencies, evaluated the elements of a MPP. After discussing boating speed limits, boater education, law enforcement, manatee refuges and sanctuaries, and marina siting, the panel unanimously agreed that improved law enforcement and improved boater education should be a priority. Additionally the panel agreed that speed zones and sanctuaries were both effective means of protecting manatees. Governor Bush envisioned that the results of the summit would be used to develop more detailed budget priorities, legislation, and local plans for the protection and conservation of manatees, while preserving Florida's traditional culture of recreational and commercial boating.

3.3.7 Implement approved MPPs. MPPs approved by FWC and FWS should be implemented with the assistance of the action agencies, as appropriate. Copies of these plans should be provided to federal and state agencies as reference documents for decision-making with regard to permitting, leasing submerged lands, project review, or other agency actions. To affirm federal support for the county MPP process, COE should incorporate county MPPs into their permit review process and consult with FWS regarding the adoption of MPPs for the purpose of permit review.

As new information becomes available on manatees and the effectiveness of measures to protect manatees and manatee habitat, there may be a need to modify MPPs. FWC and FWS shall take the lead in periodically reviewing MPPs and make recommendations regarding the need to modify and/or update them.

3.3.8 Protect existing SAV and promote re-establishment of NSAV. Manatees in most Florida waters depend upon the prolific growth of SAV (e.g., seagrass and freshwater submerged plant communities). Coastal construction activities (e.g., dock development, dredging, shoreline stabilization, and urbanization) have contributed to the destruction of SAV habitat. Water pollution contributing to reduced water transparency has reduced the abundance of SAV in most water bodies around the state. Introduction of exotic plant species has eliminated or threatened diverse assemblages of freshwater NSAV communities, providing manatees with restricted food resources in many accessible rivers, lakes, and springs. Nutrient pollution, through contamination of ground and surface waters at major manatee aggregation areas like Crystal and Homosassa Rivers, has contributed to a reduction of available food plants in these areas. Such pollution has caused dramatic increases in certain blue-green algae species (most notably *Lyngbia spp*.) that covers over SAV and prevents growth of manatee food plants.

All manatee research, resource protection, and conservation agencies/organizations should actively support the establishment of water quality standards that will protect the existing and promote the regeneration of SAV in all Florida waters. In particular, FDEP and WMDs actively should pursue changing water transparency and nutrient pollution standards to reflect the light requirements of seagrass and other NSAV species. Water transparency standards should be based on light regimes needed for native rooted aquatic plant species historically found in affected waters.

3.3.8.1 Develop and implement a NSAV protection strategy. Protection and restoration of NSAV communities can be accomplished by enforcing and augmenting existing regulatory programs. Prior to a permit being issued, an assessment of seagrass resources should be required, involving site sampling. This sampling should occur between May and October to coincide with the seagrass growing season and should be based on a standardized sampling methodology so that the assessments can be compared equitably. For seagrass communities, regulatory agencies should standardize monitoring of seagrass damage and alterations authorized through environmental resource permitting activities. The HWG should develop and implement standardized seagrass mitigation criteria for all projects proposing any activities resulting in damage to seagrass. Freshwater NSAV communities considered for state and federal permitting programs should be afforded the same level of protection as seagrass, because the destruction or alteration of such communities often leads to dominance of exotic species. FWS and FWC should participate actively in regional and local seagrass protection working groups (e.g., National Estuarine Program focus groups) to assist in directing protection efforts in areas important to manatees.

3.3.8.2 Develop and implement a state-wide seagrass monitoring program. FWS, NFS, FWC, and FDEP should develop and implement a regular statewide seagrass monitoring program based on a biennial remote sensing effort. Monitoring efforts should involve trend analysis and comparison to historical distribution of all areas supporting seagrass growth. The FMRI should continue to be the central repository for all collected seagrass monitoring information in Florida. FDEP and FWC should establish a task force to identify total state-wide losses of seagrass due to human activities including, but not limited to, dredge-and-fill projects, dock construction, propeller-scarring, vessel-groundings, freshwater diversion projects, and industrial/municipal pollution changing water transparency. This task force should use the best available scientific data to assess the magnitude of statewide seagrass loss and modify regulatory practices to allow for recovery of seagrass in areas where it has been lost and to protect it in areas where it currently exists.

3.3.8.3 Ensure aquatic plant control programs are properly designed and implemented. Aquatic plant control programs around the state are conducted mostly in freshwater systems and are designed to control the dominance of certain species of exotic or native nuisance plants. Introduced species quickly can displace native plant communities and cause a reduction of diversity, fluctuations in NSAV abundance, and nutritional value of the habitat for manatees. It should be noted, however, that manatees have come to rely on exotic vegetation in some areas. Therefore, while efforts should support NSAV restoration, care must be taken to ensure adequate supplies of winter forage, including both native and exotic species. Such programs are especially important in areas of large manatee aggregations, such as Crystal River, Homosassa River, Warm Mineral Spring, and Blue Spring.

FWC, FWS, FDEP, and COE should continue to coordinate aquatic plant control programs for these systems through established working groups that address the protection of manatee habitat. The focus of these groups should be to: (1) reduce the need for excessive aquatic herbicide use through a policy of maintenance control for nuisance species; (2) focus control efforts during periods of minimal manatee use; (3) remove infestations of new exotic plant species; and (4) maintain a historically diverse NSAV community accessible to manatees as much as possible. New working groups should be established for waterways where aquatic plant control programs may jeopardize the aquatic plant abundance and diversity needed to sustain recognized manatee aggregations. FWC, FDEP, and FWS should continue to coordinate state-wide aquatic plant control policies, such as the exclusion of the use of copper herbicides in manatee habitat and on areas where conflicts between manatees and aquatic herbicide use may develop.

3.3.9 Conduct research to understand manatee ecology. Habitat-oriented research is important in identifying key habitats and the factors that determine what features are important for manatees and their recovery. Research should focus on the interrelationships between humans, manatees and their environment. Researchers should continue to monitor free-ranging manatees throughout their habitat, observe behaviors, document habitat use, and define how these influence the status of the manatee. Such research will help to understand and protect the manatees' environment; therefore, efforts should be made to improve ongoing studies and methods and to develop new ones.

3.3.9.1 Conduct research and improve databases on manatee habitat. Habitat-related research should focus on: (1) evaluating food preferences, nutritional requirements, and freshwater requirements; (2) development of body condition indices as potential indicators of environmental conditions; (3) evaluation of and monitoring the extent and condition of seagrass beds; (4) the effects of manatee grazing on seagrass ecology and recovery; and (5) continuing current studies outside Florida on the relationships between manatee health and reproduction with habitat condition. Results from these studies should provide information useful in the design of monitoring studies, estimation of manatee carrying capacity of seagrass beds in key areas, and a better understanding of the manatee's role in maintaining healthy, diverse seagrass communities.

3.3.9.2 Continue and improve telemetry and other instrumentation research and methods. Radio tracking provides an extremely valuable tool to determine and monitor manatee habitat use and behavior associated with environmental and habitat changes. Studies using telemetry should be designed to monitor a large number of manatees for short periods (cross-sectional studies) and individual animals (longitudinal studies) to better understand both population and individual responses to habitat change and habitat use. These studies should be coupled with health and reproductive assessments in order to make comparisons with habitat condition.

The use of conventional VHF and satellite telemetry should continue. Data generated from tracking studies should be entered into GIS databases and analyzed for correlations with habitat preferences and requirements. Verified point data should be provided to management as quickly as possible through technical reports and data transfer. Telemetry results should be published with appropriate analyses in refereed journals as frequently as the data allow.

Emerging technologies such as radio tags utilizing a Global Positioning System (GPS) and data loggersshould be further investigated and incorporated to provide better resolution of manatee movements and habitat use. Tags allowing the compilation and transfer of environmental, acoustical, and physiological data should be developed further and implemented to improve our ability to correlate with environmental and habitat parameters or disturbances.

3.3.9.3 Determine manatee time and depth pattern budgets. Time/depth recorders will allow evaluation of risks to manatees from vessel traffic in various habitat types by identifying the position of the animals in the water column. Such information can be related to vessel draft in the area, availability of waters deeper than vessel drafts, and time spent by manatees at specific depths. This information will contribute to a comprehensive risk assessment described in Task 3.3.11.4.

3.3.10 Define the response to environmental change. The Florida environment is not static. Future variation and change are anticipated and could impact survival, reproduction, and distribution of animals among regions, which in turn may affect population growth rates. In order to assess recovery, a need to understand how individual manatees, and consequently the population at large, respond to changes in the environment (e.g., changes in minimum flows at natural springs and elimination of industrial warm-water sources) on the redistribution of fresh water through the Everglades. Research to address such response should proceed at two levels: (1) test for correlation of changes in population parameters with known changes in the environment during long-term monitoring studies; and (2) test of hypothesized cause-effect relationships with behavioral and physiological studies and/or manipulative experimental trials.

3.3.10.1 Define response to changes in fresh water flow patterns in south Florida as a consequence of the Everglades' Restoration. Restoration of the Everglades to its historic water flow pattern is scheduled for the near future. This restoration will affect not only the distribution of fresh water leaving the Everglades, but also the estuarine ecosystem located off the south Florida coast. Studies should be structured to define how changes in sedimentation, bathymetry, seagrass beds, and fresh water input from restoration affects the distribution, survival, and reproduction of manatees.

3.3.10.2 Define response to degradation and rehabilitation of feeding areas. Marine seagrasses and fresh water aquatic vegetation are primary foods for manatees. Regionally, there have been documented declines in seagrass beds and freshwater aquatics resulting from pollution, hurricane-related die-offs, and scarring from boat propellers. Management is making attempts to reverse those declines and has been successful in areas such as Tampa Bay. Studies should be structured to define how changes in the distribution or abundance of feeding areas impact the distribution, survival, and reproduction of manatees.

3.3.11 Maintain, improve, and develop tools to monitor and evaluate manatee habitat. Protection of the manatee from human-related threats in part requires the determination of what constitutes optimal manatee habitats. Resource managers need to know what types of habitat are important to the species, including both natural and manmade features. Understanding manatee distribution in relation to the spatial arrangement of their habitat requires: (1) volumes of data; and (2) specialized computer software and appropriate techniques to analyze the data. GIS is used as an important geo-spatial tool and data-management system to store, synthesize, retrieve, and analyze these large volumes of data on manatees and manatee habitat. Site-specific data stored in GIS include: (1) manatee carcass recovery sites; (2) manatee sighting from aerial surveys; (3) ground research; (4) telemetry studies; (5) water depths; (6) vegetation coverage; (7) waterway speed and access zones; (8) shoreline characteristics and development patterns; etc. Computer hardware, software, and databases are used by researchers, resource managers, and conservationists for scientific analyses, permit reviews, developing waterway speed and access rules, and preparing county MPPs. Programs with theoretical and technical expertise need to focus on research and development of geo-spatial techniques to foster proactive manatee conservation strategies.

3.3.11.1 Maintain, improve, and develop tools to monitor and evaluate natural and human-related habitat influences on manatee ecology, abundance, and distribution. Utilize spatial models linked to a GIS to synthesize data and knowledge and to predict the most suitable habitats for manatees in Florida. GIS tools have the potential of evaluating human use impacts on manatees and their habitat. Analyses should be conducted to determine how human activities, such as coastal development and boating, affect manatee habitats and manatee distribution. These analyses will contribute to a comprehensive risk analysis.

3.3.11.2 Maintain, improve, and develop tools to evaluate the relationship between boating activities and watercraft-related mortality. Utilize GIS and manatee carcass information to create density models to spatially explore areas where manatees may be at higher risk. Evaluate the mortality density information in combination with human-use data, such as boating, to contribute to a comprehensive risk assessment.

3.3.11.3 Evaluate impact of changes in boat design and boater behavior. In recent years, changes in boat designs have resulted in changing threats to manatees. For example, the development of shallow draft vessels, such as flats boats and personal watercraft, along with high speed operation of these vessels over seagrass and other shallow water habitats used by manatees have created new threats to manatees in habitats where they were previously free of vessel interactions. The level of risk imposed by changing boating patterns needs to be evaluated. The boating industry, boating community, scientists, and wildlife managers should work to develop predictions of threats resulting from changes in boat designs and market-trend projections.

3.3.11.4 **Conduct a comprehensive risk assessment.** Utilize the results from the above Recovery Tasks and information from other databases to conduct a comprehensive risk assessment for the manatee.

3.4 **Ensure that minimum flows and levels are established for surface waters to protect resources of importance to manatees.** Minimum flows and levels are being established by state WMDs for surface waters throughout the state, including those used by manatees (*e.g.*, Biscayne Bay, Florida Bay and the Caloosahatchee River). Current and future withdrawals from surface waters have the potential to impact aquatic resources (e.g., SAV) important to manatees. Managers and researchers should participate in WMD efforts to set these limits to ensure that resources of importance to manatees are minimally affected.

3.5 **Assess the need to revise critical habitat.** Critical habitat for the Florida manatee was designated in 1976 (50CFR 17.95(a)). Much has been learned about manatee distribution in the decades since manatee critical habitat was originally defined. The FWS should assess the need to revise critical habitat for the Florida manatee.

Objective 4. Facilitate manatee recovery through public awareness and education. Compliance with regulations and management plans depends on broad public support for manatee recovery, which includes both manatee and habitat protection elements. Public support, in turn, depends on an informed public who understands manatee conservation issues and the rationale behind necessary regulatory and management actions. Knowledge of manatees, their habitat requirements, general biology, and protection measures can contribute toward the minimization of manatee disturbance, harassment, injury, and mortality. This information must be clear, consistent, concise, and readily available to the general public and target user groups. Many manatee and habitat education programs and materials are produced and made available to school systems as well as the general public and user groups; however, such efforts need to be continually evaluated and updated.

4.1 **Identify target audiences and key locations for outreach**. The success of a manatee/habitat conservation effort requires identification of target audiences and locations. Target audiences and key locations should be prioritized by need, i.e., areas where manatee mortality and injury are highest, areas where manatee/human interaction occurs frequently, and areas where habitat is most at risk. These areas include, but are not limited to, the thirteen key manatee counties, high watercraft use areas, boat ramps, manatee aggregation sites, manatee observation areas, fishing piers, seagrass areas, and other areas identified as having important habitat features (e.g., fresh water areas and areas used for resting and/or calving).

4.2 Develop, evaluate, and update public education and outreach programs and materials. There are many existing manatee and habitat awareness and education materials. Materials should be developed and updated for the general public, including students. As future stewards of our environment, it is important for students to learn about endangered species and their habitats and how to take positive actions to care for our fragile ecosystems. It is also important that some materials explicitly target specific user groups, such as: (1) boaters in areas of high watercraft mortality; (2) snorkelers/divers in areas where interaction and harassment occur; (3) recreational and/or commercial fishermen in areas where entanglements are prevalent; and (4) commercial/port facilities. Innovative ways to reach the public should be explored.

4.2.1 Develop consistent and up-to-date manatee boater education courses/programs. Boater education is critical to minimizing disturbance, harassment, injury, and mortality to manatees throughout Florida. Both resident and non-resident boat use in Florida continues to increase as water-related activities become more popular throughout the state. With the increasing traffic on our waterways, education becomes crucial for both manatee and public safety. Educating the boating public about the manatee will provide a better understanding of how the manatee lives and create a greater public appreciation toward the species. Efforts should continue to update and implement a consistent manatee education program for use in federal, state, and local boater education and training programs (e.g,. USCG Auxiliary Boating Safety Courses, U.S. Power Squadron Boat Safety Course, FWC On-Line Boating Safety Course).

4.2.2 Publish and post manatee protection zone information. To educate the boating community and public, organizations that produce materials (e.g., boater's guides, waterway guides, and fishing guides) should add or update the manatee protection zone information in forthcoming editions of their documents. A standardized format should be utilized to develop consistency throughout manatee habitat. Further, at all boat ramps, marinas, vessel rental operations and other access areas, efforts should be made to post signs containing information on manatee zones and "you are here" maps. Additionally, a website should be established allowing the public easy access to manatee protection zone information on the internet. This website could contain rules and regulations, detailed maps of the zones, sign locations within individual zones, examples of each type of sign, and definitions and explanations of manatee protection zones.

4.2.3 Update nautical charts and Coast Pilot to reflect current manatee protection zone information. FWS should request National Oceanic and Atmospheric Administration (NOAA) to update these documents to include: (1) a chart note referencing manatee protection zones for applicable nautical charts; and (2) information regarding the manatee protection zones for specific water bodies in Coast Pilot 4 and 5.

4.3 Coordinate development of manatee awareness programs and materials in order to support recovery. There are overlap and conflicting messages among existing materials produced by various agencies and conservation organizations. A Manatee Education Committee should be convened to review materials and programs with emphasis on reducing redundancy, providing consistent, standardized messages, and coordinating production of materials among participating organizations. All appropriate recovery plan tasks for education and public awareness materials and programs which have not been developed should be identified by the committee, and any unmet needs should be addressed.

4.4 Develop consistent manatee viewing and approach guidelines. Harassment is a violation of federal and state laws such as the MMPA, ESA, and Florida Manatee Sanctuary Act. While manatees may occasionally approach people on their own accord, people often chase after and pursue interactions with the animals. Human interference can disturb manatees and disrupt their natural behaviors (e.g., feeding, breeding, parenting, sheltering). Manatees which are harassed may leave preferred habitats or flee into areas with heavy vessel traffic. With increasing popularity of ecotourism, manatee harassment is an issue of growing concern statewide. Consistent viewing guidelines and education programs will be developed to teach responsible manatee viewing and approach practices, while ultimately serving to minimize disturbance. Coordination with agencies responsible for upholding marine mammal protection laws will allow for pooling of resources, thereby increasing the effectiveness of outreach materials and projects. A working group to address manatee harassment has been formed; the objective of this group is to develop easy-to-understand and comprehensive marine mammal and marine wildlife viewing education materials that promote responsible wildlife watching ethics.

4.5 Develop and implement a coordinated media outreach program. Public awareness and understanding is crucial to the recovery of the manatee in Florida. Whenever possible, when media opportunities occur, all recovery partners should make an effort to coordinate information prior to release. This coordination would serve to inform the general public with a consistent message on manatee biology, status, laws affecting them, how those laws benefit their quality of life, and why these laws are important to the recovery of the species. Such opportunities include, but are not limited to, annual mortality updates, synoptic survey results, manatee rescues and releases, and annual implementation of seasonal manatee protection zones and sanctuaries.

4.6 Utilize the rescue, rehabilitation, and release program to educate the public. The media heavily publicize rescues and releases and millions of visitors see and learn about manatees at critical- and long-term care facilities every year. Program participants should incorporate accurate, up-to-date information in their news releases, publications, presentations, displays, and other media to accurately portray the status of the manatee.

4.7 Educate state and federal legislators about manatees and manatee issues. Legislators in Tallahassee and Washington, D.C. can enact manatee protection regulations, or conversely, they can enact legislation that could result in harm to the species and/or its habitat. Holders of some legislative seats change as frequently as every two years, making the issue of educating legislators an ongoing one. To the greatest extent possible, at a frequency of at least every to years, recovery team partners should provide legislators with manatee awareness and education materials, as well as available status reports on the species and its management.

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PART III. IMPLEMENTATION SCHEDULE

The Implementation Schedule indicates task priorities, task numbers, task descriptions, duration of tasks, potential or participating parties, and lastly estimated costs (Table 6). These tasks, when accomplished, will bring about the recovery of the Florida manatee as discussed in Part II of this plan.

Parties with authority, responsibility, or expressed interest to implement a specific recovery task are identified in the Implementation Schedule. When more than one party has been identified the proposed lead party is indicated by an asterisk (*). The listing of a party in the Implementation Schedule does not imply a requirement or that prior approval has been given by that party to participate or expend funds. However, parties willing to participate will benefit by being able to show in their own budget submittals that their funding request is for a recovery task which has been identified in an approved recovery plan and is therefore part of the overall coordinated effort to recover the Florida manatee. Also, Section 7(a)(1) of the ESA directs all federal agencies to utilize their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of threatened and endangered species.

Following are definitions to column headings and keys to abbreviations and acronyms used in the Implementation Schedule:

PRIORITY NUMBER

Priority 1 **-** An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2 **-** An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant impact short of extinction.

Priority 3 **-** All other actions necessary to provide for full recovery of the species.

TASK NUMBER AND TASK Recovery tasks as numbered in the Narrative Outline.

RESPONSIBLE OR PARTICIPATING PARTY

C Fish Industry	Commercial Fishing Industry
COE	U.S. Army Corps of Engineers
CZS	Chicago Zoological Society
DERM	Miami-Dade Department of Environmental Resources Management
EPA	U.S. Environmental Protection Agency
Ecotour Ind	Ecotourism Industry
FDEP	Florida Department of Environmental Protection
FIND	Florida Inland Navigation District
FPL	Florida Power and Light Company
FWC	Florida Fish and Wildlife Conservation Commission
	Bureau of Protected Species Management
	Florida Marine Research Institute
	Division of Law Enforcement
FWS	U.S. Fish and Wildlife Service
GDNR	Georgia Department of Natural Resources
LE	Law Enforcement
Local Gov'ts	Local Governments
M Industry	Marine Industries
MML	Mote Marine Laboratory
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OC	The Ocean Conservancy (formerly the Center for Marine Conservation)
Oceanaria	Cincinnati Zoo, Columbus Zoo, Homosassa Springs State Wildlife Park, Living Seas, Lowry Park Zoo, Miami Seaquarium, Mote Marine Laboratory, Sea World Florida and California, South Florida Museum
P Industry	Power Industries
Port Auth	Port Authorities
R Fish Industry	Recreational Fishing Industry
Sirenia	U.S. Geologic Survey - Sirenia Project
SMC	Save the Manatee Club
USCG	U.S. Coast Guard
USN	U.S. Navy
WMD's	Water Management Districts

ESTIMATED ANNUAL BUDGETS AND OTHER PROJECTIONS OF RECOVERY PARTNERS

Based upon recovery partners' current or proposed FY2001 budgets, it is estimated that close to $10 million is being spent annually on manatee recovery. This estimate does not include several significant recovery initiatives. Costs for USCG and FWC-DLE's manatee law enforcement efforts are not included in this total, nor are estimates included for COE, FDEP, and WMD regulatory programs which work regularly on manatee issues. Additionally, the COE's and the South Florida WMD's multi-million dollar project to retrofit navigational locks and water control structures with manatee protection technology in South Florida and FDEP's plan to retrofit structures at the Rodman Reservoir are not included in this total. It is possible that these programs may total an additional $4 to 5 million annually.

FWS FY 2001-2002 budget proposal for $1.36 million includes staff salary, recovery implementation projects, and a $1 million congressional add-on for: (1) manatee law enforcement; (2) a new manatee sanctuary and refuges initiative; and (3) a warm-water refuge initiative. In addition, regulatory consultations pertaining to manatee issues cost approximately $350 thousand annually in Florida. There is a need for two additional full time employees to handle the projected increase in consultations at a cost of $150 thousand.

COE, USCG, FDEP, and WMD's regulatory programs work regularly on manatee issues; however it was not possible to project the annual costs of these programs.

COE and South Florida WMD have partnered through the Central and Southern Florida Project, including matching funds, over $6.3 million has been budgeted to retrofit navigational locks and water control structures in South Florida with manatee protection technology during the next five years. In designing and constructing critical projects for the Everglades Restoration Project, water control structures are being designed to be manatee-safe, and cost estimates are not available for these projects.

USCG No estimate regarding the cost of USCG enforcement efforts has been provided. When on patrol, the USCG enforces all applicable federal laws and regulations. Costs of enforcing specific regulations, such as manatee speed zones, are not determinable. However, the USCG spends a significant amount of time patrolling navigable waterways that have speed zone regulations, and enforcement of speed zones is a high priority.

Sirenia FY 2001-2002 projected budget is $683 thousand.

FWC **BPSM** FY July 2000 - June 2001 budget of $1.566 million.

FMRI FY July 2000 - June 2001 budget of $3.325 million. This includes: (1) FMRI's research budget for $1.9 million; (2) $1.1 million administered by FMRI and earmarked for the critical care Oceanaria facilities and to the University of Florida Veterinary School; and (3) an additional $325 thousand in research contracts with MML that are administered by FMRI.

DLE No estimates were made regarding manatee law enforcement efforts, but the effort probably exceeds $1.0 million.

FDEP is budgeting to retrofit the Buchman Lock and Kirkpatrick Dam with manatee protection technology. Costs are anticipated to exceed $600 thousand over the next several years, however, this total is not included in the annual estimate.

GDNR FY 2001 budget of $19 thousand.

SMC FY 2001 proposed budget of $1.535 million.

MML FY 2001 manatee budget is $366 thousand. This includes $325 thousand in research contracts administered by FMRI and $41 thousand from MML and CZS.

Oceanaria estimated costs of $1.5 million for 50 manatees annually at $30 thousand per animal for basic maintenance of captive and rehabilitating animals. The critical care facilities receive $400 thousand from the Florida's Save the Manatee Trust Fund, and these funds are administered through the FWC-FMRI budget.

FPL projects FY 2001 budget that includes $110 thousand for studying warm-water refuge issues and for education.

Implementation Schedule

Florida Manatee Recovery Plan — **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	1.1	Promulgate special regulations for incidental take under the MMPA for specific activities.	5 yrs	**FWS** COE	95	95	95	50	50	
2	1.2	Continue state and federal review of permitted activities to minimize impacts to manatees and their habitat.	Continuous	**FWS** **FWC** COE FDEP **GDNR** M Industry SMC USCG WMDs	500 278 4	500 278 4	500 278 4	500 278 4	500 278 4	
2	1.2.1	Continue to review coastal construction permits to minimize impacts.	Continuous	FWS FWC COE GDNR SMC WMDs						
2	1.2.2	Minimize the effect of organized marine events on manatees.	Continuous	FWS FWC GDNR M Industry SMC USCG						

Implementation Schedule										
Florida Manatee Recovery Plan										**U.S. Fish and Wildlife Service**
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	1.2.3	Continue to review NPDES permits to minimize impacts.	Continuous	FWS FWC EPA FDEP GDNR P Industry SMC						
2	1.2.4	Pursue regulatory changes, if necessary, to address activities that are "exempt," generally authorized, or not covered by state or federal regulations.	2 yrs	FWS COE M Industry SMC						
1	1.3	Minimize collisions between manatees and watercraft.	Continuous	**FWS** **FWC** FIND GDNR Local Gov'ts Local LE M Industry OC SMC USCG	25 439	25 439	25 439	25 439	25 439	

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	1.3.1	Develop and refine state waterway speed and access rules.	5 yrs to Develop Continuous to Refine	FWS FWC Local Gov'ts M Industry OC SMC						
1	1.3.2	Develop and refine federal waterway speed and access rules.	3 yrs to Develop Continuous to Refine	FWS FWC COE Local Gov'ts M Industry NPS OC SMC						
1	1.3.3	Post and maintain regulatory signs.	Continuous	FWS FWC FIND Local Gov'ts NPS USCG						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	1.4	Enforce manatee protection regulations.	Continuous	**FWS** **FWC** Local LE MML NPS USCG	655 9	655 9	655 9	655 9	655 9	
2	1.4.1	Coordinate law enforcement efforts.	Continuous	FWS FWC Local LE NPS USCG						
2	1.4.2	Provide law enforcement officer training.	Continuous	FWS FWC Local LE NPS USCG						
2	1.4.3	Ensure judicial coordination.	Continuous	FWS						
2	1.4.4	Evaluate compliance with manatee protection regulations.	Periodic	FWS FWC MML SMC						

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	1.4.5	Educate boaters about manatees and boater responsibility.	Continuous	FWS FWC Local Gov'ts Local LE M Industry MML OC SMC USCG						
2	1.4.6	Evaluate effectiveness of enforcement initiatives.	Periodic	FWS FWC Local Gov'ts MML						
2	1.4.7	Provide updates of enforcement activities to managers.	Continuous	FWS Local LE USCG						
1	1.5	Assess and minimize mortality caused by large vessels.	1 yr to Assess Continuous to Reduce	**FWS** FWC COE Port Auth. USCG USN	5	5	5	5	5	
2	1.5.1	Determine means to minimize large vessel-related manatee deaths.	2 yrs	FWS						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	1.52	Provide guidance to minimize large vessel-related manatee deaths.	Continuous	FWS FWC COE FDEP USCG						
1	1.6	Eliminate manatee deaths in water control structures, navigational locks, and drainage structures.	Continuous	FWS FWC **COE** DERM FDEP **WMDs**	10 10	10 10	10 10	10 10	10 10	
1	1.6.1	Install and maintain protection technology at water control structures where manatees are at risk and monitor success.	5 yrs to Install Continuous to Maintain & Monitor	FWS FWC COE FDEP WMDs						
1	1.6.2	Install and maintain protection technology at navigational locks where manatees are at risk and monitor success.	5 yrs to Install Continuous to Maintain & Monitor	FWS FWC COE FDEP WMDs						

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	1.6.3	Minimize injuries and deaths attributable to entrapment in drainage structures.	Install or Retrofit as Needed	FWS COE FDEP FWC Local Gov'ts WMDs						
1	1.6.4	Assess risk at existing and future water control structures and canals in South Florida.	2 yrs to Assess Continuous Monitoring	FWS COE FDEP FWC Local Gov'ts WMDs						
2	1.7	Minimize manatee injuries and deaths caused by fisheries and entanglement.	Continuous	**FWS** FWC GDNR SMC C Fish Indus R Fish Indus	10 10 1	10 10 1	10 10 1	10 10 1	10 10 1	
2	1.7.1	Minimize injuries and deaths attributed to crab pot fishery.	Continuous	FWS FWC C Fish Indus R Fish Indus						

Implementation Schedule

Florida Manatee Recovery Plan — **U.S. Fish and Wildlife Service**

Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	1.7.2	Minimize injuries and deaths attributed to commercial and recreational fisheries, gear, and marine debris.	Continuous	FWS FWC Local Gov't C Fish Indus R Fish Indus OC SMC						
3	1.8	Investigate and prosecute all incidents of malicious vandalism and poaching.	As Needed	**FWS** **FWC** Local LE SMC USCG						
3	1.9	Update and implement catastrophic plan.	As Needed	**FWS** **FWC**	2	2	2	2	2	
2	1.10	Rescue and rehabilitate distressed manatees and release back into the wild.	Continuous	**FWS** Sirenia **FWC** GDNR MML **Oceanaria** SMC	50 1,130 1,000	50 1,130 1,000	50 1,130 1,000	50 1,130 1,000	50 1,130 1,000	
2	1.10.1	Maintain rescue network.	Continuous	FWS FWC MML						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	1.10.2	Maintain rehabilitation capabilities.	Continuous	FWS Oceanaria						
2	1.10.3	Release captive manatees.	Continuous	FWS FWC Oceanaria						
3	1.10.4	Coordinate program activities.	Continuous	FWS						
3	1.10.5	Provide assistance to international Sirenian rehabilitators.	Continuous	FWS FWC Oceanaria SMC						
3	1.10.6	Provide rescue report.	Annually	FWS						
2	1.11	Implement strategies to eliminate or minimize harassment due to other human activities.	Continuous	**FWS** FWC Local Gov't OC SMC	5	5	5	5	5	
2	1.11.1	Enforce regulations prohibiting harassment.	Continuous	FWS FWC USCG						
2	1.11.2	Improve the definition of "harassment" within the regulations promulgated under the ESA and MMPA.	2 yrs	FWS						
		Totals for Objective 1.			4,238	4,238	4,238	4,193	4,193	$21,100

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	2.1	Continue the MPSWG.	Continuous	**FWS** **Sirenia** FWC	5 20 12	5 20 12	5 20 12	5 20 12	5 20 12	
2	2.2	Conduct status review.	1 yr	**FWS**			25			
2	2.3	Determine life history parameters, population structure, distribution patterns, and population trends.	Continuous	FWS **Sirenia** Academia **FWC** GDNR MML	110 342 360 3	110 383 360 3	110 415 360 3	110 430 360 3	110 445 360 3	
2	2.3.1	Continue and increase efforts to collect and analyze mark/recapture data to determine survivorship, population structure, reproduction, and distribution patterns.	Continuous	Sirenia FWC MML SMC						
2	2.3.2	Continue collection and analysis of genetic samples to determine population structure and pedigree.	Continuous	Sirenia FWC MML						
2	2.3.3	Continue carcass salvage data analysis to determine reproductive status and population structure.	Continuous	FWC						

Implementation Schedule

Florida Manatee Recovery Plan — **U.S. Fish and Wildlife Service**

Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	2.3.4	Continue and improve aerial surveys and analyze data to evaluate fecundity data and to determine distribution patterns, population trends, and population size.	Continuous	FWS Sirenia FWC MML						
2	2.3.5	Continue collection and analysis of telemetry data to determine movements, distribution, habitat use patterns, and population structure.	Continuous	Sirenia FWC						
2	2.3.6	Continue to develop, evaluate, and improve population modeling efforts and parameter estimates and variances to determine population trend and link to habitat models and carrying capacity.	Continuous	Sirenia FWC						
2	2.3.7	Conduct a PVA to help assess population parameters as related to the ESA and MMPA	2yrs	FWS						
2	2.4	Evaluate and monitor causes of mortality and injury.	Continuous	**FWS** **Sirenia** **FWC** CZS GDNR MML	15 12 1,102 5	15 12 1,022 5	15 12 1,022 5	15 12 1,022 5	15 12 1,022 5	

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	2.4.1	Maintain and improve carcass detection, retrieval, and analysis.	Continuous	FWS FWC GDNR						
2	2.4.2	Improve evaluation and understanding of injuries and deaths caused by watercraft.	Continuous	FWS Sirenia FWC M Industry						
2	2.4.3	Improve the evaluation and understanding of injuries and deaths caused by other anthropogenic causes.	Continuous	FWS Sirenia FWC COE FDEP M Industry OC WMDs						
2	2.4.4	Improve the evaluation and understanding of naturally-caused mortality and unusual mortality events.	Continuous	FWS Sirenia Academia FWC MML						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	2.5	Define factors that affect health, well-being, physiology, and ecology.	Continuous	FWS **Sirenia** Academia **FWC** MML Oceanaria	10 22 470	10 22 470	10 22 470	10 22 470	10 22 470	
2	2.5.1	Develop a better understanding of manatee anatomy, physiology, and health factors.	Continuous	Sirenia Academia FWC MML Oceanaria						
2	2.5.2	Develop a better understanding of thermoregulation.	Continuous	FWC Academia Oceanaria						
2	2.5.3	Develop a better understanding of sensory systems.	Continuous	FWS Sirenia Academia FWC MML Oceanaria						
2	2.5.4	Develop a better understanding of orientation and navigation.	Continuous	Sirenia Academia FWC Oceanaria						

Implementation Schedule Florida Manatee Recovery Plan U.S. Fish and Wildlife Service										
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	2.5.5	Develop a better understanding of foraging behaviors during winter.	Continuous	Sirenia FWC Academia Oceanaria						
2	2.5.6	Develop baseline behavior information.	Continuous	FWC Academia Oceanaria						
2	2.5.7	Develop a better understanding of disturbance.	Continuous	FWS Academia CZS FWC MML Oceanaria						
2	2.5.7.1	Continue to investigate how a vessel's sound affects manatees.	Continuous	FWS Academia FWC M Industry MML Oceanaria						

Implementation Schedule										
Florida Manatee Recovery Plan										U.S. Fish and Wildlife Service
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	2.5.7.2	Investigate, determine, monitor, and evaluate how vessel presence, activity, and traffic patterns affect manatee behavior and distribution.	Continuous	FWS Sirenia Academia FWC CZS M Industry MML Oceanaria						
2	2.5.7.3	Assess boating activity and boater compliance.	Periodic Assessment Continuous to Improve Compliance	FWS Sirenia FWC Local Gov'ts M Industry MML SMC						
2	2.5.7.4	Evaluate the impacts of human swimmers and effectiveness of sanctuaries.	2 yrs	FWS FWC						
2	2.5.7.5	Evaluate the impacts of viewing by the public.	2 yrs	FWS FWC						
2	2.5.7.6	Evaluate the impacts of provisioning.	2 yrs	FWS FWC						
		Totals for Objective 2.			2,488	2,449	2,506	2,496	2,511	$12,450

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	3.1	Convene a Habitat Working Group.	Continuous	**FWS** **Sirenia** **FWC** M Industry OC SMC	5 20 80	5 22 80	5 24 80	5 26 80	5 28 80	October 2002, HWG will make recommendations to refine and improve habitat criteria
1	3.2	Protect, identify, evaluate, and monitor existing natural and industrial warm-water refuges and investigate alternatives.	Continuous	**FWS** **Sirenia** **FWC** FPL MML P Industry SMC	10 120 50 80	10 126 50 20	10 132 50	10 160 50	10 160 50	
2	3.2.1	Continue the Warm- Water Task Force.	Continuous	FWS Sirenia FWC FPL P Industry SMC						
1	3.2.2	Develop and implement an industrial warm-water strategy.	2 yrs to Develop Continuous to Implement	FWS Sirenia FWC EPA FDEP P Industry						

Implementation Schedule										
Florida Manatee Recovery Plan									U.S. Fish and Wildlife Service	
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
1	3.2.2.1	Obtain information necessary to manage industrial warm-water refuges.	3 yrs	FWS FWC FPL P Industry						
2	3.2.2.2	Define manatee response to changes in industrial operations that affect warm-water discharges.	Continuous	FWS Sirenia FWC FPL						
1	3.2.3	Protect, enhance, and investigate other non-industrial warm-water refuges.	Continuous	FWS FWC FDEP SMC WMDs						
1	3.2.4	Protect and enhance natural warm-water refuges.	Continuous	FWS FWC FDEP SMC WMDs						
3	3.2.5	Assess changes in historical distribution due to habitat alteration.	1yr	FWS MMC Sirenia FWC						

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	3.2.4.1	Develop and maintain a database of warm-water refuge sites.	Continuous	FWS Sirenia FWC						
1	3.2.4.2	Develop comprehensive plans for the enhancement of natural warm-water sites.	Continuous	FWS FWC						
1	3.2.4.3	Establish and maintain minimum spring flows and levels at natural springs.	Continuous	FWS FWC EPA SMC WMDs						
1	3.3	Establish, acquire, manage, and monitor regional protected area networks and manatee habitat.	Continuous	**FWS** **Sirenia** **FWC** FDEP Local Gov'ts SMC WMDs	290 165 547	290 180 547	290 190 547	290 160 547	290 170 547	
1	3.3.1	Establish manatee sanctuaries, refuges, and protected areas.	2 yrs Periodic Update	FWS FWC						

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
	3.3.2	Identify and prioritize new land acquisition projects.	Annually	FWS Sirenia FWC FDEP FWC SMC WMDs						
2	3.3.3	Acquire land adjacent to important manatee habitats.	Continuous	FWS FDEP Land Trusts Local Gov'ts WMDs						
2	3.3.4	Establish and evaluate manatee management programs at protected areas.	Continuous	FWS FWC						
3	3.3.5	Support and pursue other habitat conservation options.	Continuous	FWS FWC SMC						
1	3.3.6	Assist local governments in development of county MPPs.	Continuous	FWS FWC Local Gov'ts M Industry R Fish Indus OC SMC						

Implementation Schedule										
Florida Manatee Recovery Plan										**U.S. Fish and Wildlife Service**
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
1	3.3.7	Implement approved MPPs.	Continuous	FWS FWC Local Gov'ts						
2	3.3.8	Protect existing SAV and promote re-establishment of NSAV.	Continuous	FWS FWC FDEP FWC WMDs Local Gov'ts						
2	3.3.8.1	Develop and implement a NSAV protection strategy.	2 yrs to Develop Continuous to Implement	FWS Sirenia FWC FDEP FWC WMDs Local Gov'ts						
2	3.3.8.2	Develop and implement a state-wide seagrass monitoring program.	Continuous	FWS Sirenia FWC FWC NMFS WMDs Local Gov'ts						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
21	3.3.8.3	Ensure aquatic plant control programs are properly designed and implemented.	Continuous	FWS Sirenia FWC COE FDEP FWC						
2	3.3.9	Conduct research to understand and define manatee ecology.	Continuous	Sirenia Academia FWC MML SMC						
2	3.3.9.1	Conduct research and improve databases on manatee habitat.	Continuous	Sirenia FWC						
2	3.3.9.2	Continue and improve telemetry and other instrumentation research and methods.	Continuous	Sirenia FWC						
2	3.3.9.3	Determine manatee time and depth pattern budgets.	Continuous	FWC MML						
2	3.3.10	Define the response to environmental change.	Continuous	FWS Sirenia FWC						

Implementation Schedule Florida Manatee Recovery Plan — U.S. Fish and Wildlife Service										
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	3.3.10.1	Define response to changes in fresh water flow patterns in south Florida as a consequence of the Everglades' Restoration.	Continuous	Sirenia Academia FWC						
2	3.3.10.2	Define response to degradation and rehabilitation of feeding areas.	Continuous	Sirenia FWC						
2	3.3.11	Maintain, improve, and develop tools to monitor and evaluate manatee habitat.	Continuous	FWS Sirenia FWC						
2	3.3.11.1	Maintain, improve, and develop tools to monitor and evaluate natural and human-related habitat influences on manatee ecology, abundance, and distributions.	Continuous	FWS Sirenia FWC						
1	3.3.11.2	Maintain, improve, and develop tools to evaluate the relationship between boating activities and watercraft-related mortality.	Continuous	FWS FWC M Industry MML						
3	3.3.11.3	Evaluate impact of changes in boat design and boater behavior.	Continuous	FWS M Industry MML						
2	3.3.11.4	Conduct a comprehensive risk assessment.	1 yr	FWS						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	3.4	Ensure that minimum flows and levels are established for surface waters to protect resources of importance to manatees.	Continuous	**FWS** FWC SMC WMDs	3	3	3	3	3	
3	3.5	Assess the need to revise critical habitat.	1yr	**FWS**						
		Totals for Objective 3.			1,370	1,333	1,331	1,331	1,343	$6,708
3	4.1	Identify target audiences and key locations for outreach.	3 yrs Periodically Update	FWS FWC GDNR OC SMC	5 5 2	5 5 2	5 5 2	5 5 2	5 5 2	
2	4.2	Develop, evaluate, and update public education and outreach programs and materials.	3 yrs to Develop Periodically Update	FWS FWC FPL GDNR OC SMC	5 205 30 2	5 205 2	5 205 2	5 205 2	5 205 2	
1	4.2.1	Develop consistent and up-to-date manatee boater education courses/programs.	2 yrs to Develop Periodically Update	FWS FWC M Industry OC SMC USCG						

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	4.2.2	Publish and post manatee protection zone information.	Annually Publish Continuous	FWS FWC COE Local Gov'ts M Industry						
1	4.2.3	Update nautical charts and Coast Pilot to reflect current manatee protection zone information.	1 yr	FWS NOAA						
3	4.3	Coordinate development of manatee awareness programs and materials in order to support recovery.	Continuous	FWS FWC COE FDEP GDNR Local Gov'ts OC SMC USCG WMDs	5 14 2	5 14 2	5 14 2	5 14 2	5 14 2	
2	4.4	Develop consistent manatee viewing and approach guidelines.	2 yrs	**FWS** FWC OC SMC Ecotour Ind	3 1	3 1	3 1	3 1	3 1	

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
3	4.5	Develop and implement a coordinated media outreach program.	1 yr to Develop Continuous to Implement	FWS FWC Local Gov'ts OC Oceanaria SMC	5	5	5	5	5	
3	4.6	Utilize the rescue, rehabilitation, and release program to educate the public.	Continuous	**FWS** FWC Oceanaria	3 1	3 1	3 1	3 1	3 1	
3	4.7	Educate state and federal legislators about manatees and manatee issues.	Continuous	FWS FWC M Industry OC P Industry SMC						
		Totals for Objective 4.			288	258	258	258	258	$1,320
		Total for Recovery.			8,384	8,278	8,333	8,278	8,305	$41,578

Manatee Population Status Working Group's (MPSWG) Recommendation of Population Benchmarks To Help Measure Recovery

RECOMMENDED POPULATION BENCHMARKS

The Manatee Population Status Working Group developed the following population benchmarks to assist in evaluating the status of the Florida manatee for reclassification to threatened status. In each of the four regions of the Florida manatee population (Northwest, Southwest, Atlantic, and Upper St. Johns River):

1. the average annual estimated rate of adult survival is at least 94%, with statistical confidence that the rate is not less than 90%;
2. the average annual percentage of adult females with calves during winter is at least 40%; and
3. the average annual rate of population growth is at least 4%, with statistical confidence that the rate is not less than 0 (no growth).

The MPSWG recommended that estimates of the benchmark statistics (survival, reproduction, and population growth rate) be determined over a minimum of a 10-year time period, and that no significant downward trend be detectable in these parameters, before FWS considers reclassification of the Florida manatee from endangered to threatened status. The MPSWG did not propose delisting criteria, as specific, quantitative habitat criteria have yet to be developed.

Table 4. Published population benchmark values for each region.

Region	Percent Survival	Proportion of Females with Calves	Percent Growth
Northwest	96.5 (95.1 - 97.5)[a] (1982 -1993)	.431 (1977 - 1991)	7.4 (1978 - 1991)
Southwest	unknown	unknown	unknown
Upper St. Johns River	96.1 (90.0 - 98.5)[a] (1978 - 1993)	.407 (1979 - 1993)	5.7 (3 - 8) (1978 - 1991)
Atlantic	90.7 (88.7 - 92.6)[a] (1985-1993)	.423 (1979 - 1992)	1.0 (1985 - 1991)

[a] 95% Confidence Interval

Data Sources: **Percent Survival** - Langtimm, O'Shea, Pradel, and Beck 1998. **Proportion of Females with Calves** - Rathbun, Reid, Bonde, and Powell, 1995 (Northwest); O'Shea and Hartley, 1995 (St. Johns River); and Reid, Bonde, and O'Shea, 1995 (Atlantic). **Percent Growth** - Eberhardt and O'Shea, 1995.

METHODS FOR DETERMINING THE POPULATION BENCHMARKS

Criterion A: average annual adult survival estimates, is based upon a mark-recapture approach, using resightings of distinctively marked individual manatees (Langtimm et al. 1998; see p. 11 for further details). Using open population models, adult survival probabilities were estimated for manatees in the Northwest, Upper St. Johns River, and Atlantic regions of Florida. After using goodness-of-fit tests in Program RELEASE to search for violations of the assumptions of mark-recapture analysis, survival and sighting probabilities were modeled with Program SURGE. Statistically robust population models with explicit assumptions will continue to be the basis for estimation of this benchmark.

Criterion B: average annual percentage of adult females with calves, is also based upon resightings of distinctively marked individual manatees. Ongoing development of multi-state models that account for misclassification of breeders and non-breeders will improve the accuracy of regional estimates of productivity. Efforts are also being made to develop a statistically valid method for estimation of a confidence interval for this benchmark.

Criterion C: average annual rate of population growth, is based upon a deterministic population model (Eberhardt and O'Shea 1995). Parameters in the model were primarily derived from life history information obtained through resightings of distinctively marked individual manatees in the Northwest, Upper St. Johns River, and Atlantic regions. It is a simple, 2-stage (calves and adults) model that does not incorporate stochasticity (variability in survival and fecundity rates caused by changes in environmental, demographic, and genetic factors). Future models of population growth rates will undoubtedly incorporate more stages (e.g., juvenile and subadult year classes) and stochasticity. New analyses of life history data (obtained through both carcass salvage data and resightings of known individuals), will undoubtedly improve parameter estimates and reduce uncertainty in modeling results.

BASIS FOR THE POPULATION BENCHMARKS

The benchmarks were based on published estimates of survival, reproduction, and population growth rate (Table 1). Adult survival is the most influential factor determining manatee population dynamics (Eberhardt and O'Shea 1995; Marmontel et al. 1997; Langtimm et al. 1998). Since there is currently no method for determining juvenile survival rates, the MPSWG included a reproduction benchmark. Manatee population growth is less sensitive to changes in reproductive rates than adult survival rates (Marmontel et. al. 1997); however, the average proportion of females with calves over long time spans (at least 10 years) is remarkably consistent across regions (O'Shea and Hartley 1995). The MPSWG concluded that changes in reproductive rates could be a useful indicator of manatee population status, but recognized that a relatively high level of variation in reproductive rates among years requires that a period of at least 10 years be used to estimate this parameter.

Survival rates are estimated from resightings of known individuals in the photo-identification catalog, using adults only (at least 5 years of age), resighted between December and February each year (Langtimm *et al.* 1998). Survival rates for three regions (the Northwest, Upper St. Johns, and Atlantic) were estimated using state-of-the-art statistical methods (Langtimm *et al.* 1998). The target is an adult survival rate of at least 94%, that is, at least 94 of each 100 adult manatees survive from one year to the next. This benchmark is less than the estimated survival rates (96%) in two regions (the Northwest, Upper St. Johns), and higher than the lowest estimated survival rate (91%) in the Atlantic region. The lower bound of the 95% confidence interval should be greater than 0.90 (95% certainty that survival rate is actually greater than 0.90).

Similarly, reproductive rates were estimated from resightings of known individuals in the photo-identification catalog, using adult females only (at least 5 years of age), resighted between December and February of each winter (O'Shea and Hartley 1995, Rathbun *et al.* 1995, Reid *et al.* 1995). The target is 40% of known adult females seen with calves in winter each year (1^{st} or 2^{nd} year calves). The target level has been reached in all three regions (the Northwest, Upper St. Johns, and Atlantic) for which adequate data exist to determine reproductive status of adult females (Table 2). The similarity across regions in the average proportion of adult females observed with calves in winter (43%, 41% and 42%, respectively) suggests that Florida manatees may have achieved a maximum level of reproduction (O'Shea and Hartley 1995).

The population growth rates for each region were calculated using a population model that incorporated estimated survival rates for adults, subadults, and calves, and reproductive rates (Eberhardt and O'Shea 1995). The target is a population growing at 4% per year, which is below the estimated growth rate for the Northwest and Upper St. Johns regions (Table 2). There is a one-to-one correspondence between adult survival above 90% and population growth rate (Eberhardt and O'Shea 1995). Thus, an adult survival rate of 94% corresponds to an annual population growth rate of 4%. In addition, 4% is mid-way between 0 and 8% growth, and 8% is likely to be the maximum manatee population growth rate through internal recruitment. Eberhardt and O'Shea (1995) estimated an annual growth rate of 7.4% for the Crystal River. Without any human-related deaths, this population could almost certainly attain a growth rate of 8%.

The proposed benchmark for population growth (4%) is based upon the results of the Eberhardt and O'Shea (1995) deterministic population model. These authors did not attempt to estimate confidence intervals for two of the three regions for which they estimated population growth rates (Northwest and

Atlantic), and used two different methods to estimate (relatively large) confidence intervals for the growth rate of the Upper St. Johns region. There is clearly uncertainty in their model results. Additionally, they did not attempt to account for the effect of environmental variability over time on population trend. It is essential either to be conservative in selecting a minimum growth rate benchmark, as in selecting 4%, or to require a high degree of statistical confidence that the average growth rate is not lower than 0 in all regions. The latter alternative will require development of new models that include statistically robust methods for estimating confidence intervals.

Research Plan to Determine and Monitor the Status of Manatee Populations

The success of efforts to develop and implement measures to minimize manatee injury and mortality depends upon the accuracy and completeness of data on manatee life history and population status. Population data are needed to identify and define problems, make informed judgments on appropriate management alternatives, provide a sound basis for establishing and updating management actions, and to determine whether or not actions taken are achieving management objectives.

MANATEE POPULATION STATUS WORKING GROUP

The interagency Manatee Population Status Working Group (MPSWG) was established in March 1998. The group's primary tasks are to: (1) assess manatee population trends; (2) advise the U.S. Fish and Wildlife Service (FWS) on population criteria to determine when species recovery has been achieved; and (3) provide managers with interpretation of available information on manatee population biology. The group also has formulated strategies to seek peer review of their activities. The working group should continue to hold regular meetings, refine recovery criteria, annually update regional and statewide manatee status statements, and convene a population biology workshop early in 2002, analogous to the one held in 1992.

STATUS REVIEW

Following the Population Status Workshop in 2002, FWS will conduct a status review of the Florida manatee. The review will include: (1) a detailed evaluation of the population status of the species; (2) an evaluation of existing threats to the species and the effectiveness of existing mechanisms to control those threats, particularly with respect to the five listing factors identified under the Endangered Species Act of 1973, as amended (ESA); and (3) recommendations, if any, regarding reclassification and additional and/or revised recovery objectives, criteria and tasks to deal with remaining threats.

LIFE HISTORY PARAMETERS AND POPULATION TREND

Many manatees have unique features, primarily scars caused by boat strikes. When carefully photographed, these features can provide a means of identifying individuals. **Photographs of distinctively-marked manatees** collected by researchers in the field are compiled in a database begun in 1981 by the U.S. Geological Service Sirenia Project (USGS-Sirenia) with support from the Florida Power and Light Company (FPL). Since its inception, the database has been expanded greatly and improved. It is now a photo CD-based computerized system, known as the Manatee Individual Photo-identification System (MIPS), that utilizes digitized images and PC-based search technologies. The Florida Fish and Wildlife Conservation Commission's (FWC) Marine Research Institute (FMRI) and Mote Marine Lab (MML) now assist in maintaining portions of the database.

It is essential to maintain the photography efforts of the USGS-Sirenia, FMRI, and MML to ensure that vital information on manatee sightings, movement patterns, site use and fidelity, reproductive histories, and related databases remain current for further analyses of survival and reproductive rates. Photos routinely should be collected in the field, especially at the winter aggregation sites, according to standardized protocols for data collection and coding by all cooperators. Annual collection of photographs is essential, as the loss of feature information for individuals in one season could result in an inability to recognize the individual in subsequent years, and potentially compromise the value of the database. Efforts to gather photographic documentation of known females should be continued and expanded to the Southwestern region (Naples through Ten Thousand Islands and the Everglades).

One of the most important parameters for estimating trends in population status is age-specific survival. Photographs documenting sightings of individually-identifiable manatees can be used to estimate minimum ages of manatees in the database and **annual survival rates**. Data on manatees overwintering at specific sites (e.g., Crystal River, Blue Spring, and the warm-water discharges on the Atlantic Coast) are extensive. Analyses using mark-resighting modeling procedures to estimate annual survival rates at these sites have been completed through 1993. Analyses to update these estimates and add additional survival estimates for sites in Southwest Florida (Tampa Bay to the Caloosahatchee River) are underway.

Dead manatees previously identified by photographic documentation must be noted in the database before sight-resighting analyses are undertaken. It is crucial that carcasses continue to be photographically documented and those images distributed to managers of the photo-ID databases, to enhance the accuracy and precision of survival estimates.

Concurrently with photography of individual manatees, information on the **reproductive status of each manatee** (e.g., calf associated with female) should continue to be collected whenever possible. Minimum ages of documented manatees and information such as age at first reproduction, calving interval, and litter size can be determined either during photo-documentation or by timely examination of the database. Long-term studies of reproductive traits and life histories of individual females provide data on age-specific birth rates and success in calf-rearing. The relative success of severely- and lightly-scarred females in bearing and rearing calves should be determined.

Information and tissue samples should continue to be collected from all carcasses recovered in the **salvage program** to determine reproductive status. Resulting estimates of reproductive parameters complement information obtained from long-term data on living manatees and will help to determine trends and possible regional differences in reproductive rates.

Paternity cannot be established in wild manatees without the ability to determine family pedigrees. This information is needed to determine if successful reproduction is limited to a small proportion of adult males, which has important implications for the **genetic diversity** of the Florida manatee population. By continuing the development of nuclear DNA markers, pedigree analysis can be applied to the growing collection of manatee tissue samples. Pedigree analysis also would greatly improve our knowledge of matrilineal relationships and female reproductive success. Identification of factors associated with successful breeding by males is important in assessing reproductive potential in the wild and in captivity.

Aerial surveys provide information on the proportion of calves which may provide insights on reproductive trends when a long time-series of surveys have been conducted by one or relatively few individuals in the same geographic regions. Calf counts from such surveys should be continued (particularly the state-wide surveys conducted by FMRI since 1991, the power plant surveys sponsored by FPL since 1977, and the Crystal/Homosassa River surveys conducted by FWS since 1983). The results should be compared to those obtained by photo-ID methods (particularly for the Crystal/Homosassa River wintering group).

Passive Integrated Transponder (PIT) tags should be inserted under the skin of all manatees captured during the course of ongoing research or rescues. All manatees that are recaptured, rescued, or salvaged should be checked for PIT tags, and identification information should be provided to FMRI. By comparing data on manatee size, reproductive status, and general condition between time of tagging and recovery, one can increase the amount of information obtained on life history parameters. This technique is particularly useful in identifying carcasses, which is very important in obtaining accurate survival estimates. Methods for checking for PIT tags reliably on free-swimming manatees should further be developed and tested. When the latter work shows promise, plans should be developed for re-examining the utility of PIT-tagging manatees of certain age classes (juveniles and subadults) or in specific areas where photo-ID is not a feasible way to re-identify individuals. This research should include estimates of sample sizes required to determine population traits, such as survival and reproductive rates.

POPULATION STRUCTURE

Information on population structure can be obtained through the carcass salvage program, the

MIPS database, and telemetry studies. This information is important for the development of realistic population models.

Collection of tissue samples from salvage specimens and from living manatees at winter aggregation sites, captured during research, or rescued for rehabilitation should continue. Continued genetic analysis through collaborations with state and federal genetics laboratories may reveal greater population structure than has been demonstrated thus far (i.e., a significant difference between east and west coasts, but not within coasts). Such research will improve our ability to define regional populations and management units. Stock and individual identity for forensic purposes ultimately will be possible. Analytical techniques recently developed for identifying the structure of other marine stocks also should be investigated.

To aid in characterizing population structure, life history information (e.g., sex and size class) should continue to be collected concurrent with photographs to augment similar information collected from other sources (e.g., carcasses and telemetry). Long-term patterns of fidelity to winter aggregation sites and summer ranges, as well as movement among sites, also can be documented.

Radio-tracking has provided substantial documentation of seasonal migrations, other long-distance movements, and local movements that reveal patterns of site fidelity and habitat use. In Brevard County, for example, a large group of manatees overwinters in the Indian River, using two power plants for thermal refuge, and another group travels south to Palm Beach and Dade counties, using several power plants for refuge along the way. While these two groups are not entirely mutually exclusive, many individuals consistently display the same pattern each year, in timing and distance of moves as well as destinations. Such information is needed from other regions, particularly Southwest Florida, in order to develop management strategies for all significant subgroups within the regional population, however transitory they may be.

The **salvage program** yields important information on the manatee population sex ratio and proportion of age classes (adult, subadult, juvenile, and perinatal) within each cause-of-death category. Annual changes in these proportions may indicate increases or decreases in certain types of mortality, and thus should be considered as part of the weight of evidence that supports (or rejects) a downlisting decision. Ear bone growth-layer-group analysis should be continued to determine more exact ages of dead manatees, particularly those that have a known history through the photo-ID or telemetry studies, or received PIT tags. Although the age structure of the carcass sample is biased toward younger animals, opportunities may occur to document better the natural age structure within specific regions because of age-independent mortality events.

DISTRIBUTION PATTERNS

Shifts in manatee distribution over time may interfere with our ability to assess accurately regional population trends. Changes may occur in response to human activities, such as modifications of warm-water discharges, enforcement of boat speed regulations, or restoration programs, and because of natural events, such as hurricanes or red tides. Efforts to document manatee distribution through aerial surveys, photo-ID, and telemetry should continue, particularly at important wintering sites, areas of high use, and poorly-studied regions. The validity of the four regional subpopulation designations should be periodically re-evaluated, as they may change over time.

As discussed above, **photographs documenting individual manatees** are important to provide information on life history parameters, population trends, and population structure. Such photographs are also important to provide information on fidelity to winter and summer sites, high-use of and seasonal movements among sites. These photos should continue to be taken at aggregation sites primarily in Florida, but also opportunistically at other sites in the Southeastern United States. Photo-ID efforts recently were initiated in the Ten Thousand Islands region, and should be continued and expanded to other sites in Southwestern Florida.

As appropriate and possible, local and regional **aerial surveys** should be undertaken or continued to improve information on habitat use patterns and changes in distribution. Documentation of changes in distribution at power plants will be particularly important when changes in warm water availability occur.

Telemetry research has proceeded as a series of regional studies with tracking efforts concentrated in different areas in different years. Multi-year studies have been completed for the Atlantic coast and Southwest Florida from Tampa Bay through Lee County, and research findings have been summarized in manuscripts currently undergoing peer review. Verified high quality satellite telemetry location information, with descriptive meta data, will be added to the Marine Resources CD-ROM produced by FMRI. Areas not well-studied, such as the Everglades or where anticipated changes are likely to impact manatees, will be targeted for future research.

POPULATION MODELING

Population models are mathematical representations of the underlying biological processes that control population dynamics. In order to be useful in describing the true behavior of population growth, existing models must be evaluated and improved continually. The underlying assumptions of models, the importance of parameters used in the models, the accuracy and uncertainty of the parameter estimates, the relationships of the parameters, and the appropriateness of the mathematics implemented in the models need to be evaluated critically. Comparisons also need to be made between predicted outcomes from the models and estimates or indices of population trend from other modeling efforts or other data sets.

Eberhardt and O'Shea (1995) developed a deterministic population model using estimates of mortality, reproduction, and survivorship to calculate estimates of population growth rates for three subpopulations of manatees. They considered this a provisional model requiring further development and modification. Steps should be taken to continue to improve this model and to develop more complex models incorporating additional life history information and which reflect better our understanding of the processes involved in population dynamics. Examples of additional population parameters that most likely will be needed in future models are stochastic variation in survival and reproduction rates, genetic population structure, and movement of individuals between regional subpopulations.

To construct valid models, accurate **estimates of population parameters** are required. Where estimates of model parameters need to be developed or improved, other relevant tasks should be modified or strengthened. Because parameters can vary over space and time and such variation affects population growth rates, emphasis should be placed on **estimating variance** and 95% confidence intervals along with developing best estimates of particular population parameters.

It is important for those **developing manatee population models** to coordinate their activities and to interact directly with research biologists who have collected manatee life history data or who are very familiar with manatee ecology. Biologists will understand better how models were derived, and the modelers will obtain feedback on the reasonableness of their assumptions and interpretation of their results. Interaction with management also is needed to help focus the questions addressed by present and future modeling efforts. For example, FWS wants to know if modelers can estimate the number of manatee deaths that can be sustained per region, while still allowing population stability or growth to be achieved. The coordination and interaction of all players will lead to the adaptive development of newer and better models that meet the needs of manatee biologists, policy makers, and managers. The multi-agency MPSWG is best positioned to track research developments, link important players, and provide one level of peer review and evaluation. Peer review from internal and external sources is essential to such evaluations.

Uncorrected aerial survey data do not permit statistically valid population estimation or trend analyses. However, models to correct for some of the inherent bias and uncertainty have been developed, and these efforts should be continued. Methods to correct for various types of visibility bias in surveys should be developed. Standard procedures for survey teams involved in annual statewide surveys need to be developed and implemented. Use of strip transect aerial surveys make it possible to use survey data to detect regional population trends, e.g., in the Banana River and perhaps in Southwest Florida between the Ten Thousand Islands and Whitewater Bay. Strip transect surveys should be continued on an annual basis in the Banana River, and their feasibility should be investigated in remote coastal areas of Southwest Florida. To the extent possible, surveys should be designed to estimate accurately a minimum population number.

As manatee habitat requirements are documented and recovery criteria are identified (based on habitat needs), it will become possible to **link regional population and habitat models and estimate optimum sustainable populations for regions and subregions**. Integration of population and habitat information is essential to understand the implications of habitat change before negative impacts on manatee population trends can occur. The Population Status and Geographic Information System (GIS) working groups should meet jointly on an annual basis to coordinate their activities and progress. Reports of these meetings should be distributed to all agencies and interested parties involved in manatee recovery efforts.

The manatee salvage/necropsy program is fundamental to **identifying causes of manatee mortality and injury**. The program is responsible for collecting and examining virtually all manatee carcasses reported in the Southeastern United States, determining the causes of death, monitoring mortality trends, and disseminating mortality information. Program data help to identify, direct, and support essential management actions (e.g., promulgating watercraft speed rules, establishing sanctuaries, and reviewing permits for construction in manatee habitat). The program was started by FWS and the University of Miami in 1974 and was transferred to the State of Florida in 1985.

The current manatee salvage and necropsy program is administered through FWC 's FMRI. The major program components are: (1) receiving manatee carcass reports from the field; (2) coordinating the retrieval and transport of manatee carcasses and conducting gross and histological examinations to determine cause of death; (3) maintaining accurate mortality records (including out-of-Florida records); and (4) carrying out special studies to improve understanding of mortality causes, rates, and trends. The carcass salvage program also has permitted scientists to: (1) describe functional morphology of manatees; (2) assess certain life history parameters of the population; and (3) collect data on survival of known individuals. Program staff also coordinate rescues of injured or distressed manatees. To implement the salvage program, FWC maintains a central necropsy facility called the Marine Mammal Pathobiology Laboratory (MMPL), located on the Eckerd College campus in St. Petersburg. FWC also has three field stations on the east coast situated in Jacksonville, Melbourne, and Tequesta, and one field station on the west coast at Port Charlotte.

To improve the program, FWC is hosting a series of manatee mortality workshops to review critically its salvage and necropsy procedures and methods. These workshops: (1) establish and improve "state-of-the-art" forensic techniques, specimen/data collection, and analyses; (2) identify and create projects focusing on unresolved death categories; (3) prepare for and assist with epizootics; (4) generate reference data on manatee health; and (5) generate suggestions for attainment of a "healthy" manatee population. In addition, FMRI personnel are urged to move forward with models based on life history and mortality data, and process improvement is being implemented to expedite data dissemination.

Georgia Department of Natural Resources, South Carolina Department of Natural Resources, Louisiana Department of Wildlife and Fisheries, Texas Marine Mammal Stranding Network, University of North Carolina at Wilmington, and others help to coordinate carcass salvages and rescues in other Atlantic and Gulf coast states. Mortality information collected from these efforts needs to be centralized and should be kept in the mortality database maintained by FWC. FWS and FWC should provide assistance to these manatee salvage and rescue programs through workshops, providing equipment and assistance when possible.

While it is believed that most dead manatees are found and reported to the salvage program, an unknown proportion are unreported. Annual manatee carcass totals, therefore, under-represent the actual number of deaths, indicating the need to **improve carcass detection, retrieval, and analysis**. Decomposition, increased in part by delayed carcass retrieval, reduces the ability to assign cause of death in some cases. To estimate the number of unreported manatee carcasses, studies should be done on carcass detection and reporting rates. Studies focusing on carcass drift, rate of decomposition, and how decomposition affects necropsy results should be conducted. Periodic peer reviews should take place on necropsy methods, data recording and analysis, and documentation of tissues collected. Representative samples should be archived with appropriate national tissue banks. Workshops such as the FWC Manatee Mortality Workshop should continue to be conducted to strengthen collaborative research and information sharing. Partnerships with other agencies and process analysis of carcass retrieval protocols should be ongoing in order to improve efficiency.

Collisions between manatees and boats is the largest known cause of manatee mortality, both human and non-human related; in the late 1990s, watercraft-related deaths constituted at least 25% of the total known annual mortality. Therefore, it is essential to **improve the assessment and understanding of manatee injuries and deaths caused by watercraft**. Under-reporting of watercraft mortality may occur because individuals may not die immediately but rather may develop complications resulting from injuries sustained by boats; such deaths are difficult to attribute to watercraft.

Benchmarks have been established for survival, reproduction, and population growth.

Longitudinal studies should be established to examine the effect of boats and boating activity on these parameters. Investigations of the characteristics of lethal compared to non-lethal injuries and causes should be developed using data from carcasses, photo-ID records, and characterizing healing in rescued injured animals. Investigations on lethal and non-lethal injuries also should attempt to characterize size of vessels, relative direction of movement of vessel, and propeller vs. blunt trauma statistics. Research on mechanical characteristics of skin and bones should be developed to obtain a better understanding of the effects of watercraft-related impacts. Regional studies are needed to characterize boating intensity, types of boats, boating behavior, and boating hot spots in relation to manatee watercraft-related mortality.

Increasing numbers of manatees in the Northwest region of Florida may lead to increasing numbers of animals killed by watercraft. However, such population increases would not explain the recent increase in the percent of mortalities related to watercraft. In addition, this explanation cannot be used for areas where the number of manatees is stable or decreasing. The available data suggest that on average in 2000, collisions with watercraft killed a manatee every 4.6 days. However, these data may underestimate the number of manatee mortalities. More effective diagnosis of watercraft-related injuries and mortalities is important for describing the extent and nature of the threat posed by watercraft. Mortality workshops are intended to improve our ability to diagnose watercraft-related mortalities more effectively on both fresh and decomposed carcasses.

Prevention of such injuries and mortalities is the goal. **Research is needed to address the causes of watercraft mortality and the effectiveness of management actions**. Importantly, such research also should investigate the effects of sublethal injuries and stress occurring as a result of boating activity. Injuries and stress may: (1) lead to reductions in animal condition and reproductive success; (2) cause animals to abandon habitat important for foraging, reproduction, or thermal regulation; or (3) impair immune system function thereby increasing the vulnerability of animals to disease, pollutants, or toxins. Thus, indirect or secondary effects of boating activity also may impede population recovery in ways that have not yet been assessed.

Studies are underway to **identify and evaluate adherence to manatee speed zone restrictions through statewide boater compliance studies**. The following should be continued and assessed: (1) the frequency of boater compliance with posted manatee speed zone restrictions; (2) the degree of boater compliance with posted manatee speed zone restrictions; (3) the levels of compliance among boat classes, seasonally, and temporally; (4) changes in compliance resulting from different enforcement regimes; and (5) changes in compliance resulting from different signage. Underlying sociological factors that affect compliance also should be investigated.

MML recently completed a **study that characterizes the intensity and types of boating**

activities in Southwest Florida. Similar studies should be conducted at selected locations around the state, with emphasis on areas where boat-related mortality of manatees is highest.

MML, FWC, and others are **investigating reactions of manatees to boats**. Preliminary information indicates that manatees perceive boats, but may, under certain circumstances, react in ways that place the animals in the path of, rather than away from, the boats. Additional studies of manatee responses to boats and vessel acoustics are needed. Indirect deleterious effects of shallow-draft or jet boats that can disturb manatees and cause them to move to boating channels or interrupt normal behaviors need to be studied. An evaluation of spatial and temporal factors associated with risk to manatees (i.e., proportion of time manatees are exposed to vessels relative to depth, habitat, and manatee activity) should be conducted.

In the 1970s, Odell and Reynolds described the extent to that flood control structures killed manatees in southeastern Florida. In response, the South Florida Water Management District modified the way that the structures operate, to determine if this change would mitigate the problem. The problem, however, continues to exist, and it involves flood control structures and navigational locks located throughout the state. The U.S. Army Corps of Engineers and various flood control agencies (among others) have devoted considerable time and money to possible solutions, but mortality in the structures was the second highest ever in 1999 (15 manatees died, accounting for approximately 5% of the total deaths during this year). **Research is needed to continue to assess manatee behavior leading to vulnerability around these structures**, as well as operational or structural changes that can prevent serious injury or death of manatees.

Presently, pressure-sensitive strips are being installed on vertical lift structures, and acoustic arrays are being installed on navigational locks. Efforts continue to understand better how and why manatees are killed by structures. The MMPL will associate forensic observations obtained at necropsy with specific characteristics of the structure that caused the death. Continued testing and improvement of manatee protection technology is encouraged.

Commercial fishing is not a major culprit involved in manatee mortality, unlike the case with most other marine mammals. Commercial fishing accounts for far fewer manatee deaths than do either collisions with boats or entrapment in water control structures. Nonetheless, manatees are killed by shrimp trawls, hoop nets, monofilament entanglement, hook and line ingestion, and crab pot/rope entanglement, indicating the need to **improve the evaluation and understanding of injuries and deaths of manatees caused by commercial and recreational fishing**.

Since the introduction of Florida’s ban on the use of commercial nets in inshore waters in July

1995, manatees have been exposed to fewer opportunities to become entangled in nets. Because of the net ban, however, some former commercial net fishermen switched to crabbing using crab pots. Probably as a result of this increased number of crab pots, rescues of manatees entangled in crab pot lines have more than tripled since 1995. To reduce the increasing numbers of fishing gear entanglements by manatees, a multi-agency Manatee Entanglement Task Force has been established, focusing on creating changes in data collection protocols, potential technique/gear modifications, innovative tag designs, entanglement research, gear recovery/clean-up, and education/outreach efforts. Research on rates of entanglement, types of gear involved, and geographical and temporal changes in rates and types of entanglements should be developed. Studies on behavioral characteristics of manatees contributing to entanglement should be pursued. Hubbs-Sea World Research Institute currently is studying how manatees become entangled. Research on the amount of marine debris in inshore waters should be conducted, particularly where there are high levels of manatee entanglement. Programs to remove marine debris and recycle monofilament line also should be encouraged and continued.

Tests for several types of man-made compounds and elements have been conducted on manatee tissues. Although no known death or pathology has been associated with toxicants, some concentrations of contaminants have caused concern. Over time, concentrations of chemicals found in manatees from early studies have changed, possibly as a result of the regulation of chemical use. Such changes highlight the need to monitor tissues for chemical residues. In addition, survey studies provide insight into the presence of different or new compounds in the environment. While a broad range of tests have been conducted, there needs to be a greater focus on endocrine disruptor compounds. These compounds can alter reproductive success and have a dramatic effect on population growth.

By definition, **natural causes of mortality** are not directly anthropogenic and thus not easily targeted by management strategies. However, some aspects of natural mortality may be influenced by human activities. These activities include but are not limited to: (1) sources of artificial warm water; (2) nutrient loading; and (3) habitat modification.

Cold stress- and cold-related death are both factors contributing to manatee deaths. Acute cold-related mortality is related to hypothermia and metabolic changes which occur as a consequence to exposure to cold. Cold stress is related to the amount of cold exposure, nutritional debt, age and size of the animals, and time; cold stress can last as long as several months before the individual dies. The syndrome was originally described based upon the gross internal appearance of carcasses, combined with age of the animal (e.g., recently-weaned) and time of year (late winter to early spring). More recently, the appearance of skin lesions, not unlike frostbite, have been associated with cold stress, although the presence of these lesions is not considered to be a definitive indicator. Research continues to focus on critical cold air and water temperatures that affect manatee physiology (particularly as it pertains to acute cold- and cold stress-related mortality). To provide important clues as to how manatees deal with cold temperature, future research should study behavioral adjustments to cold (e.g., directed movement to warm-water refuges, time budget during cold periods, and surface resting intervals during warm spells). Research identifying the manatee's anatomical and physiological mechanisms for heat exchange are important to understanding the biological limitation of the species. Ancillary research should include identification of natural warm-water sites, because a growing population of manatees may be seasonally-limited by overcrowding at the larger well-known warm-water refuges.

In Florida, there are many species (approximately 20) of marine alga that can produce harmful **naturally-occurring biotoxins**. These toxins have the potential to cause massive deaths of fish, fish-eating predators (e.g., birds and dolphins), some species of sea turtles, and manatees. Many of the toxins also affect humans after they consume contaminated fish or shell fish (although human deaths are rare). One biotoxin (brevetoxin) has been the suggested cause of deaths of manatees. Brevetoxin is produced by the marine dinoflagellate, *Gymnodinium breve*, and is responsible for the red tides that occur along coastal Florida. The most recent epizootic of manatees in 1996 was attributed to brevetoxin and underscores the catastrophic effect such events can have on the population; in just 8 weeks, 145 manatees died in Southwestern Florida, representing a substantial loss to the population. Research is needed to improve our ability to detect brevetoxin in manatee tissues, stomach contents, urine, and blood. At the same time, environmental detection of red tides, their strengths, and the development of retardants are necessary. More advanced immunological research utilizing manatee cell cultures may result in the development of better treatment of manatees exposed to brevetoxin as well as the development of prophylactic vaccine.

Perinatal mortality has averaged approximately 24% of the total annual mortality for the last ten years; ranging from 11% in 1981 to 30% in 1991. The category termed "perinatal" is based on a size classification and is not a true cause of death; all manatees measuring 150 cm or less are grouped into this category regardless of developmental stage. Since the developmental stage of a young manatee may have important implications in the analysis of overall deaths, the MMPL initiated the generation of a protocol to identify characteristics of specific stages within this category. The protocol includes the documentation of changes in the circulatory system which occur around the time of birth. Improved methods are needed to subdivide the perinatal category into categories of: (1) clearly fetal; (2) at or near the time of birth; and (3) clearly born. Once these categories are well-defined, analysis can ascertain the life stage subject to the greatest impact, thus allowing for the future development of appropriate management policies. Field research focusing on factors affecting calf survival should be conducted (e.g., age of mother at reproduction, behavior, characteristics of calving areas, and human disturbance).

Periodically, **unusual mortality events** occur in which large numbers of manatees die or become moribund. In 1982 and again in 1996, manatees died or became ill from inhalation and ingestion of brevetoxin (see discussion above). Spikes in mortality also occur during periods of extreme or prolonged cold. Such events represent: (1) the potential for disastrous reductions in numbers of manatees occupying certain regions of the state; (2) the opportunity to learn about manatee response to disease agents or about manatee life history; and (3) a logistic ordeal if proper steps for coordination and communication have not been taken ahead of time. Consequently, FWS and FWC have created complementary manatee die-off contingency plans (Geraci and Lounsbury 1997; FWS 1998) that have been merged into one comprehensive document (FDEP *et al*. 1998). The document contains information and guidance from the two plans together with advice and provisions outlined in the executive summary from Wilkinson (1996). Research and investigations should follow the protocols and recommendations found in the Contingency Plans. In addition, there should be ongoing collection and storage of tissues and samples from healthy and non-mortality event manatees to establish a baseline and to aid interpretation of test results obtained during a catastrophic event and for retrospective studies. Investigators should contact and work closely with other research projects monitoring and evaluating harmful algal blooms. FWC mortality workshops should continue to facilitate and develop cooperative arrangements among investigators and institutions.

FACTORS AFFECTING MANATEE HEALTH, WELL-BEING, PHYSIOLOGY AND ECOLOGY

Relatively little attention has been paid to the health and well-being of individual manatees, although factors affecting individuals ultimately influence the overall status of the population. A variety of factors go into the making of a healthy individual, and health is defined by ranges of values rather than specific ones. Scientists discuss these ranges of values in terms of biological limits. Assessment of what is outside the range of normal values is important, and to make such assessments, baseline data are needed. This generally requires multiple samples from individuals representing a range of ages, different sexes, and a variety of reproductive stages.

There is a need to determine the relatively constant internal state in which factors such as temperature and chemical conditions remain stable and therefore within a range of values that permit the body to function well, despite changing environmental conditions. Stress is part of existence, and not all stress is bad for an individual. However, a stressor can affect homeostasis and health, and thereby precipitate a chain of events that can compromise the survival of an individual. There is also a need to understand the factors underlying large-scale trends. For example, individual manatees compromised by severe injury or disease may not be able to reproduce successfully. Similarly, sublethal effects of toxicants and even the effects of nutritional, noise-related, and disturbance-related stresses can impair immune function and potentially reduce the ability of individuals to reproduce. Study plans and protocols should be developed, collaborators identified, and results published.

Blood serum is the watery portion of the blood remaining after cells and fibrin are removed. Analysis of serum permits assessment of electrolyte levels, hormones, antibodies indicative of exposure to certain pathogens, and other factors important to the health of individual manatees. Serum can be banked for retrospective analyses. Efforts should be made to develop and publish a synthesis of: (1) current knowledge of **manatee serology**; (2) ranges of values associated with manatees in various demographic groups; (3) anomalies identified in manatees via serum analyses; and (4) any remaining unanswered questions.

Major organs and organ systems have been examined by a variety of scientists over the years. The compilation of anatomical observations by Bonde *et al*. (1983) reflects the fact that early in the evolution of manatee programs, efforts were made to understand **anatomy of manatees**. Such assessments have assisted scientists performing necropsies of dead manatees to determine morphologies and pathologies. Some systems or organs have been ignored but are important to assessing manatee health; these include: (1) the lymphatic system; (2) most parts of the endocrine system; and (3) non-cerebral parts of the brain. In addition, potential changes in reproductive tracts routinely should be assessed as part of ongoing life history assessments.

Manatee histology (microscopic anatomy) has been relatively unstudied, compared to gross anatomy. However, it is of no less importance in understanding normal organ or tissue functions, as well as abnormalities thereof. Responsible agencies should respond to this important deficiency.

Although work has been ongoing to assess effects of environmental temperatures on metabolism of manatees, the relationship among temperature change, metabolic stress, onset of chronic or acute disease symptoms, and even mortality of manatees is not perfectly understood. As noted above, the relationships among manatee reproductive status, body condition, thermal stress levels, and metabolic responses to such stress remain unclear. Answers to these **thermoregulation** questions are needed urgently as the specter of decreased availability of both natural and artificial warm-water sources looms. The research should focus not only on lower critical temperatures (the cold temperatures where metabolic stress occurs), but also on the upper critical temperature.

It is unclear whether or not manatees physiologically require fresh water to drink, and it is unknown what stresses may be created when fresh water is not available. Anatomical and experimental studies have indicated that manatees **osmoregulate** well in either fresh or salt water. The extent to which manatees seek fresh water suggests that the animals prefer it to drink, and they may be healthiest when they have at least occasional access to fresh water. Managers attempting to protect resources sought by, if not required by, manatees should bear in mind that fresh water is a desirable and possibly necessary resource for healthy manatees.

Stirling *et al*. (1999) provided an important assessment of polar bear **body condition indices** and related those values to changes in the environment and in consequent availability of polar bear food. They also related changes in reproductive performance and survival of offspring with changes in female body condition. This study exemplifies the importance of long-term data regarding animal health (as assessed by body condition), reproduction, and environmental quality. In Florida, where environmental quality varies considerably over time and space, the value of such a study is enormous. Body indices research at FMRI has initiated certain measurements documenting body condition of manatees. Maintenance of this work and refinements/extensions thereof, should be continued to gain a better understanding of physiology and health of individuals and the population.

Continuous long-term monitoring of the **health histories of individual manatees** allows for documentation of an animal's health. Information should be gathered on: (1) the acquisition and severity of new wounds to facilitate research on the length of time required for injuries to heal; and (2) any effects of injuries on behavior or reproduction. Natural factors affecting the health of the population also should be monitored during the course of photo-ID studies on wild individuals (e.g., cold-related skin damage, scars caused by fungal infections, and papilloma lesions).

As discussed earlier, brevetoxin, a **naturally-occurring toxin**, has been implicated or suspected in major and minor mortality events for manatees for decades. Tests now exist to allow pathologists to assess, even retrospectively, manatee tissues for signs of brevetoxicosis. The important questions include: (1) how many manatee deaths can be truly attributed to exposure to brevetoxin over the years; (2) if red tides are a natural occurrence, how can effects of red tides on manatees be reduced or mitigated; (3) would changes in human activities (i.e., creation of warm-water refuges which lead to aggregations of manatees) appreciably change vulnerability of the animals; and (4) have human activities contributed to increased prevalence and virulence of red tides.

Inasmuch as a single epizootic event can cause 2 to3 times as many manatee deaths as watercraft causes annually, gaining a better understanding of the issue is vital and urgent. Development of cell lines and testing of manatee tissues would represent an extremely useful approach. In particular, preliminary results indicate that exposure to brevetoxin reduces manatee immune system function. Further study of the immune system will define levels of concern and will help to identify when rehabilitated manatees are ready for release into the wild.

Other natural toxins have affected marine mammals (e.g., saxitoxin) and may represent another potential problem for manatees. Exposure of cultured cells of manatees to saxitoxin and assessment of the responses of those cells, would be useful.

To date, the only efforts to assess levels of **toxicants** in manatees have involved some organochlorines and a few metals. This situation is typical of toxicological work for marine mammals in general (O'Shea 1999; Marine Mammal Commission 1999). These studies demonstrate that a few metals occur in high concentrations in manatee tissues. Testing for toxicants can be extremely expensive; thus, a carefully-constructed study plan should be developed first to address the most critical uncertainties and to make the assessments as cost-effective as possible. Some important habitats in Dade County (e.g., Miami River and Black Creek) contain sediments contaminated with trace metals and/or synthetic organic chemicals to the extent that the sediments are considered to be toxic. Sediment chemistry/toxicity testing could be used as an indicator to direct toxicant studies in these types of areas.

A **disease** involves an illness, sickness, an interruption, cessation, or disorder of body functions, systems, and organs. In other words, disease represents the antithesis of homeostasis. As previously noted, scientists need to learn the boundaries of normal structure and function before they can diagnose what is normal or diseased. This process has occurred to some degree through the necropsy program, but it needs considerable refinement. Over the years, cause of death for about 1/3 of all manatee carcasses has been undetermined; this percentage probably would drop considerably with better information about and diagnosis of manatee disease states. Planned workshops by FMRI will attempt to bring scientists conducting necropsies on manatees together with pathologists and forensic scientists working with humans and other species. This effort should be very useful as a first step in an ongoing process of refinement.

Nutritional characteristics of manatee food plants and the importance of different food sources for different manatee age and sex classes in various regions are understood poorly. Such information is needed to help assure that adequate food resources are protected in different areas of the population's range. Ongoing studies should be completed to identify manatee food habits and the nutritional value of different aquatic plants important to manatees. In addition, seasonal patterns of food availability in areas of high manatee use need to be documented. Research also should address **manatee foraging behavior**, emphasizing ways that manatees are able to locate and utilize optimal food resources.

Catalogs of **manatee parasites** were prepared two decades ago (Forrester *et al*. 1979). A recent description of parasites for cetaceans (including manatees) in Puerto Rico also was published (Mignucci-Giannoni *et al*. 1998). Since degrees of parasitic infestation may be associated with the changes in the health of manatees, assessments of changes in prevalence of parasites over time should be undertaken. Inasmuch as parasite loads are assessed, at least qualitatively, during necropsies, this should be easy to accomplish, relatively speaking.

Vision in manatees has been well studied relatively. Tactile ability and acoustics also have been assessed. Conclusions reached as a result of acoustic studies are somewhat inconsistent and controversial, especially in terms of the extent that manatees may hear approaching watercraft. Since the auditory sense of manatees appears to be vital to their ability to communicate and to avoid injury, further studies are warranted. In addition, although chemoreception has been suggested as a mechanism by which male manatees locate estrous females, chemosensory ability of manatees is virtually unknown. Studies should continue on these topics to **develop a better understanding of manatee sensory systems**.

It is clear from various lines of evidence that manatees show site fidelity, especially in terms of their seasonal use of warm-water refuges, but also in their use of summer habitat. To some extent, calves learn locations of resources from their mothers. However, the way that manatees perceive their environment, cues they use to navigate, and the hierarchy of factors they use to select a particular spot or travel corridor are all unknown. As humans continue to modify coastal environments (physically, acoustically, visually, and chemically), it would be useful to understand better how such changes may interfere with the manatee's ability to **orient and to locate or select optimal habitat**.

Relatively few studies have been directed at **manatee behavior** since Hartman's work in the late 1970s. Rathbun (1999) summarized existing information on activity and diving, foraging, thermoregulation and movements, resource aggregations, mating, social organization, and communication. He concluded that, although the manatee's herbivorous diet is perhaps the most important factor in understanding their life history and behavior, it is the least studied aspect of manatee behavioral ecology. Both field studies and controlled experiments at captive facilities are needed to document basic behaviors. This documentation will allow detection and understanding of changes in behavior that occur through changes in allocation of essential resources, such as vegetation and warm water. To date, telemetry, photo-ID, and aerial videography have been useful tools for behavioral research. New innovative approaches are needed, particularly in habitats where visibility is poor.

Captive dolphins have developed ulcers and died when subjected to excessive human activity or excessive noise (i.e., from pumps) around their enclosures. Chronic levels of **disturbance** may create stresses to manatees; certainly, manatees change their behavior or actually leave certain areas to avoid disturbance. The stress involved would be difficult to document, but if manatees move away from critically important resources (e.g., warm water in winter) to avoid being disturbed, this movement could place the animals in immediate and acute jeopardy. Buckingham *et al*. (1999) provide an interesting case study for manatees, and data exist to support problems created by disturbance for a variety of marine mammals, including animals sympatric with Florida manatees (i.e., dolphins). Sources and level of activities eliciting disturbance responses need to be characterized further.

Manatees, particularly mothers and calves, communicate vocally. Often, while vessels are still outside of visual range, manatees initiate movements as boats approach, suggesting that they respond on the basis of hearing the boats. Noise from boats or other sources may interfere with communications or provide a source of stress. Hearing capabilities have been examined through studies involving two individuals in captivity (Gerstein 1995, 1999). There is a need for further research on hearing capabilities and the **effects of noise on manatees**. In particular, it is important to determine: (1) the sensitivity of manatee hearing to the different kinds of vessels to which they are exposed; (2) the range of frequencies of importance to manatee communication; (3) the abilities of manatees to localize sound sources; and (4) the role that habitat features may play in altering sound characteristics. The levels and characteristics of vessel sounds leading to behavioral changes, including potentially vacating an area, need to be determined.

Manatee distributions have been found to be **affected by boat traffic** in at least one study, with manatees moving into established sanctuary areas during periods of heavy boat traffic (Buckingham *et al*. 1999). Factors to be investigated include types and frequency of approaches, numbers of boats, distance of nearest approach, individual variations in manatee responses to boats, influences on diurnal activity patterns and habitat use, and effects on mothers and young.

Human swimming (and to a lesser extent diving) with manatees occurs in many parts of the species' range. In a few warm-water refuges, sanctuary areas have been established for manatees to escape from contact with human swimmers, but few data from systematic studies are available to evaluate the potential **impacts of human swimmers** or the effectiveness of the sanctuaries. The specific circumstances or characteristics of human swimming, snorkeling, or SCUBA-diving that may result in changes in manatee behavior, including vacating an area, remain to be determined. Factors to be investigated include types and frequency of approaches, numbers of swimmers, distance of nearest acceptable approach, occurrence of contact, individual variations in manatee responses to humans, influences on diurnal activity patterns and habitat use, and effects on mothers and young.

Public viewing of manatees has become increasingly popular in recent years and now occurs in many parts of the species' range. Commercial operations as well as private individuals are bringing increasing numbers of people to view manatees in areas where the animals can be found predictably. The opportunity for the public to move into close proximity to the animals typically is associated with other potentially disturbing activities such as swimming, diving, boating, or provisioning. The relative benefits of burgeoning human attention as compared to potential adverse impacts on the animals have not been evaluated properly to determine the desirability of increasing or decreasing control over manatee viewing activities. Studies relating marketing and overall levels of human viewing activities to changes in manatee behavior, including vacating an area, need to be conducted. Conversely, benefits accrued to the manatees from increased viewing by the public also should be evaluated for comparison.

In many parts of the species' range, people provide food or water to manatees, in spite of regulations prohibiting such activities. A systematic evaluation should be conducted to determine if these **provisioning** activities potentially adversely affect manatees in terms of changing their behavior, placing them at greater risk from other human activities, or encouraging them to use inappropriate habitat.

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FLORIDA MANATEE CAUSE OF DEATH BY REGION (1991-2000)
ATLANTIC, UPPER ST. JOHNS RIVER, NORTHWEST AND SOUTHWEST

Manatee carcasses reported in Florida from 1991 to 2000 (FWC, unpublished data) were assigned to four regions of the state: (1) Atlantic Coast (St. Johns River and tributaries downstream (north) of Palatka); (2) Upper St. Johns River (St. Johns River upstream (south) of Palatka); (3) Northwest (Homosassa/Crystal River and north); and (4) Southwest (Tampa Bay area). The percentage of carcasses by each cause of death was calculated for each region (Tables 5-6 and Figures 17-21).

Two regions contained most of the 2,306 carcasses located state-wide (Atlantic 50%, Upper St. Johns River 2%, Northwest 5%, Southwest 43%); however, the Atlantic and Southwest regions also have the highest numbers of living manatees. Therefore, results should be viewed cautiously because percentages among causes of death can seem contradictory. Large numbers of deaths in one region in one category can make another category seem less important. A mortality event in one region can make all the other causes seem less important (smaller percentages), when actually all of the causes take on even greater importance due to the high number of deaths in a short time period.

Carcasses (n=145) from the 1996 red tide epizootic in southwest Florida were omitted from the following analysis, because this was considered to be a non-typical situation; their inclusion here would make other human-related and natural causes of death seem less important.

Causes of death varied among regions. The percentage of watercraft-related deaths was highest in the St. Johns River region (15 carcasses, 34%) and lowest in the Atlantic (264 carcasses, 24%) region. The highest number of watercraft deaths occurred in the Atlantic and in the Southwest regions (252 carcasses, 27%).

The highest percentage of flood gate and lock deaths occurred in the Atlantic (69 carcasses, 6%) and St. Johns River regions (4 carcasses, 8%), and lowest percentage occurred in the Northwest region (1 carcasses, 1%). The highest number of gate/lock deaths occurred in the Atlantic and Southwest (19 carcasses, 2%) regions. Only a few water control structures and navigational locks are present on the west coast, and percentages were lower there.

All other human-related causes of deaths combined accounted for the highest percentage of deaths in the Atlantic (40 carcasses, 4%) and Northwest regions (4 carcasses, 4%), and accounted for the lowest in the St. Johns River (0 carcasses, 0%). The highest number of other human-related deaths occurred in the Atlantic and Southwest (14 carcasses, 2%) regions.

Perinatal deaths accounted for the highest percentage of deaths in the Northwest region (32 carcasses, 33%). The highest number of perinatal deaths occurred in the Atlantic (296 carcasses, 27%) and Southwest (190 carcasses, 20%) regions.

Cold-related deaths accounted for the highest percentage of deaths in the Atlantic region (29 carcasses, 3%). The only recent large cold mortality event primarily in Brevard County during the winter of 1989-1990. Cold-related deaths were lowest in the two regions with major natural springs, the St. Johns River (0 carcasses, 0%) and Northwest (3 carcasses, 3%) regions.

Other natural causes of death combined accounted for the highest percentage of deaths in the Southwest Region (154 carcasses, 17%), and accounted for the lowest percentage in the St. Johns River (2 carcasses, 5%). The highest number of other-natural deaths occurred in the Southwest and Atlantic (112 carcasses, 10%) regions. The high number of deaths from natural causes in the Southwest region may partly reflect occasional small red tide events.

Undetermined deaths (including verified but not recovered carcasses) accounted for the highest percentage in the Southwest Region (277 carcasses, 30%), and accounted for the lowest percentage in the Northwest (20 carcasses, 20%). The highest number of undetermined deaths occurred in the Southwest and Atlantic (279 carcasses, 26%) regions. The high number of undetermined deaths in the Southwest region may be related to the high levels of carcass decomposition because of the warm temperatures and remoteness of large parts of the region (i.e., few observers to find carcasses and long travel times required to retrieve carcasses). The high percentage of undetermined causes in the Southwest makes all the other categories proportionately smaller in that region.

Deaths of adult-sized animals (276 to 411 cm total length) were summarized separately. Analysis using only deaths of adult-sized animals eliminates all of the perinatal carcasses and most of the cold-related deaths, which are mostly sub-adult manatees. Percentages of deaths, by causes, were similar among the four regions. Regions with high percentages of perinatal and cold-related deaths showed the greatest differences when adults were considered separately.

Statewide, watercraft-related deaths accounted for 39% of adult deaths, and all human-related deaths combined comprised 53% of deaths. All human-related causes combined constituted the highest percentage of deaths in the St. Johns region (14 carcasses, 64%) and in the Atlantic region (181 carcasses, 58%). The Atlantic region has the largest coastal human population of the four regions. The health of a regional population is closely tied to the adult survival rate. Therefore, it is very important that the percentages of human-related deaths be kept as low as possible.

Table 5. Manatee deaths in Florida, 1991-2000, by 4 regions and statewide. **All size classes** (FWC, unpublished data).

CAUSE OF DEATH	ATLANTIC		ST. JOHNS		NORTHWEST		SOUTHWEST		STATEWIDE	
	Number	%	Number	%	Number	%	Number	%	Number	%
Watercraft	264	24.2	15	34.1	26	26.5	252	27.1	557	25.8
Gate/Lock	69	6.3	4	9.1	1	1.0	19	2.0	93	4.3
Other Human	40	3.7	0	0.0	4	4.1	14	1.5	58	2.7
Perinatal	296	27.2	11	25.0	32	32.7	190	20.4	529	24.5
Cold-Related	29	2.7	0	0.0	3	3.1	24	2.6	56	2.6
Other Natural	112	10.3	2	4.5	12	12.2	154*	16.6	280*	12.9
Undetermined	279	25.6	12	27.3	20	20.4	277*	29.8	588*	27.2
TOTAL	1089	100.0	44	100.0	98	100.0	930*	100.0	2161*	100.0

* Omit n=145 Red Tide deaths in Southwest Florida, 1996

Table 6. Manatee deaths in Florida, 1991-2000, by 4 regions and statewide. **Adult-only size class** (>275 cm total length). FWC unpublished data.

CAUSE OF DEATH	ATLANTIC		ST. JOHNS		NORTHWEST		SOUTHWEST		STATEWIDE	
	Number	%	Number	%	Number	%	Number	%	Number	%
Watercraft	122	39.0	11	50.0	8	33.3	103	39.3	244	39.3
Gate/Lock	37	11.8	3	13.6	0	0.0	13	4.9	53	8.5
Other Human	22	7.0	0	0.0	2	8.3	6	2.3	30	4.8
Perinatal	—	—	—	—	—	—	—	—	—	—
Cold-Related	1	0.3	0	0.0	2	8.3	0	00.0	3	0.5
Other Natural	35	11.2	1	4.6	5	20.9	51*	19.5	92*	14.8
Undetermined	96	30.7	7	31.8	7	29.2	89*	34.0	199*	32.1
TOTAL	313	100.0	22	100.0	24	100.0	262*	100.0	621*	100.0

* Omit n=145 Red Tide deaths in Southwest Florida, 1996

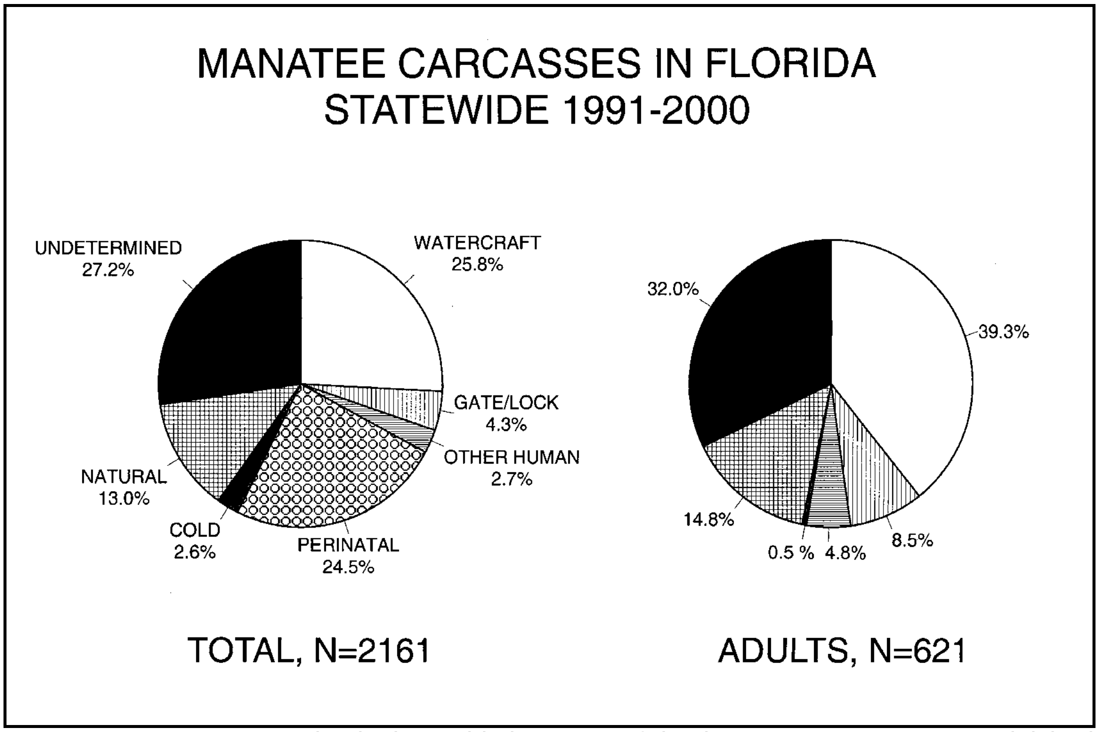

Figure 17. Manatee deaths in Florida by cause of death, 1991-2001. FWC unpublished data.

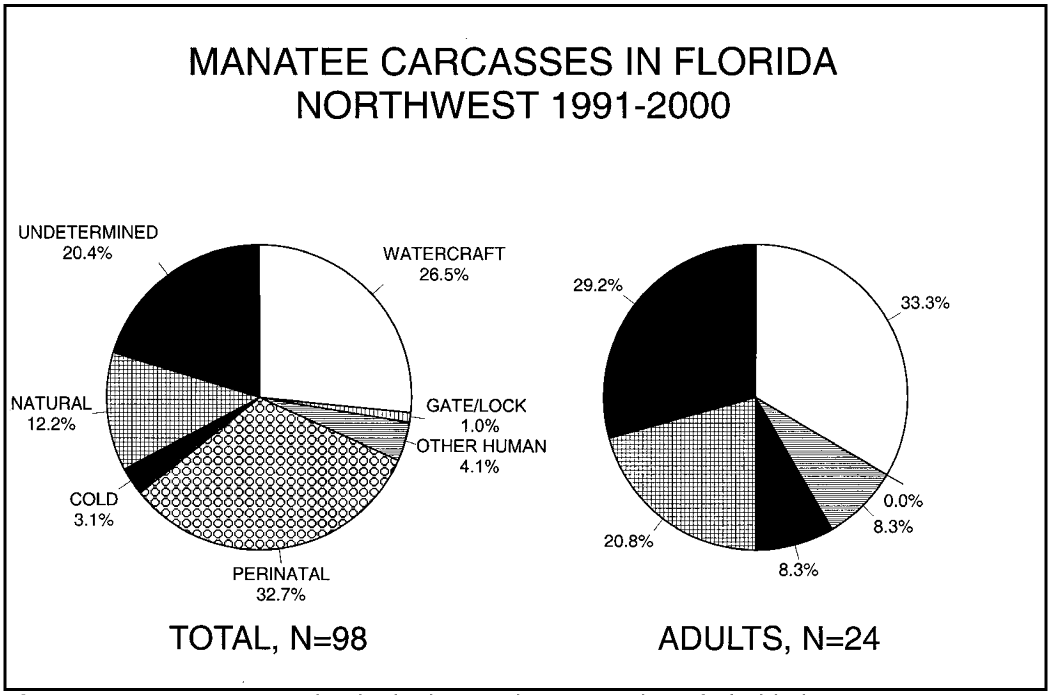

Figure 18. Manatee deaths in the Northwest Region of Florida by cause, 1991-2000. FWC unpublished data.

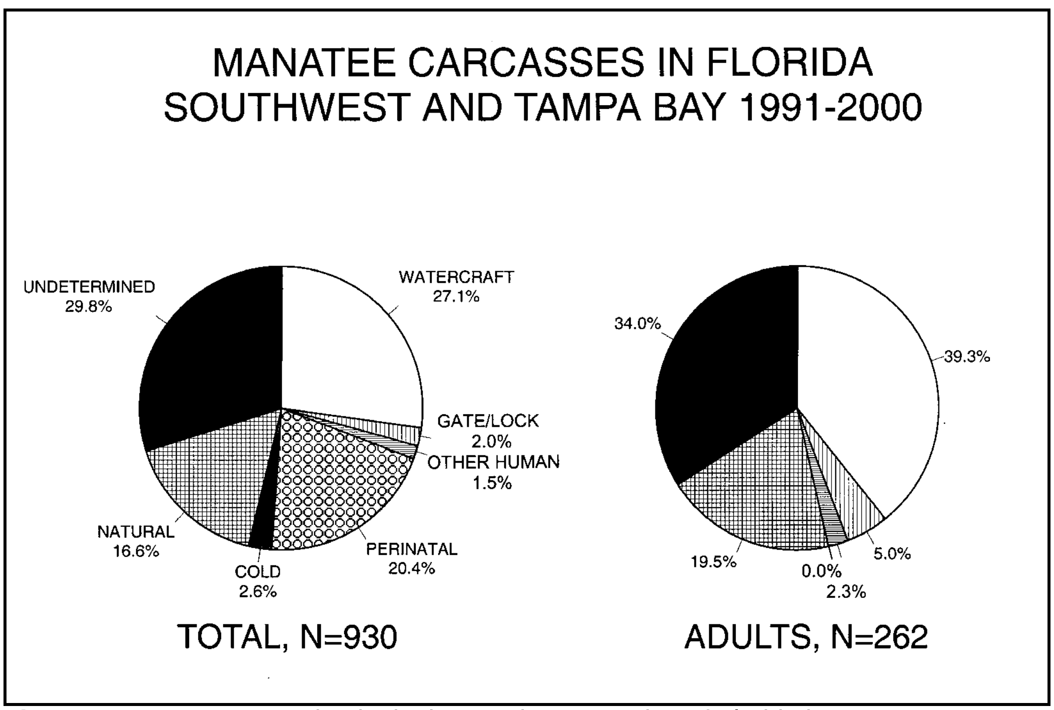

Figure 19. Manatee deaths in the Southwest Region of Florida by cause, 1991-2000. FWC unpublished data.

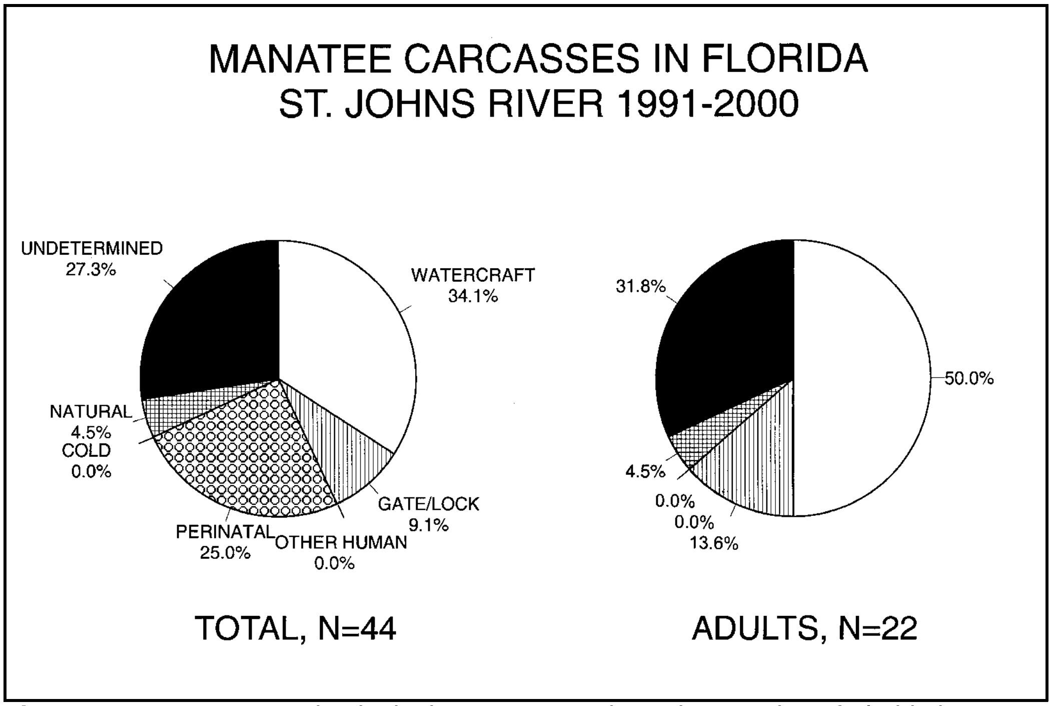

Figure 20. Manatee deaths in the upper St. Johns River Region of Florida by cause, 1991-2000. FWC unpublished data.

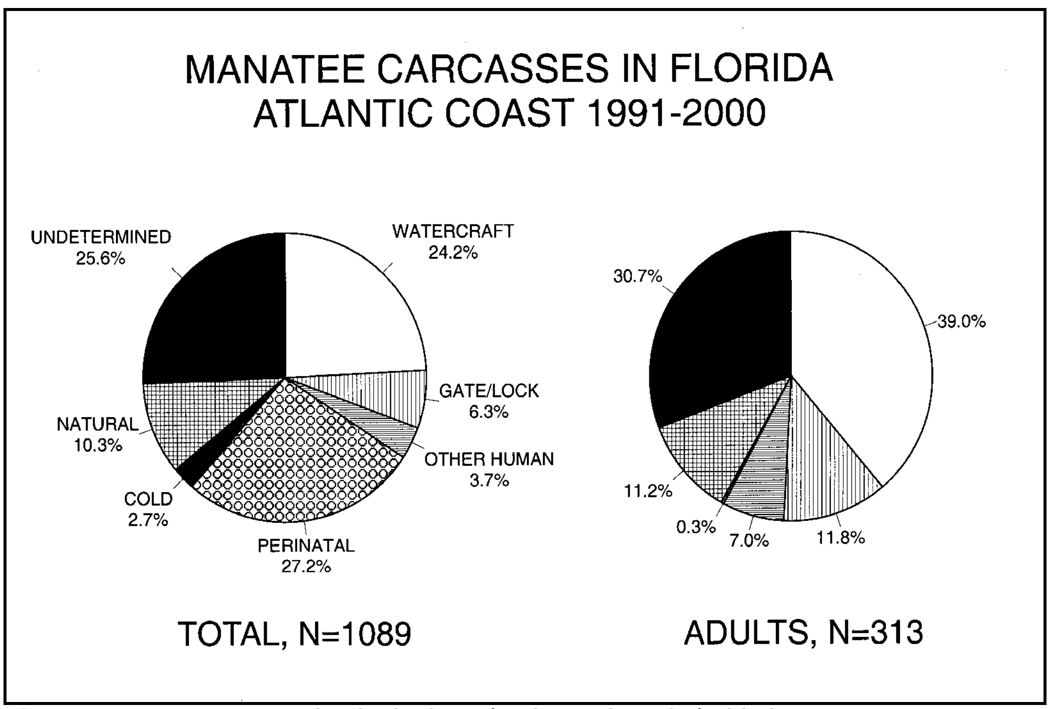

Figure 21. Manatee deaths in the Atlantic Region of Florida by cause, 1991-2000. FWC unpublished data.

FLORIDA MANATEE STATUS STATEMENT

Manatee Population Status Working Group

9 March 2001

Years of scientific study of the Florida manatee have revealed both good news and some cause for concern regarding the status of this endangered aquatic mammal, according to the interagency Manatee Population Status Working Group. The Manatee Population Status Working Group comprises biologists from the U.S. Geological Survey, U.S. Fish and Wildlife Service, Florida Fish and Wildlife Conservation Commission, Chicago Zoological Society, and Wildlife Trust. The group's primary tasks are to assess manatee population trends, to advise the U.S. Fish and Wildlife Service on population criteria to determine when species recovery has been achieved, and to provide managers with interpretation of available information on manatee population biology.

Long-term studies suggest four relatively distinct regional populations of the Florida manatee: Northwest, Southwest, Atlantic (including the St. Johns River north of Palatka), and St. Johns River (south of Palatka). These divisions are based primarily on documented manatee use of wintering sites and from radio-tracking studies of individuals' movements. Although some movement occurs among regional populations, researchers found that analysis of manatee status on a regional level provided insights into important factors related to manatee recovery.

The exact number of manatees in Florida is unknown. Manatees are difficult to count because they are often in areas with poor water clarity, and their behavior, such as resting on the bottom of a deep canal, may make them difficult to see. A coordinated series of aerial surveys and ground counts, known as the statewide synoptic survey, has been conducted in most years since 1991. The synoptic survey in January 2001 resulted in a count of 3,276, the highest count to date. The highest previous count was 2,639 in 1996. Survey results are highly variable, and do not reflect actual population trend. For example, statewide counts on 16 and 27 January 2000 differed by 36% (1,629 and 2,222, respectively). Excellent survey conditions and an unusually cold winter undoubtedly contributed to the high count in 2001.

Evidence indicates that the Northwest and Upper St. Johns River subpopulations have steadily increased over the last 25 years. This population growth is consistent with the lower number of human-related deaths, high estimates of adult survival, and good manatee habitat in these regions. Unfortunately, this good news is tempered by the fact that the manatees in these two regions probably account for less than 20% of the state's manatee population.

The picture is less optimistic for the Atlantic coast subpopulation. Scientists are concerned that the adult survival rate (the percentage of adults that survives from one year to the next) is lower than what is needed for sustained population growth. The population on this coast appears to have been growing slowly in the 1980s but now may have leveled off, or could even be declining. In other words, it's too close to call. This finding is consistent with the high level of human-related and, in some years, cold-related mortality in the region. Since 1978, management efforts to reduce human-related manatee deaths have included strategies focused on reducing manatee collisions with boats, reducing hazards such as entrapment in water control structures and entanglement in fishing gear, and protecting manatee winter aggregation sites to reduce cold-related mortality. Managers are continually challenged to develop innovative protection strategies, given the rapidly growing human population along Florida's coasts.

Estimates of survival and population growth rates are currently underway for the Southwest region. Preliminary estimates of adult survival are similar to those for the Atlantic region, i.e., substantially lower than those for the Northwest and Upper St. Johns River regions. This area has had high levels of watercraft-related deaths and injuries, as well as periodic natural mortality events caused by red tide and severe cold. However, pending further data collection and analysis, scientists are unable to provide an assessment of how manatees are doing in this part of the state.

Over the past ten years, approximately 30% of manatee deaths have been directly attributable to human-related causes, including watercraft collisions, accidental crushing and drowning in water control structures, and entanglements in fishing gear. In 2000, 34% (94 of 273) of manatee deaths were human-related. The continued high level of manatee deaths raises concern about the ability of the overall population to grow or at least remain stable. The Manatee Population Status Working Group is also concerned about the negative impacts of factors that are difficult to quantify, such as habitat loss and chronic effects of severe injuries.

The group agrees that the results of the analyses underscore an important fact: Adult survival is critical to the manatee's recovery. In the regions where adult survival rates are high, the population has grown at a healthy rate. In order to assure high adult survival the group emphasizes the urgent need to make significant headway in reducing the number of human-related manatee deaths.

Appendix D Conservation Measures

Appendix D-1: Protected Species Construction Conditions

PROTECTED SPECIES CONSTRUCTION CONDITIONS, NOAA FISHERIES SOUTHEAST REGIONAL OFFICE

The action agency and any permittee shall comply with the following construction conditions for protected species under the jurisdiction of NOAA Fisheries Southeast Regional Office (SERO) Protected Resources Division (PRD):[1]

Protected Species Sightings–The action agency and any permittee shall ensure that all personnel associated with the project are instructed about the potential presence of species protected under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). All on-site project personnel are responsible for observing water-related activities for the presence of protected species. All personnel shall be advised that there are civil and criminal penalties for harming, harassing, or killing listed species and all marine mammals. To determine which protected species and critical habitat may be found in the transit area, please review the relevant marine mammal and ESA-listed species at Find A Species (https://www.fisheries.noaa.gov/find-species) and the consultation documents that have been completed for the project.

1. **Equipment**–Turbidity curtains, if used, shall be made of material in which protected species cannot become entangled and be regularly monitored to avoid protected species entrapment. All turbidity curtains and other in-water equipment shall be properly secured with materials that reduce the risk of protected species entanglement and entrapment.

    a. In-water lines (rope, chain, and cable, including the lines to secure turbidity curtains) shall be stiff, taut, and non-looping. Examples of such lines are heavy metal chains or heavy cables that do not readily loop and tangle. Flexible in-water lines, such as nylon rope or any lines that could loop or tangle, shall be enclosed in a plastic or rubber sleeve/tube to add rigidity and prevent the line from looping and tangling. In all instances, no excess line shall be allowed in the water. All anchoring shall be in areas free from hardbottom and seagrass.

    b. Turbidity curtains and other in-water equipment shall be placed in a manner that does not entrap protected species within the project area and minimizes the extent and duration of their exclusion from the project area.

    c. Turbidity barriers shall be positioned in a way that minimizes the extent and duration of protected species exclusion from important habitat (e.g. critical habitat, hardbottom, seagrass) in the project area.

2. **Operations**–For construction work that is generally stationary (e.g., barge-mounted equipment dredging a berth or section of river, or shore-based equipment extending into the water):

    a. Operations of moving equipment shall cease if a protected species is observed within 150 feet of operations.

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[1] Manatees are managed under the jurisdiction of the U.S. Fish and Wildlife Service.

b. Activities shall not resume until the protected species has departed the project area of its own volition (e.g., species was observed departing or 20 minutes have passed since the animal was last seen in the area).

3. **Vessels**–For projects requiring vessels, the action agency, and any permittee shall ensure conditions in the Vessel Strike Avoidance Measures are implemented as part of the project/permit issuance (https://www.fisheries.noaa.gov/southeast/consultations/regulations-policies-and-guidance).

4. **Consultation Reporting Requirements–**Any interaction with a protected species shall be reported immediately to NOAA Fisheries SERO PRD and the local authorized stranding/rescue organization.

   To report to NOAA Fisheries SERO PRD, send an email to takereport.nmfsser@noaa.gov. Please include the species involved, the circumstances of the interaction, the fate and disposition of the species involved, photos (if available), and contact information for the person who can provide additional details if requested. Please include the project's Environmental Consultation Organizer (ECO) number and project title in the subject line of email reports.

   To report the interaction to the local stranding/rescue organization, please see the following website for the most up to date information for reporting sick, injured, or dead protected species:

   Reporting Violations–To report an ESA or MMPA violation, call the NOAA Fisheries Enforcement Hotline. This hotline is available 24 hours a day, 7 days week for anyone in the United States.

   NOAA Fisheries Enforcement Hotline (800) 853-1964

5. **Additional Conditions–**Any special construction conditions, required of your specific project, outside these general conditions, if applicable, will be addressed in the project consultation and must also be complied with.

For additional information, please contact NOAA Fisheries SERO PRD at:
NOAA Fisheries Service
Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701
Tel: (727) 824-5312
Visit us on the web at Protected Marine Life in the Southeast
(https://www.fisheries.noaa.gov/region/southeast#protected-marine-life)

Revised: May 2021

Appendix D-2: Vessel Strike Avoidance Measures

VESSEL STRIKE AVOIDANCE MEASURES, NOAA FISHERIES SOUTHEAST REGIONAL OFFICE

Background

Vessel strikes can injure or kill species protected under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). NOAA Fisheries Southeast Regional Office (SERO) Protected Resources Division (PRD) recommends implementing the following identification and avoidance measures to reduce the risk of vessel strikes and disturbance from vessels to protected species under our jurisdiction.[1]

Protected Species Sightings

All vessel operators and crews should be informed about the potential presence of species protected under the ESA and the MMPA and any critical habitat in a vessel transit area. All vessels should have personnel onboard responsible for observing for the presence of protected species. All personnel should be advised that there are civil and criminal penalties for harming, harassing, or killing listed species and all marine mammals. To determine which protected species and critical habitat may be found in the transit area, please review the relevant marine mammal and ESA-listed species at Find A Species (https://www.fisheries.noaa.gov/find-species) and any ESA Section 7 consultation documents if applicable.

Vessel Strike Avoidance

The following measures should be taken when they are consistent with safe navigation to avoid causing injury or death of a protected species:

1. Operate at the minimum safe speed when transiting and maintain a vigilant watch for protected species to avoid striking them. Even with a vigilant watch, most marine protected species are extremely difficult to see from a boat or ship, and you cannot rely on detecting them visually and then taking evasive action. The most effective way to avoid vessel strikes is to travel at a slow, safe speed. Whenever possible, assign a designated individual to observe for protected species and limit vessel operation to only daylight hours.

2. Follow deep-water routes (e.g., marked channels) whenever possible.

3. Operate at "Idle/No Wake" speeds in the following circumstances:
   a. while in any project construction areas
   b. while in water depths where the draft of the vessel provides less than four feet of clearance from the bottom, or
   c. in all depths after a protected species has been observed in and has recently departed the area.

[1] Manatees are managed under the jurisdiction of the U.S. Fish and Wildlife Service.

4. When a protected species is sighted, attempt to maintain a distance of 150 feet or greater between the animal and the vessel. Reduce speed and avoid abrupt changes in direction until the animal(s) has left the area.

5. When dolphins are bow- or wake-riding, maintain course and speed as long as it is safe to do so or until the animal(s) leave the vicinity of the vessel.

6. If a whale is sighted in the vessel's path or within 300 feet from the vessel, reduce speed and shift the engine to neutral. Do not engage the engines until the animals are clear of the area. *Please see below for additional requirements for North Atlantic right whales.*

7. If a whale is sighted farther than 300 feet from the vessel, maintain a distance of 300 feet or greater between the whale and the vessel and reduce speed to 10 knots or less. *Please see below for additional requirements for North Atlantic right whales.*

Injured or Dead Protected Species Reporting

Vessel crews should report sightings of any injured or dead protected species immediately regardless of whether the injury or death is caused by your vessel. Please see How to Report a Stranded or Injured Marine Animal (https://www.fisheries.noaa.gov/report) for the most up to date information for reporting injured or dead protected species.

If the injury or death is caused by your vessel, also report the interaction to NOAA Fisheries SERO PRD at takereport.nmfsser@noaa.gov. Please include the species involved, the circumstances of the interaction, the fate and disposition of the animal involved, photos (if available), and contact information for the person who can provide additional details if requested. Please include the project's Environmental Consultation Organizer (ECO) number and project title in the subject line of email reports if a consultation has been completed.

Reporting Violations

To report any suspected ESA or MMPA violation, call the NOAA Fisheries Enforcement Hotline. This hotline is available 24 hours a day, 7 days week for anyone in the United States.

NOAA Fisheries Enforcement Hotline: (800) 853-1964

Additional Transit and Reporting Requirements for North Atlantic Right Whales

1. Federal regulation prohibits approaching or remaining within 500 yards of a North Atlantic right whale (50 CFR 224.103 (c)). All whales sighted within North Atlantic right whale critical habitat should be assumed to be right whales. Please be aware and follow restrictions for all Seasonal Management Areas along the U.S. east coast. These areas have vessel speed restrictions to reduce vessel strikes risks to migrating or feeding whales. More information can be found at Reducing Vessel Strikes to North Atlantic Right Whales (https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales).

2. Ships greater than 300 gross tons entering the WHALESOUTH reporting area are required to report to a shore-based station. For more information on reporting procedures consult 33 CFR Part 169, the Coast Pilot, or at Reducing Vessel Strikes to North Atlantic

Right Whales (https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales).

3. From November through April, vessels approaching/departing Florida ports of Jacksonville and Fernandina Beach as well as Brunswick Harbor, Georgia are STRONGLY RECOMMENDED to use Two-Way Routes displayed on nautical charts. More information on Compliance with the Right Whale Ship Strike Reduction Rule can be found at (https://media.fisheries.noaa.gov/2021-06/compliance_guide_for_right_whale_ship_strike_reduction.pdf)

4. Mariners shall check with various communication media for general information regarding avoiding vessel strikes and specific information regarding North Atlantic right whale sighting locations. These include NOAA weather radio, U.S. Coast Guard Broadcast to Mariners, Local Notice to Mariners, and NAVTEX. Commercial mariners calling on United States ports should view the most recent version of the NOAA/USCG produced training CD entitled “A Prudent Mariner’s Guide to Right Whale Protection” (contact the NOAA Fisheries SERO, Protected Resources Division for more information regarding the CD).

5. Injured, dead, or entangled right whales should be immediately reported to the U.S. Coast Guard via VHF Channel 16 and the NOAA Fisheries Southeast Marine Mammal Stranding Hotline at (877) WHALE HELP (877-942-5343).

For additional information, please contact NOAA Fisheries SERO PRD at:
NOAA Fisheries Service
Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701
Visit us on the web at Protected Marine Life in the Southeast (https://www.fisheries.noaa.gov/region/southeast#protected-marine-life)

Revised: May 2021

Appendix D-3: Standard Manatee Conditions for In-Water Activities

STANDARD MANATEE CONDITIONS FOR IN-WATER ACTIVITIES

During in-water work in areas that potentially support manatees all personnel associated with the project should be instructed about the potential presence of manatees, manatee speed zones, and the need to avoid collisions with and injury to manatees. All personnel should be advised that there are civil and criminal penalties for harming, harassing, or killing manatees which are protected under the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973. Additionally, personnel should be instructed not to attempt to feed or otherwise interact with the animal, although passively taking pictures or video would be acceptable.

All on-site personnel are responsible for observing water-related activities for the presence of manatee(s). We recommend the following to minimize potential impacts to manatees in areas of their potential presence:

- All work, equipment, and vessel operation should cease if a manatee is spotted within a 50-foot radius (buffer zone) of the active work area. Once the manatee has left the buffer zone on its own accord (manatees must not be herded or harassed into leaving), or after 30 minutes have passed without additional sightings of manatee(s) in the buffer zone, in-water work can resume under careful observation for manatee(s).
- If a manatee(s) is sighted in or near the project area, all vessels associated with the project should operate at "no wake/idle" speeds within the construction area and at all times while in waters where the draft of the vessel provides less than a four-foot clearance from the bottom. Vessels should follow routes of deep water whenever possible.
- If used, siltation or turbidity barriers should be properly secured, made of material in which manatees cannot become entangled, and be monitored to avoid manatee entrapment or impeding their movement.
- Temporary signs concerning manatees should be posted prior to and during all in-water project activities and removed upon completion. Each vessel involved in construction activities should display at the vessel control station or in a prominent location, visible to all employees operating the vessel, a temporary sign at least 8½ " X 11" reading language similar to the following: "CAUTION BOATERS: MANATEE AREA/ IDLE SPEED IS REQUIRED IN CONSTRUCTION AREA AND WHERE THERE IS LESS THAN FOUR FOOT BOTTOM CLEARANCE WHEN MANATEE IS PRESENT". A second temporary sign measuring 8½ " X 11" should be posted at a location prominently visible to all personnel engaged in water-related activities and should read language similar to the following: "CAUTION: MANATEE AREA/ EQUIPMENT MUST BE SHUTDOWN IMMEDIATELY IF A MANATEE COMES WITHIN 50 FEET OF OPERATION".
- Collisions with, injury to, or sightings of manatees should be immediately reported to the Service's Louisiana Ecological Services Office (337/291-3100) and the Louisiana Department of Wildlife and Fisheries, Natural Heritage Program (225/765-2821). Please provide the nature of the call (i.e., report of an incident, manatee sighting, etc.); time of incident/sighting; and the approximate location, including the latitude and longitude coordinates, if possible.

Appendix D-4: Alligator Snapping Turtle Conservation Measures

Fish and Wildlife Service general information and guidance for FEMA projects regarding the proposed alligator snapping turtle

Louisiana Ecological Services Office

Areas and Habitat Conditions likely to host AST

The alligator snapping turtle (AST) has a wide geographic range and occurs in bayous, rivers, streams, swamps, and lakes in Texas, Louisiana, Oklahoma, Arkansas, Missouri, Illinois, Kentucky, Tennessee, Mississippi, Alabama, Georgia, and Florida. They prefer water bodies (small streams [perennial], bayous, canals, swamps, lakes, reservoirs, ponds, and oxbows) with overhang banks and adjacent riparian forest, especially bald cypress bordered banks. Sections of waterways with steep-sloped banks, or those lined with concrete, stone, etc. are likely avoided, especially when there are no trees on the bank. However, relatively short sections of non-preferred bank composition do not necessarily preclude occupation of the entire waterway. They may venture onto the adjacent floodplain during high water events. Although they have been found at the edge of the Gulf of Mexico, coastal marshes and saline water are not their preferred habitat type. They also prefer waterbodies with snags and submerged logs, tree root masses, or other debris in the water. Adults generally stick to deeper water (enough to cover their body to deeper than 20ft), but in areas with deep, loose mud, they have been found in 10 inches of water with a mud layer of several feet. Juveniles can be found in shallow streams less than 1 foot deep. AST are sensitive to water temperature and will change locations as needed to thermoregulate. AST generally stay on the water bottom, but they do move along the bottom, and can travel considerable distances (miles) in just days or weeks. Trapping surveys are generally effective at locating AST, but lack of capture, especially during short-term limited area survey efforts, does not confirm absence.

AST rarely leave the water except for nesting females generally from April to early July (typically April-May in southern parts of the range including Louisiana and May-July in north/western portion of the range). Egg incubation time is generally between 96 and 143 days. Nesting areas may have varying amounts of canopy cover. Nests are generally located between 4 and 656 feet from the water line, and more likely less than 300 feet from the water line.

Potential project effects on the species

<u>Individuals</u>

Adults, juveniles, and hatchlings could be killed, injured, or stressed by instream operation of heavy equipment (e.g., excavator, bucket dredge, hydraulic dredge, shallow water watercraft, etc.)

Nesting females, eggs, and hatchlings could be killed, injured, or stressed by operation of heavy equipment or other disturbance in the riparian zone adjacent to waterbodies during the nesting/hatching season.

<u>Habitat</u>

Removal of snags, submerged logs, and other debris would decrease the value of or eliminate aquatic habitat.

Removal of trees at the bank and adjacent forest could degrade nesting habitat and would likely decrease the use of adjacent aquatic habitat.

Bank hardening and change of bank incline would likely eliminate nesting in the area, and significant use of the adjacent aquatic habitat.

Conservation Recommendations

To minimize effect on AST habitat:

Limit work to deepest part of channels

Limit work to areas previously disturbed or lacking snags, submerged logs or other cover used by AST

Use floating work platform instead of ground-based equipment

Relocate woody debris to streamside instead of removing completely

Minimize removal of trees and brush on bank adjacent to waterbodies

Avoid the use of concrete or other bank hardening methods

To minimize effect on individuals:

Limit work to areas unlikely to be occupied by adult or juvenile AST or live AST nests

Use floating work platform instead of ground-based equipment

If removing snags is necessary, pull up from above water instead of digging out

Avoid work on streamside from the water's edge to 200 meters away during times of the year when nesting/hatching are occurring

Limit work to deepest part of main channels except during the hottest times of the year

Conferencing with Fish and Wildlife Service

Because the AST is proposed, the only requirement for federal agencies is to "confer" (rather than consult) with the Service if any proposed actions are determined by them to be likely to jeopardize the existence of a proposed species or result in destruction or adverse modification of critical habitat. There is currently no critical habitat designated, or proposed, for the AST, so the focus would be mostly on the species itself. Note that regardless of critical habitat, effects on habitat are still considered when analyzing effects on species. (Note: *In certain circumstances, emergency actions in presidentially declared disaster areas can be exempted from the requirements of consultation under sec 7(a)(2) of the Endangered Species Act*.).

Project actions that "may affect" the species do not necessarily make the action, "likely to jeopardize the existence of a proposed species". Actions that kill an individual or even multiple individuals also may not necessarily result in a likely jeopardy determination. The AST has a large multistate range, and the

species is estimated to be comprised of many thousands of individuals. Any effects determination should consider the spatial extent of project effects when analyzing effects on populations and ultimately the species as a whole.

It is the policy of the Service to conduct conferencing if the lead federal agency requests a conference. The Service would require all the same types of information about the project(s) including project timing, specific work, equipment, and expected effects on the species, as when conducting a consultation for a listed species. The Service's practice is to conduct and conclude conferencing in the same manner and time frame as consultations which require variable amounts of time to complete depending on complexity and whether the conference is informal or formal.

Appendix E Species Habitat Analysis

Appendix E-1: Gopher Tortoise Survey

JOHN BEL EDWARDS
GOVERNOR

JACK MONTOUCET
SECRETARY

LOUISIANA DEPARTMENT OF WILDLIFE & FISHERIES

PO BOX 98000 | BATON ROUGE LA | 70898

MEMORANDUM

TO: Amy Dixon, Project Manager, U.S. Army Corps of Engineers- New Orleans District

FROM: Keri Lejeune, State Herpetologist, LA Department of Wildlife and Fisheries

DATE: August 21, 2022

SUBJECT: Gopher Tortoise Survey for the St. Tammany Parish Levee Project (STPFPS)

LA Department of Wildlife and Fisheries staff, along with U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service personnel, conducted gopher tortoise surveys within the project area on 14 June 2022. Right of Entry (ROE) 1, 2 and 3 were assessed from the public roads adjacent to these areas. ROE 1, 2, and 3 appeared to be uninhabitable for gopher tortoises due to the dense forests completely covering these areas. No evidence of gopher tortoises or their burrows were observed.

Permission from landowner(s) was granted for access to ROE 4, 5, and 6. Transects were conducted on all areas with suitable soils that were not heavily forested, which would be appropriate for gopher tortoises. No evidence of gopher tortoises or their burrows were observed. Due to the proximity of ROE 6 to hydric soils and marsh habitat, a minimal amount of this area appeared suitable for gopher tortoises. However, all areas that appeared suitable for gopher tortoises along the levee near ROE 6 were surveyed and no evidence of tortoises or their burrows were observed.

If you need additional information or at any time gopher tortoises or their burrows are encountered within the project area prior to or during development, please contact Keri Lejeune at 337-735-8676 or klejeune@wlf.la.gov.

Appendix E-2: Red-cockaded woodpeckers habitat foraging analysis

Cluster / Habitat Acres	Good	Fair	Fair quality requiring treatment	Poor	Private	Unsuitable	Total
Paquet 3 (cluster #18)	37.53	13.41	0	13.26	0	0	**64.19**
Salmen 1 (cluster #19)	0	46.30	3.97	12.79	8.25	60.76	**132.07**
Salmen 2 (cluster #20)	0	112.79	0	60.20	0	17.63	**190.62**
Salmen 3 (cluster #21)	0	0	0	162.53	0	104.00	**266.53**

Cluster/Habitat in South & West ROW	Fair	Poor	Unsuitable	Private
Paquet 3 (cluster #18)	0	0	0	0
Salmen 1 (cluster #19)	8.314	0	16.429	0.662
Salmen 2 (cluster #20)	5.122	0	0	0
Salmen 3 (cluster #21)	0	4.763	19.084	0

No Habitat	Total Acres
10.678	**10.678**
0	**25.406**
0	**5.122**
0.052	**23.898**

Cluster/Habitat	Good	Fair	Fair quality requiring treatment	Poor	Unsuitable	Total Acres
Paquet 3 (cluster #18)	37.53	13.407	0	13.263	0	**64.195**
Salmen 1 (cluster #19)	0	37.984	3.97	12.789	44.327	**99.074**
Salmen 2 (cluster #20)	0	107.665	0	60.199	17.633	**185.497**
Salmen 3 (cluster #21)	0	0	0	157.769	84.915	**242.684**

Note:
No loss of habitat under post project conditions

Appendix A Detailed Project Description

SUMMARY

PROJECT DESCRIPTION
for the
Optimized Tentatively Selected Plan
St Tammany Parish Louisiana Feasibility Study

1.0 INTRODUCTION

Subsequent to the release of the June 2021 Draft Integrated Feasibility Report and Draft Environmental Impact Statement (DIFR and DEIS), the Project Delivery Team (PDT) conducted additional engineering, economic, and environmental investigations on the individual features of the Optimized Tentatively Selected Plan (TSP) which is comprised of a structural plan and a non-structural plan. Information gathered by the PDT through these additional investigations, together with the consideration of comments received from the public, stakeholders, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service assisted the PDT in further refining the design of the Draft TSP. This document is a summary project description of the proposed Optimized TSP. Refer to Appendix F and H for the full description of the non-structural plan and Appendix D for full description of the structural plan.

1.1 SCOPE OF WORK

The Optimized TSP includes a non-structural plan and a structural plan. For planning purposes, the 50-yr period of analysis for the study was estimated to be from the year 2032 to 2082. Project authorization would occur in the year 2024 and kick-off planning, engineering, and design (PED). PED was originally estimated to be complete by the year 2027. Initial construction of the project would begin 2027 and conclude by the year 2032 (base year). These original assumptions will be revised once the construction schedule is prepared by the Cost team in MVN Engineering. Figure 1-1 illustrates the optimized TSP including a non-structural and a structural plan.

<u>Non-Structural Plan</u>:

Insert summary of the non-structural plan from Economics.

<u>Structural Plan</u>:

The structural plan consists of construction of a levee and floodwall system along an alignment in South and West Slidell and channelization of a portion of the Mile Branch in Covington.

1.2 **Mile Branch Channel Improvement:** This measure consists of channel improvements on the lower 2.15 miles (11,341 ft channel) of Mile Branch in Covington, Louisiana. The proposed work would consist of approximately 20 acres of channel that would be cleared and grubbed prior to mechanical dredging.

The mechanical dredging would consist of a maximum of 130,000 cubic yards of fill dredged from the channel. There are no surveys available for this area for this study, and no surveys will be conducted during the study phase. The existing elevations used for the hydraulic analysis and design of the Optimized TSP were obtained from the LIDAR raster dataset. Designs are based on existing information gathered from reports provided by the non-Federal sponsors as shown on Table 1.2 in the main report.

Design refinements would occur during PED based on field data collections. Based on data collected, the design would be refined to minimize impacts to aquatic and riparian habitat and real estate. Riparian Zone bioengineering techniques and nature-based-solutions (NBS) would be incorporated as appropriate during PED in coordination with the NFS and resource agencies. A backwater area has been incorporated in the design of Mile Branch.

Table 1.1 lists the Mile Branch attributes of the TSP for the 50-year period of analysis.

Table 1.1 Summary Table of TSP for Mile Branch

Attribute	**Mile Branch Channel Improvements**
Total Length of improvements	2.15 miles (11,341 feet)
Material to be Mechanically Dredged	130,000 cubic yards
Access Roads for both clearing and for bridge replacement?	0 acres
Number of staging areas for clearing and grubbing and mechanical dredging and for culvert/bridge replacement	19 (7 for culvert/bridge replacements, 11 for clear and grubbing and mechanical dredging and one that becomes a backwater area)
Number of Bridge Replacements of Culverts	7
Temporary ROW	7.3 acres (2.2 acres for culvert/bridge replacements and 5.1 acres for clear and grubbing and mechanical dredging)
Permanent ROW	38.5 acres (34 acres for clear and grubbing and mechanical dredging and 4.5 acres for one staging area that becomes a backwater area)

The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and end at the intersection of Mile Branch and the Tchefuncte River. Assumptions for channel improvements included a 65-ft from the centerline of each side of the channel for ROW as a general guideline (total width of 130 ft).

The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel would be widened as well as deepened. The channel bottom would be lowered by 5 ft. All work would be performed from the bank. The trees located close to the bank would be removed. The banks would be stabilized and seeded and fertilized to have a grass cover. Work would be done by excavators or small skid steers.

Material removed may include sediment, trees, debris, or other obstructions within the waterway. Removed material would be trucked off-site and disposed at a facility licensed to handle the material. Site access to Mile Branch would be via public roads and public rights of way.

For the channel improvements, approximately 34 acres of permanent ROW would be needed. This area would include 25 ft on each side of the Mile Branch channel. Within the 34 acres, approximately 21 acres of channel would be cleared and grubbed prior to mechanical dredging. An assumed maximum of 130,000 cubic yards of material may be mechanically dredged from the channel.

Mile Branch improvements may include bridge replacements or culverts. Approximately 2.2 acres would be required for staging along the various areas of the bridge/culvert replacements.

1.3 South and West Slidell Levee and Floodwall Alignment: The levee and floodwall system would consist of a total of approximately 18.4 miles (96,950 feet) of earthen levee and floodwall which includes approximately 15 miles (79,100 feet) of levees constructed in separate (non-continuous) segments, and 3.4 miles (17,850 feet) of separate (non-continuous) segments of a floodwall. Construction of the levee alignment would impact approximately 520.7 acres of permanent ROW and it would require approximately 7,069,000 cubic yards of fill, including fill material required for future levee lifts (estimates include a 30 percent contingency). Table 1.2 provides a summary of the attributes of the South and West Slidell Levee and Floodwall System. Table 1.3 is a summary of the levee quantities required for the initial construction.

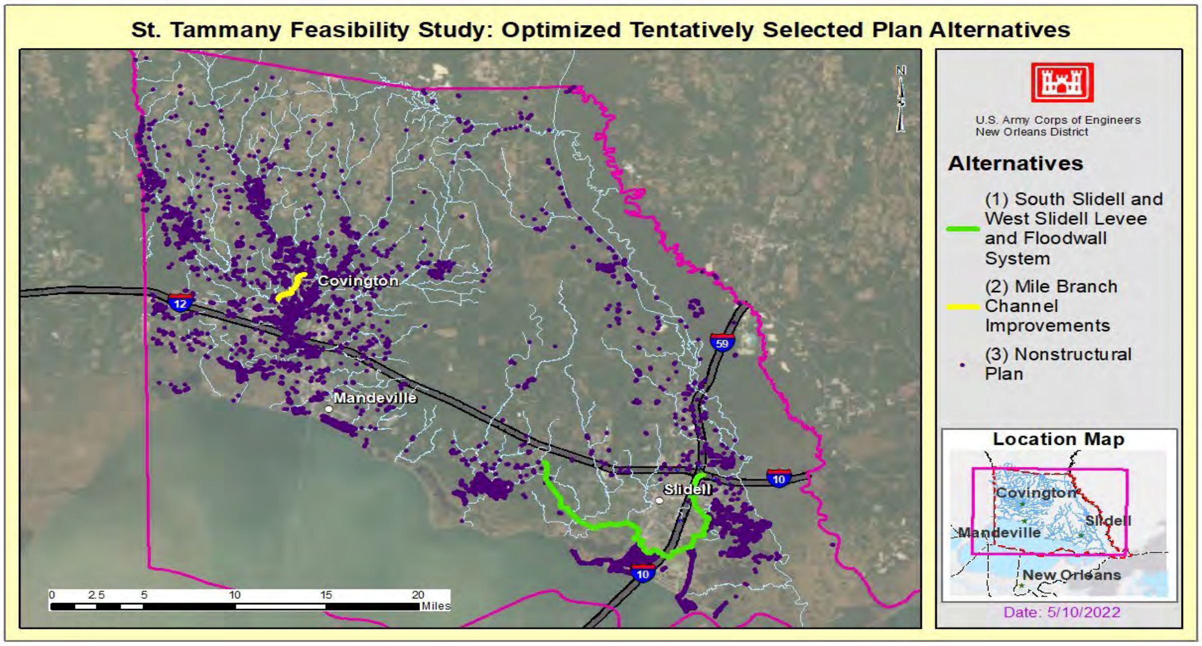

Figure 1-1. Optimized Tentatively Selected Plan

Table 1.2 Summary Table of South Slidell and West Slidell Levee and Floodwall System

Attribute	**South Slidell and West Slidell Levee and Floodwall System**
Total Length of alignment	18.4 miles (96,950 feet)
Length of Floodwall	3.4 miles (17,850 feet)
Length of earthen Levee	15 miles (79,100 feet)
Temporary Acres of Construction for Levee and Floodwall system	109 acres
Permanent Acres for Levee and Floodwall system	521 acres
Hydraulic Design Elevation Range (Dependent on location)	13.5 to 16 (year 2032) 17.5 to 20 (year 2082)
Pump Stations	8
Sluice Gates/Lift Gates	13
Number of Vehicular Floodgates	16
Number of Pedestrian Floodgates	1
Number of Railroad Gates	1
Number of Road Ramps	11
Fill (Borrow Material) Required	7,069,000 cubic yards

The existing elevations utilized were obtained from the LIDAR raster dataset. No survey data was obtained at this stage of the study; therefore, a 30% contingency was

used for the calculation of the borrow quantities for the South Slidell and West Slidell levee alignment.

Table 1.3 Summary Table: TSP Levee Quantities for Initial Construction

Levee Alignment ROW and Levee Quantities Initial Construction (Year 2032)	
WEST SLIDELL	
Permanent ROW	240 acres
Fill Material (includes 30% contingency)	2,007,000 cubic yards
SOUTH SLIDELL	
Permanent ROW	120 acres
Fill Material (includes 30 %contingency)	825,000 cubic yards**
TOTAL	
Permanent ROW	360 acres
Fill Material (includes 30 % contingency)	2,832,000 cubic yards

**includes quantities for I-10 portion of the alignment.

Levee lifts would be required over the 50-yr period of analysis. The levee lift schedule would follow the hydraulic design elevation requirements and thus were divided into 3 geotechnical reaches: Oak Harbor South; I-10 Crossing and Slidell East/Northeast as illustrated in Table 1-4. The fourth lift (final lift for the 50-year period of analysis), projected to occur in year 2076 would elevate the levee to a construction elevation of 19 ft. It is during the scheduled 4th lift that construction of the Western High Ground Tie-in would be necessary for year 2082. The fill quantities listed for the 4th lift, include quantities for the construction of the Western High Ground Tie-In.

Table 1.4. Future Levee Lifts

	Construction Lift (year)	Construction Elevation (feet)	Permanent ROW (acres)	Fill Material (+30% contingency; cubic yards)
WEST SLIDELL				
First lift	2033	16	N/A	771,000
Second lift	2038	17.5	N/A	901,000
Third lift	2051	19	N/A	685,000
Fourth lift	2076	19	30 *	709,000 *
SOUTH SLIDELL				
Oak Harbor South				
First Lift	2035	17	N/A	106,000
Second Lift	2048	18	N/A	120,000
Third Lift	2064	19	N/A	115,000
I-10 Crossing**				
Slidell East / Northeast				

First Lift	2034	19	N/A	271,000
Second Lift	2047	20.5	N/A	295,000
Third Lift	2064	21.5	N/A	264,000
Total For Future Lifts				
			30	4,237,000
Total for Life of the Project (initial construction + lifts)				
			390	**7,069,000**

***** Includes the levee quantities (192,000 cubic yards) for the Western High Ground Tie-in for Year 2082.
** I-10 Crossing features would be constructed to the 2082 elevation and therefore would not require additional lifts.

2 LEVEE AND FLOODWALL SYSTEM DESCRIPTION

The levee and floodwall system consists of a combination of portions of the West Slidell levee alignment and the South Slidell levee alignment. The two alignments would be connected by a new railroad gate across the existing Norfolk Southern Railway Corp. railroad tracks. The alignment is shown in lime green in Figure 1-2.

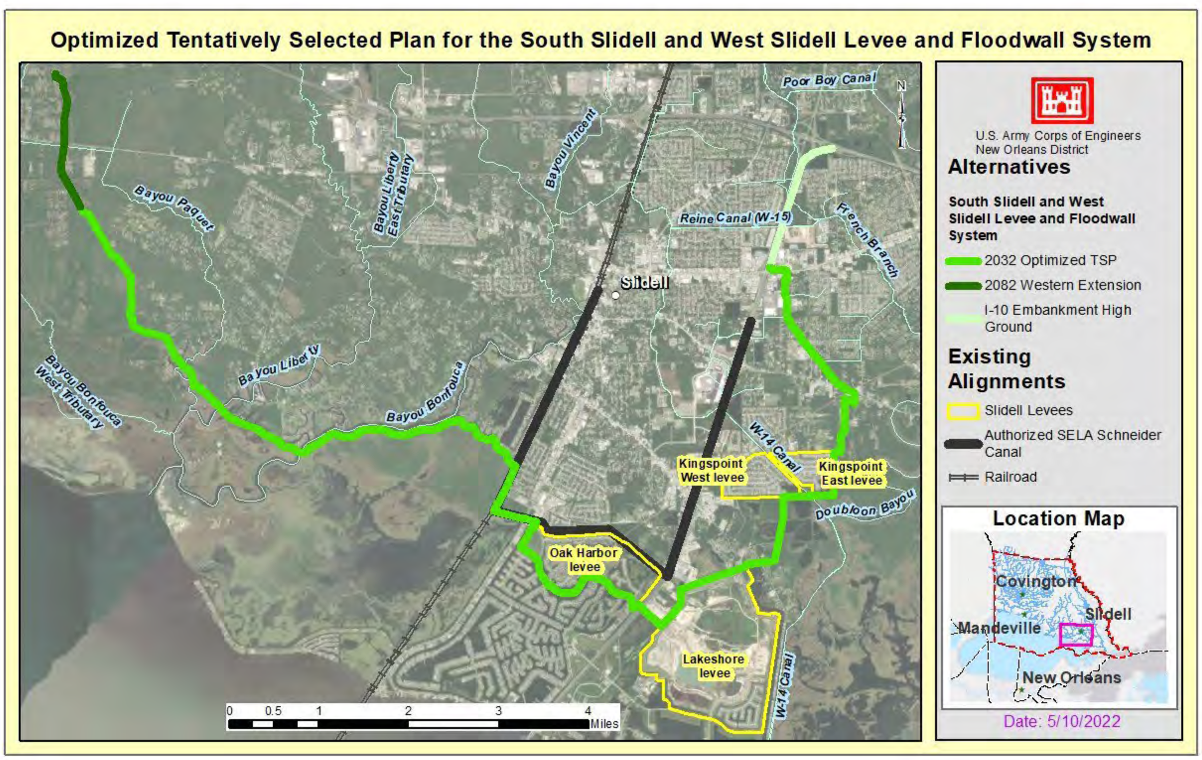

Figure 2-2. Optimized TSP for the West Slidell and the South Slidell Levee and Floodwall System

2.2 LEVEE AND FLOODWALL ALIGNMENT AND STRUCTURES

This section describes the alignment starting on the northwest end and continuing east. For floodwall segments refer to table 2.4, for pump stations refer to Table 2.9, for sluice, lift and sector gates refer to table 2.7, and for vehicular, pedestrian, and railroad floodgates refer to Table 2.8. All structural components would be constructed during initial construction.

2.2.1 WESTERN EXTENTION

Western Terminus: The intermediate scenario of relative sea level change between years 2032 and 2082 was used to develop the 2082 hydraulic design elevations. Based on that analysis, the levee was extended to the west to maintain a 1% risk reduction. The Western High Ground Tie-in for Year 2082 is shown in dark green in Figures 1-3 and 1-4. Based on modeling, the western extension would not be necessary until the year 2076 when the risk reduction would be needed. It is anticipated that this levee segment would be constructed during the fourth levee lift of the West Slidell alignment.

The alignment would commence north of US Highway 190 in the neighborhood near the intersection of North Tranquility Road and Shannon Drive between two properties. The alignment would be a berm with hydraulic design elevation of 17.5 ft for year 2082. The alignment would switch to levee (hydraulic design elevation of 17.5 ft (Year 2082)) and would continue south on the edge of the properties and cross US Highway 190, the Tammany Trace Bike Trail and South Tranquility Road on the eastern side of Pineridge Road. The alignment would run south southeast an additional 890 feet past the intersection with South Tranquility Road and tie with the existing year 2032 alignment for West Slidell.

2.2.2 WEST SLIDELL ALIGNMENT

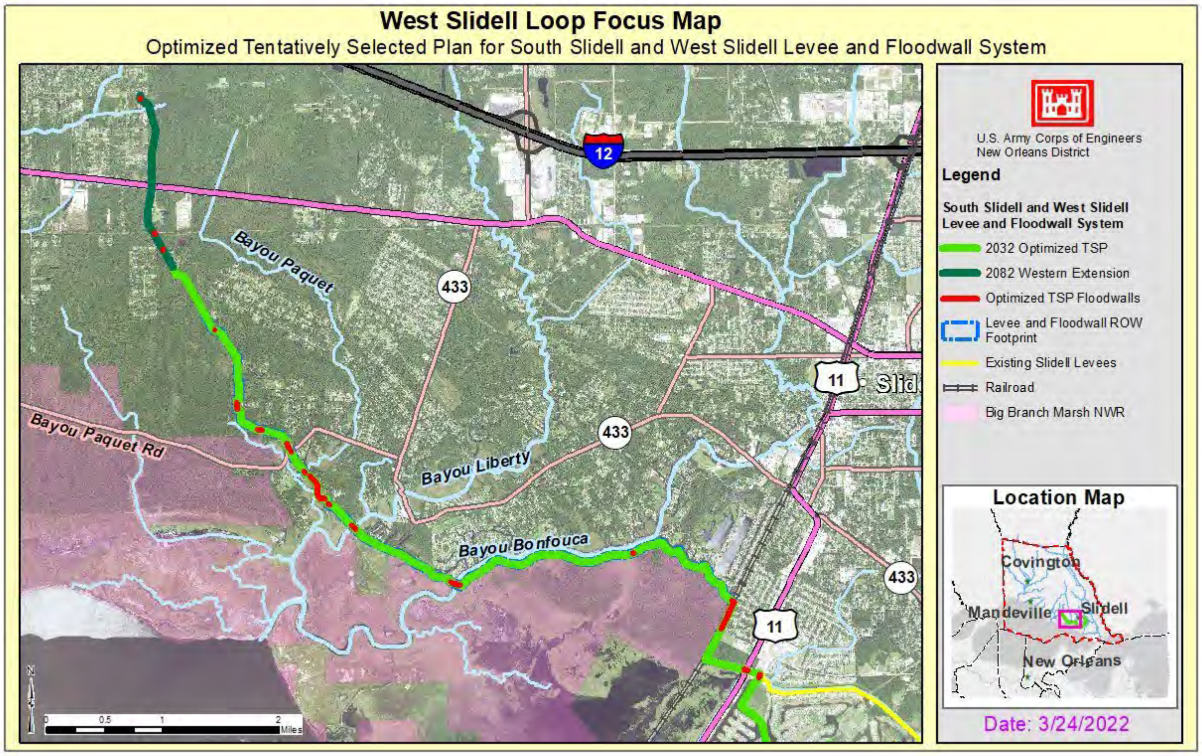

Figure 1-3. West Slidell Levee and Floodwall System- Optimized Tentatively Selected Plan Focus with Floodwall Segments

West Slidell Levee Segment: Levee construction would commence on the south side of US Highway 190 and South Tranquility Road, and on the eastern side of Pineridge Road. For the West Slidell portion of the alignment, the levee segments would have a hydraulic design elevation of 13.5 ft (Year 2032).

The alignment would run southward and would run on the west side of Tranquility Road (CC Road) and then it would turn in the southeast direction crossing Bayou Paquet Road and would stay on the east side of Bayou Paquet Channel to avoid impact to the Big Branch Marsh National Wildlife Refuge (NWR). The alignment would cross Bayou Paquet and Bayou Liberty and would continue eastward on the northside of the Big Branch Marsh NWR. The alignment would cross Bayou Bonfouca and would continue on the south bank of the bayou (northern side of the refuge) until reaching the Norfolk Southern Railway Corp. railroad tracks west of US Highway 11 in the vicinity of Dellwood Pump Station in Slidell.

2.2.3 SOUTH SLIDELL ALIGNMENT

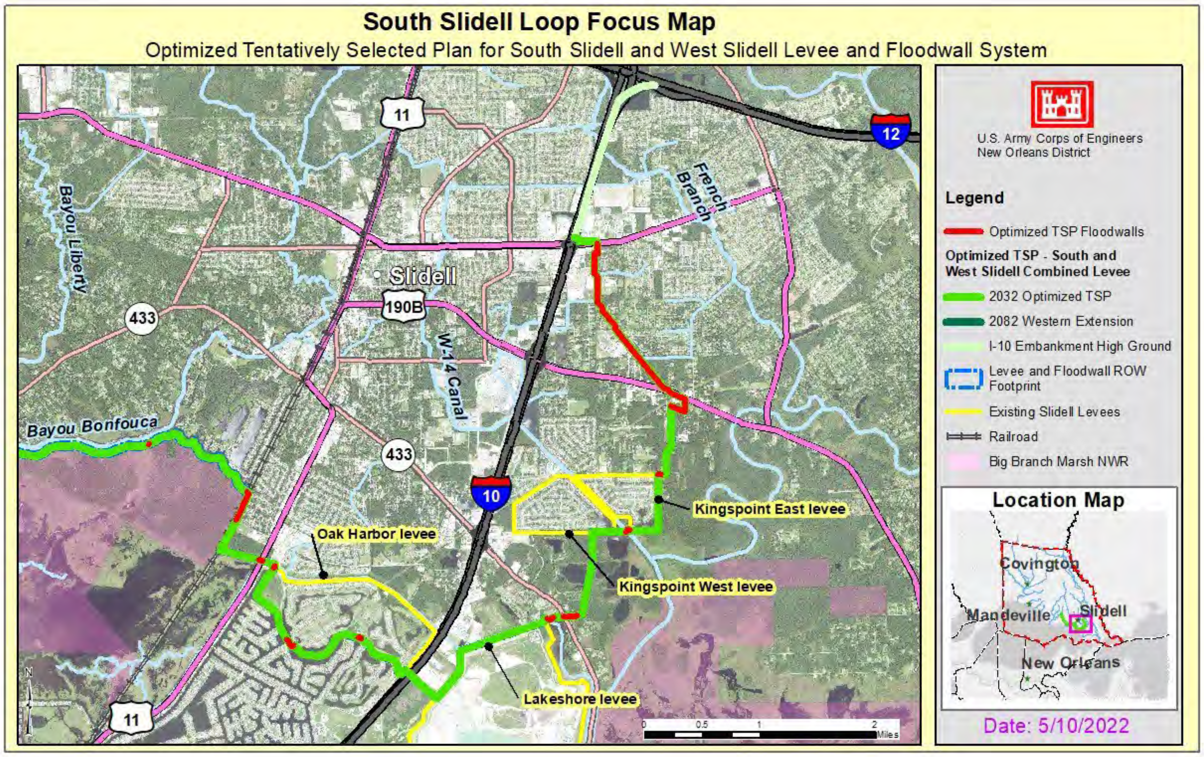

Figure 1-4. South Slidell Levee and Floodwall System- Optimized Tentatively Selected Plan Focus

<u>South Slidell Levee Segment</u>: The levee and floodwall system alignment from West Slidell would continue to South Slidell. From the railroad gate connecting West Slidell with South Slidell, the alignment would transition to a floodwall running parallel along the east side of the railroad tracks. The floodwall by the railroad tracks would have a hydraulic design elevation of 16.5 ft for year 2082.

The alignment would transition to levee when it turned east toward Highway 11. The alignment would cross Highway 11 and would turn south in the vicinity of the existing Schneider Canal Pump Station and then turn east (on a portion of the existing Oak Harbor ring levee). The alignment would run on the south side of Oak Harbor Boulevard and would cross to the north side immediately past Mariners Cove Boulevard. The levee along the south side of the Oak Harbor would have a hydraulic design elevation of 14 ft for year 2032.

The alignment would run on a portion of the existing Oak Harbor ring levee. The alignment would turn north and then east in the vicinity of the I-10. The I-10 would be raised to ramp over the new levee section (hydraulic design elevation of 18.5 ft for year 2082).

The alignment would continue southeast and would tie to an existing portion of the Lakeshore Estates ring levee. The alignment then would turn north and then east and cross Old Spanish Trail/Highway 433. The alignment would continue north and tie to a portion of the existing King's Point west levee. The section of levee would have a hydraulic design elevation of 16 ft for year 2032.

The alignment would cross the W-14 Canal and would tie to a portion of the existing King's Point east levee and would turn north. The levee would have a hydraulic design elevation of 16 ft for year 2032. The levee would turn east and then north. Immediately south of Highway 190 Business the alignment would turn from levee to floodwall to provide risk reduction to the existing Hardin Road power substation. The floodwall would have a hydraulic design elevation of 18.5 ft for year 2082.

The alignment would cross Highway 190 Business and continue northwest on the west side of the existing CLECO Corporate Holdings, LLC utility corridor. The alignment would cross South Holiday Drive and continue north. The alignment would turn east on Manzella Drive and turn north in the middle of the block between Yaupon Drive and Malbrough Drive.

The alignment would cross Gause Boulevard as a ramp crossing and would turn west and tie to high ground (hydraulic design elevation of 18.5 ft for year 2082) in the vicinity of the I-10. There would be additional road ramps for businesses on the north side of Gause Boulevard, the I-10 Service Road and the I-10 on-ramp for the I-10 eastbound at Gause Boulevard.

The existing highway embankment would serve as the means of risk reduction in order for the project to form a continuous system up to the elevation required in 2082. Refer to light green portion of the alignment in Figure 1-5.

CLECO Corporate Holdings, LLC has right-of-way use requirements pertaining to USACE work around their existing utility lines on the northeast corner of the floodwall alignment that would have to be met to provide clearance for construction activities (i.e., pile driving).

INTERSTATE 10 ELEVATION

The I-10 road surface would be raised to construction elevation 21.5 ft to ramp over the new levee section to stay above the hydraulic design elevation for year 2082, to ensure the entire pavement section remains above the hydraulic design elevation across the interstate. The hydraulic design elevation at this location for year 2082 is 18.5 ft. The pavement section was assumed to have a thickness of 2.5 ft.

The existing elevation of the I-10 at the proposed location is approximately 12.8 feet as per LIDAR raster dataset. This proposed location is the highest elevation of the I-10 in the vicinity of the proposed alignment. The I-10 elevation is lower (approximately 10 feet) on the adjacent areas.

The levee and the Interstate 10 would be lifted during initial construction in year 2032 to construction elevation of 21.5 ft to avoid future disruptions to the traffic on the interstate.

2.3 TYPICAL SECTION AND ELEVATIONS

2.3.1 WEST SLIDELL LEVEE DIMENSIONS AND QUANTITIES

The dimensions for the new West Slidell levee may be found in Table 2.1 and Figure 1-5.

Geotextile would be placed for West Slidell during initial construction under the levee. Geotextile would be placed 70 ft from the centerline of the levee on the floodside and 40 ft from the centerline of the levee on the land side for a total of 110 ft.

Table 2.1. West Slidell Levee

West Slidell Levee **Initial Construction**	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Floodside Berm Slope	1V:42H
Landside Berm Slope	1V:33H
Construction Elevation	14.5 ft
Geotextile	13,200 lbs/ft

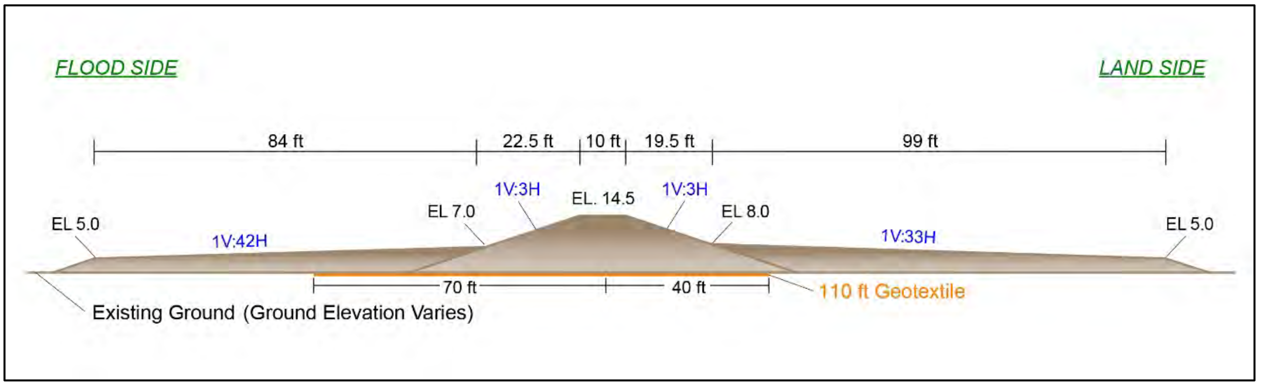

Figure 1-5. Typical Cross-Section with Berms for West Slidell

The hydraulic design elevations of the new West Slidell levee would be 13.5 feet (year 2032) and the 17.5 ft (year 2082). Right of way for the levee was assumed to be 300 ft wide.

2.3.2 SOUTH SLIDELL DIMENSIONS QUANTITIES

The dimensions for the new South Slidell levee may be found in Table 2.2 and Figure 1-6. The construction elevation for the first lift would vary depending on location. This portion of the alignment would not have berms or geotextile.

Table 2.2. South Slidell Levee

South Slidell Levee **Initial Construction**	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Construction Elevation	Varies

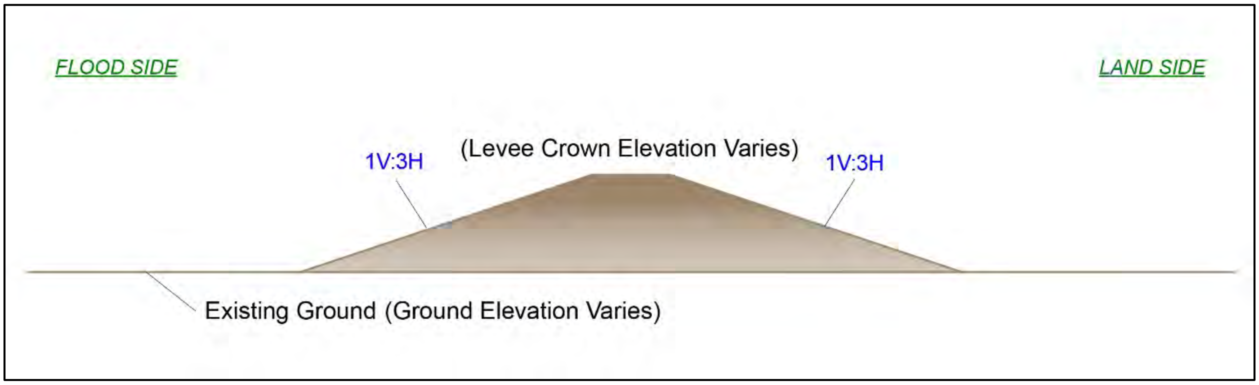

Figure 1-6. Typical Cross-section for South Slidell

The hydraulic design elevation of the new South Slidell levee would vary between 14 ft and 16 ft (year 2032) depending on the location.

2.4 FUTURE LEVEE LIFTS

To maintain the levee crown at or above the base year (2032) and future year (2082) design elevations while accounting for levee settlement and relative sea level rise, levees would be constructed in multiple lifts over the period of analysis. Both the design elevations and constructed "top of levee" elevations vary by location. Design elevations vary by levee location because of surge and wave differences due to storm path, wind speeds and direction, etc.

Levee portions of the Optimized TSP would require future lifts to bring the levees to hydraulic design elevations for year 2082.

For West Slidell, four future levee lifts are projected to be needed. The assumed cross-section for these lifts would have a 10 ft wide levee crown and side slopes of 1V:3H.

Existing berm sections from initial construction would be in place on both sides of the levee.

For the first lift (Year 2033) and the second lift (Year 2038), it was assumed that in addition to elevating the levee, the berm previously built during initial construction would settle 25 percent. Additional material would be placed on the berms during these two lifts.

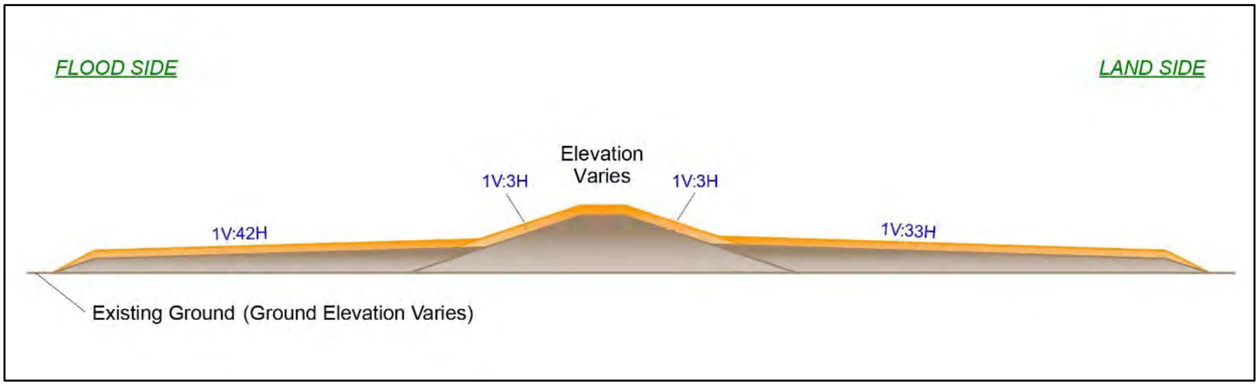

Figure 1-7. Typical Cross-section with berms for First and Second Lifts for West Slidell

For the third lift (Year 2051) and the fourth lift (Year 2076), it was assumed that no additional material would be placed on the berms.

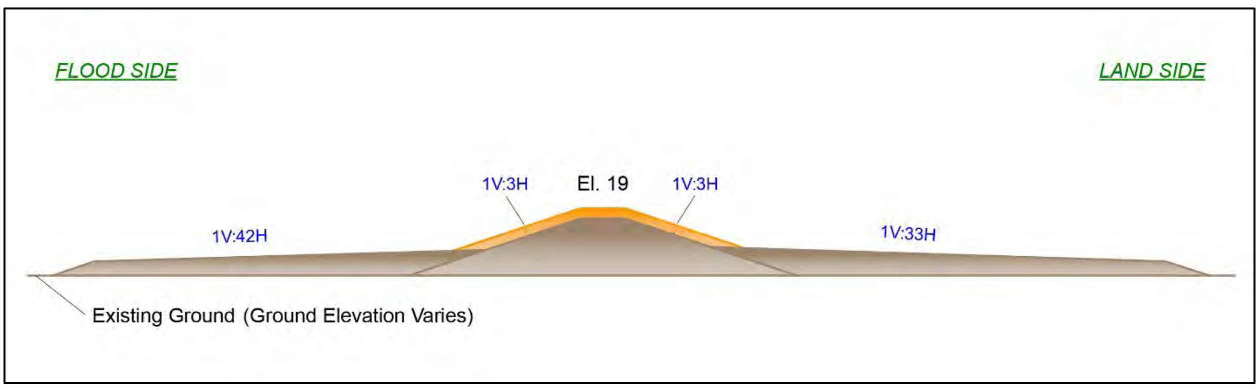

Figure 1-8. Typical Cross-section with berms for Third and Fourth Lifts for West Slidell

2.4.1 WESTERN HIGH GROUND TIE-IN LEVEE CONSTRUCTION

The construction of the Western High Ground Tie-In would be performed during the fourth lift for West Slidell which is projected for year 2076. The dimensions for the Western High Ground Tie-In may be found in Table 2.3 and Figure 1-9. This portion of the alignment would not have berms or geotextile.

Table 2.3. Western High Ground Tie-In *Levee*

Western High Ground Tie-In	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Construction Elevation	19 ft

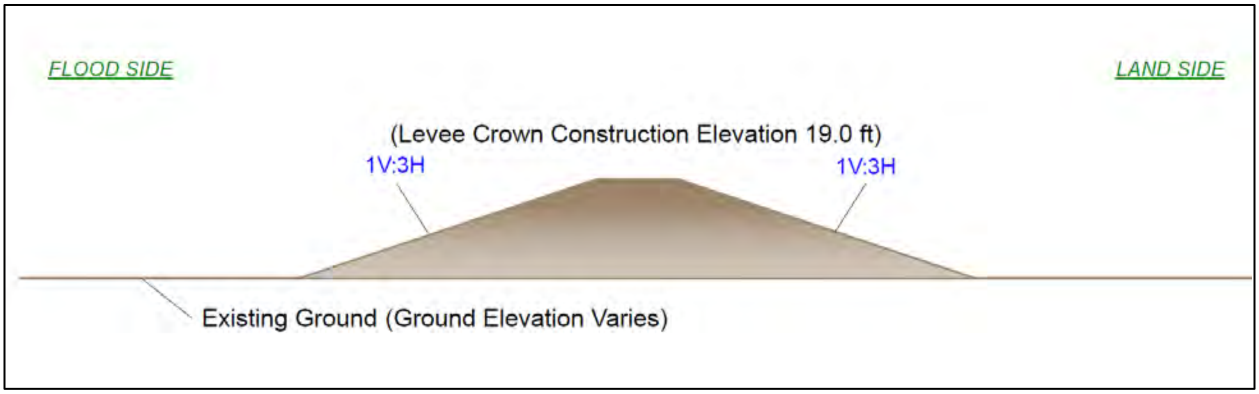

Figure 1-9. Typical Cross-section for the Western High Ground Tie-in for Year 2082

The lift schedules for West Slidell consisted of one geotechnical reach as shown in Figure 1-9. The hydraulic design elevation is 13.5 ft for year 2032 and 17.5 ft for year 2082 are shown in the design line in blue. The red lines represent the projected lifts.

2.4.2 SOUTH SLIDELL LEVEE TYPICAL CROSS SECTION FOR FUTURE LIFTS

The future lifts for South Slidell levee would have a 10 feet wide levee crown and side slopes of 1V:3H.

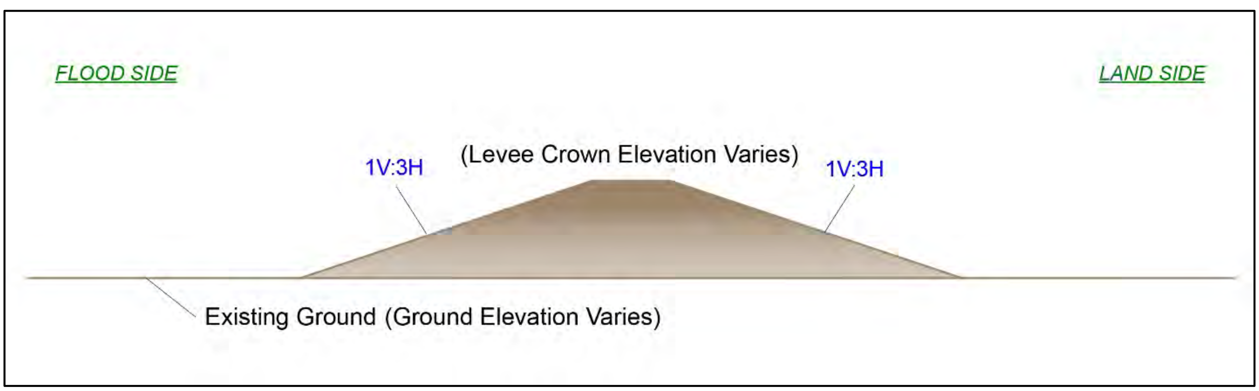

Figure 1-10. Typical Cross-section for South Slidell for Future Lifts

2.5 Typical Floodwall Section and Elevations

The T-wall sections would vary based on location. Table 2.4 lists the floodwall segment and the various dimensions for each floodwall segment.

Table 2.4. Floodwall Segment dimensions

Description of Floodwall Segment	Length of Floodwall Segment (ft)	Base of Slab BOS (ft)	Base of Wall BOW (ft)	Top of Wall TOW (ft)	Stem Height (ft)	Wall Thick (ft)	Slab Width (ft)	Number of piles per row
Western High Ground Tie-in for Year 2082								
N/A								
West Slidell								
Properties at the end of West Doucette	350	1.5	4.5	17.5	**13**	2	15	3
North Side Bayou Paquet Dr.	250	-1.5	1.5	16.5	**15**	2.5	20	4
Bayou Paquet/Mayer Dr.	1400	-1.5	1.5	16	**14.5**	2.5	20	4
South Slidell								
Front Street/ Railroad	1375	-0.5	2.5	16.5	**14**	2.5	20	4
Old Spanish Trail	300	-2.5	0.5	18.5	**18**	2.5	20	4
Esprit du Lac Street	450	1	4	18.5	**14.5**	2.5	20	4
Substation Floodwall	1950	4.5	7.5	18.5	**11**	2	15	3
Highway 190 Business	430	5	8	18.5	**10.5**	2	15	3
Utility Corridor	3530	5	8	18.5	**10.5**	2	15	3
Hollywood Dr. to Yaupon	3700	9	12	18.5	**6.5**	1.5	10	2
Manzella Dr. to Gause	650	10.5	13.5	18.5	5	1.5	10	2

2.6 CONCRETE AND PILE QUANTITIES FOR FLOODWALL SEGMENTS

The floodwall segments would require the following concrete quantities during initial construction as shown on Table 2.5.

Table 2.5: Concrete Quantities for Floodwall Segments

CONCRETE FLOODWALL SEGMENTS	
Total Concrete Quantities	36,200 cubic yards
Total Sheetpile Quantities	451,400 square feet
Total Length of Piles	887,000 linear feet

Total Slope Paving for floodwall/levees tie-ins	7,000 square feet

Table 2.6: Pile Quantities for Floodwall Segments

PILES FOR FLOODWALL SEGMENTS	
Type of pile	18-inch pipe
Configuration	1H:2V battered
Length of each pile	101 feet
Total Length of Piles	26,300 linear feet

2.7 FLOODGATES DESIGN INFORMATION

The Optimized TSP would include a total of 13 gates. Three (3) gates would be lift gates and one gate would be a sector gate. These gates would allow navigation of recreational vessels. There are nine (9) sluice gates which would be control structures (non-navigable).

During construction of the gated structures, temporary bypass channels would be constructed for recreational vessels in Bayous Paquet, Bonfouca, and Liberty.

Table 2.7: Floodgate Dimensions

Description of the Floodgate	Type of Gate	Width of Opening of the Gate (ft)	Ground/ Sill Elevation (ft)	Structural Height of Drainage Gate (ft)
Western High Ground Tie-in for Year 2082				
Sluice gate near Shannon Drive	Sluice	4	15.5	2.0
Tammany Trace Sluice Gate	Sluice	15	12	5.5
West Slidell				
Sluice Gate # 7 (Near CC Road)	Sluice	25	8.6	8.9
Sluice Gate # 6 (Bayou Paquet North Tributary)	Sluice	75	0.8	15.2
Bayou Paquet Gate Nav. Gate	Lift	90	-0.5	16.5
Bayou Liberty Nav. Gate	Lift	80	-6.8	22.8
Bayou Bonfouca Nav. Gate	Lift	110	-9	25.0
Sluice Gate # 2 (Bayou Bonfouca Sluice Gate)	Sluice	50	0.4	15.6
South Slidell				
W-14 Canal Nav. Gate	Sector	90	0.1	18.4
Sluice Gate # 8 (Kings Point East)	Sluice	90	4.4	14.1

Sluice Gate # 10 (Near Eastern Terminus)	Sluice	20	10.5	8.0
Reine Canal	Sluice	30	7.5	11.0
French Branch at I-10	Sluice	25	8.3	10.2

The floodgate locations and minimum sizes above are an estimate. A detailed interior drainage design would be provided during PED.

Limited information and estimates of channel depths and widths has been considered in estimates of the minimum gated opening dimensions. An increase in the size of the gated openings would likely benefit environmental conditions and would provide additional flood flow conveyance. Any channel constriction such as a gate has the potential to locally increase velocities, which could erode natural channels.

It is assumed that most of these floodgate locations would need to retain some flood conveyance capacity during construction. During PED, bypass channels would be considered as part of the design.

Temporary Bypass Channel

Temporary bypass channels would be constructed at locations where a pump station or floodgate is proposed within the limits of a channel. The temporary bypass channel would route water around the structure in order for the construction to be done in dewatered conditions.

In order to maintain pre-construction flow conditions and minimize environmental impacts during construction, the temporary bypass channels would be similarly sized to the channels being impacted. After construction, the bypass channel is assumed to be included in the footprint of the structure site and the channel flow would be rerouted through the new structure feature. Navigation of common local vessels would be considered for the bypass channels, and design features of a navigable bypass channel would be developed during PED.

Temporary Retaining Structures (TRS)

Temporary Retaining Structures (cofferdams) are temporary features that facilitate the construction of major structures. Cofferdams allow water or other materials to be removed inside the TRS in order to work in an excavated and/or dewatered condition.

Cofferdams would be required during the construction of the pump stations and floodgates. Qualified designers employed or sub-contracted by the construction contractors would design the TRS for this project.

2.8 TYPES OF FLOODGATES

2.8.1 FISH-FRIENDLY LIFT GATE

For Bayou Paquet, Bayou Bonfouca and Bayou Liberty, the proposed navigable gates would be designed to have a small amount of restriction and a gradual slope so that fish and larvae may traverse the structures. The navigable gates would consist of a lift gate which would be raised during open mode to let water and recreational vessels traverse. This design would include smaller sluice gates on both sides of the lift gate to simulate the natural opening of the bayous.

During PED, the PDT would consider additional fish-friendly studies and input provided by the NFS, USFWS and National Marine Fisheries Service criteria, including the rock arch and rock ramp designs.

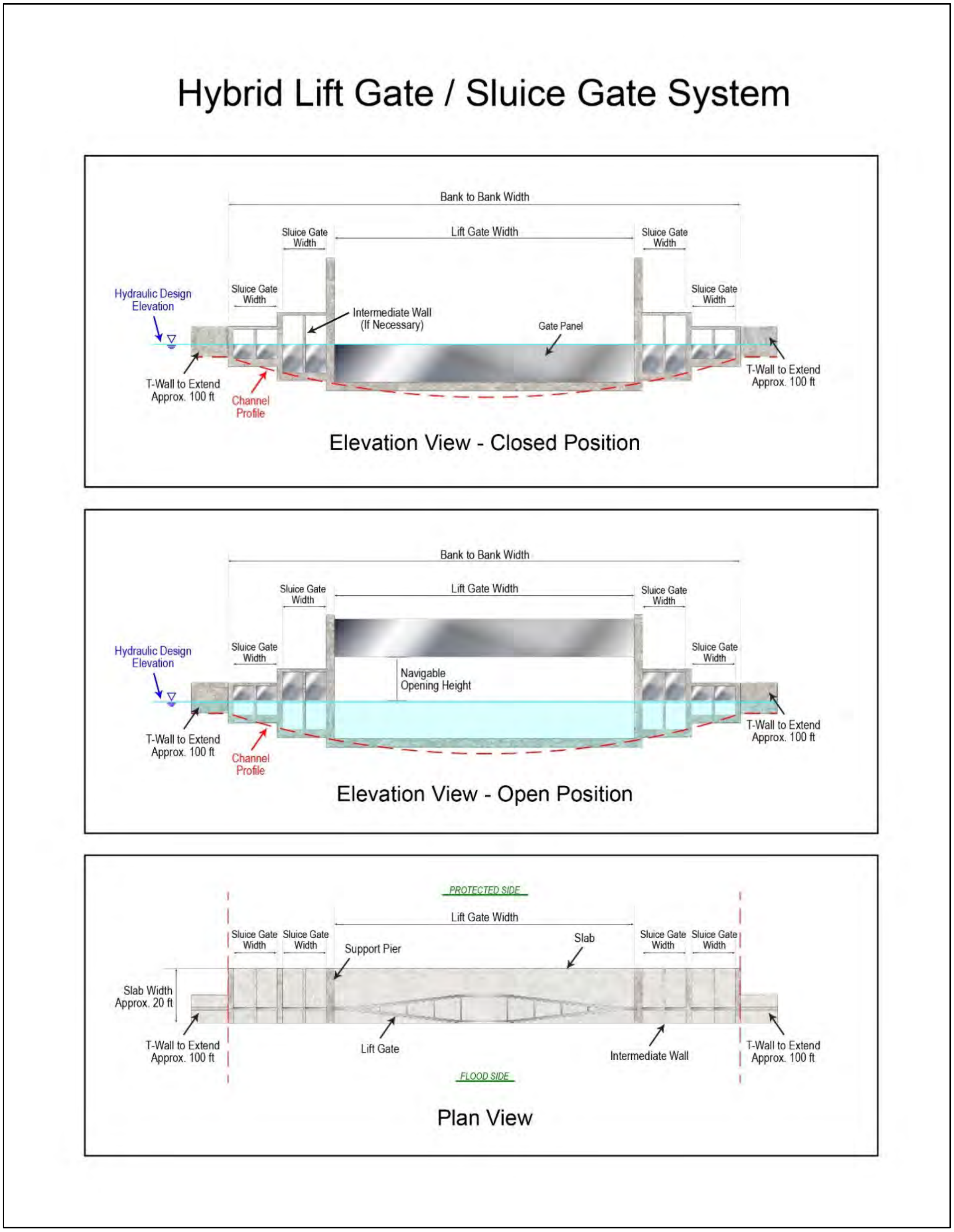

Figure 1.11. Typical Fish-Friendly Gate - Elevation and Plan Views

2.8.2 SLUICE GATE

A sluice gate is a structure that contains a movable gate or series of movable gates that, when lifted, allow material and water to flow under it. Generally, sluice gates are not navigable as they do not raise high enough, or they have fixed components that do not allow vessels to pass through."

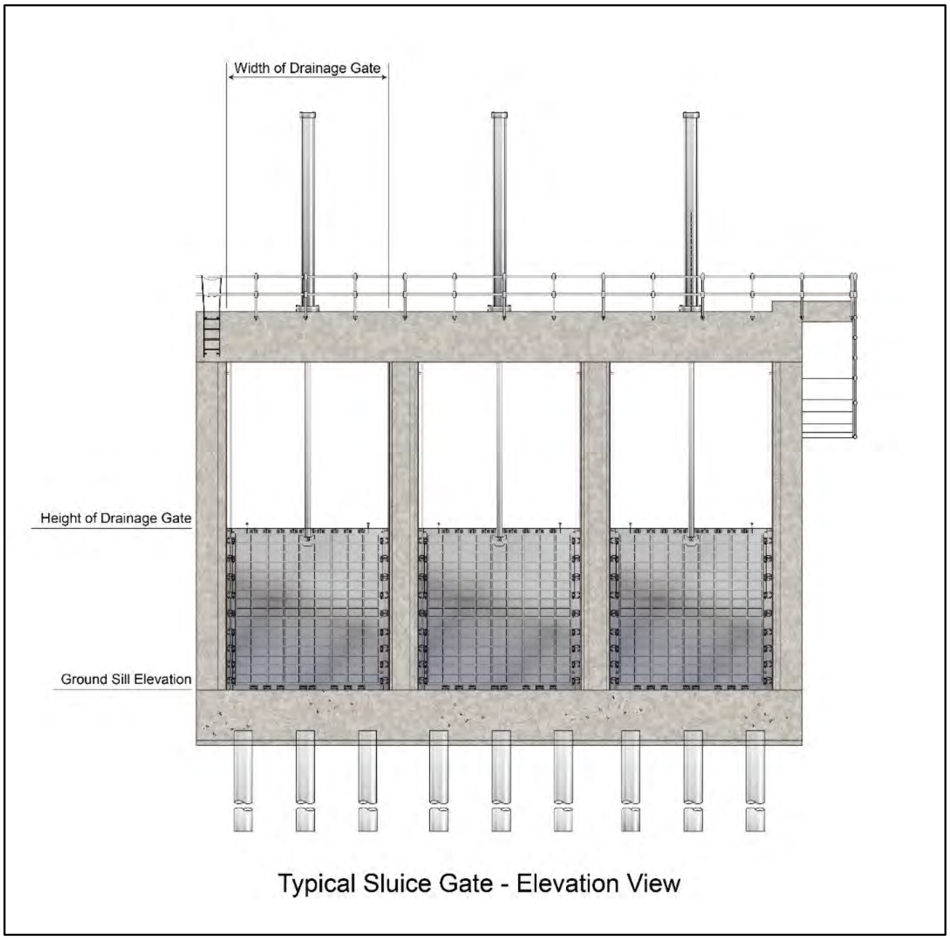

Figure 1-12. Sluice Gate - Elevation View

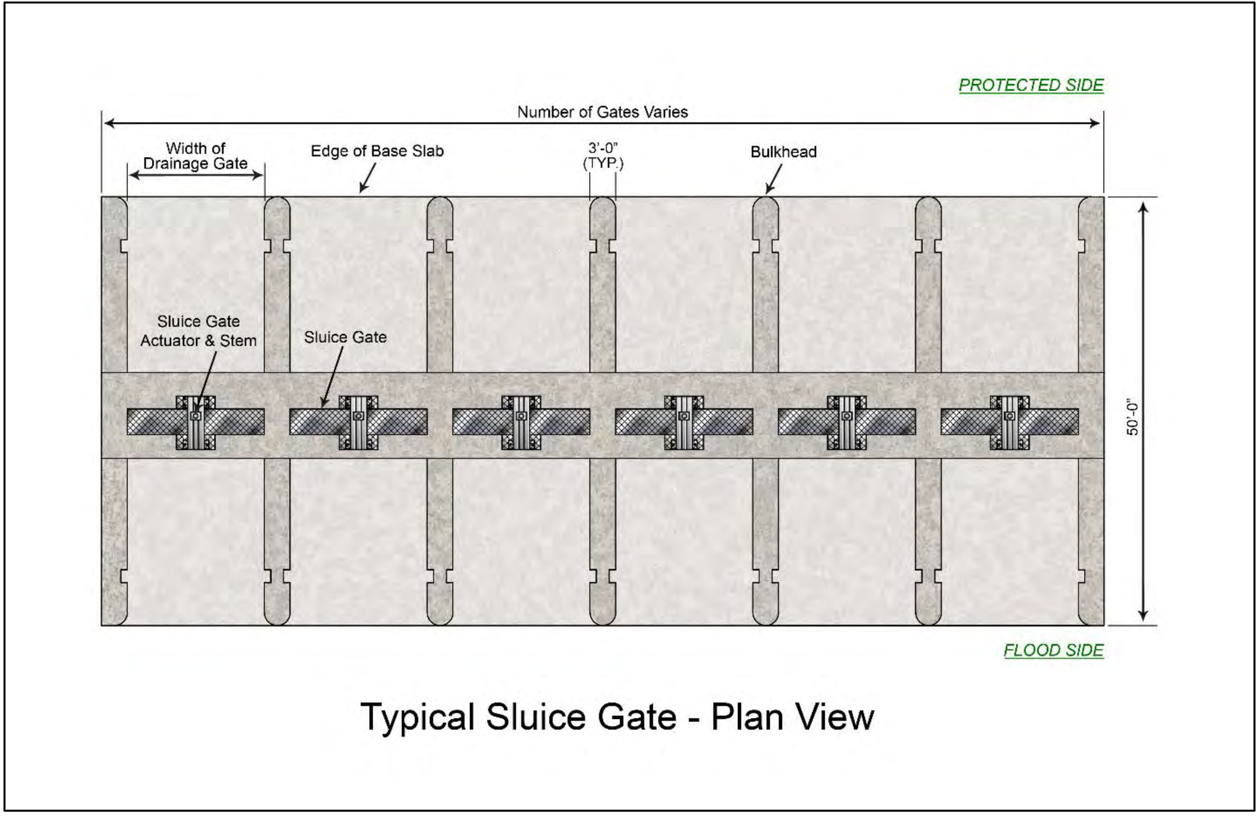

Figure 1-13. Sluice Gate - Plan View

2.8.3 SECTOR GATE

A sector gate is a pie-slice structure that allows navigation to get through when in the open position.

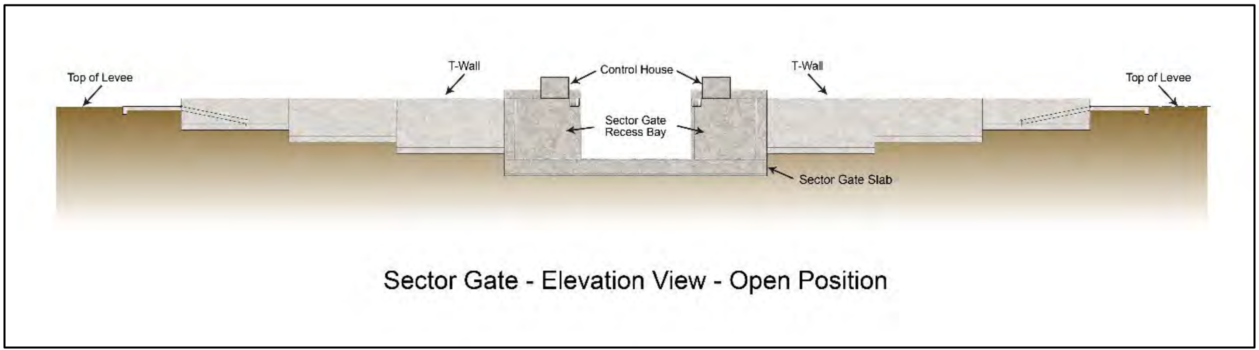

Figure 1-14. Sector Gate - Elevation View with Gates in Open Position

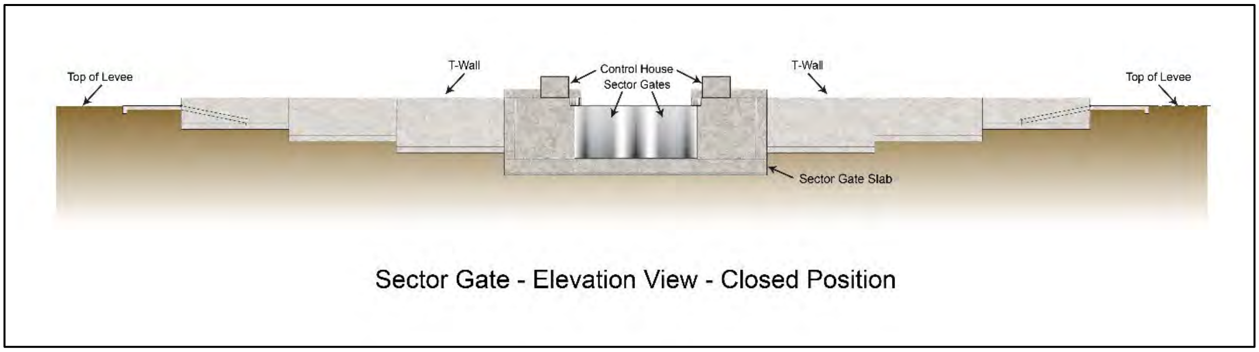

Figure 1-15. Sector Gate - Elevation View with Gates in Closed Position

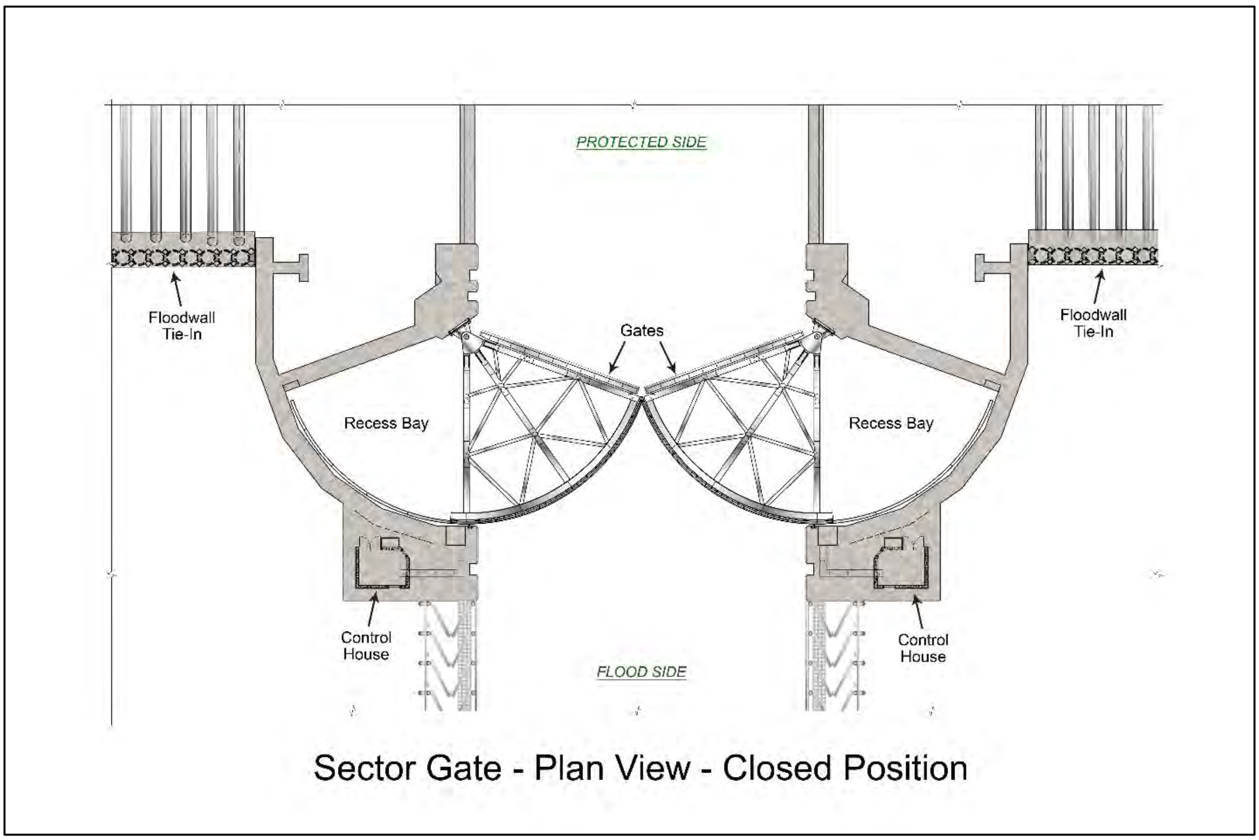

Figure 1-16. Sector Gate - Plan View

2.8.4 ROLLER GATE

A roller gate is a structure that uses rollers for the gate to open and close. The operating motion of the gate is typically parallel to the skin plate face of the gate.

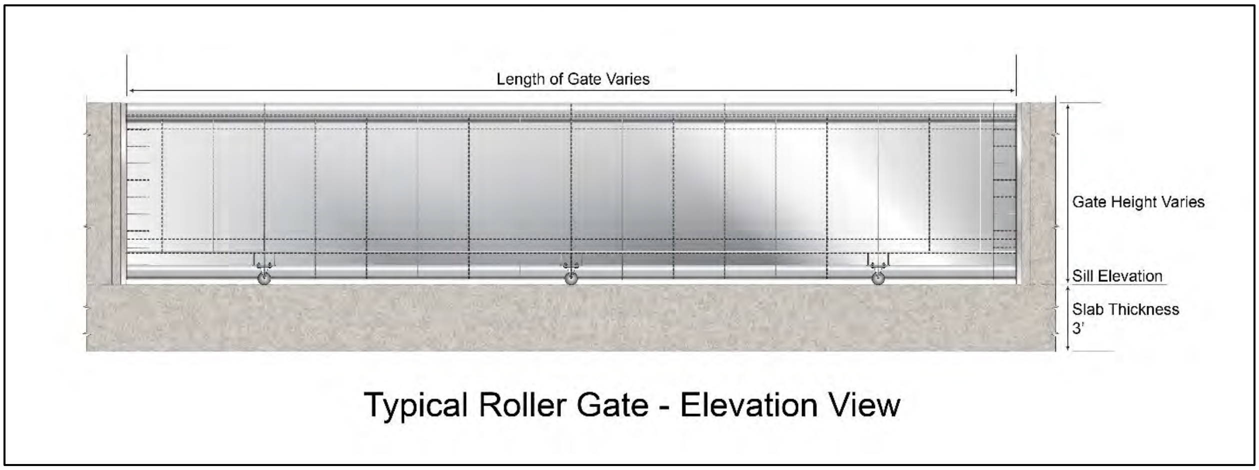

Figure 1-17. Roller Gate - Elevation View

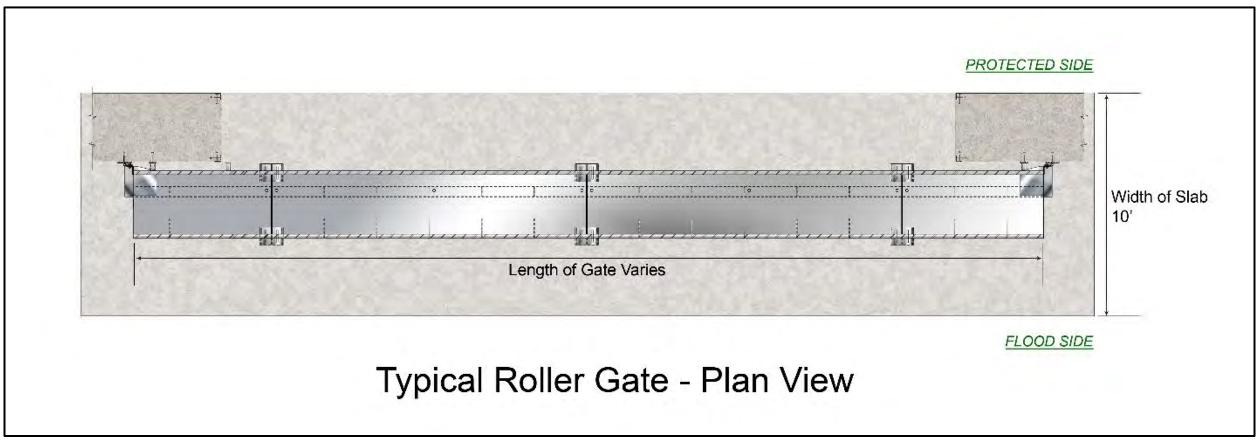

Figure 1-18. Roller Gate - Plan View

2.8.5 SWING GATE

A swing gate is a structure that uses a hinge system to open horizontally. The gate can be actuated through automated mechanical means such as hydraulic arm or manually.

It was assumed that a swing gate would be constructed where the alignment crosses the Southern Railway Corp. railroad tracks. (The analysis for this gate was based on Mississippi River Levee (MRL) Carrollton Railroad Gate.)

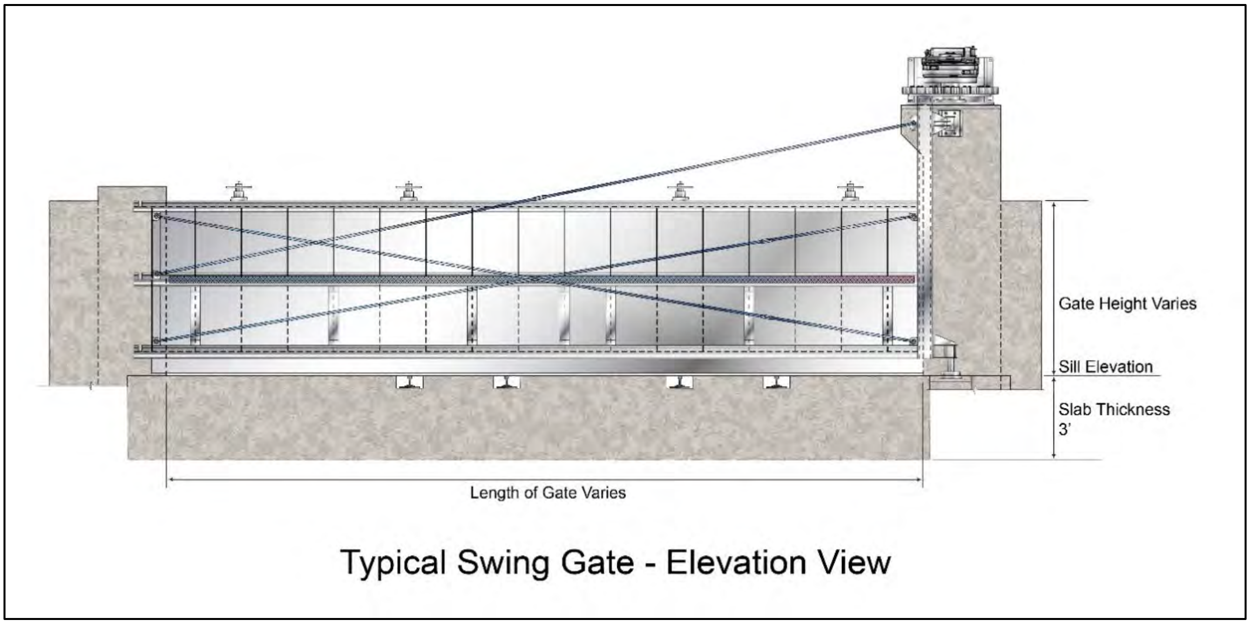

Figure 1-19. Swing Gate - Elevation View

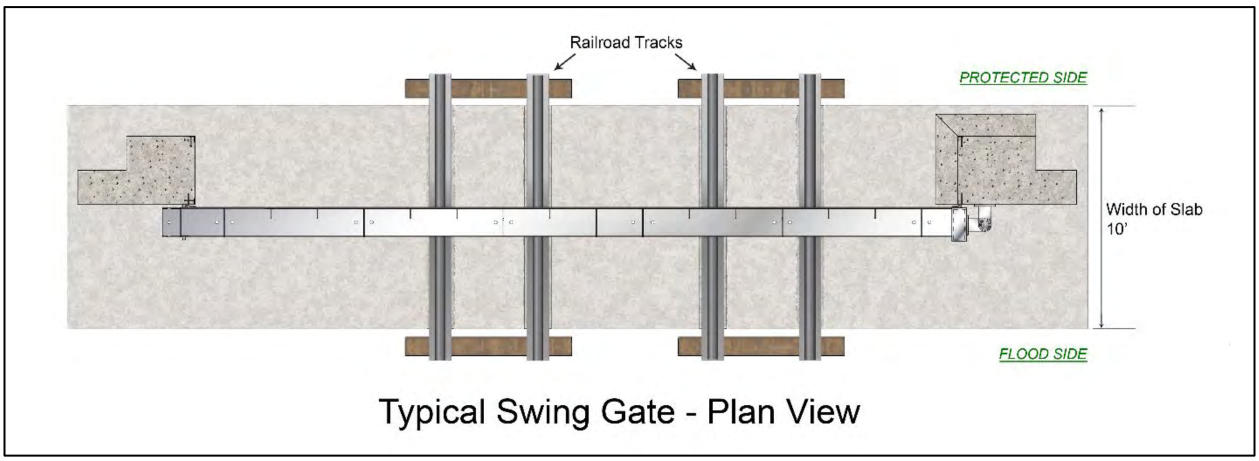

Figure 1-20. Typical Swing Gate - Plan View

2.9 VEHICULAR, PEDESTRIAN AND RAILROAD GATES DESIGN INFORMATION

Table 2.8 contains the design information for the vehicular, pedestrian and railroad gates for the Optimized TSP.

Table 2.8: Vehicular, Pedestrian and Railroad Gates

Name	Description	Type	Mode	Width	Ground/ Sill Elevation (ft)	Design Height (ft)	Height of Gate (ft)
Western High Ground Tie-in for 2082							
Tammany Trace Pedestrian Gate and Culvert	10-ft Pedestrian Gate at Tammany Trace with Lift Gate for Culvert on south side	Swing	Pedestrian	10	13	17.5	3.5
Tranquility Road Vehicular Gate	20-ft Vehicular Gate at Tranquility Road	Roller	Vehicle	20	12	17.5	4.5
West Slidell							
Bayou Paquet Road Floodgate # 2	60-ft Floodgate at Bayou Paquet Road	Roller	Vehicle	60	3	16	13
Mayer Drive Vehicular Gate	20-ft Vehicular Gate at Mayer Road	Roller	Vehicle	20	2.5	16	13.5
Railroad Floodgate	60-foot floodgate for Railroad	Swing	Railroad	60	0.5	16.5	16
South Slidell							
Hwy 11 Vehicular Gate	75-ft Roller Gate at Hwy 11 (Pontchartrain Drive)	Roller	Vehicle	75	4	16.5	12.5
Mariners Cove Floodwall and Vehicular Gate	500 Linear feet of floodwall for narrow section of Oak Harbor levee at Mariners Cove Blvd	Roller	Vehicle	50	10.5	16.5	6
Oak Harbor Vehicular Gate	Floodwall and 20-foot Vehicular Gate for Oak Harbor	Roller	Vehicle	20	11.5	16.5	5
Oak Harbor Country Club Vehicular Gate	Floodwall and 20-foot Vehicular Gate for access to Oak Harbor Country Club	Roller	Vehicle	20	11.5	16.5	
Old Spanish Trail Floodgate (Hwy 433)	30-foot roller gate at Hwy 433 east crossing (Old Spanish Trail)	Roller	Vehicle	30	3.5	18.5	15

Hardin Rd Substation Gate	20-foot roller gate for access from Hardin Road to power substation	Roller	Vehicle	20	8	18.5	10.5
Hwy 190-B Floodgate (East Floodwall)	50-foot roller gate at Hwy 190-B east crossing (Fremaux Road)	Roller	Vehicle	50	9	18.5	9.5
South Holiday Drive Vehicular Gate	20-foot roller gate at South Holiday Drive	Roller	Vehicle	20	14	18.5	4.5
Jaguar Drive Vehicular Gate	20-foot roller gate at Jaguar Avenue	Roller	Vehicle	20	12	18.5	6.5
Natchez Drive Vehicular Gate	20-foot roller gate at Natchez Avenue	Roller	Vehicle	20	12	18.5	6.5
Kisatchie Drive Vehicular Gate	20-foot roller gate at Kisatchie Avenue	Roller	Vehicle	20	14	18.5	4.5
Manzella Drive Vehicular Gate	20-foot roller gate at Manzella Drive (Added to extend floodwall to 18.5 ft ground elevation south of Hwy 190)	Roller	Vehicle	20	15	18.5	3.5

2.10 PUMP STATIONS DESIGN INFORMATION

The Optimized TSP would include a total of eight (8) pump stations. These pump stations are divided into large pumping capacity and small pumping capacity.

In West Slidell there would be two (2) pump stations with large pumping capacity and two (2) pump stations with small pumping capacity. In South Slidell there would be four (4) pump stations with small pumping capacity.

Table 2.9: Pump Stations

Pump Station Location	Pump Station Capacity
Western High Ground Tie-in for 2082	
N/A	
West Slidell	
Bayou Liberty	1,800 cfs

Bayou Bonfouca	2,000 cfs
Bayou Paquet North Tributary	300 cfs
Bayou Paquet	500 cfs
South Slidell	
W-14 Canal	1,000 cfs
Kings Point	200 cfs
Reine Canal	200 cfs
French Branch at the I-10	450 cfs

The Optimized TSP would include two (2) pump stations with large pumping capacity at Bayou Liberty (1,800 cfs) and Bayou Bonfouca (2,000 cfs). These pump stations were assumed to have similar components and configuration as the USACE West Shore Lake Pontchartrain Reserve Relief Canal Pump Station (WSLP Pump Station). The structural quantities from the Reserve Relief Canal Pump Station were scaled accordingly to reflect the size of the pump stations for this study.

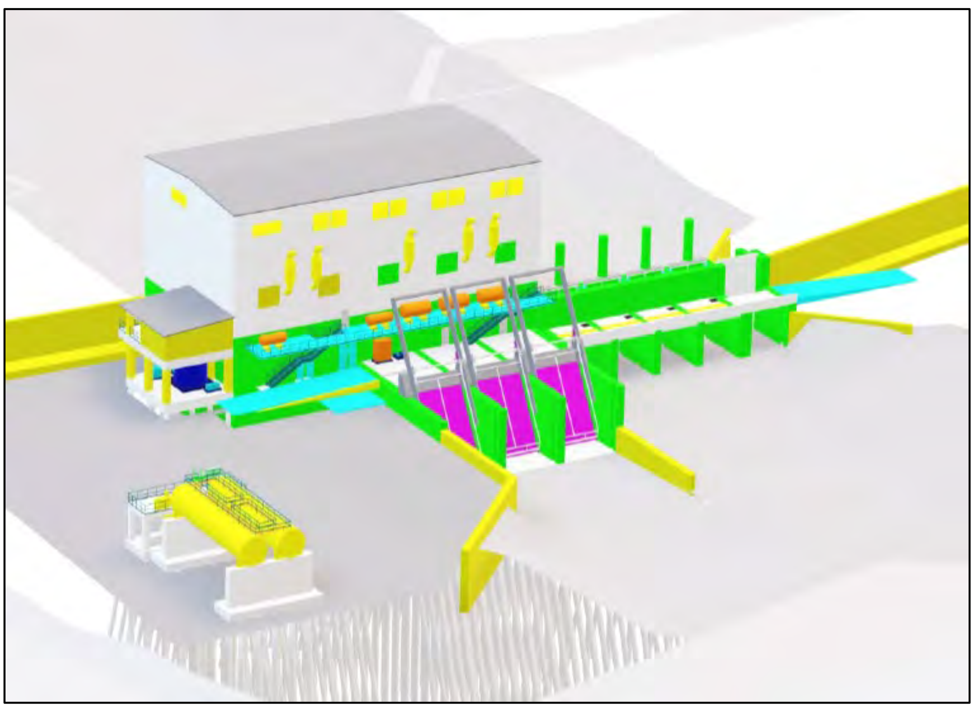

Figure 1-21. Typical Site Plan of a Pump Station with Large Pumping Capacity

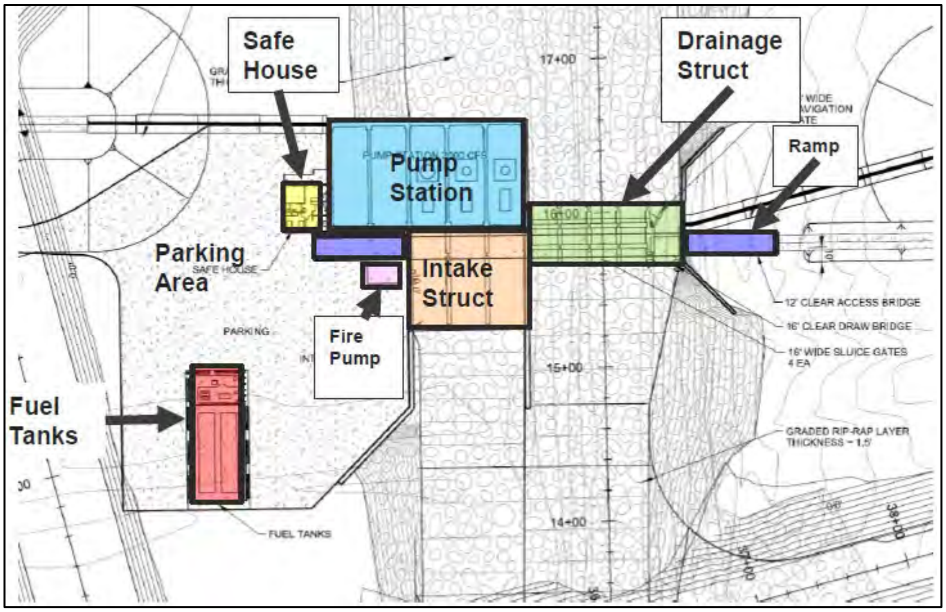

Figure 1-22. Typical Layout of a Pump Station with Large Pumping Capacity

The TSP would include six (6) pump stations with small pumping capacity at sluice gate #6 on the Bayou Paquet North Tributary (300 cfs), Bayou Paquet lift gate (500 cfs), W-14 Canal (1,000 cfs), sluice gate # 8 at Kings Point (200 cfs), Reine Canal (200 cfs) and at French Branch at the I-10 (450 cfs).

These pump stations would have similar pumping capacities to the Prescott Road Pump Station for the Lake Pontchartrain Lakeshore study. The structural quantities from the Prescott Road Pump Station were scaled accordingly to reflect the size of the pump stations for this study.

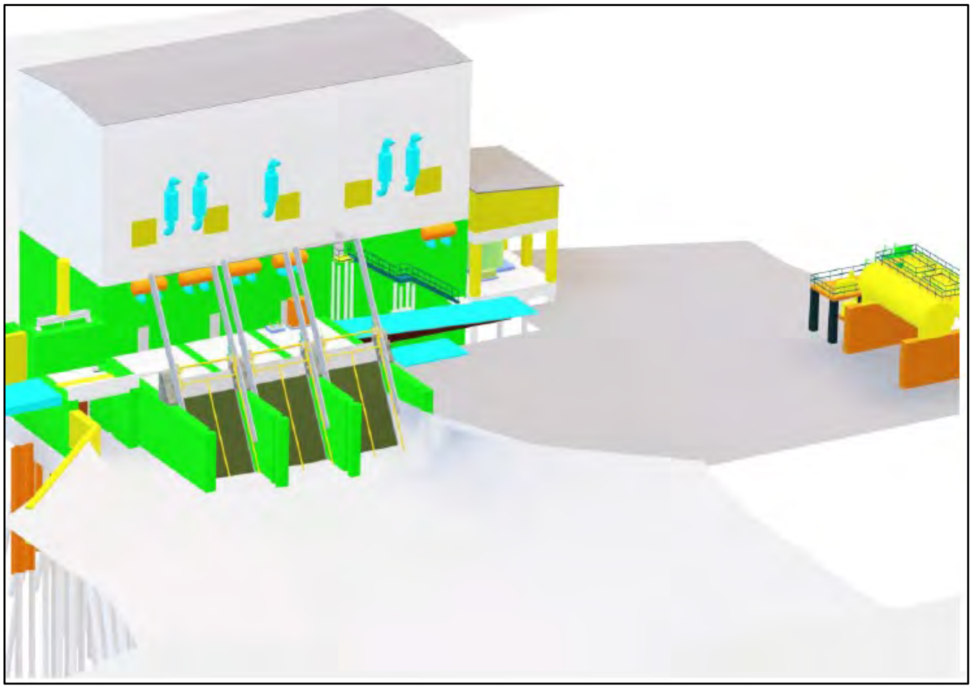

Figure 1-23. Typical Site Plan of a Pump Station with Small Pumping Capacity

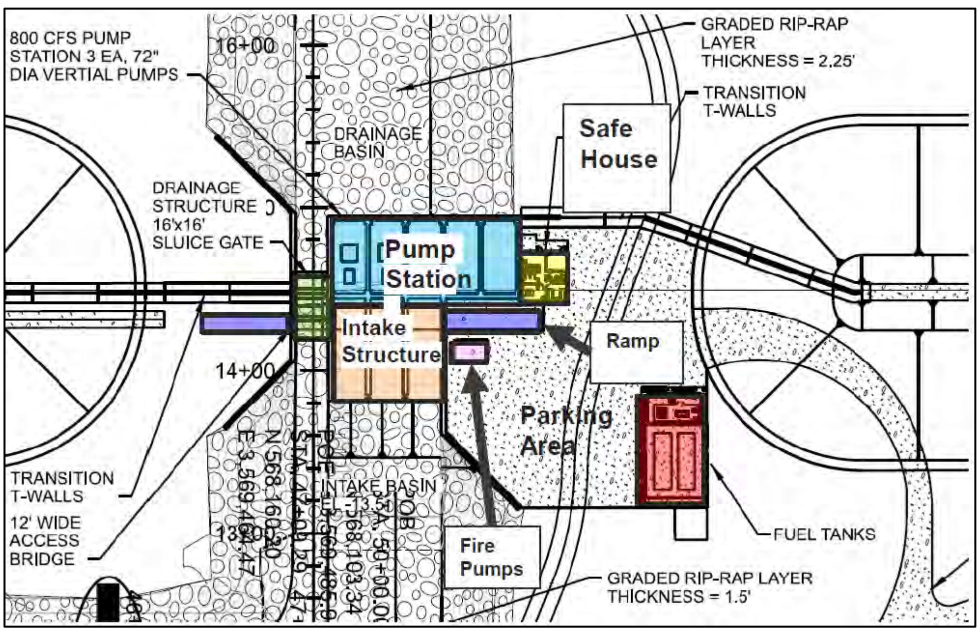

Figure 1-24. Typical Layout of a Pump Station with Small Pumping Capacity

Note: the schematics on this section were obtained from a presentation prepared by Stantec.

3 ACCESS ROUTES AND STAGING AREAS REQUIRED

Table 3.1 provides a summary of the necessary staging areas and permanent ROW required for construction of the levee and floodwall segments for the 50-yr period of analysis. The staging areas required during initial construction of the levee alignment would be the same staging areas required for construction of future levee lifts.

Table 3.1 Summary of Staging Areas and Permanent ROW

SUMMARY of STAGING AREAS AND PERMANENT ROW		
Levees	**Staging Areas (Acres)**	**Permanent ROW (Acres)**
Western High Ground Tie In	2	30
West Slidell	8	270
South Slidell (includes 23 acres for I-10)	29	120
Sub-Total for Levees	**39**	**420**
Floodwall Segments		
Western High Ground Tie In	NA	NA
West Slidell	0	3.7
South Slidell	0	22.7
Sub-Total for Floodwall Segments	**0 ***	**26.4**
Floodgates and Pump Stations		
Western High Ground Tie In	1.5	2.5
West Slidell	11	21
South Slidell	3.75	6.25
Sub-Total for Floodgates and Pump Stations	**16.25**	**29.75**
Vehicular, Pedestrian, and Railroad Gates		
Western High Ground Tie In	1.5	1.25
West Slidell	1.25	0
South Slidell	9	0
Sub-Total for Vehicular, Pedestrian, and Railroad Gates	**11.75**	**1.25**
Road Ramps		
Western High Ground Tie In	0.5	0
West Slidell	0	0
South Slidell	5	0
Sub-Total for Road Ramps	**5.5**	**0**
Access Roads - New		
Western High Ground Tie In	0.1	0.1
West Slidell	0.45	0.45
South Slidell	2.75	2.75
Access Roads - Existing		
Western High Ground Tie In	0	0
West Slidell	15.8	0
South Slidell	9.9	0
Sub-Total for Access Roads	**29**	**3.3**
Mile Branch Channel Improvements	7.3	38.5

Sub-Total for Mile Branch Channel Improvements	**7.3**	**38.5**
Total Acres for 50-year Period of Analysis	**109**	**520**

*for floodwall segments, staging areas would be included in the 80 ft wide permanent ROW.

Table 3-2 lists the ROW width required per levee or floodwall segment. The width includes a 15 ft of vegetation free zone (VFZ) on each side of the levee/floodwall segment.

Table 3.2 Typical Widths of Permanent ROW for Levee and Floodwalls Segments

Levee and Floodwall Segments	Width of Permanent ROW (ft)*
Western High Ground Tie-in	160
West Slidell	300
South Slidell	160
Floodwall Segments	80
Access Roads	NA

***(Includes 15-ft VFZ on both sides)**

3.1 ACCESS ROUTES AND STAGING FOR MILE BRANCH

Site access to Mile Branch would be via public roads and public rights of way.

Staging areas are assumed to be dry. Any trees would be removed and hauled away to an approved facility. If necessary, crushed stone would be placed in the staging area prior to construction. After construction, the crushed stone would be removed and the disturbed areas would be fertilized and seeded.

For the culvert and bridge replacement work, all staging areas were assumed to be located within the individual structure construction areas. Staging areas are to be tree and vegetation free and covered with crushed stone.

3.1 ACCESS ROUTES AND STAGING FOR LEVEE CONSTRUCTION

There are locations where an existing road would be used for access. In other locations, a new road would be built.

New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for VFZ on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

LEVEE CONSTRUCTION EXCEPT REFUGE AREA

For staging areas for levee construction, crushed stone would be placed (assuming crushed stone for vehicle parking/staging and for path from road to area).

Any trees would be removed and hauled away to an approved facility. Contractor would use the area to process material prior to levee construction.

LEVEE CONSTRUCTION ON REFUGE AREA

For the construction of the levee on the refuge land (from Bayou Bonfouca to the railroad tracks), the ingress and egress would be at the Norfolk Southern railroad tracks on the east side of Bayou Bonfouca and existing roads on the west side. A one-way flow of traffic would be maintained. The USACE would need to obtain permission from the railroad owner (Norfolk Southern Railway Corp.) prior to construction. An access road would be constructed on the protected side of the ROW between the proposed crown of the levee and Bayou Bonfouca. The access road would be a temporary road. Once construction is complete, the area would be cleared of vegetation within the right of way and graded to drain away from the levee. Access during future inspections would be done by driving on the crown of the levee.

There would be one 2-acre staging area on the reach on the refuge land that would be considered a temporary easement. The staging area would be located off the refuge and would be used to process the material prior to building the levee. Staging areas would be required to be continuously accessible. Any trees would be removed and hauled away to an approved facility. The area would be restored to pre-construction elevation that existed prior to impacting the site due to construction activities.

3.2 ACCESS ROUTES AND STAGING AREAS FOR STRUCTURES

Existing public roads would be utilized for access to the maximum extent as possible. In locations where access cannot be achieved via existing roadways, a new road would be constructed. Construction of new roads would require permanent ROW.

New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for VFZ on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

For the floodwall segments, the temporary ROW (during construction) and the permanent ROW would be as shown in Table 3.3 below.

Table 3.3: ROW for Floodwall Segments

Floodwall Segments		**Staging Area (Acres)**	**Permanent Access (Acres)**
Western High Ground Tie-in for 2082			
N/A			
West Slidell			
Properties west of Doucette Road		0.4	0.4
North Side Bayou Paquet Drive		0.3	0.3

Bayou Paquet/Mayer Drive		1.6	1.6
South Slidell			
Front Street/Railroad		1.6	1.6
Mariners Cove Boulevard		0.6	0.6
Oak Harbor Country Club		0.2	0.2
Old Spanish Trail		0.3	0.3
Esprit du Lac Street		0.5	0.5
Substation Floodwall		2.2	2.2
Highway 190 Business		0.5	0.5
Utility Corridor		4.1	4.1
Hollywood Drive to Yaupon		4.2	4.2
Manzella Drive to Gause Boulevard		0.7	0.7
Total		**18**	**18**

For the floodgates and pump stations, the temporary ROW (staging area during construction) and the permanent ROW would be as shown in Table 3.4.

Table 3.4: ROW for Floodgates and Pump Stations

Floodgates and Pump Stations	Pump Station	Pumping Capacity (cfs)	Staging Area (Acres)	Permanent Area (Acres)
Western High Ground Tie-in for 2082				
Sluice gate near Shannon Drive	No		0.75	1.25
Sluice gate at Tammany Trace	No		0.75	1.25
West Slidell				
Sluice Gate # 7 (Near CC Road)	No		0.75	1.25
Sluice Gate # 6 (Bayou Paquet North Tributary)	Yes	300	0.75	1.25
Bayou Paquet Navigable Gate and Pump Station	Yes	500	0.75	1.25
Bayou Liberty Navigable Gate and Pump Station	Yes	1800	4	8
Bayou Bonfouca Navigation Gate and Pump Station	Yes	2000	4	8
Sluice Gate # 2 (Bayou Bonfouca Sluice Gate)	No		0.75	1.25
South Slidell				
W-14 Canal Navigable Gate and Pump Station	Yes	1000	0.75	1.25
Sluice Gate # 8 (Kings Point East) and Pump Station	Yes	200	0.75	1.25

Sluice Gate # 10 (Near East Terminus)	No		0.75	1.25
Reine Canal and Pump Station	Yes	200	0.75	1.25
French Branch at I-10 and Pump Station	Yes	450	0.75	1.25
Total for Floodgates and Pump Stations			**16.25**	**29.75**

3.3 ACCESS ROUTES AND STAGING AREAS FOR VEHICULAR, PEDESTRIAN AND RAILROAD GATES INITIAL CONSTRUCTION

For the vehicular, pedestrian and railroad gates, the temporary ROW (staging area during construction) and the permanent ROW would be as shown in Table 3.5:

Table 3.5: ROW for Vehicular, Pedestrian and Railroad Gates

Name	Staging Area (Acres)	Permanent ROW (Acres)
Western High Ground Tie-in for 2082		
Tammany Trace Pedestrian Gate	0.75	1.25
Tranquility Road Vehicular Gate	0.75	0
West Slidell		
Bayou Paquet Road Floodgate # 2	0.75	0
Mayer Drive Vehicular Gate	0.75	0
Railroad Floodgate	0.75	0
South Slidell		
Hwy 11 Vehicular Gate	0.75	0
Mariners Cove Floodwall and Vehicular Gate	0.75	0
Oak Harbor Vehicular Gate	0.75	0
Oak Harbor Country Club Vehicular Gate	0.75	0
Old Spanish Trail Floodgate (Hwy 433)	0.75	0
Hardin Road Substation Gate	0.75	0
Hwy 190-B Floodgate (East Floodwall)	0.75	0
South Holiday Drive Vehicular Gate	0.75	0
Jaguar Drive Vehicular Gate	0.75	0
Natchez Drive Vehicular Gate	0.75	0
Kisatchie Drive Vehicular Gate	0.75	0
Manzella Drive Vehicular Gate	0.75	0

3.4 STAGING AREAS AND ACCESS MATERIALS

LEVEE

For staging areas and access roads for levee construction, not including area for material processing during levee construction, a 7-inch depth of stone, and 115 lbs/cubic feet stone weight was assumed.

MILE BRANCH AND STRUCTURES

For the construction in Mile Branch and for the construction of structures, the staging areas and access roads, were assumed to have a 7-inch depth of crushed stone.

4 MILE BRANCH CHANNEL IMPROVEMENTS

The proposed work at Mile Branch would be located in a heavily populated area. There are properties in close proximity of the Mile Branch. There are no surveys available for this area.

Figure 4-1 provides the location of this work.

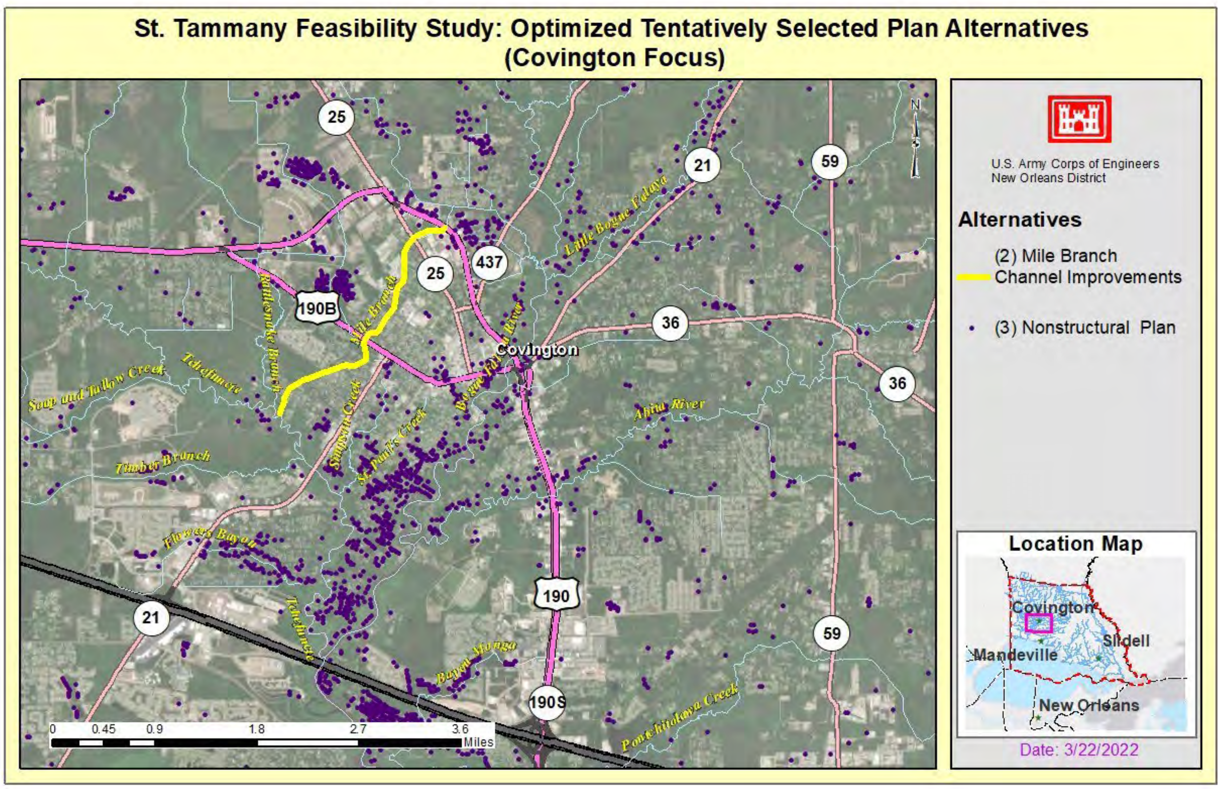

Figure 4-1. Optimized Tentatively Selected Plan Alternatives- Covington Focus

The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and ending at the intersection of Mile Branch and the Tchefuncte River. Refer to Figure 4-2.

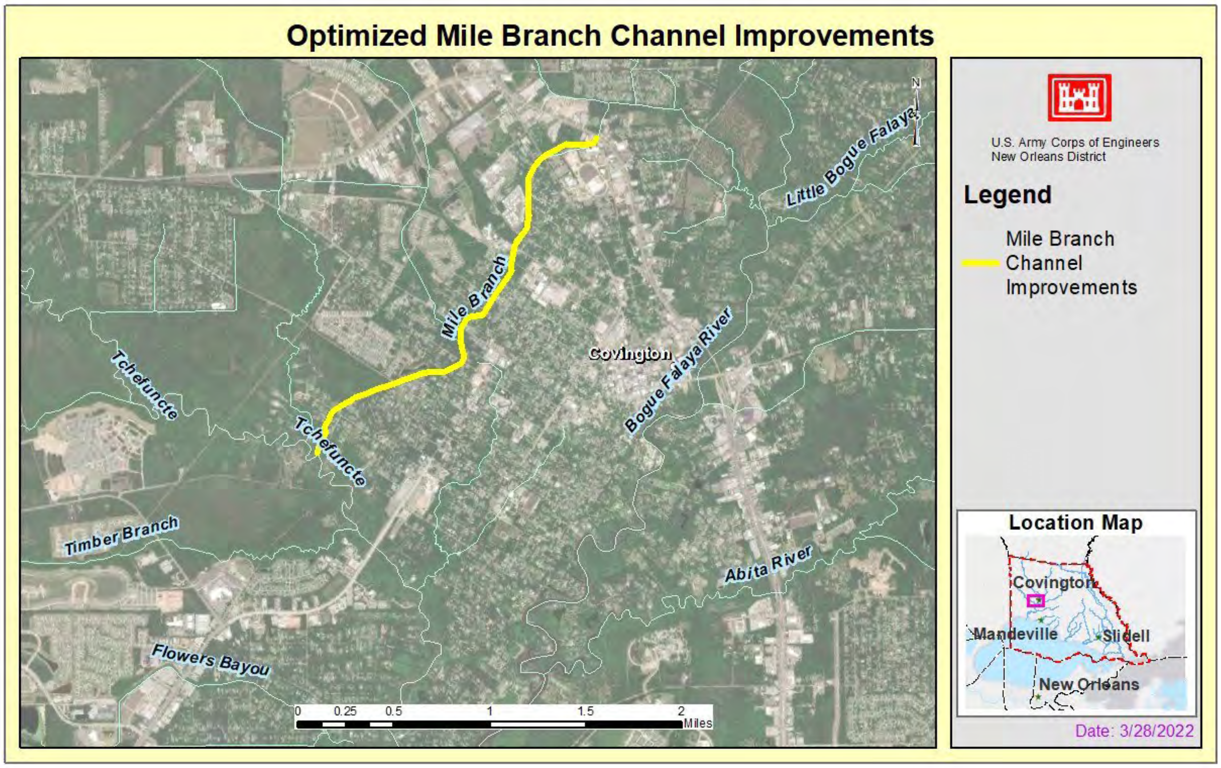

Figure 4-2. Optimized Mile Branch Channel Improvements

The preliminary design assumes an existing bank elevation of 1 ft, a 10-ft bottom width at elevation (-) 5 ft. The bank is at 1V:3H slope. The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel bottom would be lowered by 5 ft. Refer to Figure 4-3 for typical cross-section.

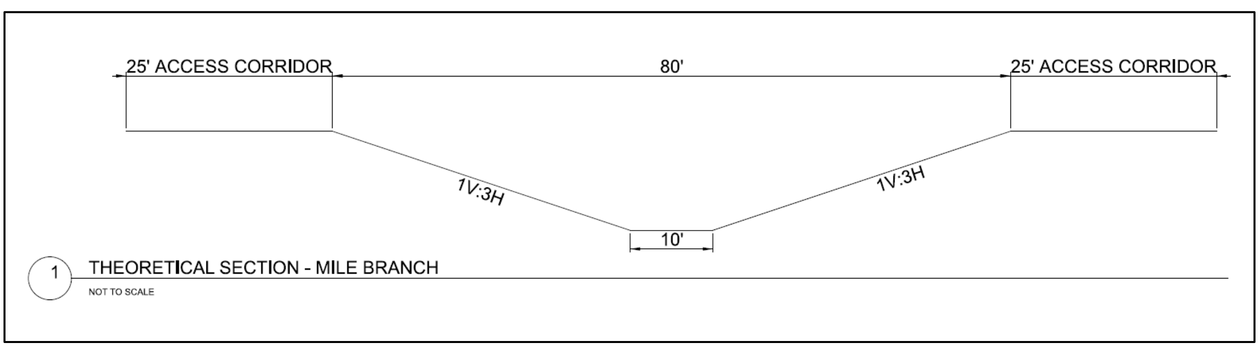

Figure 4-3. Mile Branch Improvements- Typical Cross-Section

Approximately 20 acres of channel would be cleared and grubbed prior to mechanical dredging. An assumed maximum of 130,000 cubic yards of material may be mechanically dredged from the channel. Material removed may include sediment, trees, debris, or other

obstructions within the waterway. For the channel improvements, approximately 34 acres of ROW would be needed for a temporary easement.

Riparian Zone bioengineering techniques and nature-based-solutions (NBS) would be considered as appropriate for Mile Branch FRM during PED in coordination with the NFS and resource agencies. A backwater area was included in the study phase.

4.1 STRUCTURAL IMPROVEMENTS

The Mile Branch channel improvements may include bridge replacements or new culverts (starting from north to south) at 29th, 28th, 25th, 23rd, 21st, 19th, and 18th Avenues. No work is anticipated at the 15th and 11th Avenue channel crossings as those bridges have been replaced prior to this study (and the new bridges were designed to safely pass higher flows on Mile Branch).

Assumptions for channel improvements included a 65 ft from the centerline of each side of the channel for ROW as a general guideline (total width of 130 ft); which includes space for equipment access. All work would be within the project footprint. Temporary work easement would be within ROW. The material to be disposed of would be trucked away from the site. Assumption is that all access would be through public lands.

Additional refinements would occur during PED. Future surveys would determine final channel section and bridge replacements or new culverts. Impacts to habitat and real estate would also be minimized. Opportunities to include natural features would be considered in future designs.

4.2 ACCESS ROUTES AND ROW CRITERIA FOR MILE BRANCH

Figure 4-4 provides the locations of the Mile Branch channel improvements including the structural improvements.

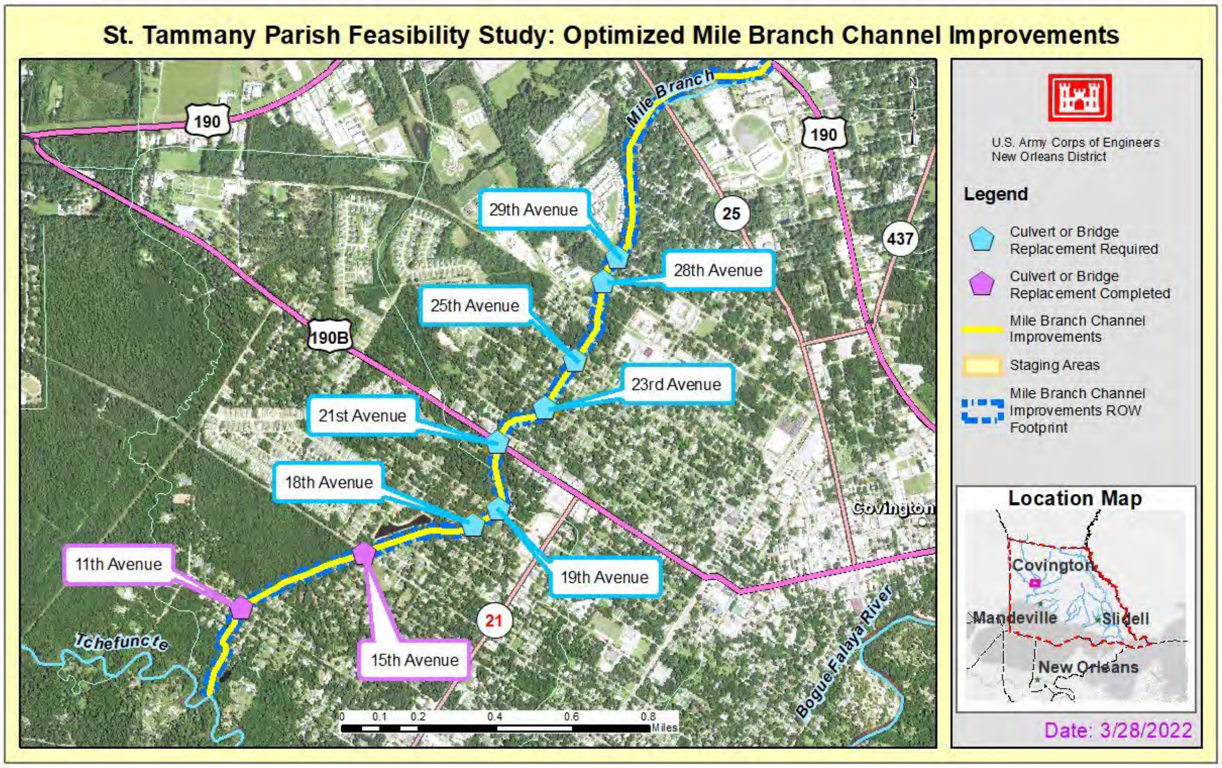

Figure 4.4. Optimized Mile Branch Improvements- Structural Improvements

Reference Table 3.1 for a listing of the staging areas and acres required for the structural improvements for Mile Branch. Table 4-1 below lists the staging area locations required for the bridge/culvert replacements and the necessary acres.

Table 4.1: Staging areas for the bridge/culvert replacements

Location	Temporary ROW Staging Area (Acres)
29th Avenue	0.37
28th Avenue	0.35
25th Avenue	0.20
23rd Avenue	0.21
21st Avenue	0.36
19th Avenue	0.36
18th Avenue	0.38
TOTAL	**2.23**

Appendix B IPaC report and USFWS email confirmation

United States Department of the Interior

FISH AND WILDLIFE SERVICE
Louisiana Ecological Services Field Office
200 Dulles Drive
Lafayette, LA 70506
Phone: (337) 291-3100 Fax: (337) 291-3139

In Reply Refer To: February 23, 2023
Project Code: 2023-0030784
Project Name: St. Tammany Parish Study

Subject: List of threatened and endangered species that may occur in your proposed project location or may be affected by your proposed project

To Whom It May Concern:

The enclosed species list identifies threatened, endangered, and candidate species, as well as designated and proposed critical habitat that may occur within the boundary of your proposed project and may be affected by your proposed project. The Fish and Wildlife Service (Service) is providing this list under section 7 (c) of the Endangered Species Act (Act) of 1973, as amended (16 U.S.C. 1531 et seq.). Changes in this species list may occur due to new information from updated surveys, changes in species habitat, new listed species and other factors. Because of these possible changes, feel free to contact our office (337-291-3109) for more information or assistance regarding impacts to federally listed species. The Service recommends visiting the ECOS-IPaC site or the Louisiana Ecological Services Field Office website (https://www.fws.gov/southeast/lafayette) at regular intervals during project planning and implementation for updated species lists and information. An updated list may be requested through the ECOS-IPaC system by completing the same process used to receive the enclosed list.

The purpose of the Act is to provide a means whereby threatened and endangered species and the habitats upon which they depend may be conserved. Under sections 7(a)(1) and 7(a)(2) of the Act and its implementing regulations (50 CFR 402 et seq.), Federal agencies are required to utilize their authorities to carry out programs for the conservation of Federal trust resources and to determine whether projects may affect Federally listed species and/or designated critical habitat.

A Biological Assessment is required for construction projects (or other undertakings having similar physical impacts) that are major Federal actions significantly affecting the quality of the human environment as defined in the National Environmental Policy Act (42 U.S.C. 4332(2) (c)).

Bald eagles have recovered and were removed from the List of Endangered and Threatened Species as of August 8, 2007. Although no longer listed, please be aware that bald eagles are protected under the Bald and Golden Eagle Protection Act (BGEPA) (16 U.S.C. 668 et seq.).

The Service developed the National Bald Eagle Management (NBEM) Guidelines to provide landowners, land managers, and others with information and recommendations to minimize potential project impacts to bald eagles, particularly where such impacts may constitute “disturbance”, which is prohibited by the BGEPA. A copy of the NBEM Guidelines is available at: https://www.fws.gov/migratorybirds/pdf/management/ nationalbaldeaglenanagementguidelines.pdf

Those guidelines recommend: (1) maintaining a specified distance between the activity and the nest (buffer area); (2) maintaining natural areas (preferably forested) between the activity and nest trees (landscape buffers); and (3) avoiding certain activities during the breeding season. Onsite personnel should be informed of the possible presence of nesting bald eagles within the project boundary, and should identify, avoid, and immediately report any such nests to this office. If a bald eagle nest occurs or is discovered within or adjacent to the proposed project area, then an evaluation must be performed to determine whether the project is likely to disturb nesting bald eagles. That evaluation may be conducted on-line at: https://www.fws.gov/ southeast/our-services/eagle-technical-assistance/. Following completion of the evaluation, that website will provide a determination of whether additional consultation is necessary. The Division of Migratory Birds for the Southeast Region of the Service (phone: 404/679-7051, e-mail: SEmigratorybirds@fws.gov) has the lead role in conducting any necessary consultation.

Activities that involve State-designated scenic streams and/or wetlands are regulated by the Louisiana Department of Wildlife and Fisheries and the U.S. Army Corps of Engineers, respectively. We, therefore, recommend that you contact those agencies to determine their interest in proposed projects in these areas.

Activities that would be located within a National Wildlife Refuge are regulated by the refuge staff. We, therefore, recommend that you contact them to determine their interest in proposed projects in these areas.

Additional information on Federal trust species in Louisiana can be obtained from the Louisiana Ecological Services website at: https://www.fws.gov/southeast/lafayette

We appreciate your concern for threatened and endangered species. The Service encourages Federal agencies to include conservation of threatened and endangered species into their project planning to further the purposes of the Act. Please include the Consultation Tracking Number in the header of this letter with any request for consultation or correspondence about your project that you submit to our office.

Attachment(s):

- Official Species List
- USFWS National Wildlife Refuges and Fish Hatcheries
- Marine Mammals

OFFICIAL SPECIES LIST

This list is provided pursuant to Section 7 of the Endangered Species Act, and fulfills the requirement for Federal agencies to "request of the Secretary of the Interior information whether any species which is listed or proposed to be listed may be present in the area of a proposed action".

This species list is provided by:

Louisiana Ecological Services Field Office
200 Dulles Drive
Lafayette, LA 70506
(337) 291-3100

PROJECT SUMMARY

Project Code: 2023-0030784
Project Name: St. Tammany Parish Study
Project Type: Levee / Dike - New Construction
Project Description: The proposed project consists of construction of a levee and floodwall system along an alignment in South and West Slidell, Louisiana and channelization of a portion of the Mile Branch in Covington, Louisiana. Project authorization would occur in the year 2024 and kick-off planning, engineering, and design (PED). PED was originally estimated to be complete by the year 2027. Initial construction of the project would begin 2027 and conclude by the year 2032 (base year).

Project Location:

The approximate location of the project can be viewed in Google Maps: https://www.google.com/maps/@30.347470649999998,-90.05709851555773,14z

Counties: St. Tammany County, Louisiana

ENDANGERED SPECIES ACT SPECIES

There is a total of 9 threatened, endangered, or candidate species on this species list.

Species on this list should be considered in an effects analysis for your project and could include species that exist in another geographic area. For example, certain fish may appear on the species list because a project could affect downstream species.

IPaC does not display listed species or critical habitats under the sole jurisdiction of NOAA Fisheries[1], as USFWS does not have the authority to speak on behalf of NOAA and the Department of Commerce.

See the "Critical habitats" section below for those critical habitats that lie wholly or partially within your project area under this office's jurisdiction. Please contact the designated FWS office if you have questions.

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1. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

MAMMALS

NAME	STATUS
West Indian Manatee *Trichechus manatus* There is **final** critical habitat for this species. Your location does not overlap the critical habitat. ***This species is also protected by the Marine Mammal Protection Act, and may have additional consultation requirements.*** Species profile: https://ecos.fws.gov/ecp/species/4469	Threatened

BIRDS

NAME	STATUS
Eastern Black Rail *Laterallus jamaicensis ssp. jamaicensis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/10477	Threatened
Red-cockaded Woodpecker *Picoides borealis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7614	Endangered

REPTILES

NAME	STATUS
Alligator Snapping Turtle *Macrochelys temminckii* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/4658	Proposed Threatened
Gopher Tortoise *Gopherus polyphemus* Population: Western DPS No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/6994	Threatened
Ringed Map Turtle *Graptemys oculifera* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/2664	Threatened

FISHES

NAME	STATUS
Gulf Sturgeon *Acipenser oxyrinchus (=oxyrhynchus) desotoi* There is **final** critical habitat for this species. Your location overlaps the critical habitat. Species profile: https://ecos.fws.gov/ecp/species/651	Threatened

INSECTS

NAME	STATUS
Monarch Butterfly *Danaus plexippus* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/9743	Candidate

FERNS AND ALLIES

NAME	STATUS
Louisiana Quillwort *Isoetes louisianensis* No critical habitat has been designated for this species. Species profile: https://ecos.fws.gov/ecp/species/7756	Endangered

CRITICAL HABITATS

There is 1 critical habitat wholly or partially within your project area under this office's jurisdiction.

NAME	STATUS
Gulf Sturgeon *Acipenser oxyrinchus (=oxyrhynchus) desotoi* https://ecos.fws.gov/ecp/species/651#crithab	Final

USFWS NATIONAL WILDLIFE REFUGE LANDS AND FISH HATCHERIES

Any activity proposed on lands managed by the National Wildlife Refuge system must undergo a 'Compatibility Determination' conducted by the Refuge. Please contact the individual Refuges to discuss any questions or concerns.

The following FWS National Wildlife Refuge Lands and Fish Hatcheries lie fully or partially within your project area:

FACILITY NAME	ACRES
BIG BRANCH MARSH NATIONAL WILDLIFE REFUGE https://www.fws.gov/refuges/profiles/index.cfm?id=43558	19,394.796

MARINE MAMMALS

Marine mammals are protected under the Marine Mammal Protection Act. Some are also protected under the Endangered Species Act[1] and the Convention on International Trade in Endangered Species of Wild Fauna and Flora[2].

The responsibilities for the protection, conservation, and management of marine mammals are shared by the U.S. Fish and Wildlife Service [responsible for otters, walruses, polar bears, manatees, and dugongs] and NOAA Fisheries[3] [responsible for seals, sea lions, whales, dolphins, and porpoises]. Marine mammals under the responsibility of NOAA Fisheries are **not** shown on this list; for additional information on those species please visit the Marine Mammals page of the NOAA Fisheries website.

The Marine Mammal Protection Act prohibits the take of marine mammals and further coordination may be necessary for project evaluation. Please contact the U.S. Fish and Wildlife Service Field Office shown.

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1. The Endangered Species Act (ESA) of 1973.
2. The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a treaty to ensure that international trade in plants and animals does not threaten their survival in the wild.
3. NOAA Fisheries, also known as the National Marine Fisheries Service (NMFS), is an office of the National Oceanic and Atmospheric Administration within the Department of Commerce.

NAME

West Indian Manatee *Trichechus manatus*

Species profile: https://ecos.fws.gov/ecp/species/4469

IPAC USER CONTACT INFORMATION

Agency: Army Corps of Engineers
Name: Kristin Gunning
Address: 7400 Leake Ave
City: New Orleans
State: LA
Zip: 70118
Email kristin.t.gunning@usace.army.mil
Phone: 5048621514

Gunning, Kristin T MVN

From: Soileau, Karen <karen_soileau@fws.gov>
Sent: Tuesday, April 25, 2023 12:25 PM
To: Gunning, Kristin T MVN
Subject: [Non-DoD Source] Re: [EXTERNAL] Biological Assessment for St. Tammany SEIS

Hey Kristen,

For the threatened and endangered listed species we should address:

- West Indian manatee
- Louisiana quillwort
- Gulf sturgeon
- gopher tortoise
- RCW

We do not have any reports of black rails within the proposed project area. This species is known to occur in the Gulf Coast Chenier Plain of Louisiana (specifically Cameron and Vermilion Parishes); therefore, a "no affect" determination can be made for this species.

The Louisiana quillwort grows on sand and gravel bars on the accreting sides of streams and moist overflow channels within riparian forest and bay head swamp communities. We do not have suitable habitat in Mile Branch; therefore, a survey is not needed.

Gulf sturgeon - the proposed project does not occur within Gulf sturgeon critical habitat; however, potential impacts to the species should be addressed.

AST - proposed species are not protected by the take prohibitions of section 9 of the ESA until the rule to list is finalized. Under section 7(a)(4) of the ESA, Federal agencies must confer with the Service if their action will jeopardize the continued existence of a proposed species. Because of the scale of the project relative to the range of this species and the availability of suitable habitat a conference is not necessary. I am going into the office tomorrow, I'll get with our AST biologist to ask about minimization features for this species.

Monarch - candidate species receive no statutory protection under the ESA. I'll check tomorrow to see if there are any minimization features that we recommend for this species.

Let me know if you have any additional questions and I'll be back in touch with you tomorrow.

Thanks,

Karen Soileau
Fish and Wildlife Biologist
U.S. Fish and Wildlife Service
200 Dulles Drive
Lafayette, La 70506
Office: 337/291-3132

From: Gunning, Kristin T MVN <Kristin.T.Gunning@usace.army.mil>
Sent: Tuesday, April 25, 2023 10:57 AM
To: Soileau, Karen <karen_soileau@fws.gov>
Subject: [EXTERNAL] Biological Assessment for St. Tammany SEIS

This email has been received from outside of DOI - Use caution before clicking on links, opening attachments, or responding.

Hi Karen,

I'm finishing up the BA for this St. Tammany project and I was hoping you could provide some guidance on a few things before I submit. I've included the project description, a KMZ of the proposed alignment, and the official species list for your reference. Listed species in the project area include:

- West Indian Manatee – Threatened
- Eastern Black Rail – Threatened
- RCW – Endangered
- Alligator Snapping Turtle – Proposed Threatened
- Gopher Tortoise – Threatened
- Ringed Map Turtle – Threatened
- Gulf Sturgeon – Threatened
- Monarch Butterfly – Candidate
- Louisiana Quillwort – Endangered
- Gulf Sturgeon CH

Do I need to consult on proposed threatened of candidate species? If so, does the service have any recommendations/requirements to minimize and/or avoid impacts to ASTs or monarchs?

From the map on IPaC, it appears that the Louisiana quillwort occurs in the area where the Mile Branch channelization will be occurring. Based on the Recovery Plan for the quillwort, this action has the potential to adversely affect the species. Do you know if any surveys for the presence of the quillwort have been done in the area and are there any recommendations/requirements that need to be implemented to reduce impacts on the species?

Thanks,

Kristin Gunning
Biologist, Environmental Studies Section
Regional Environmental Planning Division, South
USACE, New Orleans District

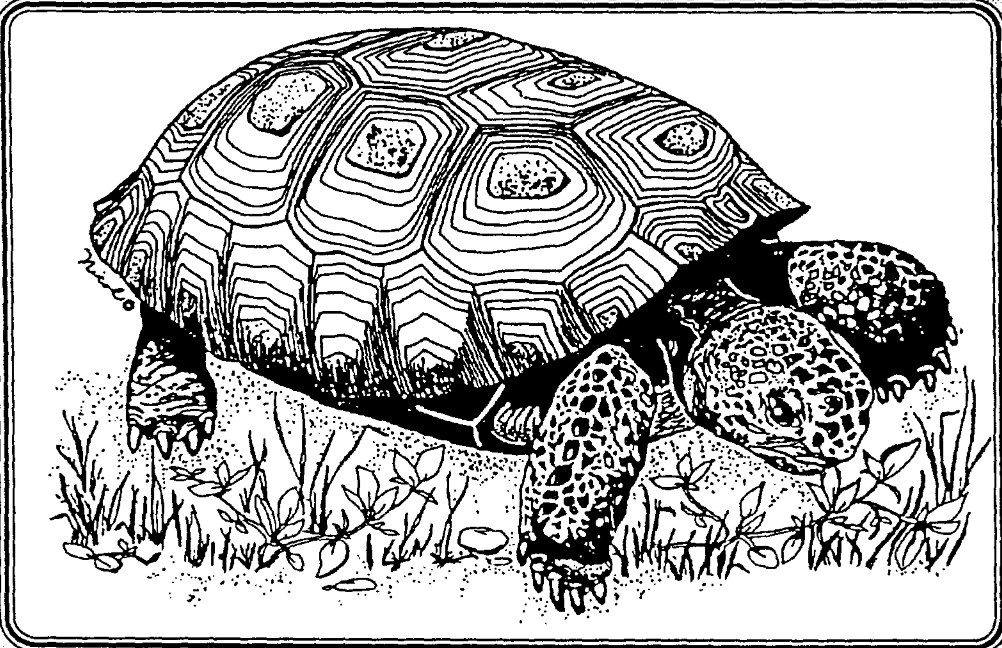
Appendix C Species Recovery Plans and Status Assessment Reports

Appendix C-1: Gopher Tortoise Recovery Plan and Species Status Assessment Report

Gopher Tortoise

(*Gopherus polyphemus*)

Recovery Plan



U.S. FISH AND WILDLIFE SERVICE
Southeast Region, Atlanta, Georgia

GOPHER TORTOISE

Gopherus polyphemus

RECOVERY PLAN

Prepared by
Wendell A. Neal
U.S. Fish and Wildlife Service

for

Southeast Region
U.S. Fish and Wildlife Service
Atlanta, Georgia

Approved: ______________________________
Regional Director, U.S. Fish and Wildlife Service

Date: December 26, 1990

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the listed species. Plans are prepared by the U.S. Fish and Wildlife Service, sometimes with the assistance of recovery teams, contractors, State agencies, and others. Objectives will only be attained and funds expended contingent upon appropriations, priorities, and other budgetary constraints. Recovery plans do not necessarily represent the views nor the official positions or approvals of any individuals or agencies, other than the U.S. Fish and Wildlife Service, involved in the plan formulation. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director or Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species' status, and the completion of recovery tasks.

Literature Citations should read as follows:

U.S. Fish and Wildlife Service. 1990. Gopher Tortoise Recovery Plan. U.S. Fish and Wildlife Service, Jackson, Mississippi. 28 pp.

ADDITIONAL COPIES MAY BE PURCHASED FROM:

Fish and Wildlife Reference Service:
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814

301/492-6403 or
1/800/582-3421

The fee for the plan varies depending on the number of pages.

ACKNOWLEDGEMENTS

Ed Wester of Auburn University circulated this plan among knowledgeable persons on the Gopher Tortoise Council for review. Robert H. Mount, Professor Emeritus, Auburn University; Joan Diemer of the Florida Game and Fresh Water Fish Commission and Ren Lohoefener of the U.S. Fish and Wildlife Service are gratefully acknowledged for making significant contributions to the development of this plan.

The U.S. Fish and Wildlife Service thanks Ellen Nicol, an artist, writer, and reptile breeder from Anthony, Florida, for the cover sketch.

EXECUTIVE SUMMARY

<u>Current Status:</u> The western population of the gopher tortoise is listed as threatened. This population lies west of the Tombigbee and Mobile Rivers in Alabama, across south Mississippi and including extreme southeastern Louisiana. Threats include habitat alterations and illegal taking.

<u>Habitat Requirements and Limiting Factors:</u> The species is found on droughty, deep sand ridges which originally supported longleaf pine and patches of scrub oak. The most significant threats to the species are adverse habitat alteration, taking, and development of occupied habitats.

<u>Recovery Objective:</u> The two objectives of this plan consist of an immediate objective which is prevention of the listed population from becoming endangered and a long-term objective which is delisting.

<u>Recovery Criteria:</u> The necessary criteria for the above objectives are:

(1) Successful prevention of endangered status would be considered by evidence of an average of 5 gopher tortoise burrows per hectare (ha) on deep sandy soils (1.52 meters(+)) for a period of 30 years on the DeSoto National Forest. This would equate to an estimated population of 22,400 gopher tortoises on 7,343 ha of suitable habitat.

(2) For delisting, evidence is required of an average of 3 gopher tortoise burrows per ha on deep sandy soils (1.52 meters(+)) on private lands. This would equate to an estimated population of 34,000 gopher tortoises on 18,594 ha on privately-owned lands.

<u>Actions Needed:</u>

(1) Survey, monitor and assess status of populations as baseline for recovery actions.
(2) Protect and manage habitat on Federal lands.
(3) Encourage management of populations on private lands.
(4) Develop law enforcement strategy to curb illegal taking.
(5) Conduct population viability studies.
(6) Conduct telemetry studies to determine extent of reproductive isolation as a threat.
(7) Conduct genetic studies.
(8) Relocate threatened isolated individuals/colonies to protected and managed lands.

Total Estimated Costs of Recovery: Implementation of the recovery tasks for which cost estimates have been made total $433,000.00.

Date of Recovery: Unable to determine at this time due to the unknown response of the gopher tortoise population to improved management activities.

TABLE OF CONTENTS

I. INTRODUCTION

A. Background

The gopher tortoise (Gopherus polyphemus) is the only tortoise indigenous to the southeastern United States. It is found in varying numbers in xeric sandy habitats from South Carolina through Florida and west to extreme southeastern Louisiana. Within xeric sandy habitats, the range of G. polyphemus nearly coincides with the original range of the longleaf pine (Pinus palustris).

On July 18, 1984, Drs. Ren Lohoefener and Lynn Lohmeier petitioned the U.S. Fish and Wildlife Service to list the population of G. polyphemus west of the Tombigbee and Mobile Rivers under provisions of the Endangered Species Act. The petition and accompanying report (Lohoefener and Lohmeier 1984) presented substantial information on numbers and distribution of the western population. The Fish and Wildlife Service reviewed the petitioned action and on July 7, 1987, listed the western population as threatened under the Endangered Species Act (52 FR 25376-25380).

The basic biology of the tortoise has been reasonably well documented, although many specific details remain unknown. Many biological parameters for this species vary considerably, including: age (or size) at sexual maturity, clutch size, growth rates, phenological characteristics, burrow depths, specific food habits, and others (Diemer 1986). Biological information on G. polyphemus mostly originates from Georgia and Florida. This plan draws primarily from the research in Georgia by Landers and Buckner (1981) since their study sites are more similar to the western population (by latitude) than to populations in Florida. This recovery plan is aimed specifically at the western population, but of necessity relies greatly upon data sources and expertise developed elsewhere.

B. Description and Taxonomy

Gopherus polyphemus (Testudines, Testudinidae), described in 1802 by F.M. Daudin, is the only Gopherus in the southeastern United States. The gopher tortoise has a large shell, 15-37 centimeters (cm) (5.9-14.6 inches) long. It is a dark-brown to grayish-black terrestrial turtle with elephantine hind feet, shovel-like forefeet, and a gular projection beneath the head on the yellowish, hingeless plastron or undershell (Ernst and Barbour 1972). Gopher tortoise hatchlings are yellowish-orange, have a soft shell, and are 4-5 cm (1.5-2.0 inches) long at hatching.

Gopherus polyphemus is sexually dimorphic. In most cases, the sex of adults can be determined by shell dimensions. The male has a greater degree of plastral (lower shell) concavity, and a longer gular projection. However, the sex of tortoises around the size of maturity can be almost impossible to assess.

C. Life History and Ecology

Distribution

Historically, the western population was found in the longleaf pine hills of northern Mobile, Washington, and southeastern Choctaw Counties in Alabama; in the southeastern upland areas of the pinehills province in Mississippi (a 14-county area); and in the upland pine ridges in St. Tammany, Washington, and Tangipahoa Parishes, Louisiana (Lohoefener and Lohmeier 1984) (Figure 1). The amount of gopher tortoise habitat, as defined by Lohoefener and Lohmeier (1984), for the listed population by State is as follows: southwestern Alabama - 40,770 hectares (ha) or 100,741 acres (A); Louisiana - 4,815 ha or 11,898 A; and Mississippi - 102,084 ha or 252,246 A. The entire western population is found within the original range of the longleaf pine.

Habitat

Gopher tortoises occupy a wide range of upland habitat types; however, general physical and biotic features provided by Landers (1980) with slight modifications, characterize most suitable habitat. These are:

1. the presence of well-drained, sandy soils, which allow easy burrowing (because of lower ambient temperatures, the western population may require a meter or more of sandy soil depths);

2. an abundance of herbaceous ground cover; and

3. a generally open canopy and sparse shrub cover, which allow sunlight to reach the forest floor.

Juvenile habitat is generally considered to be similar to that of adults.

The traditional habitats of the western population of gopher tortoises are natural xeric communities, mostly of the longleaf-pine-scrub oak type, located on sand ridges. The original ecology of these xeric, fire-dependent communities has been significantly altered. Gopher tortoises may also be found in ruderal habitats such as fence rows, pastures, and field edges and power lines.

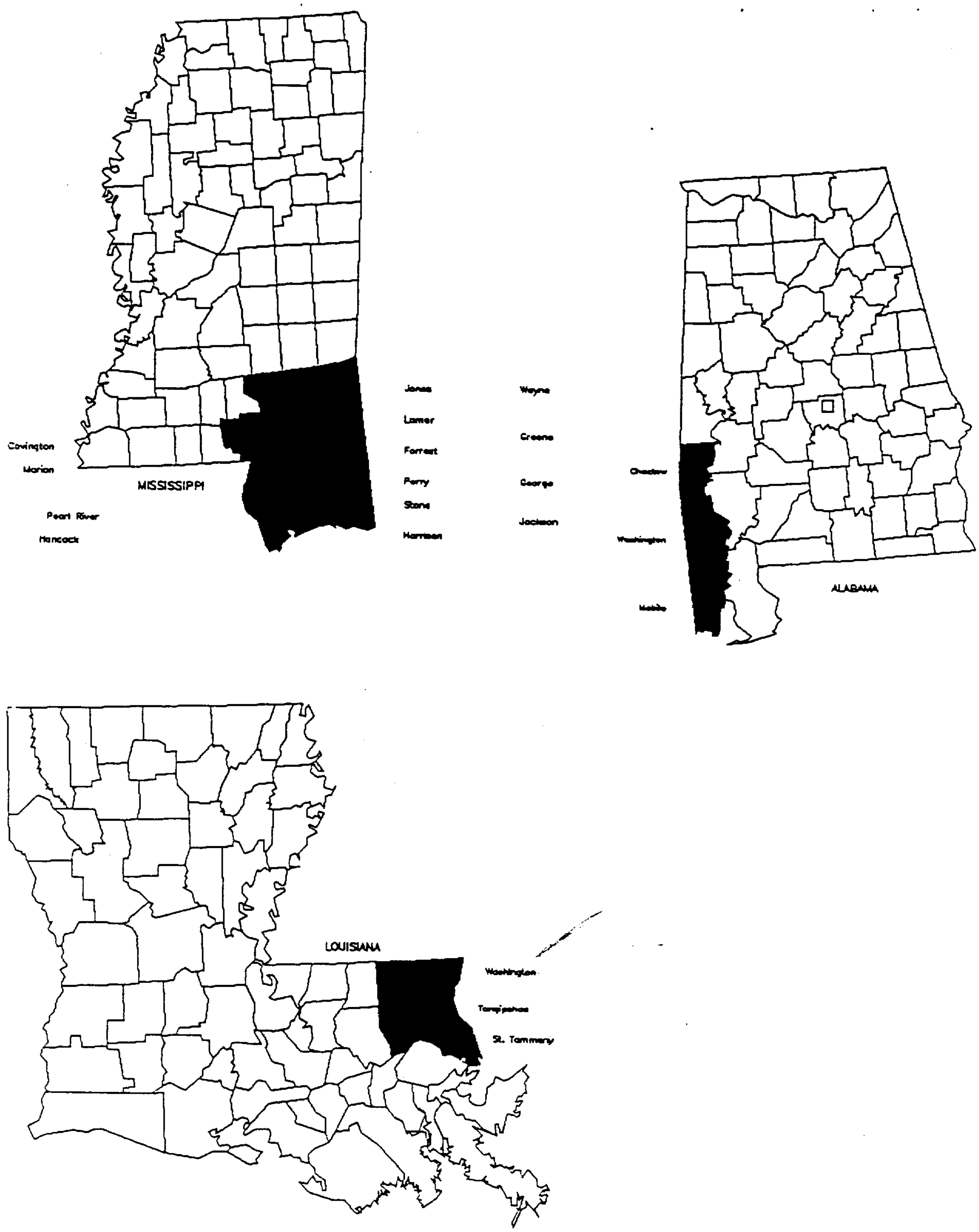


Figure 1. Range of Western Population of the Gopher Tortoise.

Soil conditions are responsible for the xerophytic nature of gopher tortoise habitats. Auffenberg and Iverson (1979) report a positive correlation between the amount of herbaceous ground cover and tortoise density, with grasses, grass-like plants and legumes being the most important food plants (Garner and Landers 1981). The amount and kind of low growing (within reach of a gopher tortoise) herbaceous plants may be a function of many variables, including timber age, density and species composition, burning history, nature and timing of past soil disturbance, and inherent soil fertility.

A relatively open canopy is necessary not only for herbaceous food plants but also for egg incubation. The female gopher tortoise selects a bare spot for nest excavation, normally in the mound of excavated sand at the burrow entrance. Landers and Buckner (1981) noted that when overstory overshadowed the burrow entrance, nests were selected in openings such as firelanes or roadsides.

The burrow is the focal point of many above ground activities and a major portion of the gopher tortoise's life is spent in the burrow. Most burrows have a single entrance, and adult burrows average about 4.5 meters (m) (15 feet) in length with a depth of 1.8 m (6 feet) (Hansen 1963). Small juveniles use similarly small burrows, often as shallow as a few inches. Single tortoises often excavate more than one burrow. Lohoefener and Lohmeier (1984) reported a correction factor of 0.625 in Mississippi for converting burrows counted to burrows occupied. The burrow provides protection from fire, predators, and climatic extremes, and habitat for a host of unique species. Jackson and Milstrey (1989) reported more than 60 vertebrate and 302 invertebrates species using gopher tortoise burrows. Some of the more commonly known burrow associates include the eastern diamondback rattlesnake (*Crotalus adamanteus*), the gopher frog (*Rana areolata*), and the eastern indigo snake (*Drymarchon corais couperi*).

Longevity and Reproduction

Longevity is estimated at 40-60 years (Landers 1980) and may extend to 80-100 years (Landers *et al*. 1982). Growth annuli on scutes become worn at 20-40 years, making age determination imprecise. Age at sexual maturity in the Georgia study (Landers *et al*. 1982) ranged from 19-21 years for females. These animals had a plastral length of 25-26.5 cm (9.8-10.4 inches). Males normally reach reproductive maturity at a smaller size and younger age than females. Growth rates vary with environmental and genetic factors among gopher tortoise populations.

Breeding periods may begin as early as February and extend into September, depending on location. The period of maximum reproductive activity reported by Landers et al. (1980) is May 18 through June 27. Iverson (1980) reported the nesting peak in Florida also to be May and June. Clutch sizes in Mississippi average 4.8 eggs (Lohoefener and Lohmeier 1984); however, this report was based on a rather small sample (N=14). Landers et al. (1980) reported a range in clutch size of 4-12 eggs with a mean and SD of 7.0 ± 1.7. He also found that clutch size increased with the size of the female. The lower value reported by Lohoefener and Lohmeier (1984) may have been due to limited sampling, the result of human depredation (leaving primarily smaller nesting females), or a combination of both. The nest is usually 15-25 cm (6-10 inches) beneath the surface (Landers et al. 1980). Incubation periods range from 80-90 days in northern Florida (Iverson 1980) to 110 days in South Carolina, the northern limit of the gopher tortoise's range (Wright 1982). Most gopher tortoise eggs never hatch because of predation.

Food

The gopher tortoise is the primary grazer in its xeric habitats (Landers 1980) and aids in seed dispersal for native grasses (Auffenberg 1966). Observations and studies of food habits come mainly from Georgia and Florida where wiregrass (Aristida stricta) is often considered an important food plant and is a common member of the longleaf-scrub oak community. However, in western parts of the coastal plain, bluestem grasses (Andropogon) are often the most common herbaceous species in mature longleaf pine forests (Wahlenberg 1946). Lohoefener and Lohmeier (1981) observed tortoises in Mississippi eating crabgrass (Digitaria sanguinalis) and panic grasses (Panicum). Garner and Landers (1981) found that broad-leaved grasses were staple foods while wiregrass was used mainly in early spring and summer. Their study also showed that wild legumes (Fabaceae), which are high in protein, were used extensively by juveniles. Garner and Landers (1981) also found that fleshy fruits were readily consumed, including blackberry (Rubus cunefolius), sloeplum (Prunus umbellata), blueberry (Vaccinium), maypop (Passiflora lutea), and hawthorne (Crataegus). Regardless of the specific plants available for forage, the conclusion reached by Garner and Landers (1981) that "grasses, grass-like plants and legumes are the most important food plants and evidently determine carrying capacity" is likely a statement equally applicable to the western population.

Activity/Movement

McRae et al. (1981) found activity to be very restricted during winter months. In fact, from late November through February, feeding activity was observed only five times. On unusually warm winter days when maximum temperature exceeded 26° Celsius (C) or 79° Fahrenheit (F), tortoises were occasionally observed at the burrow entrance (McRae et al. 1981). No crepuscular or nocturnal activity is reported. As temperatures rose during the spring (March and April), outside burrow activity was most often observed in the Georgia study during the warmest part of the day, 1600-1800h (hours). During July and August, McRae et al. (1981) found a bimodal movement pattern, the feeding forays peaking at mid-morning (1000-1200h) and mid-afternoon (1600-1800h), with much reduced activity during the hottest part of the day, 1300-1500h. They concluded that "activity throughout the year was correlated with ambient temperature; movement from the burrow was rare at coolest temperatures (<22° C or 72° F), was greatest at 28 to 31° C (82 to 88° F), and was curtailed at >32° C (90° F)."

Adult Movements

McRae et al. (1981) studied movement related to feeding separately from movements related to other behavior and determined 95 percent of all feeding activity took place within 30 m (33 yards) of the burrow being used. Auffenberg and Iverson (1979) reported increasing foraging radii from the burrow in areas with reduced ground cover. This suggests that food availability can increase or decrease foraging distances. McRae et al. (1981) trailed 13 adults and determined their movements to be in a nearly circular or elliptical pattern around the burrow. Depletion of preferred foods near burrows by late summer is thought to contribute to larger movements later in the year. In the Georgia study, the home ranges of males were much larger than females; males had a home range of 0.06-1.44 ha (0.14-3.56 A) with a mean of 0.47 ha (1.16 A), while females had a home range of 0.04-0.14 ha (0.10-0.35 A) with a mean of 0.08 ha (0.20 A) (McRae et al. 1981). The sexual differences are attributed to breeding forays by the males. Landers and Speake (1980) found the average colony typically used an area less than 4 ha (9.88 A).

Behavior

Gopher tortoises have a well-developed social structure, courtship, and territorial combat (Auffenberg 1966, Douglass 1976, McRae et al. 1981). Males bob their heads to attract females during the breeding season. The speed and amplitude of the head bobbing increases as the male draws closer to a reproductively active female, and the first contact between individuals consists of males biting females on the forelimbs and around the gular area, perhaps seeking olfactory cues (Auffenberg 1966). When males confront each other, there is usually some manifestation of dominance or submissive behavior. According to McRae et al. (1981), there is a dominance hierarchy in males based on size. In dense populations, smaller males are found around the colony's periphery rather than in the middle, close to the breeding females, as is the case with larger males.

D. Threats and Causes for Decline

Habitat Alteration

An understanding of the reasons behind the threatened status of G. polyphemus is perhaps the most essential step in developing this recovery plan. The gopher tortoise, historically and currently, is a component of xeric plant communities originally identified mostly by the occurrence of longleaf pine. The changes altering the original longleaf pine communities also changed the ecosystem of the gopher tortoise. This species was an animal of these forests, and to the extent maintenance of the listed population is possible, that goal is inextricably tied to forestland conditions.

Before the arrival of European colonists in the New World, the longleaf pine was the principal tree species on southeastern coastal plain upland soils. Croker (1987) cites 60 million acres in the original stands which he concludes are now reduced to about 4 million acres. After the red and white pine forests of New England and the Great Lake States were cut, lumbermen turned to the virgin longleaf stands, the mining of which peaked in 1909 (Croker 1987). Power skidders and railroad logging supported these final assaults.

Second growth longleaf pine stands came from the ruins of timber mining operations, but these second forests constituted a small fraction of the area of virgin stands. Because of planting difficulties with the longleaf pine, these droughty sites were often planted in slash (P. elliottii) and loblolly (P. taeda) pines. This practice, along with excessive burning intervals and intensive site preparation methods, continues on soils which originally supported longleaf pine.

Artificial planting of longleaf is now successful and many foresters are rediscovering the valuable traits of longleaf pine, including the fact that it can be successfully regenerated naturally through a shelterwood system of cutting combined with burning just in advance of an adequate seed fall. The U.S. Forest Service recently has adopted a practice of regenerating only longleaf pines on longleaf sites in the DeSoto National Forest. However, the agency's preferred method is by planting. Most private landowners continue to regenerate longleaf pine sites to off-site species.

The original longleaf pine community burned and reseeded naturally. It contained trees of many ages and a diverse ground cover with much edge, which would be of particular importance to the gopher tortoise. Landers and Speake (1980) found better gopher tortoise densities in longleaf pine - scrub oak stands that were thinned and burned every 2-4 years. Slash pine plantations, with a similar system of thinning and burning, had sparser population densities. While it is apparent that gopher tortoises can be maintained under a modified (heavily thinned, frequently burned) plantation system of management, Landers and Buckner (1981) showed that gopher tortoise densities are significantly greater (32 percent) in more naturally managed stands of longleaf.

The natural longleaf pine community and its associated biological diversity represent optimal forest habitat for the gopher tortoise. This community occurred in pure stands, constantly trending toward small even-aged groups of a few hundred square feet (Chapman 1909). Larger even-aged patches and strips were found following blowdowns from severe weather. These were often interspersed with patches or single survivors, creating open glades and a patchiness which favored the gopher tortoise. Management practices which alter this system include: clearcuts of large blocks (including the crowded planting of off-site species), diversity-diminishing soil churning activities that often accompany even-aged timber management, and prolonged burning intervals. Timber practices that most nearly mirror the natural system, such as a shelterwood regeneration system with frequent burning and natural regeneration, improve the soil and herbaceous cover condition to optimally support the gopher tortoise.

Longleaf pine trees, as well as fire-dependent annuals and perennials, originally existed in a summer burning cycle which has long since been interrupted. The change in fire frequency and timing may be the single most important factor influencing other alterations which have changed the original xeric communities. For example, it has been a common practice to remove most of the longleaf pines from these dry ridges and then to exclude fire (or at least fail to burn). This allows eventual occupancy by poor site oaks (Quercus laevis, Q. incana, Q. marilandica, and Q. margaretta) and woody shrubs such as yaupon (Ilex vomitoria) and gallberry (I. glabra). When the leaf litter from oaks becomes a thick mat, it retards fires that would otherwise be carried by longleaf pine needles and the common grass associates under the open longleaf pine canopy. Fire exclusion allows the oaks to mature and shade out herbaceous ground cover needed by gopher tortoises. This situation is not uncommon throughout the range of the gopher tortoise. Landers and Speake (1980) provided substantial evidence that these altered sites originally were good gopher tortoise habitat but now support the fewest gopher tortoises.

Hedrick and Zimmermann (1988) monitored gopher tortoise densities in various forest types and classes for a two-year period on the Conecuh National Forest in Alabama. Their unpublished data indicate gopher tortoise densities through three stand conditions (seedling/sapling stands, pole stands, and sawtimber stands). Gopher density was greatest (1 active burrow/1.51 ha or 3.73 A) in the seedling/sapling stands, greatly reduced (200 percent) in pole stands (1 active burrow/3.10 ha or 7.66 A) and followed by a large recovery (177 percent) in sawtimber (1 active burrow/1.75 ha or 4.32 A).

The current threats to the western population of the gopher tortoise in terms of habitat loss or degradation consist of certain forest management practices, conversion of dry sites to agriculture, road placement and other developments on these higher ridges, and urbanization (Lohoefener and Lohmeier 1984).

Predation

The gopher tortoise was a significant food source during the Great Depression, as reflected in the name "Hoover Chicken" (Hutt 1967). Gopher pulling removes an average of 20 percent of the larger tortoises, according to Taylor (1982). The taking of gopher tortoises by pulling (use of a long flexible rod with a hook) remains a cultural ethos in rural areas where the western population is found. The gopher tortoise's low reproductive rate, high mortality of eggs and young, slow growth to sexual maturity, and long life indicate a K-selected strategy adapting to xeric communities (Landers 1980). Annual population growth may only be 3-5 percent (Landers et al. 1980); accordingly, human predation on mature adults may produce long term adverse effects which are difficult to overcome. Because many gopher tortoises exist in degraded or declining habitats and populations are often fragmented, the adverse effects of even limited taking may be exacerbated. Lohoefener and Lohmeier (1984) report a significant number of Mississippi gopher tortoises being taken for pets.

Gopher tortoise predators, other than human beings, are many. The most important egg and hatchling predator appears to be the raccoon (Procyon lotor) (Landers and Speake 1980); however, a variety of mammals are reported predators of G. polyphemus, including gray foxes (Urocyon cinereoargenteus), striped skunks (Mephitis mephitis), opossums (Didelphis virginiana), armadillos (Dasypus novemcinctus) (Landers et al. 1980), and dogs (Canis domesticus) (Causey and Cude 1978). Imported fire ants (Solenopsis saevissima and/or S. victa) are reported as hatchling predators (Landers et al. 1980, Lohoefener and Lohmeier 1984). Snakes and raptors have also been reported as preying on G. polyphemus. Reported clutch and hatchling losses often approach 90 percent (Landers et al. 1980).

Other Mortality

Road mortality is reported by Landers and Buckner (1981) and Lohoefener and Lohmeier (1984) as a significant mortality factor. Lohoefener and Lohmeier (1984) believe nests and juveniles are often destroyed by intensive site preparation (heavy equipment). Tanner and Terry (1981) report a major reduction in burrow density in Florida which was believed attributable to roller chopping or web plowing. Diemer and Moler (1982) demonstrated that tortoises are able to dig out following chopping treatment on deep sandy soils, but concluded that additional data were needed regarding tortoise response to various site preparation techniques in different soil types.

Lohoefener and Lohmeier (1981) believed that a serious problem for the Mississippi gopher tortoise was isolation of sexually mature animals because of habitat fragmentation aggravated by forest management practices. Only 14 percent of the tortoises encountered in density survey transects by Lohoefener and Lohmeier (1981) in Mississippi were considered so situated that interactions with other sizeable (sexually mature) tortoises might occur. As further support for this hypothesis, the discontinuous nature and small size of Mississippi sand ridges, which are often separated by streams or wet boggy areas, may serve as impediments to courtship travels of adult males (Lohoefener and Lohmeier 1984).

Population Viability

Local populations of the western gopher tortoise can in theory become extirpated through chance events and these extirpations (and thus more rangewide extirpations) are inversely related to population size. Shaffer (1981) cites four sources of uncertainty to which a population may be subject: (1) demographic stochasticity, which arises from chance events in the survival and reproductive success of a finite number of individuals; (2) environmental stochasticity due to temporal variation of habitat parameters and the populations of competitors, predators, parasites, and diseases; (3) natural catastrophes, such as floods, fires, and droughts, which may occur at random intervals through time; and (4) genetic stochasticity resulting from changes in genetic frequencies due to founder effect, random fixation, or inbreeding. Based on the concern expressed by Lohoefener and Lohmeier (1984) regarding reproductive isolation, genetic drift and inbreeding may already be occurring.

Recovery, therefore, must consider population viability in establishing both the objectives and the procedures for meeting those objectives.

II: RECOVERY

A. Biological Perspective

The listed population of *G. polyphemus* could be considered relatively abundant. Lohoefener and Lohmeier (1984) estimated 10,923 tortoises of >23 cm (9.1 inches) carapace length (CL) in 102,084 ha (252,246 A) of Mississippi habitat; and 12,900 tortoises >23cm (9.1 inches) CL were estimated to occur in 40,370 ha (99,753 A) of Alabama habitat west of the Tombigbee and Mobile Rivers. However, the species is nearing extinction in an estimated 4,815 ha (11,898 A) of Louisiana habitat. About 80 percent (121,000 ha) of the available habitat occurs on corporately-owned lands.

Despite the relatively large number of extant individuals estimated, the long-term prospects for survival of the western population are dimming. In view of past, current, and predicted forest management practices, continued illegal taking, development on dry uplands, and private ownership of much of the gopher tortoise's habitat, this species is truly threatened in the western portion of its range. According to Donner and Hines (1987), timberland ownership in south Mississippi is mostly private (85 percent belonging to individuals, the forest industry and corporations, 11 percent belonging to the Federal government, with the remainder in State or county ownership).

Section 7 of the Endangered Species Act requires Federal agencies to insure that their actions do not jeopardize the continued existence of listed species. Beyond the jeopardy prohibition, Section 7 requires Federal agencies to use their authorities to further the purpose of the Act. The essential purpose of the Act is conservation of listed species. Section 7 is limited in scope to Federal actions. Thus, the role of Section 7 in recovery of this species will be limited because the majority of habitat is in non-Federal ownership. However, any advice given by Federal foresters or soil scientists to manage forests on state, local, and private lands is also subject to Section 7. Outside of Section 7, the Act may serve in protection, and therefore, possibly contribute to recovery, through exposure of certain activities under Section 9 (prohibition of take).

Through consultations with Federal landowners, it is expected that forest management practices will be designed to contribute significantly to recovery on these lands. However, because Federal ownership is comparatively small, rangewide recovery for this population requires significant success on privately-owned lands as well. Examples of such activities can be found in Mount *et al.* (1988).

Unfortunately, among private timberland owners, there are perceived problems with longleaf pine, its growth, value, and availability of seed stock. Individual small landowners often high grade their longleaf stands with little forethought to long-term timber production; they then exclude fire, thus creating a situation where the longleaf pine sites convert to scrub oak stands. If these landowners decide to regenerate, they will most often, on the advice of foresters, choose the off-site slash or loblolly. Such advice from Federal foresters or foresters supported by Federal monies should be subject to Section 7 consultation. The corporate or industrial landowner usually farms these sandy sites by clearcutting, replanting to off-site species, and starting over with the same practices at a 25-35 year rotation, devoting little attention between planting and harvest. These management policies, along with intensive site preparation, thick planting rates, and fire exclusion continue to threaten the existence of the western population.

B. Recovery Objectives

The immediate recovery objective is to prevent the western population from becoming an endangered species. To achieve this, the species' overall status must be stabilized or enhanced. Lohoefener et al. (in review) considers three to seven burrows per hectare as representing a recovered population density for a land unit the size of DeSoto National Forest. The upland forested habitat expected to support this density is likely underlain by Lakeland, Troup, or one of the more rarely encountered deep, sandy soils in excess of 1.52 meters (5 feet). On the Desoto National Forest, these soils are estimated to comprise 7,343 ha (18,144 A) (Arnold 1989). The best hope for recovery of the gopher tortoise is on these 7,343 ha of deep sands that represent original sandhill communities [and potentially provide the best chance for a large block of contiguous habitat being made available to gopher tortoises]. A range of three to seven burrows per ha = 22,029-51,401 x 0.61 (correction factor of tortoises per burrow) = 13,437-31,354 gopher tortoises. If a mid-range density of five gopher tortoise burrows per ha (approximately equating to a total of 22,400 gopher tortoises]) is accomplished on the Desoto National Forest, and maintained for a period of 30 years, the immediate goal of preventing the listed population from becoming endangered would be reached. Although little is known about the rates of gopher tortoise recruitment and present age-class distribution, this recovery objective assumes that once the stated density is maintained for 30 years that the recruitment rate is adequate for short-term stability.

A long-term objective, that of recovery to the point of no longer requiring protection of the Act, requires significant successes on the privately-owned lands having these deep sand ridges. Within the range of the western population, on private land, there are approximately 18,594 ha (45,945 A) of what originally constituted sandhill communities. Attaining the lower range of the recovery density for deep sands based on Lohoefener et al. (in review) would mean three burrows per ha (18,594 x 3 x 0.61) = (approximately 34,000 gopher tortoises on privately owned forested deep sands. To measure these goals, some form of survey is necessary and must be comparable to the original statistically derived estimate (Lohoefener and Lohmeier 1984).

C. Narrative Outline

1. Survey, monitor, and assess the status of populations. The original survey work by Lohoefener and Lohmeier (1984) needs to be updated to monitor status. There remains controversy about the abundance of the gopher tortoise. A survey will clarify the tortoise's status; moreover, it will provide an essential baseline for measuring the effectiveness of recovery activities. Surveys should also attempt to determine recruitment rates and age-class distribution, if possible.

1.1 Survey gopher tortoise populations on Federal and other public lands not previously surveyed. Baseline surveys will be necessary to track the effectiveness of habitat management.

1.1.1 Conduct status surveys on Camp Shelby. This requirement is incorporated into Section 7 compliance.

1.1.2 Conduct status surveys on DeSoto National Forest. This requirement is incorporated into Section 7 compliance.

1.1.3 Conduct surveys on State-owned Parklands, Wildlife Management Areas and 16th Section School lands. Colonies on public lands offer possibilities for conservation unavailable on private lands.

1.2 <u>Conduct rangewide surveys at 5-year intervals on public and private land.</u> This is necessary to determine the effectiveness of recovery activities. Surveys must be comparable by technique to existing data (Lohoefener and Lohmeier 1984), repeatable, and carried out during the same month because tortoise movements and burrow use may vary monthly.

1.2.1 <u>Assess the status of individual populations and of the species rangewide.</u> The goal of the recovery plan is to eliminate factors detrimental to the survival and recovery of the gopher tortoise. As data are acquired, the status of populations throughout the range will be reviewed and assessed as appropriate.

2. <u>Implement protection and management of habitat on Federal lands.</u> The principal threats on Federal lands, specifically the DeSoto National Forest, have been: (1) adverse timber management practices on the high, dry ridges where gopher tortoises occur, and (2) the military use of about 136,000 acres. These threats are being addressed through Section 7 consultation involving both Camp Shelby's land-altering activities and a habitat management plan by the Forest Service. The review of these actions will be an ongoing activity.

2.1 <u>Protect and manage all existing gopher tortoise colonies.</u> The colony sites on Camp Shelby will be protected either by staking burrows with steel posts or by fencing the colony site. For management purposes, a gopher colony is defined as three or more active adult burrows ($\geq$9 inches in width) within 300 feet of each other, or any combination of active adult and active hatchling/sub-adult burrows within 100 yards of each other; the colony site is defined as the active burrows making up a colony plus a 200-foot buffer around them.

Timber stands on Federal lands, where a colony is located, will be managed primarily for the gopher tortoise. Such management considerations will address: canopy closure in the stand, mid-story management, regeneration and site-preparation, planting rates, thinnings, burning and/or chemical treatment of hardwoods for colony site reclamation, and scheduling of harvest to avoid disturbance during nesting periods.

2.2 Manage habitat for present and future expansion. In order to reverse declines in gopher tortoise populations, it will be necessary to manage for optimum habitat conditions on some part of Federal ownerships. The Camp Shelby Section 7 consultation has resulted in the establishment of a 2,200-acre gopher refuge where military use is restricted and forest management is aimed at achieving and maintaining optimal habitat conditions.

2.3 Assess adequacy of established and proposed management plans. This is a continuous task accomplished largely through Section 7 of the Endangered Species Act. All Federal agencies must review their established and proposed programs, and for those that may affect the species, initiate consultation with the Fish and Wildlife Service. The Service will then review the action and prepare a biological opinion which addresses the likelihood of jeopardy to the continued existence of the species if the action is carried out. If jeopardy is likely, alternatives to remove jeopardy are presented in the opinion. All management programs for the species represent a "may affect" situation requiring consultation.

3. Encourage protection and management on private lands. Private lands contain the vast majority of forest possibly containing gopher tortoises. Accordingly, maintenance of the population is not possible without some significant successes on privately-owned timberlands. Promotion of protection and management of habitat on private lands is difficult because of the few legal responsibilities and the perceived economic interests of landowners. Therefore, special efforts are needed on private lands.

3.1 Provide information on management and legal requirements to private landowners and managers.

3.1.1 Develop informational articles and management guidelines oriented to private lands. Informational articles and management guidelines oriented to private lands should be developed. These articles and guidelines should include information and visual aids which identify the habitat of the species, and give detailed options by which the species' welfare can be maintained or enhanced without altering the total land management objectives of the owner or manager. These educational efforts could also emphasize the compatibility of gopher tortoise management with deer and quail management. Legal responsibilities of private landowners, through Sections 7 and 9 of the Endangered Species Act, should also be explained.

3.1.2 Distribute information to private landowners and managers through professional and industrial associations. The information developed in 3.1.1 should be distributed through a variety of professional and industrial associations and agencies, such as the State and private forestry branch of the U.S. Forest Service, county agricultural extension agents, and State forestry and wildlife associations.

3.2 Develop a cooperative agreement between the Fish and Wildlife Service and private landowners and implement where feasible. This agreement should specify management actions needed to protect the species and should identify the party responsible (landowner or Federal agency) for implementing the various actions. The agreement should set forth the total commitments of the two parties including land base, funds, equipment, manpower, and time period, and provide a means and a time frame for terminating the agreement.

3.3 Protect gopher tortoise habitat through easements, acquisitions, and donations. Lands containing gopher tortoises should receive special consideration when these lands would consolidate Federal ownership or control or would contribute to overall resource management objectives of the agencies. Private landowners should be encouraged to avail themselves of these options.

3.4 Recognize or reward protection and management efforts. Management efforts on private lands should be recognized and rewarded in view of the limited legal responsibilities involved. News media should be contacted and encouraged to provide favorable publicity to deserving landowners. News articles should be prepared for the news media where desirable or requested.

4. Develop law enforcement strategy to curb illegal taking of gopher tortoises. Gopher tortoise depredation by humans remains a practice in the rural areas where the listed population occurs. Habitat protection may be for naught if "taking" pressures continue to impact populations. Law enforcement must be a cooperative effort among the Fish and Wildlife Service, U.S. Forest Service, and the States. This effort may or may not involve the use of publicity.

5. Conduct research on population viability. This is needed to determine what densities and distributions are necessary to achieve minimum viable populations necessary for recovery goals. These factors are still unknown; yet they may eventually control the results of any scheduled recovery activity. Three areas, critical to understanding population viability, requiring baseline data, are (1) recruitment rates, (2) present age-class distribution, and (3) what constitutes contiguous habitat for the species.

6. Conduct telemetry studies. This is needed to determine whether or not seemingly isolated tortoises (particularly males) are in fact interacting with other tortoises. Data from telemetry studies will also yield information on what constitutes contiguous habitat for gopher tortoises.

7. Conduct genetic studies. This is needed to answer questions on the effects of augmentation and relocation efforts.

8. Relocate reproductively isolated individuals to existing protected and managed colonies. Animals that are determined to be in this category add nothing to maintenance or recovery. If introduced into an existing small colony which is protected and managed, they may contribute to the recovery goal. Such relocation should be done in accordance with the procedures outlined in Mount et al. (1988).

D. <u>Literature Cited</u>

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PART III

IMPLEMENTATION SCHEDULE

Priorities in column one of the following implementation schedule are assigned as follows:

1. Priority 1 - An action that <u>must</u> be taken to prevent extinction or to prevent the species from declining irreversibly in the <u>foreseeable</u> future.

2. Priority 2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

3. Priority 3 - All other actions necessary to meet the recovery objective.

<u>Key to Acronyms Used in This Implementation Schedule</u>

MDWFP	=	Mississippi Department of Wildlife, Fisheries and Parks
USFS	=	U.S. Forest Service
LDWF	=	Louisiana Department of Wildlife and Fisheries
ALDNR	=	Alabama Department of Natural Resources

IMPLEMENTATION SCHEDULE										
				RESPONSIBLE PARTY			COST ESTIMATES ($K)			
				USFWS						
PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION	Region	Program	Other	FY 1991	FY 1992	FY 1993	COMMENTS/NOTES *
1	2	Protection and management of publicly-owned habitat	continuous	4	FWE	MDWFP/ USFS	25			*Other agencies' responsibilities will be a cooperative nature, possibly on projects funded
2	1.1.1	Camp Shelby survey	<1 year	4	FWE	MDWFP/ USFS	3			under a Service contract. In some cases contracts may be let to
2	1.1.2	DeSoto National Forest survey	<1 year	4	FWE	MDWFP/ USFS	25			private individuals. The Army National Guard and USFS are
2	1.1.3	State/School lands survey	< year	4	FWE	MDWFP/ USFS	20			obligated to certain actions through Section 7 of the Act.
2	1.2	Population survey/ entire populion	2 years	4	FWE	MDWFP/ USFS	35			Repeat every 5 years.
2	1.2.1	Assess rangewide status	2 years	4	FWE	MDWFP/ USFS	5			Repeat every 5 years.
3	3	Protection and management of private lands	Continuous	4	FWE	MDWFP/ USFS	10			
3	3.2	Cooperative agreements	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.
3	3.3	Easements/donations	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.

IMPLEMENTATION SCHEDULE										
				RESPONSIBLE PARTY			COST ESTIMATES ($K)			
				USFWS						
PRIORITY #	TASK #	TASK DESCRIPTION	TASK DURATION	Region	Program	Other	FY 1991	FY 1992	FY 1993	COMMENTS/NOTES *
3	3.4	Rewards	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.
2	4	Law enforcement strategy	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Continuous
3	5	Research population viability	3 years	4	FWE	MDWFP/ USFS	20	20	20	
3	6	Research genetics	1 year	4	FWE	University	20			
3	7	Telemetry studies	3 years	4	FWE	MDWFP/ USFS	15	15		
3	8	Relocate reproductively isolated tortoises	Continuous	4	FWE	MDWFP/ USFS LDWF ALDNR	15	10		
3	3	Protection and management of private lands	Continuous	4	FWE	MDWFP/ USFS	10			
3	3.2	Cooperative agreements	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.
3	3.3	Easements/donations	<1 year	4	FWE	MDWFP/ USFS	5	5	5	Costs to be determined.

IV: APPENDIX

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Species Status Assessment Report
for the
Gopher Tortoise
(*Gopherus polyphemus*)

Version 0.4

Adult gopher tortoise. Image credit: Jeffrey M. Goessling, Ph.D.

August 2021

U.S. Fish and Wildlife Service
Southeast Region
Atlanta, GA

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VERSION UPDATES

The changes from Version 0.1 (May 2021 – Internal Review) included minor grammatical and formatting changes.

The changes from Version 0.2 (June 2021 – Expert Review) included minor grammatical and formatting changes, addition of citations, incorporation of recipient sites, re-run of the future conditions modeling, and addition of pertinent information throughout the document.

The changes from Version 0.3 (Peer and Partner Review) included minor grammatical and formatting changes, addition of citations, minor map and table revisions, and addition of pertinent information throughout the document.

EXECUTIVE SUMMARY

The Species Status Assessment (SSA) reports the results of the comprehensive status review for the gopher tortoise (*Gopherus polyphemus*). For the purpose of this assessment, we define viability as the ability of the gopher tortoise to sustain resilient populations in the wild over time. Using the SSA framework, we consider what the species needs to maintain viability by characterizing the status of the species in terms of its resiliency, redundancy, and representation (USFWS 2016, entire; Wolf et al. 2015, entire). This SSA provides a thorough assessment of biology and natural history and assesses demographic risks, stressors, and limiting factors in the context of determining the viability for the species.

The gopher tortoise is a burrowing reptile species generally associated with southern pine tree species occurring in the Southeastern Atlantic and Gulf Coastal Plains, from Southeastern South Carolina to extreme Southeastern Louisiana. Typical gopher tortoise habitat consists of an open canopy with diverse herbaceous vegetation on well-drained xeric soil with widely spaced trees and shrubs. These systems depend on frequent disturbance, primarily from fire, for the perpetuation and maintenance of species composition and structure within the natural community.

For the gopher tortoise to maintain viability, its populations or some portion thereof must be resilient. The best available information regarding the gopher tortoise and gopher tortoise habitat indicates that habitat loss, degradation, and fragmentation (due to land use changes), climate change, and habitat management are the most significant factors influencing gopher tortoise viability. Other factors influencing viability include road mortality, disease, human harvesting and rattlesnake roundups, predation, invasive flora and fauna, and other conservation measures, including relocation, translocation, and headstarting programs.

For this assessment, we defined populations for the species as contiguous areas surrounding known gopher tortoise burrows with habitat conducive to survival, movement, and inter-breeding

among individuals within the area. Using spatial survey data from across the range of the gopher tortoise, we delineated populations at two spatial scales: local populations and landscape populations, as defined below.

- **Local population**: geographic aggregations of individuals that interact significantly with one another in social contexts that make reproduction significantly greater between individuals within the aggregation than with individuals outside of the aggregation. Operationally delineated by identifying aggregations of individuals or burrows where individuals were clustered together within a 1,968 feet (600 m) buffer to the exclusion of other adjacent individuals or burrows. We delineated 656 local gopher tortoise populations with available spatial data.
- **Landscape population**: a series of local populations that are connected by some form of movement; individuals within a landscape population are significantly more likely to interact with other individuals within the landscape population than individuals outside of the landscape population. Operationally delineated by identifying local populations connected by habitat within 8,202 feet (2.5 km) buffer around each local population. We delineated 253 landscape populations with available spatial data.

We lack consistent and reliable estimates of density, sex ratios, recruitment, dispersal, habitat, and management effort for all populations, thus we qualitatively assessed resiliency by evaluating the estimated abundance of adult gopher tortoises as a metric for categorical levels of resiliency: high (greater than or equal to 250), moderate (51-249), and low (less than 50). Currently, there are an estimated 149,152 gopher tortoises from 656 spatially delineated local populations across the range of the species, with local abundance categories as follow: 360 low, 169 moderate, and 127 high.

To assess representation for gopher tortoise, we delineated five analysis units based on the results of a recent genetics study (Galliard et al. 2017, entire), physiographic regions, and the input of species experts. We evaluated current representation by examining the number of populations and their associated resiliency within the five population analysis units across the species' range. We report redundancy for gopher tortoise as the total number and resiliency of populations and their distribution within and among representative units. Although representation and redundancy have likely decreased significantly relative to the historical distribution of the species, there are still many resilient populations distributed across the range of the species, contributing to future adaptive capacity (representation), and buffering against the potential of future catastrophic events. Because the species is widely distributed across its range, it is highly unlikely any single event would put the species as a whole at risk, although the western most portions of the range are likely more vulnerable to such catastrophes given that most of the populations present in this unit are of low resiliency.

To assess viability for the gopher tortoise, we developed an analytical framework that integrates projections from multiple models of future anthropogenic and climatic change to project future trajectories/trends of gopher tortoise populations and identify stressors with the greatest influence on future population persistence. The modeling framework estimates the change in population growth and persistence probability of populations while accounting for geographic variation in life history, by linking intrinsic factors (demographic vital rates) to four extrinsic anthropogenic factors that are hypothesized to threaten gopher tortoise population persistence (climate warming, sea-level rise, urbanization, and shifts in habitat management).

Six scenarios of future climate warming, sea-level rise, urbanization, and habitat management were used to simulate population growth and extinction risk for gopher tortoises for 80 years into the future. Specifically, we created three scenarios with different levels of stressors (low stressors, medium stressor, and high stressors) that experienced habitat management consistent with contemporary target management goals. We then used the medium stressor values and built three additional models that varied in habitat management treatments, ranging from ‘more management’ conditions to worsening (‘less management’) and much worse (‘much less management’) conditions (Table ES-1).

Table ES-1.

Scenarios	Climate warming (deg C)	Sea-level rise (m)	Urbanization	Management
Low stressors	1.0	0.54 m	P = 0.95	Status quo
Medium stressors	1.5	1.83 m	P = 0.50	Status quo
High stressors	2.0	3.16 m	P = 0.20	Status quo
More management	1.5	1.83 m	P = 0.50	More
Less management	1.5	1.83 m	P = 0.50	Less
Much less management	1.5	1.83 m	P = 0.50	Much less

To assess future redundancy, resiliency, and representation of the gopher tortoise, we used population projections to estimate changes in gopher tortoise populations in the future under each of the six scenarios. We assessed the **resiliency** of future populations to changing environments by estimating persistence probability, categorized as ‘extremely likely to persist’, ‘very likely to persist’, ‘more likely than not to persist’, and ‘unlikely to persist’, and simulating the number of populations predicted to persist at the end of the projection. We assessed **redundancy** by measuring predicted changes in the total number of individuals, local populations, and landscape populations in the future. We summarized population trends by estimating population growth rate as increasing (greater than 1.00), stable (equals 1.00), or decreasing (less than 1.00). We evaluated how **representation** is predicted to change in the future by examining how population growth of total population size, number of populations, and number of landscape populations will vary by the five population genetic groups of tortoises across the species’ range. For each scenario, we summarized the results among all populations across the species’ range, but also by genetic units.

Overall projections suggest that extinction risk for the gopher tortoise is relatively low in the future. Of the individuals, local populations, and landscape populations modeled (a small subset of populations likely to occur across the landscape), mean projections among scenarios for 80 years in the future suggested the presence of 47,202–50,846 individuals (females) among 188–198 local populations within 106–114 landscape populations. The persistence of relatively large numbers of individuals and populations suggests resiliency of the species in the face of global change, and redundancy to buffer from future catastrophic events. The spatial distribution of populations predicted to persist in the future are distributed evenly among genetic analysis units, which suggests the persistence of genetic representation in the future as well.

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Act	Endangered Species Act
AFB	Air Force Base
AFF	American Forest Foundation
ALRI	America's Longleaf Restoration Initiative
ASL	Above Sea Level
BMP	Best Management Practices
CCA	Candidate Conservation Agreement
CCAA	Candidate Conservation Agreement with Assurances
CFR	Code of Federal Regulations
DNA	Deoxyribonucleic Acid
DoD	Department of Defense
Forest Service	United States Forest Service
FNAI	Florida Natural Areas Inventory
FWC	Florida Fish and Wildlife Conservation Commission
FR	Federal Register
FY	Fiscal year
GDNR	Georgia Department of Natural Resources
GTC	Gopher Tortoise Council
INRMP	Integrated Natural Resources Management Plan
LIT	Local Implementation Team
LTDS	Line Transect Distance Sampling
MOA	Memorandum of Understanding
MVP	Minimum Viable Population
NCASI	National Council for Air and Stream Improvement
NF	National Forest
NOAA	U.S. National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWR	National Wildlife Refuge
RCP	Representative Concentration Pathway
Service	United States Fish and Wildlife Service
SFI	Sustainable Forestry Initiative
SLEUTH	Slope, Land use, Exclusion, Urban, Transportation, and Hill-shade model
SLR	Sea Level Rise
SSA	Species Status Assessment
SERPPAS	Southeast Regional Partnership for Planning and Sustainability
URTD	Upper Respiratory Tract Disease
U.S.	United States
U.S.C.	United States Code
USDA	United States Department of Agriculture
WLFW	Working Lands for Wildlife
WMA	Wildlife Management Area

CHAPTER 1 – INTRODUCTION

The gopher tortoise (*Gopherus polyphemus*) is a burrowing reptile species generally associated with southern pine tree species including longleaf pine (*Pinus palustris*), loblolly pine (*P. taeda*), slash pine (*P. elliottii*). Natural community associations include xeric oak (*Quercus* spp.) uplands including sandhills and scrub, longleaf pine savannas (i.e., Red Hills region), xeric hammocks, pine flatwoods, dry prairie, coastal grasslands and dunes, mixed hardwood-pine communities, and a variety of disturbed (ruderal) plant communities, occurring in the Southeastern Coastal Plain from Southeastern South Carolina to extreme Southeastern Louisiana (Auffenberg and Franz 1982, entire; Kushlan and Mazzottii 1984, entire; Diemer 1986, p. 125; Diemer 1987, p. 72; Breininger et al. 1994, entire). Typical gopher tortoise habitat consists of an open canopy with diverse herbaceous vegetation on well-drained xeric soil with widely spaced trees and shrubs. These systems depend on frequent disturbance, primarily from fire, for the perpetuation and maintenance of species composition and structure within the natural community.

Historically, lightning induced fires and later anthropogenic use of fire burned the landscape. Currently most natural fires are actively suppressed (via firefighting efforts), resulting in many areas that are overgrown and ultimately degraded (Wear and Greis 2002, 9. 135). Although current gopher tortoise management includes use of prescribed fire, many areas remain fire suppressed.

On July 7, 1987, the gopher tortoise was listed as a threatened species in the western portion of its range, from the Tombigbee and Mobile Rivers in Alabama west to southeastern Louisiana on the lower Gulf Coastal Plain under the Endangered Species Act of 1973, as amended (Act; 16 U.S.C. 1531-1543) (52 FR 25376-25380). A Recovery Plan was subsequently completed in 1990 (Service 1990, entire). On January 18, 2006, the U.S. Fish and Wildlife Service (Service), was petitioned to list the gopher tortoise in the eastern portion of its range as threatened under the Endangered Species Act of 1973, as amended (16 U.S.C. 1531-1543). On September 9, 2009, the Service published a 90-day finding (74 FR 46401) that the petition presented substantial scientific and commercial information indicating that listing may be warranted and that the Service would initiate a status review. As part of the 12-month finding published on July 27, 2011, the Service determined that the species warranted listing under the Act as threatened but listing was precluded in the eastern portion due to higher priority actions (76 FR 45130).

The Species Status Assessment (SSA) compiles the best available information and data regarding the species' biology and factors that influence the species' viability. The gopher tortoise SSA is a summary of the information assembled and reviewed by the Service and incorporates the best scientific and commercial data available. This SSA documents the results of the comprehensive status review for the entire range of the gopher tortoise and serves as the scientific document that informs future agency decisions for this species.

The SSA framework (Service 2016, entire) is intended to be an in-depth review of the species' biology and threats, an evaluation of its biological status, and an assessment of the resources and conditions needed to maintain the species' long-term viability. The intent is for the SSA to be easily updated as new information becomes available and to support all functions of the Endangered Species Program. As such, the SSA report is a living document that may be used to inform Endangered Species Act decision making, such as listing, recovery, Section 7, Section 10, and reclassification decisions (the latter four decision types are only relevant should the species warrant listing under the Act). Therefore, we have developed this SSA to summarize the most relevant information regarding life history, biology, and factors influencing viability for the gopher tortoise. Additionally, we describe the current condition and forecast the possible response of the species to various factors and environmental conditions into the future to formulate a risk profile for the gopher tortoise.

This SSA is intended to provide the biological support for the decision on whether to propose to list or reclassify the species as threatened or endangered and, if so, to determine whether it is prudent to designate critical habitat in certain areas. Importantly, the SSA is not a decisional document by the Service; rather, it provides a review of available information strictly related to the biological status of the gopher tortoise. The listing decision will be made by the Service after reviewing this document and all relevant laws, regulations, and policies, and the results of a proposed decision will be announced in the *Federal Register*, with appropriate opportunities for public input.

The objective of this SSA is to thoroughly describe the viability of the gopher tortoise based on the best scientific and commercial information available. Through this description, we determined what the species needs to support viable populations, its current condition in terms of those needs, and its forecasted future condition under plausible future scenarios. In conducting this analysis, we took into consideration likely changes in the environment – past, current, and future – to help understand what factors drive the species' viability at multiple spatial and temporal scales.

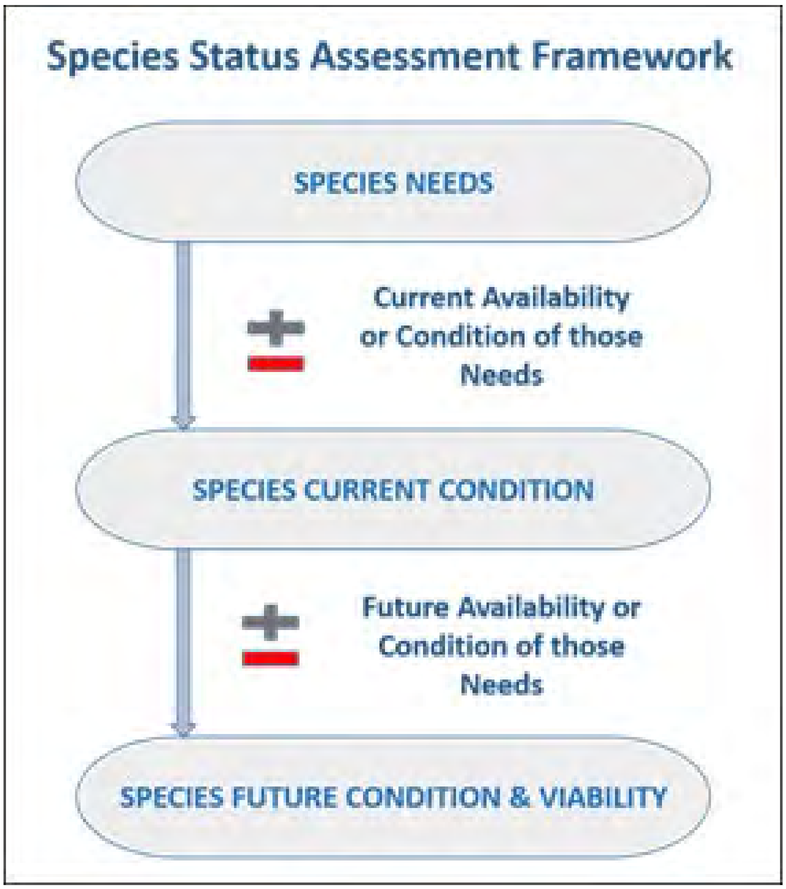

Figure 1. 1-SSA Framework

For the purpose of this assessment, we define 'viability' as the ability of a species to sustain populations in the wild over time. Viability is not a specific state, but rather a continuous measure of the likelihood that the species will sustain populations over time (Service 2016, p. 9). Using the SSA framework (Figure 1.1), we consider what the species needs to maintain viability by characterizing the status of the species in terms of the 3Rs: resiliency, redundancy, and representation (Wolf et al. 2015, entire; Service 2016, entire).

Resiliency is the ability of a species to withstand environmental stochasticity (normal, year-to-year variations in environmental conditions such as temperature and rainfall), periodic disturbances within the normal range of variation (fire, floods, storms), and demographic stochasticity (normal variation in demographic rates, such as survival and fecundity) (Redford et al. 2011, p. 40). Simply stated, resiliency is the ability to sustain populations through the natural range of favorable and unfavorable conditions.

We can best gauge resiliency by evaluating population-level characteristics such as: demography (abundance and the components of population growth rate—survival, reproduction, and migration), genetic health (effective population size and heterozygosity), connectivity (gene flow and population rescue), and habitat quantity, quality, configuration, and heterogeneity. Also, for species prone to spatial synchrony (regionally correlated fluctuations among populations), distance between populations and degree of spatial heterogeneity (diversity of cover types or microclimates) are also important considerations.

Redundancy is the ability of a species to withstand catastrophes by possessing numerous populations distributed in space. Catastrophes are stochastic events that are expected to lead to population collapse regardless of population health and for which adaptation is unlikely (Mangel and Tier 1993, p. 1083). We can best gauge redundancy by analyzing the number and distribution of populations relative to the scale of anticipated species-relevant catastrophic events. The analysis entails assessing the cumulative risk of catastrophes occurring over time. Redundancy can be analyzed at a population or regional scale, or for narrow-ranged species, at the species level. Redundancy is assessed by characterizing the number of resilient populations across a species' range. The more resilient populations a species has, distributed over a larger area, the better the chances that the species can withstand catastrophic events.

Representation is the ability of a species to adapt to both near-term and long-term changes in its physical (climate conditions, habitat conditions, habitat structure, etc.) and biological (pathogens, competitors, predators, etc.) environments. This ability to adapt to new environments—referred to as adaptive capacity—is essential for viability, as species need to continually adapt to their continuously changing environments (Nicotra et al. 2015, p. 1269). Species adapt to novel changes in their environment by either [1] moving to new, suitable environments or [2] by altering their physical or behavioral traits (phenotypes) to match the new environmental conditions through either plasticity or genetic change (Beever et al. 2016, p. 132; Nicotra et al. 2015, p. 1270). The latter (evolution) occurs via the evolutionary processes of natural selection, gene flow, mutations, and genetic drift (Crandall et al. 2000, p. 290-291; Sgro et al. 2011, p. 327).

We can best gauge representation by examining the breadth of genetic, phenotypic, and ecological diversity found within a species and its ability to disperse and colonize new areas. In assessing the breadth of variation, it is important to consider both larger-scale variation (such as morphological, behavioral, or life history differences which might exist across the range and environmental or ecological variation across the range), and smaller-scale variation (which might include measures of inter-population genetic diversity). In assessing the dispersal ability, it is important to evaluate the ability and likelihood of the species to track suitable habitat and climate over time. Lastly, to evaluate the evolutionary processes that contribute to and maintain adaptive capacity, it is important to assess [1] natural levels and patterns of gene flow, [2] degree of ecological diversity occupied, and [3] effective population size. In our SSAs, we assess all three facets to the best of our ability based on available data.

To evaluate the current and future viability of the gopher tortoise, we assessed a range of conditions to characterize the species' 3Rs. This SSA provides a thorough account of known biology and natural history and assesses the risk of threats and limiting factors affecting the future viability of the species.

This SSA includes: (1) a description of gopher tortoise resource needs at both individual and population levels; (2) a characterization of the historical and current distribution of populations across the species' range; (3) an assessment of the factors that contributed to the current and future status of the species and the degree to which various factors influenced viability; and (4) a synopsis of the factors characterized.

CHAPTER 2 – SPECIES BIOLOGY AND INDIVIDUAL NEEDS

In this chapter, we provide biological information about the gopher tortoise, including its taxonomic history, morphological description, historical and current distribution and range, and known life history. We then outline the resource needs of individuals.

2.1 Taxonomy

The gopher tortoise is one of six living North American tortoise species and the only one indigenous to the Southeastern United States (Ernst and Lovich 2009, p. 581; Edwards et al. 2016, p. 131); the other congeneric species are found in western North America. First described by F.M. Daudin in 1802, *G. polyphemus* is classified as belonging to Class Reptilia, Order Testudines, and Family Testudinidae. Two of the most recent changes affecting the genus *Gopherus* are the reclassification of the desert tortoise (*G. agassizii*) into two species (Murphy et al. 2011, entire) – Agassiz's desert tortoise (*G. agassizii*) and Morafka's desert tortoise (*G. morafkai*) – and the subsequent reclassification of *G. morafkai* into two species as well (*G. morafkai* and *G. evgoodei*) (Edwards et al. 2016, entire). Recent morphological and genetic studies have reinforced the traditional assignment of all species into genus *Gopherus* (Crumly 1994, pp. 12-16). Allozyme differentiation has indicated that *G. polyphemus* is most closely related to *G. flavomarginatus* and is thus placed in a clade (genetically related group) distinct from the clade containing *G. berlandieri* and *G. agassizii* (Morafka et al. 1994, p. 1669).

The taxonomic status of the gopher tortoise throughout its range is considered valid (Integrated Taxonomic Information System 2021, p. 1). There is no taxonomic distinction between the gopher tortoise in the western and eastern portions of its range or at any level of geographic subdivision. We are aware of no efforts to reclassify the species.

2.2 Species Description

The gopher tortoise (Figure 2.1) typically has a domed, brown to grayish-black carapace approximately 10-15 inches (in; 25-38 centimeters; cm) in length and weighing approximately 9-13 pounds (lbs; 4.08-5.9 kilograms; kg) (Ernst et al. 1994, p, 466; Bramble and Hutchison 2014, p. 4). The plastron is yellowish and hingeless (Ernst et al. 1994, p. 466). A fossorial species (a species adapted to digging and living primarily underground), its hind feet are often described as elephantine or stumpy (round and pad-like), and the forelimbs are shovel-like, with claws used for digging (Ernst et al. 1994, p. 469). In comparison to females, males are smaller; usually have a larger gland under the chin, a longer gular projection, and more deeply concave plastron (Ernst et al. 1994, p. 466). Hatchlings are about 2 inches (51.4 cm) in length, with a softer, yellow-orange shell (Iverson 1980, p. 357; Butler et al. 1995, p. 174). Hatchling gopher tortoises are classified as those less than 2.4 inches (60 millimeters) in straight-line carapace length (CL), juveniles as those greater than 2.4 inches to 5.1 inches (60 millimeters to 130 millimeters) in CL, subadults as those greater than 5.1 inches to 8.6 inches (130 mm - 219 mm) in CL, and adults as those tortoises 8.7 inches (220 mm) in CL or greater (Landers et al. 1982, entire).

Figure 2. 1-Examples of typical size and coloration of gopher tortoise adult (Left), subadults (Center), and hatchlings (Right). Image credit: Michelina Dziadzio

2.3 Range and Distribution

The gopher tortoise occurs in the Southeastern Atlantic and Gulf Coastal Plains from southern South Carolina west through Georgia, the Florida panhandle, Alabama, and Mississippi to eastern Louisiana, and south through peninsular Florida (Figure 2.2; Auffenberg and Franz 1982, p. 95). The range of the gopher tortoise generally aligns with the historic range of the longleaf pine ecosystem (Auffenberg and Franz 1982, pp. 99-120). The eastern portion of the gopher tortoise’s range includes Alabama (east of the Tombigbee and Mobile Rivers), Florida, Georgia, and southern South Carolina. The western range, west of the Tombigbee River in Alabama, Mississippi, and Louisiana, is currently listed as threatened under the Act (Figure 2.2). The core of the current distribution of the gopher tortoise occurs in the eastern portion of the range and includes peninsular Florida and southern Georgia. The gopher tortoise is more widespread and abundant in the core of its distribution, where these areas have been referred to as the “central” portion of the tortoise’s geographic extent previously in the literature (Tuberville et al. 2009, p. 12) and more recently as east Georgia, west Georgia and peninsular Florida genetic units (Gaillard et al. 2017, pp. 500-502). It is estimated that approximately 86 percent of the forest area in the south is in private ownership and approximately 80 percent of the gopher tortoise range occurs in private ownership, with the remainder owned or managed by local, state, federal, or private conservation entities (Wear and Greis 2013, p. 103; NRCS 2018, p. 2).

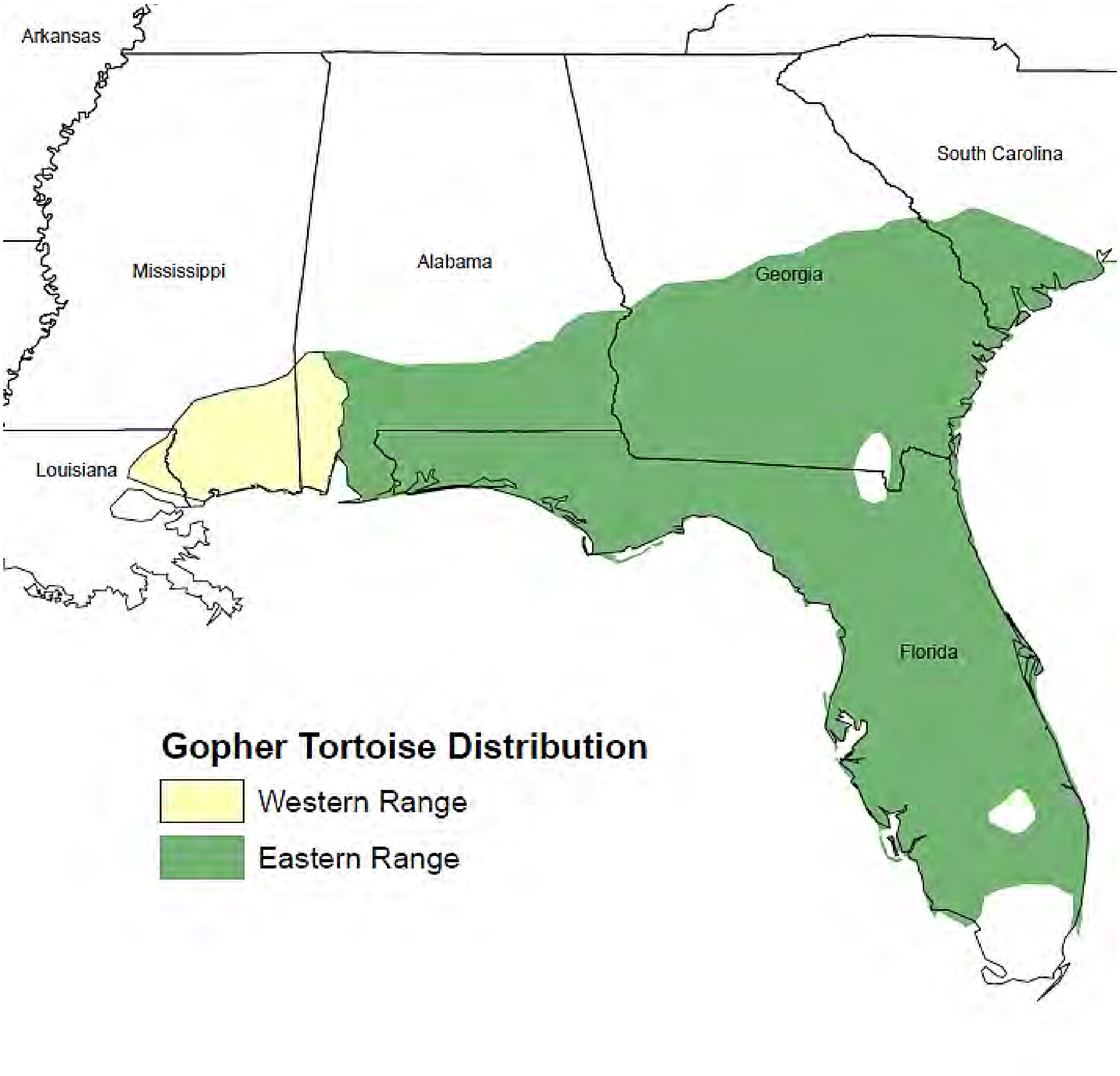

Figure 2. 2-Distribution of the gopher tortoise across the Southeastern United States.

2.4 Life History

Some of the challenges for the conservation of this species lie in its life history traits; specifically, the late age of reproductive maturity (estimated to be between 12 – 20 years), low reproductive output (estimated to be between 4 – 8 eggs/clutch), and long lifespan (generally estimated at 50–80 years) (Service 2013, p. 21). Below is a synthesis of the current state of knowledge of gopher tortoise life history.

Activity

Tortoises spend most of their time within burrows and emerge during the day to bask, feed, and reproduce (Service 2013, p. 21). Tortoises are active above ground when daytime temperatures range from 75 - 87 °Fahrenheit (F) (23.9 - 30.6 °Celsius; C) (McRae et al. 1981, pp. 167-168). Daily active periods are typically unimodal in spring and fall, with bimodal periods (early to mid-morning, middle to late afternoon) during the hotter temperatures of summer. Daily activity above ground becomes significantly reduced by the end of the growing season during October as temperatures begin to cool (McRae et al. 1981, p. 167-168). Gopher tortoises throughout most of the range shelter within their burrows during the dormant season, become torpid, do not eat, and rarely emerge, except on warm days to bask in sunlight at the burrow entrance (Service 2008, p. 10). Gopher tortoises become active again in April or when air temperatures are above 73.4 °F (23 ℃) (Douglass and Layne 1978, p. 364; Butler et al. 1995, pp. 175-177). One exception is in southern Florida, where the gopher tortoise is active every month of the year, though winter activity is restricted to warm (> 69.8 °F [21℃]) days (Douglass and Layne 1978, pp. 361-364; Moore et al. 2009, pp. 390-391; Castellon et al. 2018, pp. 9-10).

In a study that examined gopher tortoise populations on fire maintained longleaf pine stands, females may use an average of 5 burrows per year, while males occupy an average of 10 burrows per year (Ott-Eubanks et al. 2003, p. 318). In lower quality habitat, tortoises may use many more burrows and incur more significant energy expenditures, ultimately leading to low population densities and increased clumping of individuals into small enclaves (Ott-Eubanks et al. 2003, pp. 319-320). Males tend to use more burrows and move more frequently among their different burrows than females as they seek breeding opportunities (McRae et al. 1981, p. 174; Diemer 1992a, p. 285; 1992b, p. 162; Smith 1995, p. 12; Ott-Eubanks et al. 2003, p. 318).

Tortoises select and prefer burrow sites in open canopy areas where sunlight reaches the ground (Boglioli et al. 2000, pp. 703-704; Rostal and Jones 2002, pp. 484-485; McIntyre et al. 2019, p. 287). Such sites reflect areas where herbaceous forage plants are more abundant and for females, sunlight and soil temperatures for egg incubation are more suitable. Also, males select sites and burrows that increase their proximity to females and breeding opportunities (Boglioli et al. 2000, pp. 703-704; Ott-Eubanks et al. 2003, pp. 318-319). The repeated use and travel to the same burrows by individual tortoises on relatively pristine sites in some studies suggests that tortoises know the geography of their home range, burrows, and the location of neighboring tortoises (Ott-Eubanks et al. 2003, p. 318). In habitat of exceptionally poor quality, small groups of gopher tortoises will restrict movements to a few burrows and socialize only with a few neighboring individuals (Guyer et al. 2012, pp. 131–132). Burrow site selection within populations in coastal or other geographically isolated areas may be influenced by environmental conditions, such as storms and drought (Kushlan and Mazzotti 1984, p. 237; Waddle et al. 2006, pp. 282 – 283, Blonder et al. 2021, pp. 9–11)

Diet and Foraging

Gopher tortoises were found to mostly forage on foliage, seeds, and fruits of grasses and forbs, generally in an area of about 150 feet (45.7 meters; m) surrounding burrows (McRae et al. 1981, p. 169). Although they feed primarily on broadleaf grasses, wiregrass (*Aristida stricta var. beyrichiana*), asters, legumes, and fruit, they are known to eat more than 300 species of plants (Garner and Landers 1981, pp. 123–130; Ashton and Ashton 2004, pp. 33-35; Richardson and Stiling 2019, pp. 387-388). The diet of adults resembles that of a generalist herbivore, with at least some preference for certain plants over others, and may also include insects and carrion (Macdonald and Mushinsky 1988, pp. 349-351; Birkhead et al. 2005, p. 155; Richardson and Stiling 2019, pp. 387–388). Legumes are thought to be particularly important for re-conditioning females after egg laying, and it has been shown that clutch sizes and percent of gravid females were lowest in areas with low percent cover of legumes (White 2009, p. 12). In a study on patterns of gastrolith ingestion by adult female gopher tortoises, over 85% of gravid tortoises contained shell and stone gastroliths while only 5% of non-gravid female tortoises had shells and stones in the gut, suggesting opportunistic intake of calcium-rich gastroliths may provide important nutritional supplements for reproductive female gopher tortoises (Moore and Dornburg 2014, p. 57). Juvenile gopher tortoises tend to forage on fewer plant species, eat fewer grasses, and select more forbs, including legumes, than adults (Garner and Landers 1981, p. 131; Mushinsky et al. 2003, p. 352).

Reproduction and Growth

Gopher tortoises mostly breed from May through October (Landers et al. 1980, p. 355; McRae et al. 1981, pp. 172-173; Taylor 1982, entire; Diemer 1992a, pp. 282-283; Ott-Eubanks et al. 2003, p. 317). However, gopher tortoise populations in south Florida show courtship behavior year-round and have an extended reproductive season, producing young over a much longer period than other populations further north (Moore et al. 2009, p. 391). Females ovulate during the spring, but likely store sperm so that active breeding during ovulation may not always be required for fertilization (Ott et al. 2000, p. 308). Males travel to female burrows and copulation occurs above ground, often at the burrow entrance, more frequently during July to September, a period of peak sex and adrenal steroid hormones (Ott et al. 2000, p. 299; Ott-Eubanks et al. 2003, p. 318).

Females may mate with several males during a single mating season and males may search for prolonged periods for receptive females (Boglioli et al. 2003, p. 849; Johnson et al. 2009, p. 217). The multiple paternities of about 30 percent of the clutches in a Florida gopher tortoise population was confirmed to indicate males fertilizing multiple clutches and females with multiple mates. Paternity analysis of the above study also suggested that larger males may have a reproductive advantage over smaller males in mating with females (Colson-Moon 2003, pp. 38-40). Mean body mass of males mounting females did not differ from the mean mass of all other males from a study of 20 females that received 286 visits from males in a large population in southwestern Georgia (Boglioli et al. 2003, pp. 848-849). Local gopher tortoise populations have been described as colonies, with aggregations of burrows in which dominant males competitively and behaviorally exclude other males at female burrows to maintain a loose female harem as a mating system (Douglass 1986, pp. 175-176). However, recent literature has failed to support the conclusion that the term colony is appropriate for gopher tortoises or that the breeding system is consistent with defense of a harem. Instead, the activities are most consistent with scramble competition (Boglioli et al. 2003, p. 849; Johnson et al. 2009, p. 217). Tuberville et al. (2011, p. 181) compared successful mating (in terms of number of known offspring sired) of relocated males to resident males and found that size was unlikely to be the only or primary cue used by females in choosing males. Johnson et al. (2009, p. 217) found that males appear to chase other males during mating season, but females never do. In addition, aggregations of burrows in some areas and study sites may be an artifact of fragmentation and the concentration of burrows in the available remaining habitat (Mushinsky and McCoy 1994, pp. 44-45; Boglioli et al. 2003, p. 849). Outside influences such as geographic or environmental factors often play a role in shaping differences of behavior in local breeding populations.

Rangewide, average clutch size varies from about four to eight eggs/clutch (Ashton et al. 2007, p. 357). Clutch size generally is positively correlated with adult female size (Diemer and Moore 1994, p. 132; Smith 1995, pp. 22-23; Rostal and Jones 2002, p. 482). Female gopher tortoises with lower body condition scores and lower plasma phosphorus levels were less likely to have eggs (White 2009, pp. 84-97). Average clutch size in the western range, from 4.8 - 5.6 eggs/clutch, is comparably low (Seigel and Hurley 1993, p.6; Seigel and Smith 1996, pp. 10-11; Tuma 1996, pp. 22-23; Epperson and Heise 2003, pp. 318-321). Studies have examined the percentage of females gravid per year (Diemer and Moore 1994, pp. 133-134; Smith et al. 1997a, p. 598), however, it was unknown whether non-gravid females either did not ovulate or deposited their clutch before researchers caught them.

Female gopher tortoises usually lay eggs from mid-May through mid-July, and incubation lasts 80 - 110 days (Diemer 1986, p. 127). Tortoises may nest in the soil at the entrance of a burrow (Figure 2.3; Butler and Hull 1996, p. 16; Smith et al. 1997a, p. 599), or in other open sandy areas, when available (Landers et al. 1980, p. 357).. In an analysis of 19 gopher tortoise populations from across the geographic range, larger clutches were produced in areas that were more southern, warmer, had greater site productivity, and were less seasonal (Ashton et al. 2007, p. 359). In Mississippi, nests are up to 16 cm (6.3 in) in depth and located about 46 cm (18.1 in) from the opening of the burrow (Epperson and Heise 2003, p. 318). Incubation at temperatures from 27°C to 32°C (80.6°F to 89.6°F) is required for successful development and hatching (DeMuth 2001, pp. 1611-1613; Rostal and Jones 2002, p. 482). Sex determination is temperature dependent for gopher tortoises, with lower temperatures producing more males and higher temperatures producing more females. The pivotal temperature for a 1:1 sex ratio has been observed to be 29.3°C (84.7°F) (DeMuth 2001, pp. 1612-1613).

Figure 2. 3-Gopher tortoise burrow showing sandy apron and mouth/entrance (left) and gopher tortoise eggs in a nest excavated in a burrow apron (right). Image credit: Michelina Dziadzio.

Nest depredation by vertebrates can be a substantial threat to some gopher tortoise populations (See Chapter 3 below). A study in southern Georgia, found approximately 90 percent of nests were destroyed by predators (Landers et al. 1980, p. 355, 358), while in a controlled study in southwest Georgia, a nest predation rate of 65 percent was observed (Smith et al. 2013, p. 4). In a smaller study from southern Alabama, about 46 percent of nests (n = 11) were destroyed by raccoons (*Procyon lotor),* Virginia opossums *(Didelphis virginiana),* and nine-banded armadillos (*Dasypus novemcinctus)* (Marshall 1987, pp. 29-32). Egg hatching success at experimentally protected nests has ranged from 28-97 percent in Florida and Georgia (92 percent, Arata 1958, pp. 276-279; 86 percent, Landers et al. 1980, p. 359; 28 percent, Linley 1986, p. 23; 67 to 97 percent, Smith 1995, p. 25; 80.6 percent, Butler and Hull 1996, p. 16). In Mississippi, mean hatching success from protected nests in the field has ranged from 28.8-56 percent (Epperson and Heise 2003, p. 319; Noel et al. 2012, pp. 328-329).

Hatchlings excavate themselves from the nest and typically emerge from the middle of August through September (Epperson and Heise 2003, p. 319). Hatchlings and yearlings (zero to one year old) may temporarily shelter in adult burrows, bury under sand or leaf litter, or excavate a small burrow nearby (Douglass 1978, pp. 413-415; Wilson 1991, pp. 377-378; Butler et al. 1995, pp. 175-179; Pike 2006, pp. 70-73).

Gopher tortoise growth is most rapid during the juvenile stage, becoming slower at the onset of adulthood and reproductive maturity, followed by little or no adult growth, particularly later in maturity (Mushinsky et al. 1994, p. 122). Generally, tortoises become adults between 9 to 20 years of age, although reproductive maturity is determined by size rather than age. Growth rates and sizes at sexual maturity can vary among populations and habitat quality (Landers et al. 1982, pp. 104-105; Mushinsky et al. 1994, pp. 123-125).

Home range and Movement

Hatchling and yearling gopher tortoises initially move up to about 50 feet (15 m) from their nest to establish their first burrow, from which they will subsequently excavate and use about five burrows in a home range as small as about 0.5 acres (0.2 hectares; ha), to as large as 11.8 acres (4.8 ha) (Wilson 1991, p. 39; Butler et al. 1995, pp. 177-178; Epperson and Heise 2003, pp. 320-321; Pike 2006, pp. 70-72). On average, yearling gopher tortoises move relatively short distances to establish new burrows, although they are known to have traveled up to 1,485 ft (450 m) to new burrows (Butler et al. 1995, p. 178; Epperson and Heise 2003, pp. 320). Hatchlings and yearlings may also take shelter beneath litter and woody debris (Diemer 1992b, p. 163, pp. 178-179). Yearling and juvenile gopher tortoises typically forage within about 23 feet (7 m) of their burrow (McRae et al. 1981, pp. 175-176; Butler et al. 1995, pp. 178-179; Epperson and Heise 2003, pp. 320-321).

The burrows of a gopher tortoise represent the general boundaries of a home range, which is the area used for feeding, breeding, and sheltering (McRae et al. 1981, p. 176). The home range area tends to vary with habitat quality, becoming larger in areas of poor quality (Auffenberg and Iverson 1979, pp. 559-561; Castellon et al. 2012, p. 159; Guyer et al. 2012, p. 130). Males typically have larger home ranges than females (McRae et al. 1981, p. 175; Guyer et al. 2012, p. 130; Castellon et al. 2018, pp. 11–12). Mean home ranges of individual tortoises in Mississippi, Alabama, Florida, and Georgia have varied from 0.15–39.8 acres (0.06–16.1 ha) for males and 0.1–20.8 acres (0.04 – 8.4 ha) for females (McRae et al. 1981, pp. 175–176; Diemer 1992b, pp. 160-161; Tuma 1996, pp. 28-43; Ott-Eubanks et al. 2003, pp. 315–316; Guyer et al. 2012, pp. 128-129; Castellon et al. 2018, p. 17). In comparison to females, male gopher tortoises use more burrows, and during breeding season, move among burrows more frequently over longer distances (McRae et al. 1981, p. 174; Auffenberg and Iverson 1979, pp. 548–549; Diemer 1992b pp. 160-162; Smith 1995, p. 108; Tuma 1996, pp. 28-43; Ott-Eubanks et al. 2003, pp. 115-117; Guyer et al. 2012, pp. 128-129; Castellon et al. 2018, p. 17).

Home ranges are larger in the western portion of the range than those typically observed for tortoises in Alabama, Georgia, and Florida, most likely due to habitat quality differences (Lohoefener and Lohmeier 1984, p. 1-25; Epperson and Heise 2003, p. 315; Richter et al. 2011, p. 408). Gopher tortoise movements increase as herbaceous biomass and habitat quality decrease (Auffenberg and Iverson 1979, p. 558; Auffenberg and Franz 1982, p. 121. Castellon et al. 2018, p. 18). It is common for peripheral populations to differ from populations found in a species' core range where the habitat quality tends to be higher (Prieto-Ramirez et al. 2020, pp. 2–3), which may influence tortoise average home range size and movements but also highlights the species' plasticity.

As distances increase between gopher tortoise burrows, isolation among gopher tortoises also increases due to the decreasing rate of visitation and breeding by males to females (Boglioli et al. 2003, p. 848; Guyer et al. 2012, p. 131). Using extensive data from individual gopher tortoise inter-burrow movements and home range size, most breeding population segments have been found to consist of burrows no greater than about 549 feet (167 m) apart, (Ott-Eubanks et al. 2003, p. 320). Other studies and data show that gopher tortoises rarely move long distances from their burrows when mating (Guyer and Johnson 2002, pp. 6-8; Guyer et al. 2012, p. 131), though males will move longer distances from their burrows, up to 1,640 feet (500 meters), to a female burrow for mating opportunities. Gopher tortoises have been observed to move distances of over 4,921 feet (1,500 m) throughout multiple years (McRae et al. 1981, p.172; Diemer 1992b, p. 163; Castellon et al 2018, p. 20), however movements of this distance are not considered to be normal movements within a home range.

2.5 Genetics

Genetic flow in gopher tortoise populations is known to be influenced by distance, geographic features, and human influence by transporting tortoises across the range. There have been several phylogeographic studies of the gopher tortoise including mitochondrial DNA (Osentoski and

Lamb 1995 entire; Clostio 2012, entire) and microsatellites (Schwartz and Karl 2005, entire; Ennen et al. 2012, pp. 112 - 122; Clostio et al. 2012, entire; Gaillard et al. 2017, entire). Several studies showed genetic assemblages across the geographic range (Osentoski and Lamb 1995, p. 713; Ennen et al. 2012, pp.113-120; Clostio et al. 2012, pp. 617-620; Gaillard et al., 2017, pp. 501-503) but these studies were not entirely congruent in their delineations of western and eastern genetic assemblages. Recent microsatellite analysis suggests there are five main genetic groups, delineated by the Tombigbee and Mobile rivers, Apalachicola and Chattahoochee rivers, and the transitional areas between several physiographic province sections of the Coastal Plains (i.e., Eastern Gulf, Sea Island, and Floridian), and the authors suggest use of these groups as management units for conservation planning (Gaillard et al. 2017, pp. 505 - 507). In addition to the five genetic groups suggested by Gaillard et al. (2017), two additional genetic groups were loosely delineated by the Pascagoula and Chickasawhay rivers, and four genetic groups within the Florida region that seemed to reflect the influence of the local physiography (e.g., Atlantic Coast Ridge) (Gaillard et al. 2017, pp. 497-509).

A phylogenetic break (difference in genetics) had been reported between the western and eastern portions of the tortoise's range based on a 712 base pair portion of a mitochondrial gene (Ennen et al. 2012, pp. 113-116). However, the phylogenetic break did not entirely correspond to a particular geographic barrier because shared haplotypes from the eastern and western portions of the tortoise's range were found in the panhandle of Florida and in Georgia populations (Ennen et al. 2012, pp. 113-116). Research using another mitochondrial gene similarly found no shared haplotypes across the Mobile and Tombigbee Rivers (Clostio et al. 2012, pp. 619-620) but a recent study that genotyped 933 tortoises across the species' range recognizes five groups (or regions) delineated by the Tombigbee-Mobile Rivers, Apalachicola-Chattahoochee Rivers, and the transitional areas between several physiographic province sections of the Coastal Plains (i.e., Eastern Gulf, Sea Island, and Floridian) (Gaillard et al. 2017, entire). In addition, the periphery of the range is identified as having lower genetic diversity relative to the core and genetic admixture at sampling sites along the boundaries of the genetically defined groups (Gaillard et al. 2017, p. 509).

There are several smaller scale genetic analyses that have been conducted to better understand local and regional genetic variation in gopher tortoises. In the Florida panhandle, mitochondrial DNA analysis found minimal genetic diversity among six populations and suggested that gene flow occurred among these populations (Sinclair-Winters et al. 2011, pp. 153–155), which would be contrary to the findings of Clostio et al. (2012, pp. 617-618) and consistent with Ennen et al. (2012, p. 113). Subsequent analysis compared the above-referenced Florida panhandle genetics with those collected by Schwartz and Karl (2005, entire) and found a genetic break between peninsular Florida and the Florida panhandle, as did Osentoski and Lamb (1995, pp. 713-714), but these data indicated genetic exchange across the panhandle of Florida from Wakulla County to Escambia County, with no significant break at the Apalachicola River as suggested by Clostio et al. (2012, p. 618). Microsatellite DNA markers and mitochondrial DNA were used to determine whether gopher tortoise populations on Camp Shelby, Mississippi, were spatially structured, if spatial structure was affected by military activity and habitat quality, and whether there was a correlation between geographic distance and genetic relatedness (Richter et al. 2011, entire). Results indicated that there was genetic structure within these populations, and that genetic diversity and gene flow were affected by habitat quality and land use. Genetic distance did not seem to correlate with geographic distance (Richter et al. 2011, p. 412).

Analyses of mitochondrial DNA and nuclear DNA microsatellite markers showed that four gopher tortoise populations in Mississippi have lower genetic diversity than some populations in the eastern portion of the tortoise's range (Ennen et al. 2010, p. 34). This lower genetic variation and heterozygocity suggests either a prior population bottleneck, a historical persistence of the western populations with naturally low genetic diversity, or the fact that western sites are located on the periphery of the range (Ennen et al. 2010, p. 35; Ennen et al. 2011, p. 210; Gaillard et al. 2017, p. 509).

The last decade of genetic research has shown that genetic diversity exists among individuals in a population, among populations and across the range (Ennen et al. 2010, entire; Clostio et al. 2012, entire; Gaillard et al. 2017, entire). The most recent rangewide genetic analysis also confirmed that the periphery of the range has lower levels of genetic diversity relative to the core but also showed genetic admixture between units (Gaillard et al. 2017, p. 507). Evidence of tortoises with ancestry from different genetic sites is most likely due to the decades of tortoises being moved by humans (Gaillard et al. 2017, pp. 504-505). Gene flow is asymmetric from the Central genetic sites (Alabama) to the peripheral sites and gene flow is higher from the Central genetic sites (Alabama) to the Western site (western range). The Florida and the Western Georgia genetic sites has had low genetic flow in the Florida panhandle area (Gaillard et al 2017, pp. 504-509).

2.6 Population Dynamics

As long-lived animals, gopher tortoises naturally experience delayed sexual maturity, low reproductive rates, high mortality at young ages and small size-classes, and relatively low adult mortality. The growth and dynamics of populations are stochastically affected by natural variation due to demographic rates, the environment, catastrophes, and genetic drift (Shaffer 1981, pp. 131-132). Factors affecting population growth, decline, and dynamics include the number or proportion of annually breeding and egg-laying females (breeding population size), clutch size, nest depredation rates, egg hatching success, mortality (hatchling/yearling, juvenile-subadult, adult), the age or size at first reproduction, age- or stage-class population structure, maximum age of reproduction, and immigration/emigration rates.

These factors and data have been evaluated in several investigations of population viability to estimate the probabilities of gopher tortoise population extinction over time and the important factors affecting persistence (Cox et al. 1987, pp. 24-34; Cox 1989, p. 10; Lohoefener and Lohmeier 1984, entire; Miller 2001, entire; Epperson and Heise 2001, pp. 37-39; Wester 2004, pp. 16-20; McDearman 2006, entire; Tuberville et al. 2009, entire). These gopher tortoise population models and simulations varied with regard to specific objectives, model structure, transparency, simulation time, and actual demographic parameters. Nevertheless, the various projections of population growth, decline, and persistence time in different scenarios are plausible.

Using demographic data from various tortoise populations in Florida, it has been shown that more than 90 percent of simulated populations with 50 annually breeding individuals can persist up to 200 years under favorable habitat and management conditions, and a threshold of 130-150 tortoises were needed for persistence under moderate conditions (Cox et al. 1987, pp. 27-29). Favorable conditions reflected relatively high adult survival and fecundity in areas maintained by prescribed fire and protected from human encroachment and development. Populations of this size and demographic characteristics were considered the smallest potentially viable by their definition of persistence for at least 200 years. However, in another viability analysis using a different model with slightly different demographic parameters, it was reported that larger populations of about 200 gopher tortoises were required to achieve a 0.9 or greater probability of persisting for 200 years (Cox et al. 1994, p. 29).

Populations as small as 50 tortoises, exhibited positive growth rates and persistence, as modeled with VORTEX (Lacy and Pollak 2014, entire) by Miller (2001, p. 13) using demographic data from Florida. The potential effect of upper respiratory tract disease (URTD) was evaluated by increasing annual mortality as compared to a baseline model. URTD reduced the stochastic population growth rate, particularly in the panhandle population models, to such an extent that populations declined to eventual extirpation (Miller et al. 2001, pp. 26-27). An assumption was also made that a severe localized outbreak of URTD would only occur every 50 years (Miller et al. 2001, p. 28). Because this parameter was based on little quantifiable information, precise conclusions for how URTD impacts populations could not be made. However, this analysis highlights a need to better understand the extent with which URTD impacts gopher tortoise populations, and its frequency of occurrence.

The potential additive effects of fire ant (*Conomyrma* spp., *Solenopsis invicta*) predation on hatchling mortality was simulated, based on field and experimental data for clutch size, hatching success, and predation in the western range from study sites at Camp Shelby and DeSoto National Forest, Mississippi (Epperson and Heise 2001, entire). Without fire ants, the annual multiplicative population growth rate (lambda) was 1.018, with stable, slightly growing populations. With fire ants, lambda was 0.977, with a declining population trend and eventual extirpation. In subsequent VORTEX modelling, it was found that if the mortality from fire ant depredation is additive to other mortality sources, then all populations with an initial size from 10 to 200 gopher tortoises were extirpated within 200 years, with a mean time to extirpation from 32.2 to 80.9 years (McDearman 2006, pp. 6–7).

Population dynamics of turtles, as long-lived animals, have commonly been considered sensitive to demographic changes in adult survival and, in some cases, juvenile survival (Gibbons 1987, entire; Congdon et al. 1993, entire; Heppell 1998, entire). Likewise, models and simulations of gopher tortoise populations are most sensitive to adult, hatchling, and juvenile survival rates (Miller 2001, entire; Epperson and Heise 2001, entire; Wester 2005, entire). For example, the small but positive population growth rates modeled for a stable base population became negative when mortality of the 3–4 + year age class increased from 3.0 to 5.0 percent, or the yearling (0–1 year age class) mortality increased from 95 to 97 percent (Miller 2001, p. 10; McDearman 2006, p. 7). Hatchling survivorship has been shown to be the most critical life history stage driving viability of gopher tortoises due to the very small likelihood that hatchlings survive to their second year (Tuberville et al. 2009, p. 33). A 5 percent decrease (from 96 percent in the baseline model to 91 percent) in hatchling mortality was sufficient to shift the population growth rate from slowly declining (–1.5 percent) to slowly increasing (+1.1 percent) and to eliminate the probability of extinction within the 200 years (Tuberville et al. 2009, p. 33).

Changes in other vital parameters also affect population growth, although generally not to the proportionate extent of mortality (McDearman 2006, p. 7). The finite rate of increase changed from 1.002 to 1.006 when the minimum age of first reproduction was reduced from 20 to 17 years, and independently, average clutch size was increased from 4.79 to 5.60 (Table 2, McDearman 2006, p. 20). An increase in juvenile (0–1 year) mortality from 94.89 percent to 96.89 percent effectively reduced successful reproduction for each female by 40 percent and eliminated population growth, leading to long-term decline and/or extirpation (Miller 2001, entire).

Highly accurate measurements and assessments of sensitive demographic parameters affecting population growth and viability likely will be difficult to attain with confidence, particularly in small populations. Studies from large populations or cross-sectional studies from several populations may be required, if environmental heterogeneity can be controlled. With uncertainty in measuring key demographic and environmental factors, the goals and objectives for establishing viable populations and habitat should include larger populations than those identified as minimally viable.

The effects of geographic location and habitat quality on population growth rates for tortoises have been investigated (Tuberville et al. 2009, pp. 17-22). All model scenarios resulted in population declines of 1–3 percent per year and varied as a function of both location and habitat quality. Populations in the southern portion of the range were the most stable, whereas populations at the edge of the range were the least stable, particularly when found in marginal habitat (Tuberville et al. 2009, p 17). This highlights the importance of habitat management in stabilizing population growth for the species. While gopher tortoise populations may not persist if habitat quality remains poor for long periods of time, populations of at least 100 gopher tortoises were found to be reasonably resilient to variations in habitat quality and geographic location, but only populations of at least 250 tortoises were found to be able to persist for 200 years (Tuberville 2009 et al., p. 19).

A Gopher Tortoise Council (GTC) workshop defined minimum viable population (MVP) in terms of acceptable benchmarks for the purpose of conservation and recovery efforts and did not determine absolute minimum thresholds (GTC 2013, entire). Viability, as used under the MVP definition, is more of a "rule of thumb" for conservation planning purposes, and thus does not exactly align with the definition of viability used in this SSA (see Chapter 1, pages 7-8). A viable tortoise population, according to GTC MVP guidelines, was defined as consisting of at least 250 adult tortoises, at a density of at least 0.4 tortoises per ha, with an even sex ratio and evidence of all age classes present, on a property with at least 100 ha of high quality, well-managed tortoise habitat (GTC 2013, pp. 2-3). A primary support population was defined as consisting of 50-250 adult tortoises and these are considered as candidates of reaching viability through habitat restoration, natural recruitment increases, or population augmentation. A secondary support population was defined as <50 tortoises that have more constraints to reaching viability, but are important for education, community interest, and augmentation, and can persist long-term with rigorous habitat management and/or connectivity with other populations (GTC 2014, p. 4). It should be noted that support populations may persist for a long period of time under high-quality habitat conditions (Folt et al. 2021, p. 13), but are likely more vulnerable to stochastic events than populations that meets the minimum viable population MVP threshold (Miller et al. 2001, p. 28; GTC 2014, p. 4). In fact, a recent study from Conecuh NF demonstrated that some small populations remain stable or growing over a thirty-year period (Folt et al. 2021, entire).

2.7 Resource Needs and Habitat

Gopher tortoise habitat requirements include sufficient areas of open pine or other uplands where adequate sunlight reaches the forest floor to stimulate the growth and development of the herbaceous plant stratum for forage, with sufficient warmth for basking and the incubation of eggs (Landers 1980, p. 8; Lohoefener and Lohmeier 1981, entire; Auffenberg and Franz 1982, pp. 99, 104-107, 111, 120; Jones and Dorr 2004, p. 461; McDearman 2006, p. 2; McIntyre et al. 2019, p. 287). Low food availability negatively affects tortoise population densities and can be caused by plant growth suppression due to accumulated leaves, litter, low light associated with canopy closure (Landers and Speake 1980, p. 522), due, in turn to lack of regular disturbance such as prescribed fire. Longleaf pine and other open pine systems, sandhills, scrub (e.g., oak-palmetto, coastal, rosemary), xeric hammock, and ruderal (disturbed; e.g., roadsides, rights-of-way, grove/forest edges, fencerows, and clearings) plant communities most often provide the conditions necessary to support gopher tortoises (Auffenberg and Franz 1982, p. 99).

In the western fringe of the range, soils are loamy and contain more clay (Lohoefener and Lohmeier 1981, p. 240; Auffenberg and Franz 1982, pp. 114-115, Mann 1995, pp. 10–11). Higher clay content in soils may contribute to lower abundance and density of tortoises such as in Mississippi versus the eastern portion of the range (Estes and Mann 1996, p. 24; Jones and Dorr 2004, p. 461). Xeric (dry) conditions are less common west of the Florida panhandle (Craul et al. 2005, pp. 11-13). Ground cover in the Coastal Plains can be separated into two general regions, with the division in the central part of southern Alabama and northwest Florida. To the west, bluestem (*Andropogon* spp.) and panicum (*Panicum* spp.) grasses predominate (Mann 1995, p. 11); to the east, wiregrass (*Aristida stricta*) is most common (Boyer 1990, p. 3). However, gopher tortoises do not necessarily respond to specific plants but rather the physical characteristics of habitat (Diemer 1986, p. 126). Historically, gopher tortoises occurred in open longleaf pine forests, savannas, and xeric grasslands that covered the coastal plain in the Southeastern United States, and while some areas of habitat might have had wetter soils at times and been somewhat cooler, these areas were generally xeric, open, and diverse (Ashton and Ashton 2008, p. 73).

In addition to meeting foraging needs, gopher tortoises require a sparse canopy and litter-free ground for nesting (Landers and Speake 1980, p. 522). In Florida, the number of active burrows per gopher tortoise was found to be lower where canopy cover was high (McCoy and Mushinsky 1988, p. 35). Females require almost full sunlight for nesting (Landers and Buckner 1981, p. 5) because eggs are often laid in the burrow apron or other warm, sunny areas for appropriate incubation (Landers and Speake 1980, p. 522).

At one site in southwest Georgia, most gopher tortoises were found in areas with 30 percent or less canopy cover (Boglioli et al. 2000, p. 703). However, more extensive examination of the same site revealed that canopy cover alone may not always be indicative of gopher tortoise habitat (McIntyre et al. 2019, p. 288 – 289). Ecotones created by clearing were also favored by gopher tortoises in north Florida (Diemer 1992b, p. 162). When canopies become too dense, usually due to fire suppression, gopher tortoises tend to move into ruderal habitats such as roadsides with more herbaceous ground cover, lower tree cover, and significant sun exposure (Garner and Landers 1981, p. 122; McCoy et al. 1993, p. 38; Baskaran et al. 2006, p. 346). In Georgia, open-canopy pine areas were more likely to have burrows, support higher burrow densities, and have more burrows used by large, adult gopher tortoises than closed-canopy forests (Hermann et al. 2002, p. 294). Historically, open-canopied southern pine forests were maintained by frequent, lightning generated fires. Subsequently, in addition to prescribed fire, grazing, mowing, roller chopping, timber harvesting, and selective herbicide application may be used in the restoration, enhancement, and maintenance of some gopher tortoise habitat (Cox et al. 2004, p. 10; Ashton and Ashton 2008, p. 78; GDNR 2014, unpaginated; Rautsaw et al. 2018, p. 141).

Burrows

The burrows of a gopher tortoise (Figure 2.4) are the center of normal feeding, breeding, and sheltering activity. As mentioned above, gopher tortoises excavate and use more than one burrow for shelter beneath the ground surface. Burrows, which may extend for more than 30 feet, provide shelter from canid predators, fire, winter cold and summer heat (Hansen 1963, p. 359; Landers 1980, p. 6; Wright 1982, p. 50; Diemer 1986, p. 127; Boglioli 2000, p. 699). Digging burrows benefits the surrounding habitat by returning leached nutrients to the surface (Auffenberg and Weaver 1969, p. 191; Landers 1980, p. 2), and increasing the heterogeneity (diversity) of the habitat in the vicinity of the burrow (Kaczor and Hartnett 1990, p. 107). Burrows can also serve to shelter seeds from fires (Kaczor and Harnett 1990, p. 108). Many organisms adapted to hot summers and cool winters use gopher tortoise burrows for refuge (Landers and Speake 1980, p. 515). An estimated 60 vertebrates and 302 invertebrates share tortoise burrows (Jackson and Milstrey 1989, p. 87). Gopher tortoise burrows not only provide other species shelter from extreme environmental conditions and predation but may also be used as feeding or reproduction sites, and as permanent microhabitats for one or all life stages (Jackson and Milstrey 1989, p. 86).

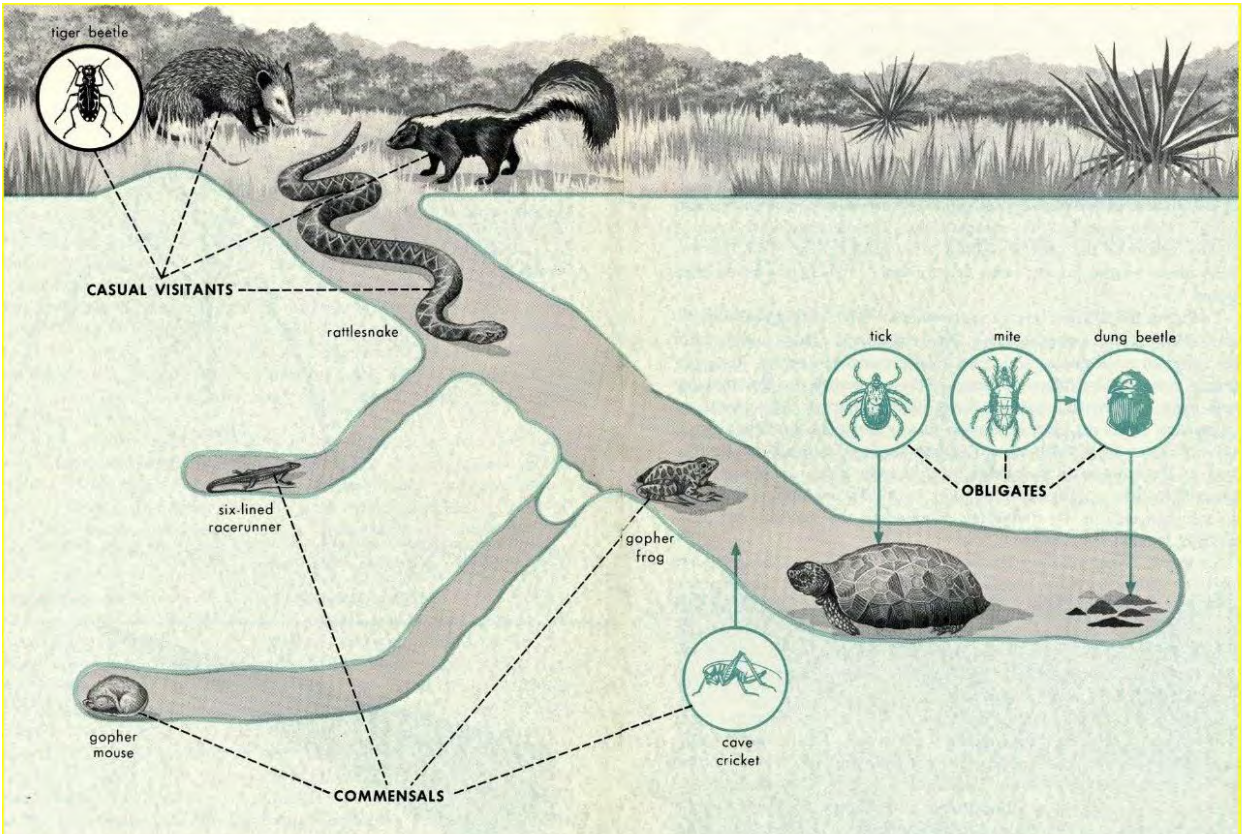

Figure 2. 4-Diagram of a gopher tortoise burrow showing a gopher tortoise near the end chamber, commensal species using side chambers, and casual visitants near the burrow opening. Image source: Dr. Walter Auffenberg, Florida Museum of Natural History (Auffenberg 1969).

In poor quality habitat where shrubs and hardwoods have encroached, gopher tortoises tend to excavate and use fewer burrows, likely due to limited availability of sites that are sufficiently open. The term “active burrow” is applied to burrows exhibiting indications they are likely inhabited by a gopher tortoise. Characteristics of active burrows (Figure 2.5) include fresh soil excavated from the interior of the burrow, deposited on the apron at the burrow entrance; tortoise feces on the apron or near the burrow entrance; and presence of eggshells and tracks (Auffenberg and Franz 1982, p. 76; Estes and Mann 1996, p. 11). Inactive burrows, which do not display conditions of recent use and occupancy by a gopher tortoise, are considered to be used as part of the annual home range of one or more gopher tortoises but are not currently occupied by a gopher tortoise. Indicators of inactive burrows include suitable size and shape of the burrow entrance; a recognizable apron of bare soil with or without encroachment of grasses or shrubs; and small amounts of leaf litter in the entrance that have not been moved by a gopher tortoise (Auffenberg and Franz 1982, p. 76; Estes and Mann 1996, p. 11). Abandoned burrows are unlikely to be used by a gopher tortoise and, normally, exhibit indications of erosion, a loss of shape and structure, and no apron. Occupancy of gopher tortoise burrows cannot be confirmed based on these characteristics.

Figure 2. 5-Images showing active gopher tortoise burrows, one in an open-canopy pine area (left) and the other showing gopher tortoise tracks (right) in a recently planted pine stand. Image credit: Angela Larsen-Gray.

Sand texture is most important in the formation of the burrow apron, which impedes rain from entering the burrow (Landers 1980, p. 6). Sand depth is also important because soil layers underlying it, such as clay, can impede digging and influence burrow depth (Baskaran et al. 2006, p. 347). Burrows in clay-type soils are more susceptible to regular winter flooding (Means 1982, p, 524). Additionally, burrows are shorter in clay soils, and clay soils may adversely affect nest success because these soils reduce exchange of oxygen and carbon dioxide (Wright 1982, p. 21; Ultsch and Anderson 1986, p. 790; Smith et al. 1997a, p. 599). Larger diameter burrow openings tend to result in longer burrows (Hansen 1963, p. 355). Burrows are usually distributed on higher ridge tops and their depths are sometimes limited by the water table (Baskaran et al. 2006, p. 346).

Tortoises select and prefer burrow sites in open canopy areas where sunlight reaches the ground (Boglioli et al. 2000, p. 703; Rostal and Jones 2002, p. 485). Such sites reflect areas where herbaceous plants for food are more abundant on the forest floor and, for females, sunlight and soil temperatures for egg incubation are more suitable. Also, males select sites and burrows that increase their proximity to females and breeding opportunities (Ott-Eubanks et al. 2003, p. 318; Boglioli et al. 2003, p. 849). The repeated use and travel to the same burrows by individual tortoises in stable habitat reveal that tortoises know the geography of their home range, burrows, and the location of neighboring tortoises (Ott-Eubanks et al. 2003, p. 318).

CHAPTER 3 – FACTORS INFLUENCING VIABILITY

Gopher tortoise life history, habitat needs, potential influencing factors (negative and positive) that are likely to affect the viability (Figure 3.1) of the species currently and into the future are identified and discussed in this chapter. Specific information and metrics associated with the current condition of gopher tortoise populations and habitat are discussed in Chapter 4.

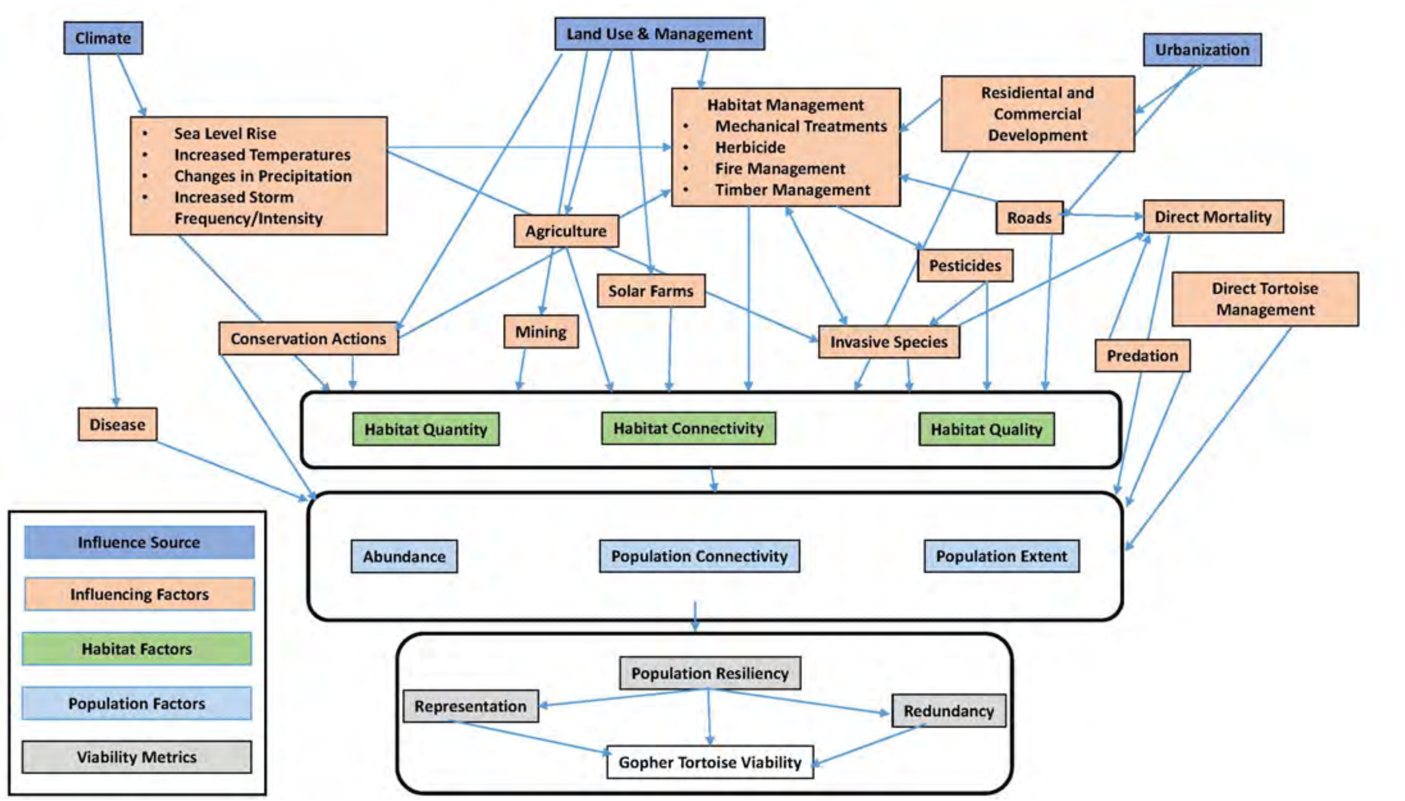

Figure 3. 1-Factors influencing the viability of the gopher tortoise.

3.1. Habitat Loss and Fragmentation

Gopher tortoise habitat comprises well-drained sandy soils (burrowing, sheltering, and breeding), with an open canopy, sparsely vegetated midstory, and abundant herbaceous groundcover (feeding). Gopher tortoise habitat occurs in a variety of upland natural communities such as sandhill, scrub, pine flatwoods (mesic and scrubby), xeric hammock, coastal habitats, and anthropogenic landscapes such as rights-of-way, pasturelands and planted pine stands. At a landscape scale, large swaths of interconnected, high quality habitat patches are likely to support viable populations, and ultimately lead to high resiliency of the species. Historically, open canopy conditions were maintained by frequent fires. Currently, habitat management is accomplished using prescribed fire, mechanical treatments (including timber harvesting), and herbicides. Habitat management activities may be implemented singularly or in combination (e.g., roller chopping followed by prescribed fire).

Urbanization and major roads (development; Auffenberg and Franz 1982, p. 112; Diemer 1986, p. 128; Diemer 1987, p. 74-75; Enge et al. 2006, p. 4), incompatible and/or insufficient habitat management, and certain types of agriculture (Lohoefener and Lohmeier 1984, pp. 2–6; Auffenberg and Franz 1982, p. 105; Hermann et al. 2002, pp. 294-295) can negatively impact gopher tortoises and gopher tortoise habitat. Invasive species can influence gopher tortoises either through direct impacts (e.g., predation; Mann 1995, p. 24;Engeman et al. 2009, p. 84; Engeman et al. 2011, p. 607; Dziadzio et al. 2016b, p. 531; Bartoszek et al. 2018, pp. 353-354) or alterations to habitat structure and/or function (Lippincott 1997, pp. 48-65; Bastios 2007, p. 24).

Climate change has the potential to negatively impact habitat through the loss of habitat due to sea level rise (Hayhoe et al. 2018, entire), limitations on number of suitable burn days due to changes in temperature (Kupfer et al. 2020, entire), precipitation, increased flooding due to predicted increases in the severity of hurricanes (Castellon et al. 2018, pp. 11-14), and human migration from inundated coastal areas, to inland areas, with subsequent impacts to gopher tortoises (Ruppert et al. 2008, p. 127).

Conservation of habitat through land acquisition and conservation actions on public and private lands and the retention of private forest lands, reduces the severity of some of these threats by providing protection of habitat across the landscape, maintaining connectivity between habitat patches, and increasing the opportunity for beneficial habitat management actions.

3.1.1. Historical Loss of Longleaf Pine and Longleaf Restoration

While gopher tortoises do occur and persist in open canopy stands of several southern pine species, gopher tortoises were historically associated with longleaf pine systems. Longleaf pine ecosystems are fire-dependent and once dominated the Coastal Plain of the Atlantic and Gulf coast regions, from Virginia to Texas (Ware et al. 1993, p. 447). Longleaf pine forests once covered an estimated 92 million acres (37 million ha) (Frost 1993, p. 20). By the 20th century, longleaf pine communities declined to less than 3 million acres due to forest clearing and conversion for agriculture, conversion from longleaf to other pine species, and development (Landers et al. 1995, p. 39). As a result of fire suppression and exclusion in many areas, currently, only an approximate 3 percent of remaining longleaf acres is in relatively natural condition (Simberloff 1993, p. 3; Frost 1993, p. 17; Jensen et al. 2008, p. 16).

America's Longleaf Restoration Initiative (ALRI) is a collaborative effort involving multiple public and private partners actively supporting efforts to restore and conserve longleaf pine ecosystems with a goal to increase longleaf coverage on the landscape to 8.0 million acres (3.2 million ha) (ALRI 2021, unpaginated). These efforts are focused within "significant landscapes" where Local Implementation Teams (LITs) are leading conservation efforts by coordinating partners, developing priorities, and fundraising to implement on-the-ground conservation (Figure 3.2). Several LITs are working within the range of the gopher tortoise to help restore longleaf pine on habitat utilized by gopher tortoises.

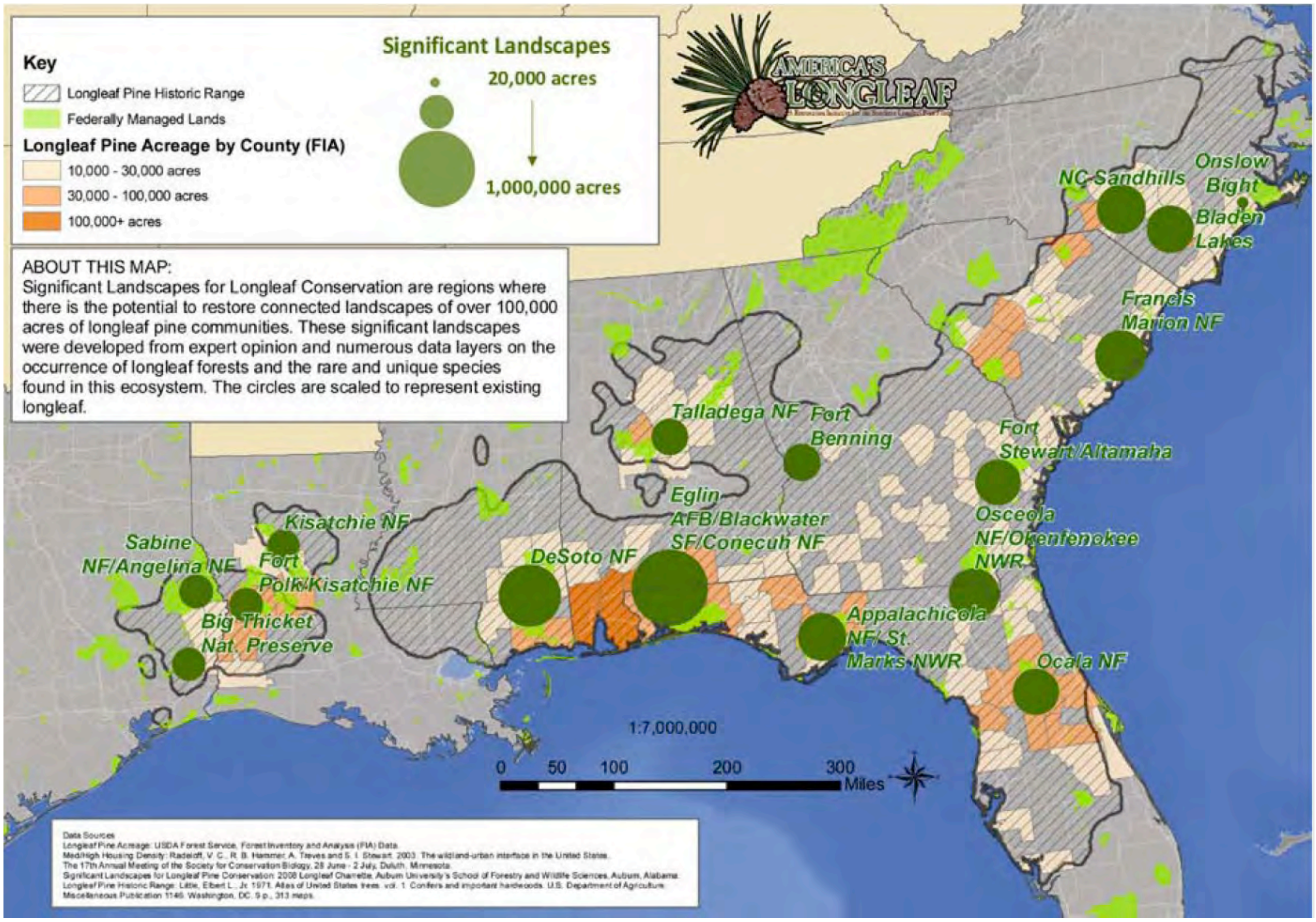

Figure 3. 2-Locations and relative size of existing longleaf acreages of Significant landscapes for Longleaf Conservation. Source: The Conservation Fund.

3.1.2 Fragmentation and Urbanization

The maintenance of habitat connectivity is important for gopher tortoise viability.

Human development of the landscape fragments and replaces natural areas with artificial structures, impervious surfaces, and manicured lawns and gardens containing non-native plant species (Sutherland 2009, p. 35), threatening wildlife communities, including gopher tortoise populations, that rely on a mosaic of interconnected uplands. In addition to the direct loss of habitat, development and urbanization may also threaten gopher tortoise populations on conservation lands by disrupting habitat connectivity across the landscape (decreasing immigration and emigration between local populations) and through the disruption of habitat management activities on conservation lands, particularly through the constraining of prescribed fire activities. In Florida, urban growth and development is identified as one of the primary threats to gopher tortoises (Auffenberg and Franz 1982, p. 112; Diemer 1986, p. 128; Diemer 1987, p. 74-75; Enge et al. 2006, p. 4). Georgia is also anticipated to see dramatic human population increases (Georgia Census 2021, unpaginated), leading to subsequent development and potential loss of gopher tortoise habitat.

Gopher tortoises can occur in residential areas despite the fact that these areas are typically of lower habitat quality. Urbanization impacts many wildlife species from direct loss of habitat, fragmentation of habitat, increased road mortality, increased human persecution, and by the increase in domestic predators, such as cats and/or dogs. Current research is lacking to quantify urbanized landscape impacts on survival, recruitment, health, and long-term persistence. However, urban tortoises may help bridge connectivity between natural habitats, though level of connectivity would vary significantly by how these areas are designed (e.g., presence of fencing, road density, habitat quality).

In addition to habitat loss, a direct impact from development could include mortality of gopher tortoises from entombment in their burrows (for more information regarding entombment, see Section 3.8). In the western portion of the range where the species is federally listed, individual gopher tortoises are translocated from development sites to avoid mortality for land development activities during consultation with the Service under sections 7 and 10 of the Act. Prior to 2007, gopher tortoise relocation was not mandated in Florida, but developers were required to mitigate for the loss of tortoises and habitat associated with the development site through an Incidental Take Permit. This mitigation was provided in the form of a monetary contribution or donation of protected habitat (i.e., conservation easement), with the goal of offsetting the effects of development projects on gopher tortoise populations in Florida. Although FWC no longer issues ITPs, they are perpetual, with many still active. Presently, Incidental Take permittees have the option to relocate gopher tortoises on-site or amend their permit to relocate tortoises to an approved recipient site for no additional mitigation. Since 2007 (76 FR 45130), in Florida, the state wildlife agency requires developers to relocate tortoises out of harm’s way (FWC 2007, p. 10). Other states (Georgia, Alabama and South Carolina) have some measure of legal protection for gopher tortoises, though gopher tortoise burrows are not protected uniformly across the range. When notified, these states work with developers when they identify tortoises on development sites. Conservation activities that assist in mitigating these direct impacts are discussed in detail in Section 3.9.3 (Relocation, Translocation, Recipient Sites, and Headstarting).

A primary driver of urbanization and subsequent habitat fragmentation impacting gopher tortoises is human population growth. Since 2010, with the exception of Mississippi, which shows a 6 percent decrease in human population, all other states within the limits of the historical range of the gopher tortoise have experienced growth in human populations with increases as of 2020 ranging from 3% in Louisiana to 15% in Florida (Table 3.1). Census projections over the next decade indicate similar percent increases from 2019 population numbers (Table 3.1). Additionally, census information available for Florida indicates an estimated 27% increase by 2045 from 2019 estimates (FEDR 2018, unpaginated).

State	2010	2020 (% change from 2010)	2030 Projections (projected % change from 2020)
Alabama	4,780,125	5,024,279 (increase 5%)	5,124,380 (increase 2%)
Florida	18,801,332	21,538,187 (increase 15%)	24,426,178 (increase13.4%)
Georgia	9,688,729	10,711,908 (increase 11%)	11,709,700 (increase 9%)
Louisiana	4,533,487	4,657,757 (increase 3%)	4,813,420 (increase 3%)
Mississippi	2,968,130	2,961,279 (decrease 6%)	3,092,410 (increase 4%)
South Carolina	4,625,366	5,118,425 (increase 11%)	5,488,460 (increase 7%)

Table 3. 1-Human population estimates and future projections (including percentage increases and decreases) for six states within historical range of the gopher tortoise (Blanchard 2007, p. 7; Culver College of Business 2021, unpaginated; FEDR 2018, unpaginated; Georgia Census

2021, unpaginated; Population Projections 2021, unpaginated; SCBCB 2009, p. 2; U.S. Census Bureau 2021, unpaginated).

3.1.3. Solar Farms

As interest in renewable energy increases, the development of solar farms across the landscape is also increasing (Figure 3.3). By 2019, Florida ranked fifth in the nation in total solar power generating capacity and utility (EIA 2018, unpaginated). In South Carolina, the state's net solar power production increased 70% between 2018 and 2019, with two dozen new solar farms becoming operational (EIA 2018, unpaginated). In Georgia, solar energy accounted for 2% of the in-state electricity in 2019 with half of the six largest facilities (capacities greater than 100 megawatts) coming on-line in 2019 (EIA 2018, unpaginated). While total solar generation is small in Alabama, it accounts for 4% of renewable energy in the state with the strongest solar resources located Southeast along the Gulf Coast (EIA 2018, unpaginated). Though the state's first facility came on-line in 2017, in Mississippi, utility-scale solar energy production is small, accounting for 0.5% of the state's total generation (EIA 2018, unpaginated). Solar power generated about one-tenth of Louisiana's renewable generation in 2020. Louisiana's utility-scale (facilities 1 megawatt or larger) solar generation was 40 times greater in 2020 than in 2019 (EIA 2018, unpaginated). A number of solar sites are known to have impacted gopher tortoise habitat. Some solar utility developers and companies recognize the potential impact that this type of development may have on rare species and their habitat and have begun working with conservation organizations to avoid and minimize impacts via strategic siting assessments (NASA Develop 2018, unpaginated). A primary concern regarding large-scale deployment of solar energy is the potentially significant land use requirements (Ong et al. 2013, p. iv), habitat fragmentation and possible exclusion of wildlife including gopher tortoises as a result of fencing, and the need to relocate tortoises from solar farm sites prior to construction. As solar farm development increases, particularly on rural lands, concerns over the protection of sensitive species such as the gopher tortoise are heightened (SELC 2017, p. 3).

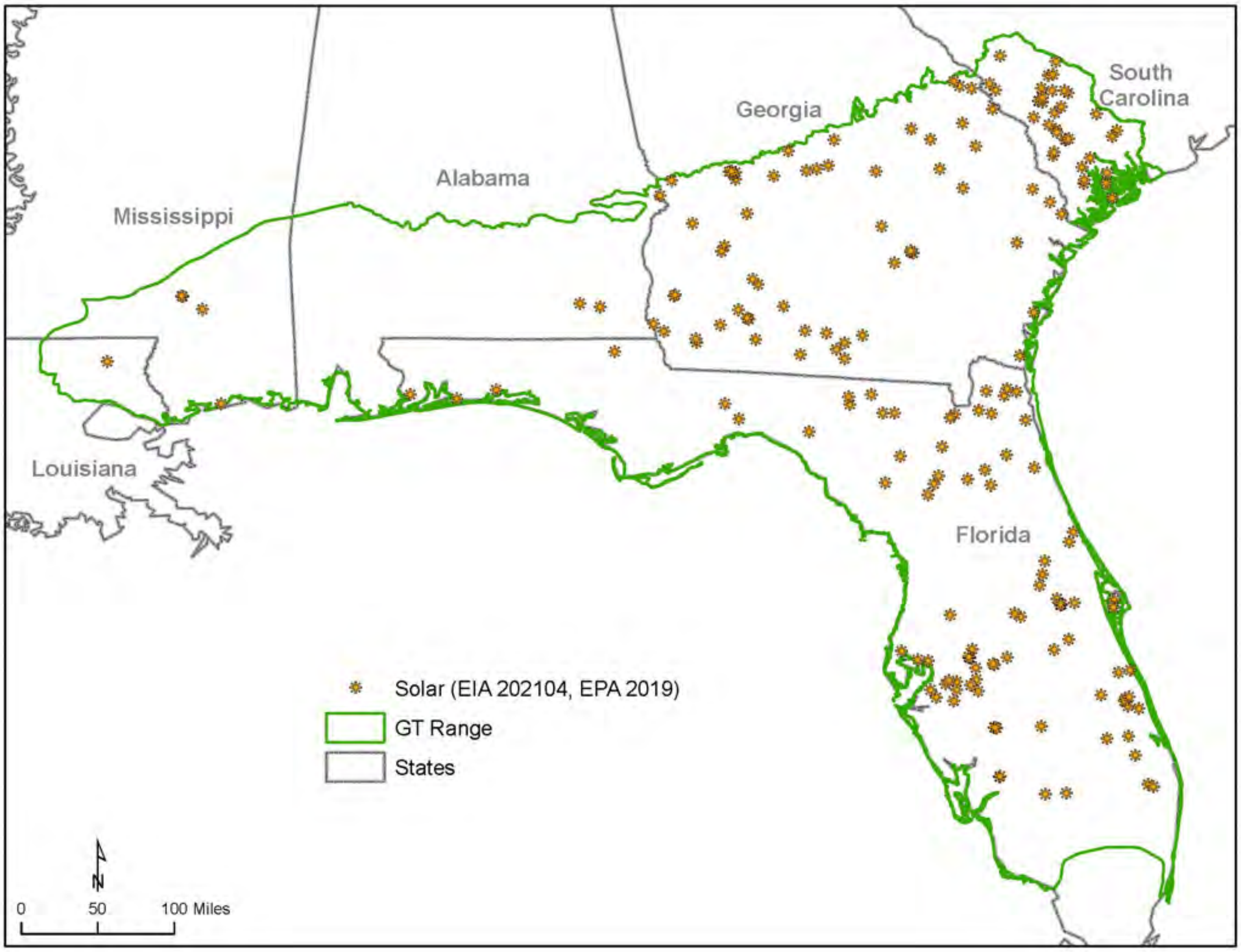

Figure 3. 3-Location of solar power plants within the range of the gopher tortoise.

3.1.4. Agricultural Lands

Over 80 percent of potential tortoise habitat is in private ownership, and much of this falls under agricultural uses. Surveys have shown that sites on suitable soils that had agriculture as the primary land use, were about 6 times less likely to have burrows and contained 20 times fewer gopher tortoise burrows than open pine sites (Hermann et al. 2002, pp. 294-295). Annually tilled agricultural fields are not inhabited by tortoises (Auffenberg and Franz 1982, p. 105). However, after several years of crop abandonment, succession of former agricultural fields into areas that are dominated by perennial herbaceous species may begin to attract gopher tortoises (Auffenberg and Franz 1982, p. 105). It may take many years for the preferred herbaceous species to be established on these fields, but if fire (or other vegetation management) is excluded from the site, the canopy will ultimately close and any gopher tortoises that may have re-colonized will evacuate the site (Auffenberg and Franz 1982, pp. 107-108). While the area of cropland in the South is forecasted to decline as much as 17 million acres (6.9 million hectares) by 2060 (from a base of 84 million acres (34 million hectares) in 1997) (Wear and Greis 2013, p. 45), it is unknown the extent to which abandoned agricultural fields will be restored to a level of suitability necessary to support viable gopher tortoise populations. However, restoration of abandoned agricultural fields into potential gopher tortoise habitat can be accomplished, provided soils are appropriate for gopher tortoises, as seen in the successes of the Conservation Reserve Program converting thousands of acres of agricultural land to forests.

3.2. Road Effects and Mortality

Roads create habitat fragmentation, isolate habitat, pose a barrier to movement, and increase direct mortality for many species of reptiles, including gopher tortoises (Andrews and Gibbons 2005, p. 772; Hughson and Darby 2013, pp. 227-228). Roads that bisect habitat pose hazards to gopher tortoises throughout the range (Figure 3.4), forcing individual gopher tortoises into unsuitable areas and onto highways (Diemer 1987, p. 75; Mushinsky et al. 2006, p. 38). Roads occurring within or adjacent to tortoise habitat are of particular concern because tortoises are attracted to road shoulders where open canopy, grassy areas are maintained (Steen and Gibbs 2004, entire; Steen at al. 2006, p. 271). In a recent study to determine if gopher tortoises use roadsides as movement pathways between larger habitat patches or as residential habitat, gopher tortoises appear to use roadsides independently of larger habitat patches, treating them as areas for residency as opposed to travel corridors among other habitat patches (Rautsaw et al. 2018, p. 141). Gopher tortoises residing along roadsides may be more susceptible to predation. Predators such as raccoons frequently use ecological edges and may occur in high densities in fragmented, suburban landscapes (Hoffman and Gottschang 1977, p. 633; Wilcove 1985, pp. 1213-1214).

While road mortality occurs in gopher tortoise populations, the extent to which it affects populations, or the species, is not well documented. Risk of road mortality on tortoises is likely related to the type of road and its traffic pattern (e.g., an unpaved rural road compared to a major highway), but this relationship has not been quantified. Increases in observed road mortality (episodic or consistent) may be a by-product of new construction, road expansion, or relocation of tortoises; however, there is no information directly linking road mortality to population declines and the magnitude of this influencing factor is uncertain. Information collected through FWC's citizen science application indicates that between 2014 and 2018, 470 tortoises were reported as sick, injured or dead, of which, 41% were tortoises injured or dead on roads (10th Annual GT CCA Report 2019, p. 95) (Figure 3.5).

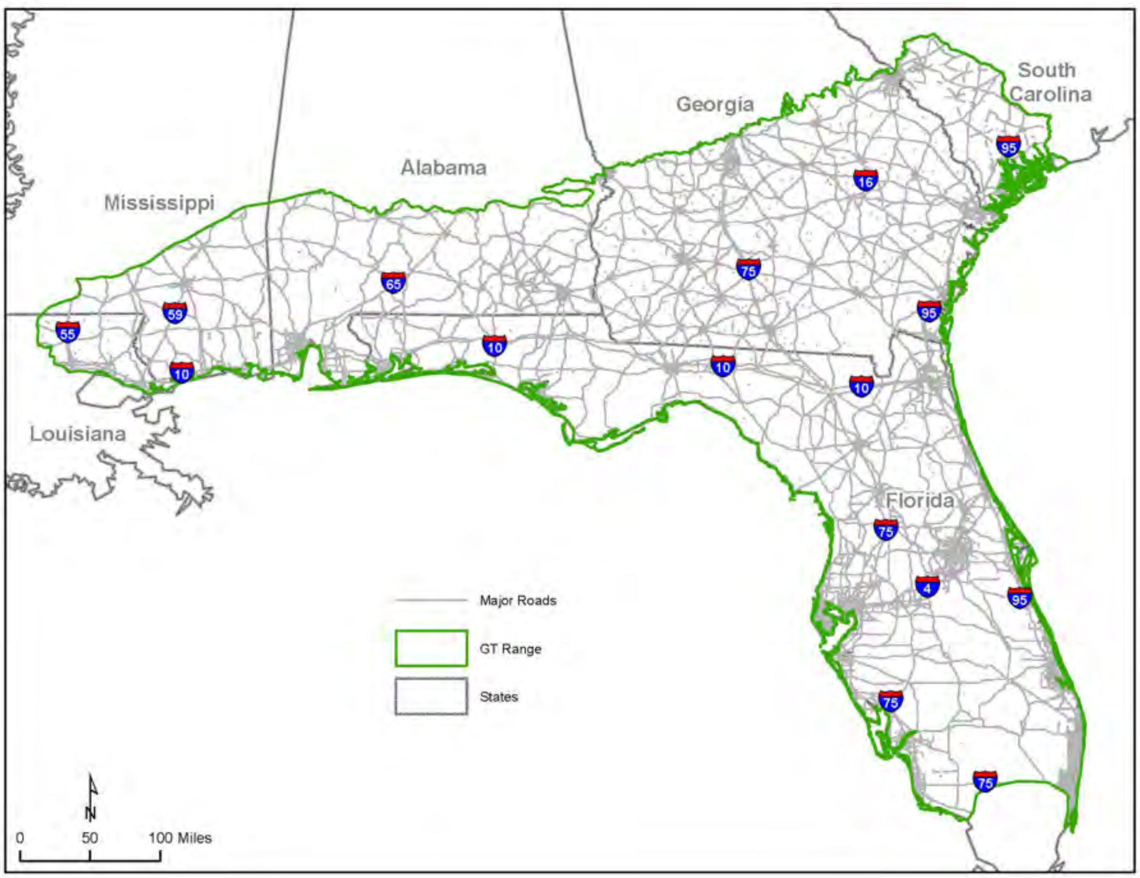

Figure 3. 4-Interstates and major freeways and highways occurring across the range of the gopher tortoise in Florida, Georgia, Louisiana, Mississippi, Alabama, and South Carolina.

Figure 3. 5-Images showing gopher tortoise burrow on road right-of-way (left) and road killed gopher tortoise (right). Image credit: Randy Browning (left) and Jeffrey M. Goessling, Ph.D. (right).

As development and subsequent habitat loss and fragmentation occurs, it is expected that gopher tortoises will continue to disperse to find better quality habitat, putting individual gopher tortoises at risk of road mortality. This threat is likely to increase as road densities and traffic volumes increase and habitat patches become more isolated and more difficult to manage (Enge et al. 2006, p. 10). Highway mortality of gopher tortoises will be highest where there are improved roads adjacent to gopher tortoise populations. Gopher tortoises in the vicinity of urban areas will be particularly vulnerable (Mushinsky et al. 2006, p. 362), especially in areas with heavy traffic patterns and/or high-speed limits. This threat is ongoing and will continue to occur in the future in peninsular Florida and urban centers in coastal portions of Georgia, Alabama and Mississippi where human populations are likely to increase as seen in urban modeling projections using SLEUTH (Terando et al. 2014, entire). Quantification of the effects of road mortality on gopher tortoise populations is difficult because there is no current rangewide monitoring effort for gopher tortoise road mortality.

The installation of wildlife barrier fences along roadways has the potential to minimize gopher tortoise road mortality. In Alabama, two road projects cumulatively resulted in the installation of approximately 16 kilometers (10 miles) of gopher tortoise fencing. The Mississippi Department of Transportation also used fencing to mitigate gopher tortoise road mortality and installed approximately 24 kilometers (15 miles) of fencing, which decreased road mortality in gopher tortoises from between 1 and 2 annually to none. The projects reduced or eliminated road mortality and contributed to sustainability of local gopher tortoise populations. However, they are small in scale and do not substantively reduce the threat of gopher tortoise road mortality throughout its range and they do not eliminate the habitat fragmentation caused by the roads. Additionally, while barrier fencing along roads may reduce road mortality, fencing may also further limit the movement of gopher tortoises.

3.3. Climate Conditions

In the Southeastern United States, the impacts of climate change are already occurring in the form of sea level rise and extreme rain events (Carter et al., 2018, p. 749). Changes in temperatures may result in more frequent drought, more extreme heat (resulting in increases in air and water temperatures), increased heavy precipitation events (e.g., flooding), more intense storms (e.g., frequency of major hurricanes increases), and rising sea level and accompanying storm surge (IPCC, 2014, entire). Higher temperatures and an increase in the duration and frequency of droughts will also increase the occurrence of wildfires and reduce the effectiveness of prescribed fires (Carter et al. 2018, pp. 773-774). Changes in climate may alter the abiotic conditions experienced by species assemblages, resulting in effects on community composition and individual species interactions (DeWan et al. 2010, p. 7; Carter et al. 2018, pp. 768-787).

Despite the recognition of climate effects on ecosystem processes, there is uncertainty about the exact climate future for the Southeastern United States and how the ecosystems and species in this region will respond. The Southeast is part of the transition zone between tropical and temperate climates where salt marshes, pine-dominated forests and hardwood forests meet mangrove forests, pine savannas and tropical freshwater wetlands in the Everglades. It should be recognized that the greatest threat to many species from climate change may come from synergistic effects. That is, factors associated with a changing climate may act as risk multipliers by increasing the risk and severity of more imminent threats. The effects of changing climate conditions are likely to influence gopher tortoises and gopher tortoise habitat.

Gopher tortoises exhibit temperature dependent sex determination, with pivotal temperature for a 1:1 sex ratio being observed at 29.3°C (84.7°F) (DeMuth 2001, pp. 1612-1613). Incubation temperature has also been shown to affect post-hatchling growth in gopher tortoises; eggs incubated at higher temperatures produced hatchlings that grew more than those incubated at lower temperatures, though growth rate was not determined to be significantly different until nearly 9-months post-hatching (Demuth 2001, p. 1614). Mean clutch sizes are also larger in warmer more productive environments (Ashton et al. 2007, pp. 355-362). Because of predicted increases in temperature across the Southeastern U.S. due to climate change, there are potential changes with skewed sex ratios, clutch sizes, hatchling success, and possibly hatchling condition. While temperatures are anticipated to increase in the future due to climate change, the extent to which this may influence gopher tortoise demography is uncertain as the gopher tortoise may modify nest site selection in at least two ways to buffer against potential impacts related to temperature dependent sex determination: selection of cooler nest sites (Czaja et al. 2020, entire), and altering timing of nesting to earlier in the season, and there is evidence that gopher tortoises may already exhibit both of these behaviors (Ashton and Ashton 2008, entire; Moore et al. 2009, entire; Craft 2021, pp. 42-45).

Frequency of severe hurricanes is predicted to increase in the future (IPCC 2014, entire; Carter et al. 2018, entire), and there is some potential for negative direct impacts to gopher tortoises. Gopher tortoise burrows may be impacted by flooding after a hurricane, causing abandonment, though the burrow may become useable again. Gopher tortoise movement was shown to significantly increase in areas that had a higher water table and frequent burrow flooding, though there does not appear to be large-scale shifts in movement to drier habitats for nesting during peak rains (Castellon et al. 2018, pp. 11-14). A study in Cape Sable, Florida, found a 76% decline in active burrows at the site during an 11-year period between 1990 and 2001, attributed largely to mortality as a result of declines in habitat quality and the effects of tropical storms (Waddle et al. 2006, pp. 281-283). Subsequently, in surveys done post hurricane Irma in 2018, evidence of activity in burrows was found but no tortoises were observed (Falk 2018, entire). In addition, over wash of coastal dunes may result in “salt burn” and loss of coastal vegetation, temporarily reducing forage availability in coastal natural communities used by gopher tortoises.

While other habitat management techniques may mitigate the reduced ability to implement prescribed fire, challenges associated with managing gopher tortoise habitat with prescribed fire are a substantial risk factor associated with climate change for this species. Predicted changes in temperature and precipitation due to climate change will limit the number of days with suitable conditions for prescribed burns (Kupfer et al. 2020, entire). This reduction in prescribed fire, combined with the effects of urbanization, will further restrict the ability to manage habitat with prescribed fire. As the ability to implement prescribed fire is increasingly constrained, the ability to reduce woody vegetation and maintain an open under- and mid-story will be limited, and gopher tortoise habitat will likely degrade. In addition to the constrained ability to implement prescribed fire in the future, modelling for the Southeastern United States suggests increased wildfire risk and a longer fire season, with at least a 30% increase from 2011 in lightning-ignited wildfire by 2060 (Vose et al. 2018, p. 239).

There is risk to coastal populations of gopher tortoises due to sea level rise and subsequent inundation and loss of habitat in coastal areas. Global mean sea level has risen 7-8 inches (16-21 cm) since 1900, with about half of that rise occurring since 1993 (Hayhoe et al. 2018, p. 85). In areas of the Southeast, tide gauge analysis reveals as much as 1 to 3 feet (0.30 to 0.91 m) of local relative SLR in the past 100 years (Carter et al. 2018, p. 757). The future estimated amount that sea level will rise depends on the response of the climate system to warming, and on the future scenarios of human-caused emissions (Hayhoe et al. 2018, p. 85). Additionally, the amount of gopher tortoise habitat predicted to be lost within a given population due to SLR varies considerably depending on the location of the population. Loss of habitat within a population will result in a decreased probability of population persistence.

Indirect impacts to gopher tortoises and their habitat may occur due to the relocation of people from flood-prone coastal areas to inland areas (Ruppert et al. 2008, p. 127), including the relocation of millions of people to currently undeveloped interior natural areas (Stanton and Ackerman 2007, p. 15). Alabama, Florida, Louisiana, and Mississippi's interior natural ecological communities will likely be impacted with the increasing need of urban infrastructure to support retreating coastal inhabitants. Increases in gopher tortoise habitat loss related to climate change would be in addition to the 20 percent loss projected to occur by 2060 due solely to people immigrating into Florida (FWC 2008, p. 2). Increasing threats of habitat loss due to coastal retreat is likely to also affect tortoise habitat inland from the Georgia, Alabama, and Mississippi coastal counties. The timing of these impacts will be dependent on the rate at which the sea level rises, and a gradual coastal retreat and concurrent impacts to gopher tortoises are likely during this time.

3.4. Disease

A number of diseases have been documented in gopher tortoises, including fungal keratitis (Myers et al. 2009, p. 582); iridovirus; ranavirus (Johnson et al. 2008, entire); herpesvirus; bacterial diseases related to *Salmonella* spp., *Mycoplasma* spp., *Helicobacter* sp. (Desiderio et al. 2021, entire), and *Dermatophilus*; and numerous internal and external parasites (Ashton and Ashton 2008, pp. 39-41). Upper Respiratory Tract Disease (URTD) resulting from two *Mycoplasma* species (*M. agassizii* and *M. testudineum*) has received the most attention recently (Figure 3.6). URTD has been documented throughout much of the tortoise's range (Berish et al. 2010, p. 696; McGuire et al. 2014a, pp. 737-739; Goessling et al. 2019, pp. 5-6), but the magnitude of threat URTD poses to gopher tortoise populations and tortoise demographics is uncertain (Karlin 2008, p. 1).

URTD has been linked to several large die-offs, the first of which occurred in 1989 on Sanibel Island, Lee County, Florida, and resulted in the estimated loss of 25-50 percent of the adult population (McLaughlin 1997, p. 6). Other large-scale mortality events implicating URTD as a causal factor have also occurred in Florida (Gates et al. 2002, entire; Rabatsky and Blihovde 2002, entire; Dziadzio et al. 2018, entire). Multiple dead individuals have also been found on sites where seroprevalence of *M. agassizii* was documented among living tortoises (Berish et al.

2000, p. 10). Other sites in the candidate range have documented instances of high seroprevalence of URTD (McGuire et al. 2014a, p. 738; Goessling et al. 2019, p. 5), but population-level effects of this disease were unknown. Additionally, there have been few symptomatic tortoises and no recorded deaths determined to be from URTD in the western range.

Figure 3. 6-Image of an adult gopher tortoise with nasal discharge associated with active Upper Respiratory Tract Disease (URTD). Image credit: Jessica McGuire.

Current hypotheses suggest that differences in virulence of various strains of Mycoplasma (Sandmeier et al. 2009, p. 1261) and increased susceptibility to infection due to environmental stressors (e.g., poor habitat quality) may increase risk of URTD outbreaks and associated mortality. However, tortoises have natural antibodies to *Mycoplasma* spp. (Hunter et al. 2008, p. 464) and these natural immune mechanisms may explain why die-offs are not more prevalent throughout the gopher tortoise's range (Gonynor and Yabsley 2009, pp. 1-2; Sandmeier et al. 2009, pp. 1261-1262). In contrast, research suggests that susceptible tortoises in high-seroprevalence (number of individuals exposed to disease) populations have decreased apparent survival and may experience a low level of increased mortality in the initial stages of disease

(Ozgul et al. 2009, p. 796). *Mycoplasma* spp. are spread through horizontal transmission via direct contact during courtship and mating activities (Jacobson et al. 2014, p. 260); thus, juvenile tortoises are less likely to be exposed to these pathogens. These juveniles may provide a pool of tortoises to aid in recruitment after a disease event (Wendland et al. 2010, p. 1257 and 1261); however, these size classes usually represent a small proportion of the overall population. Studies have documented low density populations with high proportions of immature tortoises (up to 71%) recovering from episodes of low apparent adult survival (Goessling et al. 2021, p. 140; Folt et al. 2021, p. 11).

URTD may also result in altered movement and behavior among gopher tortoises. Tortoises expressing severe clinical signs of URTD appear to alter their thermoregulatory behavior, basking outside the burrow more often at lower temperatures than asymptomatic tortoises (McGuire et al. 2014b, pp. 750-754). Tortoises have also been found to elevate their body temperatures behaviorally in response to acute infection (Goessling et al. 2017, p. 488). In addition, tortoises with severe clinical sign moved long distances over relatively short periods of time, potentially increasing dispersal rate of pathogens (McGuire et al. 2014b, pp. 750-754). Tortoises dispersing long distances increase their likelihood of encountering a road (i.e., a barrier), potentially limiting spread of disease but increasing risk of road mortality. However, other studies have found higher apparent survival of seropositive gopher tortoises than for seronegative individuals and suggested 1) this was due to seropositive tortoises representing those that survived the initial infection, and 2) that seropositive tortoises were less likely to emigrate from the site than seronegative individuals (Ozgul et al. 2009, p. 794).

The degree to which exposure to the pathogen correlates to clinical signs of URTD or die-offs is unclear, as is the degree of transfer between animals, and the potential for decreased resistance to the disease based on stresses from habitat modification or relocation. Nasal scarring has been found to be the only positive link between clinical sign and URTD diagnostic tests for *M. agassizii*, and there appears to be no connection between active clinical sign and antibody presence of *Mycoplasma* spp. (Goessling et al. 2019, p. 5). While large-scale die-offs due to URTD appear to be rare, correlations between exposure to *Mycoplasma* spp. and population declines are variable among geographic locations (McCoy et al. 2007, p. 173). Identifying effects of this disease on tortoise populations will require continuous long-term monitoring (Berish et al. 2010, p. 704).

3.5. Human Harvesting and Other Activities

3.5.1. Human Harvest

Human harvest of gopher tortoises for consumption has historically influenced gopher tortoise populations, particularly in portions of the Florida panhandle. Tortoises were harvested in large numbers during the Great Depression, a practice which continued for decades following the Depression (Tuma and Sanford 2014, pp. 145-146). Prior to the closure of tortoise harvest in the late 1980s, a community in Okaloosa County held an annual tortoise cookout (Enge et al. 2006, p. 5). Low numbers of tortoises on sites with otherwise adequate habitat were speculated to reflect episodes of human predation in the 1980s and 1990s in Mississippi (Lohoefener and Lohmeier 1984, p. 1-30; Mann 1995, p. 18; Estes and Mann 1996, p. 21). Though this practice is not as common as it was prior to the 1980's, localized harvest still occurs in some rural areas across the Southeast (Rostal et al. 2014, p. 146) but is likely not a significant threat to current populations.

3.5.2. Rattlesnake Roundups

Rattlesnake roundups are locally organized events that offer prizes for the largest and most rattlesnakes caught. Historically, there were multiple roundups throughout the Southeast. With the recent conversion of two roundups to wildlife festivals (Claxton, GA in 2012; Whigham, GA in 2021), only one roundup remains in the Southeast, in Opp, Alabama.

The technique of blowing fumes of noxious liquids (otherwise known as “gassing”) down tortoise burrows was used primarily to collect snakes for these rattlesnake roundups (Means 2009, p. 139). It is thought this practice of gassing burrows harms or harasses the resident tortoise, though research that quantifies negative direct impacts (i.e., mortality) is limited. For example, one study found that no tortoises died or showed ill-effects after being gassed in their burrows; however, this study did not examine potential long-term impacts or repeated gassing (Speake and Mount 1973, p. 273). Tortoise burrows have also been excavated to retrieve snakes, sometimes in conjunction with burrow gassing (Means 2009, p. 139), rendering the burrows unusable.

Use of gasoline or other chemical or gaseous substances to drive wildlife from burrows, dens, or retreats is now prohibited across Southeastern states (for example, see Alabama Regulation 220–2–.11, Georgia codes § 27–1–130 and 27–3–130, Florida Administrative Code 68A-4.001(2), and Mississippi Code R 5-2.2 B). Effective enforcement of existing regulations would likely be enhanced with development of a regulated harvest or a prohibition on rattlesnake harvest. The conversion of the one remaining roundup to a wildlife festival would reduce incidental mortality of tortoises during rattlesnake collection. While gopher tortoise mortality due to rattlesnake collection has not been quantified, this threat is primarily historical and is not likely a significant influence on populations as only one roundup in the Southeast remains.

3.6. Predation

Gopher tortoise nest predation (Figure 3.7) varies annually and across sites, ranging from ~45-90 percent in a given year (Landers et al. 1980, p. 358; Wright 1982, p. 59; Marshall 1987, pp. 29-32; see section 2.4 Life History above). Gopher tortoises are most susceptible to predation within their first year of life, though most predation appears to occur within 30 days of hatching (Pike and Seigel 2006, p. 128; Smith et al. 2013, pp. 4-5). For example, a 65 percent predation rate has been documented within 30 days of hatching at Camp Shelby, Mississippi; no tortoises within this sample survived to adulthood (Epperson and Heise 2003, p. 310 and 322). Overall annual hatchling survival has been estimated to be approximately 13% (Perez-Heydrich et al. 2012, p. 342). In some instances, predation-related mortality may reach 100% within one-year post-hatching (Pike and Seigel 2006, p. 128).

Raccoons are the most frequently reported predator of nests and juvenile gopher tortoises (Landers et al. 1980, p. 358; Butler and Sowell 1996, p. 456); other predators of nests and/or juvenile tortoises include gray fox (*Urocyon cinereoargenteus*), striped skunk (*Mephitis mephitis*), Virginia opossum, coyote (*Canis latrans*), nine-banded armadillo, several snake species (e.g. *Agkistrodon piscivorus*, *Drymarchon corais*, *Masticophis flagellum*), fire ants (*Conomyrma* spp., *Solenopsis invicta*)., and red-tailed hawks (*Buteo jamaicensis*) (Douglass and Winegarner 1977, p. 237; Fitzpatrick and Woolfenden 1978, p. 49; Landers et al. 1980, p. 358; Wilson 1991, p. 378; Mann 1995, pp. 24–25; Butler and Sowell 1996, pp. 456-457; Wetterer and Moore 2005, p. 353; Pike and Seigel 2006, p. 128). Twenty-five species—12 mammals, 5 birds, 6 reptiles and 2 invertebrates—are known to be predators of eggs, emerging neonates, hatchlings, and older tortoises (Ashton and Ashton 2008, p. 27). Adult gopher tortoises are less likely to experience predation except by canines (e.g., domestic dogs, coyotes, foxes) and humans (Causey and Cude 1978, pp. 94-95; Taylor 1982, p. 79; Hawkins and Burke 1989, p. 99, Mann 1995, p. 24). Some predators are subsidized by human activities such as habitat fragmentation and edge effect (e.g., red imported fire ants) (Wetterer and Moore 2005, pp. 352-353), roads and infrastructure (e.g., red imported fire ants) (Stiles and Jones 1998, p. 343), increased availability of food (e.g., raccoons), reduction or elimination of top carnivores (e.g., coyotes, red foxes) (Crooks and Soule 1999, entire), ecological perturbations allowing range expansion (e.g., coyotes), and simply because some are domestic and associated with humans (e.g., cats and dogs).

The gopher tortoise is a long-lived species, which naturally experiences high levels of mortality in early life stages. However, it is unknown what predation rate populations can sustain without impacting population resiliency. Studies on the long-term survival of juveniles across multiple populations are needed to determine the survival rates needed within this life stage to sustain viable populations.

Figure 3. 7-Image of predated gopher tortoise nest (left) and hatchling gopher tortoise predated by raccoon (right). Image credit: Michelina Dziadzio.

3.7. Non-native and Invasive Species

3.7.1. Invasive Flora

The spread of exotic plants species has the potential to alter and degrade gopher tortoise habitat and ultimately influence gopher tortoise viability on a site. Some species postulated to impact tortoise habitat include kudzu (*Pueraria montana*), Chinese privet (*Ligustrum sinense*), Callery pear (*Pyrus calleryana*), natal grass (*Melinis repens*), and Japanese climbing fern (*Lygodium japonicum*), though quantified impacts of these species on tortoises are unknown. One species known to impact gopher tortoise use of habitat is cogongrass (*Imperata cylindrica*), a prolific invasive which occurs throughout much of the gopher tortoise's range. Unlike other invasive plant species in upland communities, cogongrass can rapidly spread following disturbances including prescribed fire (Yager et al. 2010, entire; Holzmueller and Jose 2011, p. 436-437). It can quickly form a tall, dense ground cover with a dense rhizome layer and can outcompete native vegetation (Dozier et al. 1998, pp. 737-740; Mushinsky et al. 2006, p. 360; Minogue et al. 2018, p.1-4). Widespread areas of dense cogongrass (Figure 3.8) could result in habitat loss as gopher tortoises do not use these areas, nor do they consume cogongrass (Basiotis 2007, p. 21). Cogongrass can also decrease gopher tortoise habitat quality by reducing forage quality and quantity, and the availability of burrowing and nesting locations (Lippincott 1997, pp. 48-65; Basiotis 2007, p. 24). Additional research is needed to quantify the impacts of invasive vegetation spread on gopher tortoises and the quality of their habitat.

Figure 3. 8-Image of a heavy infestation of cogongrass (*Imperata cylindrica*). Image credit: Mississippi Forestry Commission

3.7.2. Invasive Fauna

The red imported fire ant was first introduced to the Southeastern U.S. in the early 1900s and now occurs throughout the gopher tortoise's range (United States Department of Agriculture, 2017, unpaginated). Fire ants frequent disturbed sites, particularly areas with disturbed soil, and are common in upland areas used by gopher tortoises (Shearin 2011, p. 22, 30). Gopher tortoises often nest in the soft disturbed soil of their burrow aprons. In one study, red imported fire ants were present at most gopher tortoise burrows, though present more often in disturbed areas (Wetterer and Moore 2005, p. 352) including recently burned sites, indicating risk of fire ant-related mortality of tortoise may be high. Fire ants are not able to breach hard smooth-shelled intact eggs (Diffie et al. 2010, p.295), such as gopher tortoise eggs, but will attack tortoises in the nest prior to emergence (Butler and Hull 1996, p. 17; Dziadzio et al. 2016b, p. 531); fire ants will also depredate hatchlings after they have left the nest (Mann 1995, p. 24)(27 percent post-hatchling mortality by fire ants; Epperson and Heise 2003, p. 320). Fire ants are aggressive, and their stings can result in direct mortality and reduced survival by limiting growth, altering behavior, and changing foraging patterns (Wilcox and Giuliano 2014, pp. 3-4; Dziadzio et al. 2016b, pp. 532-533). There is concern that fire ants could be contributing to the decline of the gopher tortoise if predation on hatchlings by fire ants is an additive source of mortality (Mann 1995, p. 24; Dziadzio et al. 2016b, p. 536). In the western range, gopher tortoise conservation banks and other related sites must include fire ant monitoring and control as part of their management plan to reduce the effects of predation on tortoise eggs and hatchlings (74 FR 46401).

The nine-banded armadillo arrived in the Southeast through a combination of natural range expansion in the mid-19th century and accidental releases of individuals (Taulman and Robbins 1996, pp. 644-645). They use a wide range of natural community types including pine forests, areas frequently occupied by gopher tortoises. They dig their own burrows, but also use the burrows of other species such as the gopher tortoise (Mengak 2004, p. 2) and are known predators of tortoise eggs (Douglass and Winegarner 1977, p. 237; Degroote et al. 2013, pp. 77-79). The relative importance of armadillos as a nest predator appears to vary by site. One study (Dziadzio et al. 2016a, p. 1318) compared predation of natural and artificial tortoise nests at burrows to nests at other open sites and found that 69 percent of natural and artificial nests were depredated by armadillos. Armadillos have the potential to negatively impact gopher tortoise populations if they are an additive source of nest predation, but additional information is needed to evaluate the potential impact of this species on gopher tortoise populations across their range.

Other invasive species that may negatively impact tortoises include the Argentine black and white tegu (*Salvator merianae*), Burmese python (*Python bivittatus*), and black spiny-tailed iguana (*Ctenosaura similis*). Breeding populations of these species are currently restricted to parts of southern and peninsular Florida (Engeman et al. 2011, p. 602, 605, 607), though tegus have recently established a new population in Southeastern Georgia (Haro et al. 2020, entire). Tegus and Burmese pythons have been occasionally found farther north, including recent sightings of numerous tegus in South Carolina (Andrew Grosse, South Carolina DNR, personal communication); Burmese pythons have been found as north as South Georgia (EDDMapS.com) though this individual was likely an escaped or released pet and not part of a breeding population. All three species have been observed using tortoise burrows (Engeman et al. 2009, p. 84; Engeman et al. 2011, p. 607; Bartoszek et al. 2018, pp. 353-354); Burmese pythons have also been observed in breeding aggregations and laying eggs within burrows (Bartoszek et al. 2018, pp. 353-354), though pythons were not documented depredating gopher tortoises in this study. Tegus and spiny-tailed iguanas are documented predators of tortoise eggs and/or juvenile tortoises (Avery et al. 2009, p. 435; Johnson and McGarrity 2017, p. 1; Offner 2017, pp. 56-57). Because of the limited current range of these species and inconsistent results predicting the potential for range expansion (Engeman et al. 2011, p. 602; Goetz et al. 2021, entire), it is unknown the extent of impact these species may have on gopher tortoise populations. New regulations in Florida (F.A.C. 68-5), Alabama (Regulation 220-2-.26), and South Carolina (Regulation123-152(A)) are being implemented to limit possession of black and white tegus to prevent the establishment of tegus in the wild. Therefore, the current threat of these species on gopher tortoise appears low in comparison to other threats.

There are additional non-native faunal species that may depredate tortoises, damage burrows, and/or degrade tortoise habitat, such as the wild pig (*Sus scrofa*), domestic dog (*Canis lupus familiaris*), and possibly domestic cat (*Felis catus*). Frequent damage to burrows could result in increased stress and eventual burrow abandonment by the tortoise. All three of these non-natives are found across the Southeast, but limited data are available to quantify their impacts on tortoise populations. Additional research is needed to determine if these non-native fauna are negatively impacting tortoise populations, and if so, to quantify the extent of this impact.

3.8. Habitat Management

During a workshop on gopher tortoise conservation at the Joseph W. Jones Ecological Research Center in Georgia in 2003, 30 invitees from 6 states ranked habitat destruction and lack of habitat management (e.g., no prescribed fire program) as the top two major threats to the gopher tortoise (Smith et al. 2006, pp. 326-327). Gopher tortoise habitat is maintained via periodic fire. High quality gopher tortoise habitat will only require prescribed fire at regular intervals for natural community maintenance. Areas of degraded gopher tortoise habitat (e.g., areas with little or no fire) require active habitat management, frequently requiring multiple habitat management tools (mechanical and chemical treatments) in conjunction with the reintroduction of prescribed fire to restore natural conditions. However, not all habitat management activities are uniformly beneficial to the species. In general, management actions that minimize soil disturbance, protect burrows, and maintain a diversity of groundcover plants by ensuring that sufficient sunlight reaches the ground are beneficial. Conversely, actions that cause significant soil disturbances or result in the loss of diverse groundcover are detrimental. Additionally, the lack of habitat management or infrequent management is also detrimental. Prescribed fire, selective use of herbicide, mechanical vegetation management (e.g., roller chopping and mowing), and timber harvesting are valuable management techniques in the restoration, management, and maintenance of gopher tortoise habitat and are frequently used in combination.

Heavy equipment is routinely used to manage gopher tortoise habitat occurring on public and private lands throughout the species range. Heavy equipment is utilized in activities such as site preparation, reforestation, restoration, prescribed fire, herbicide applications, and harvest operations (timber, pine straw, etc.). In addition to direct impacts to adult and juvenile tortoises and eggs as a result of crushing, heavy equipment can occlude burrows or cause burrow collapse. Several occasions of direct mortality from heavy equipment have been reported (Landers and Buckner 1981, pp. 1-7). Entombment from burrow collapse or occlusion was historically perceived as a threat, however numerous studies have documented survival and self-excavation by tortoises in collapsed burrows (Landers and Buckner 1981, pp. 1-7; Diemer and Moler 1982, pp. 634-637; Diemer 1992b, p. 163; Mendonca et al. 2007, pp. 3-4; Wester and Kolb 2008, pp. 505-507). No significant differences in home range sizes, number of burrows used, or movement patterns between pre and post burrow collapse were found in one study (Mendonca et al. 2007, pp. 19–21). However, they did suggest potential negative effects of burrow collapse depending upon time of collapse which may include decrease in mating opportunities and potential for gravid females to be unable to deposit eggs in suitable locations. While more information is needed, heavy machinery likely presents risks to gopher tortoise eggs and juveniles, as they are more difficult to detect and therefore more difficult to avoid (Greene et al. 2020, p. 54). A study to experimentally address the distance at which heavy equipment might collapse burrows found that on average, machinery could be operated within approximately 3 m without causing damage. This is important because forest management, including application of prescribed fire, requires operation of a variety of vehicles and heavy equipment. Increasingly, land managers are incorporating best practices into their management plans, including a buffer distance around burrows to minimize disturbance and hazards (Smith et al. 2015, pp. 459-460).

The habitat management methods discussed below are implemented to varying degrees across a variety of different land ownership and use types (e.g., conservation land, commercial forestry, family-owned lands, etc.).

3.8.1. Prescribed Fire

Historically, upland areas commonly associated with gopher tortoises were maintained by frequent, lightning-generated fires, with peak lightning ignition occurring during the growing season, spring to early summer (Knapp et al. 2009, p. 3). Additionally, Native Americans and later, early colonial settlers often burned areas in the winter, fall or late summer for specific purposes or desired effects (Fowler and Konopik 2007, pp. 165-166). While there is uncertainty regarding natural burn regimes among various cover types and along environmental gradients, fire return frequencies throughout the gopher tortoise range are estimated to range between two and six years (Guyette et al. 2012, p. 330). Anthropogenic use of fire has likely been occurring for at least 10,000 years in the Southeastern United States through the early 1900s, when the practice of fire suppression became prevalent on the landscape. Fire suppression resulted in fire being mostly absent on public lands until the 1980s, however some private working lands (farming, grazing, logging) remained managed with fire (Fowler and Konopik 2007, p. 171).

Loss and alteration of gopher tortoise habitat from fire exclusion or fire suppression has a significant effect on survival of gopher tortoises (Boglioli et al. 2000, p. 704). Although burning has generally been accepted as a primary management tool, increased urbanization limits its use in many locations (Ashton and Ashton 2008, p. 78) due to concerns for safety, particularly as it relates to smoke management. Urban sprawl can fragment habitat that supports tortoise populations, and in many areas, complicates the logistics of performing adequate and seasonally appropriate burns, further straining staff and budget resources. Human health and safety issues increasingly complicate fire management as human population grows in an area, resulting in narrow windows of opportunity to implement prescribed fire due to the required parameters (for example: weather, site specifics) for a safe burn. Because of this, many areas of habitat remain unburned each year and without other habitat management, further succeed into unsuitable conditions, hindering the viability of gopher tortoise populations (Kupfer at al. 2020, p. 765).

Many Southeastern pine forests have dense canopies, a high prevalence of mid-canopy shrubs, and suppressed or absent herbaceous ground cover due to fire exclusion (Yager et al. 2007, p. 428). Several studies have reported the direct effect to gopher tortoise populations from fire suppression. Gopher tortoise population life expectancy declined in fire-suppressed savanna communities (Auffenberg and Iverson 1979, p. 562). Gopher tortoise population reduction has been observed to be directly correlated with the degree and rate of successional habitat modification (Auffenberg and Iverson 1979, p. 562). Fire exclusion was observed to reduce a gopher tortoise population by 100 percent in 16 years (Auffenberg and Franz 1982, p. 108). In south-central Florida, sandhill and scrubby flatwoods were abandoned by gopher tortoises after about 20 years of fire exclusion (Ashton et al. 2008, p. 528). However, other types of management actions (e.g., mechanical and chemical treatments) may offset, or slow habitat degradation caused by fire suppression.

The regular application of prescribed fire is critical for the maintenance of habitat conditions required by the gopher tortoise. When applied at appropriate intervals, prescribed fire reduces shrub and hardwood encroachment, and stimulates growth of forage plants such as grasses, forbs, and legumes (Thaxton and Platt 2006, p. 1336). The physical result of fire to tree and shrub species in most cases, reduces canopy cover and creates more light gaps allowing greater sunlight penetration to the ground (Iglay et al. 2014, pp. 39–40). This promotes establishment and maintenance of understory herbaceous forage and is also important for basking and proper gopher tortoise egg incubation. Prescribed fire during the growing season often produces a more beneficial response in the herbaceous layer than dormant season fire (Fill et al. 2017, pp. 156–157). Growing season fire stimulates flowering in many grasses, increases species diversity among understory plants, and result in higher understory biomass production (FWC 2007, p. 32). Although the growing season was historically the primary season for natural lightning-strike fires, variability in fire season, intensity, and frequency may be important to maintaining herbaceous species diversity (FNAI 2010, p. 43).

Periodic burning or shrub removal can increase gopher tortoise carrying capacity (Stewart et al. 1993, p. 79). Mixed stands of longleaf pine, turkey oak, and other scrub oaks that were burned every 2 to 4 years have been found to produce high densities of gopher tortoises (Landers 1980, p. 7). In south-central Florida, tortoises moved into areas that were frequently burned and abandoned areas that were unburned or burned less frequently (Ashton et al. 2008, p. 527). Burned areas have been found to have more herbaceous ground cover and gopher tortoises than in unburned oak-palmetto (Breininger et al. 1994, p. 63). Burned pine stands and longleaf pine scrub oak ridges had nest densities four times higher than in unburned pine stands and ridges in one study (Landers and Buckner 1981, p. 5). Herbaceous ground cover was found to be 2.3 times higher and gopher tortoise density was 3.1 times higher in a frequently burned slash pine plantation compared to an adjacent unburned natural sandhill area (Landers and Speake 1980, p. 518).

On sites with advanced hardwood encroachment, prescribed fire alone may be insufficient in reducing the coverage of undesirable vegetation. Mechanical or chemical treatments are frequently utilized to reduce hardwood competition to levels where prescribed fire can be effective (Greene et al. 2020, p. 50). In addition to use in augmenting a prescribed fire program, these management techniques are increasingly important for areas where prescribed fire use is not a viable option, such as habitat in urbanized areas (Ashton and Ashton 2008, p. 78).

3.8.2. Herbicide Applications

The application of herbicide is a vegetation management tool utilized by some land managers to control unwanted/undesired vegetation, often in combination with mechanical or prescribed fire or when prescribed fire cannot be used. Herbicide may also be required in conjunction with fire, to effectively eradicate infestations of highly invasive species such as cogongrass (Sellers et al. 2018, p. 3) or mid-story overgrowth of drought resistant woody vegetation.

In gopher tortoise habitat, the type of herbicide and rate and method of application should be selected to target shrub and hardwood species with minimal impacts to nontarget plant species, especially herbaceous groundcover vegetation utilized by gopher tortoises. In managed forests, herbicide is used to suppress shrub and hardwood mid-story growth to reduce competition to planted trees or stimulate desired growth of planted trees at critical periods. Fire is often used in conjunction with herbicide treatment on private working forest lands (Miller and Chamberlain 2008, pp. 776-777; Jones et al. 2009, p. 1168, Iglay et al. 2013, p. 40; Platt et al. 2015, p. 913), especially for site preparation purposes. According to a survey of 30 private landowners, herbicide is the most common management tool in the Southeast on production timber forests (Lang et al. 2016, p. 21). Herbicide is also consistently used in public land management and to maintain utility rights-of-way, often in combination with mowing or brush-hogging, which can provide suitable conditions or dispersal corridors for gopher tortoises.

Targeted herbicide application likely has less of a direct impact to gopher tortoises than broadcast spraying, where overspray is a risk. However, no information is available on the direct adverse effects to gopher tortoises, and herbicides used for gopher tortoise habitat management are generally not toxic to wildlife when applied in accordance with label specifications. The main threat from broadcast spraying is over-application using a broad-spectrum chemical, which can kill a significant amount of gopher tortoise forage where populations occur. Cut-and-squirt methods or direct injection into unwanted shrubs or trees is also an effective and less invasive, though more labor-intensive method, of herbicide application. When used carefully, herbicide is another tool for use in the management of gopher tortoise habitat.

Rates and concentrations of herbicide application vary considerably throughout the range of the gopher tortoise and outcomes are often dependent on environmental factors. The primary purpose of herbicide application varies as well, as it is used in many industries such as production forests, agriculture, restoration, and property maintenance. Research has shown that herbaceous groundcover can be maintained and enhanced through targeted and selective herbicide treatment, especially when used in conjunction with prescribed fire (Miller and Chamberlain 2008, pp. 776-777; Jones et al. 2009, p. 1168, Iglay et al. 2013, p. 40; Platt et al. 2015, p. 913). Herbicide can reduce mid-story vegetation growth resulting in more sunlight reaching the ground. In addition, a more open canopy and mid-story allows for proper incubation of eggs and thermal regulation (basking) of tortoises. More research is needed concerning herbicides' direct and indirect effects (short and long term) on gopher tortoise populations.

3.8.3. Mechanical Vegetation Management

Habitat management using mechanical means can be effective in reducing shrub and tree density to promote conditions favorable to herbaceous vegetation. Mechanical treatments are used in habitat restoration, site preparation to promote pine seedling survival and growth, maintenance, and in other agricultural and forestry endeavors. Mechanical vegetation management examples include mulching/chipping, subsoiling, shearing, stumping, root raking into piles or windrows, roller chopping, discing, and bedding. Depending on management objectives and treatment type, mechanical site preparation may result in substantial soil disturbance, affecting soil structure and chemistry and may increase invasive species on a site (Hobbs and Huenneke 1992, pp. 324–325, Jack and McIntyre 2017, p. 189). Careful and systematic cleaning of all mechanical equipment before and after use at every site can reduce the likelihood of spreading seeds of invasive plant species and are often incorporated into best management practices employed by managers (Miller et al. 2010, pp. 10–11). Some of the more intensive mechanical soil-disturbing practices utilized on some silvicultural sites include discing and bedding. While these activities do occur in gopher tortoise habitat, they tend to occur more so on wetter sites that are less suitable for gopher tortoises. Shearing and roller chopping are more common mechanical treatments used in restoration and for site preparation in areas likely to be used by gopher tortoises (Jack and McIntyre 2017, p. 200).

Because sandy and sandy-loam soils are much more erodible and mechanical site prep costs are increasing, herbicides are increasingly replacing mechanical site preparation on working forest lands in some areas. Mechanical vegetation management may be short-term option to maintain habitat in areas where fire use is restricted. Although mechanical vegetation management is effective in reducing the vertical structure and overgrowth in the mid and overstories, it is not an exact surrogate to fire in that mechanical treatments alone do not replicate the stimulation of plant growth, flowering and seed release, and soil nutrient cycling (Dean et al. 2015, pp. 55-56) provided by fire. In addition, mechanical treatments that are not followed up with herbicide applications and/or prescribed fire often result in more dense regrowth of hardwood or shrub species originally targeted for control. While empirical data on effects of mechanical vegetation management practices on gopher tortoise populations is largely lacking, best conservation practices (FDACS 2012, entire; FWC 2013, entire; USFWS 2013, entire; GDNR 2014, entire; FDACS 20115, entire) are available and are increasingly utilized by landowners and managers when using mechanical treatments (Jack and McIntyre 2017, p. 200).

Care should be taken in certain cover types where the gopher tortoise is known to occur. For example, in scrub, mechanical vegetation management is the only way to reset late successional conditions without burning under extreme wildfire conditions. However, scrub habitat is sensitive to soil disturbance and excessive soil disturbance may permanently alter it. Low ground pressure mulching equipment can be used to reduce above ground vegetation; however, care needs to be taken to leave the vegetation in a state where it can be consumed during prescribed burning. If vegetative material is mulched too fine or too much time elapses between mulching and burning, the material may not burn and may alter the soil and enhance conditions for invasive plant species (Hobbs and Huenneke 1992, pp. 324–325, Jack and McIntyre 2017, p. 189). While soil disturbance in scrub may permanently alter conditions, in the case of fire suppressed scrub, strategically creating sandy openings through mechanical soil disturbance may be necessary to create a matrix of open areas when coppicing fire adapted plants create a dense low overstory (S. Howarter, Service Biologist, comment submitted during review, 2021).

3.8.4. Timber Management

Not all forested lands provide appropriate conditions for gopher tortoises. However, on land with suitable soils and depending on forest management objectives, forests may provide the open canopy and the dense herbaceous groundcover conditions needed for gopher tortoise viability. . Several management goals are shared between timber and gopher tortoise habitat management. For example, reduction of hardwood competition is advantageous for the management of pine production and gopher tortoises because it favors pine survival and growth while allowing increased opportunity for sunlight to reach the ground, promoting herbaceous forage proliferation and suitable conditions for gopher tortoise basking and egg incubation (NRCS 2020, entire). Several management practices associated with working forests such as planting densities, age of stand, time until first and subsequent thinning(s), have a direct influence on whether these lands provide and maintain habitat for the species.

In slash pine plantations in Alabama, tortoise burrows were found in areas with the most open canopy. Burrow abandonment averaged 22 percent annually and abandoned burrows were associated with canopy closure, higher hardwood midstory, higher tree density and higher basal area (Aresco and Guyer 1999b, p. 32). Gopher tortoises more frequently abandoned burrows and emigrated from poor habitat conditions associated with closed canopy pines plantations (Diemer 1992a, p. 288; Aresco and Guyer 1999b, p. 32). Gopher tortoises often persist in pine plantations (slash and loblolly) at lower densities than reported in other cover types, and densities may be below the threshold necessary to sustain a viable population (Wigley et al. 2012, p. 42). Closed canopy conditions do not sustain gopher tortoises. A wide range of silvicultural practices influence canopy. Even-aged regeneration harvests often used in pine management provide abundant sunlight to stimulate groundcover vegetation establishment and growth. However, benefits are ephemeral as reforested areas grow and develop closed canopy conditions that shade groundcover (Greene et al. 2019, p. 203).

Most modern production forests incorporate management strategies to maintain open canopy conditions for the majority of a commercial stand's life. Reforestation at lower seedling densities can extend the interval to canopy closure. Pre-commercial and commercial thinning operations reduce canopy coverage and favors conditions that can support increased groundcover development. Recognizing that stand growth and development include periods of higher than preferred canopy cover, yet minimizing the duration of closed canopy conditions, is important not only to gopher tortoises but also commercial forests. Additionally, landscape considerations that provide for a matrix of structural conditions and connectivity or corridors linking gopher tortoise habitat are important to sustain populations in areas with production pine objectives. A National Council for Air and Stream Improvement (NCASI Inc.) survey of Member Companies revealed that open pine conditions are maintained over 47.2 percent of the life of a stand rotation (Weatherford et al. 2020, p. 4). Open pine in the above survey were limited to upland, xeric or mesic, pine dominated sites as coded by the USDA's Forest Inventory and Analysis program, further, open canopy was based on descriptions in Nordman et al. (2016, pp. 57–58), and Greene et al. (2019, p. 204).

Privately owned production pine forests are a dominant land use within the range of the gopher tortoise. Gopher tortoise persistence has been documented when suitable conditions occur on production pine forests (Diemer-Berish et al. 2012, pp. 51-52; Greene et al. 2019, p. 51). One study demonstrated positive responses in life history parameters four years following a clearcut on a pine plantation in northern Florida (Diemer-Berish and Moore 1993, p. 426). Most commercial timber operations grow loblolly or slash pine, rather than longleaf pine. Gopher tortoises may exploit appropriate stand conditions and other habitat characteristics, such as, stand structure conditions (e.g., basal area; overstory and midstory canopy closure) or suitable soil (Greene et al. 2020, pp. 52-53; Wigley et al 2012, p. 43), rather than a particular tree species. Common practices used in operational forestry such as stand establishment, thinning, and mid-rotation management can create similar structural conditions to fire-maintained conditions (NRCS 2020, p. 20). However, more information is needed, as there is no uniform method for tracking gopher tortoise activity on private lands. Additional research is needed to understand how management can further improve conditions, especially given the large area of private, working forests within gopher tortoise range. While some information regarding gopher tortoises is available (discussed in section 3.9.9), systematic surveys in managed forests across the range of the gopher tortoise are needed to properly assess populations on these lands and to allow for a more holistic assessment of the species range wide.

Contemporary management practices on private working lands have evolved in response to market demands that require conservation of biological diversity. Furthermore, development of diversified markets for forest products has increased forest management practices that benefit gopher tortoises (Greene et al. 2020, p. 55). Many corporate and non-corporate private landowners manage to high conservation standards to meet their objectives and in some cases to maintain important forest certifications such as Sustainable Forestry Initiative (SFI) or Forest Stewardship Council certification. Thinning and planting at lower densities, using herbicides to reduce midstory vegetation, and harvesting at an older stand age are more commonly used and provide vegetation conditions that gopher tortoises can occur and persist (Greene et al. 2019, p. 201; Greene et al. 2020, p. 55).

However, not all lands, public or private, are managed to these standards, and detrimental practices and lack of management continue to affect gopher tortoise habitat. Nearly complete groundcover weed control during site preparation or release treatments degrade habitat by removing forage plants. High seedling stocking rates quickly shade groundcover. Short timber rotations with a minimal proportion of the rotation being open canopied is problematic in that this practice may result in excessive shading, suppressed groundcover vegetation, and generally unsuitable conditions for gopher tortoises. Exclusion of prescribed fire and dense hardwood midstory encroachment within open canopied forests degrade habitat through suppression of groundcover and loss of open areas for burrowing and movement.

While we cannot quantify the extent to which detrimental practices occur and while these may not be practices utilized on certified forests, there is likely some percentage of habitat that has been impacted by these practices and therefore has influenced gopher tortoise viability. While we cannot account for all land management practices, there has been significant progress made between private landowners and conservation agencies, such as best conservation practices for gopher tortoises developed by states, and conservation incentive programs and partnerships that promote compatibility between timber and gopher tortoise management.

3.9. Conservation Measures

3.9.1. Federal and State Protections and Conservation

This section includes discussions of key protections and conservation efforts provided by various federal and state entities.

Federal

Natural Resources Conservation Service (NRCS)

The NRCS offers technical and financial assistance to help agricultural producers voluntarily conserve gopher tortoise habitat on private lands. This assistance helps producers plan and implement conservation activities and practices that provide benefits to several species, including the gopher tortoise while balancing conservation practices with natural resource and production goals.

The gopher tortoise is a nationally identified target species of the Working Lands for Wildlife (WLFW) partnership, which is a collaborative approach to conserving habitat on working lands. The NRCS works to restore longleaf pine across its historical range through the Longleaf Pine Initiative (LLPI). Additionally, NRCS conservation practices that benefit gopher tortoises include prescribed fire, forest stand improvements, herbicide applications, and brush management (NRCS 2020, pp. 22-23). Since 2012, NRCS has certified 943,740 acres (378,276 ha) in which private landowners have received assistance to implement management practices that benefit gopher tortoises and gopher tortoise habitat (Table 3.2). The WLFW program focused on promoting increased use of prescribed fire, improving vegetation management, re-establishing longleaf forests, supporting prescribed grazing management, and protecting existing quality habitat to benefit gopher tortoises across the range of the species (NRCS 2018, p. 1).

Table 3. 2-Gopher Tortoise Project Boundary: WLFW and LLPI Totals by Practice and Year. Data submitted by NRCS.

	Sum of Certified Acres by Year								
Practice and Priority	**Sum of 2012**	**Sum of 2013**	**Sum of 2014**	**Sum of 2015**	**Sum of 2016**	**Sum of 2017**	**Sum of 2018**	**Sum of 2019**	**PRACTICE SUMS**
Core Practices	**8,371.0**	**52,245.8**	**79,935.7**	**34,466.3**	**20,767.8**	**5,062.4**	**6,897.4**	**5,490.8**	**213,237.2**
Gopher Tortoise	**3,507.0**	**49,873.0**	**79,749.7**	**34,269.5**	**20,552.4**	**3,896.7**	**6,742.8**	**3,975.2**	**202,566.3**
Early Successional Habitat Development-Mgt	110.0	1,459.7	1,605.4	1,924.6	3,084.0	100.4	390.7	36.0	8,710.8
Restoration of Rare or Declining Natural Communities	1,781.3	7,396.9	11,057.0	4,936.3	5,368.9	1,178.3	672.3	37.0	32,428.0
Upland Wildlife Habitat Management	1,615.7	41,016.4	67,087.3	27,408.6	12,099.5	2,618.0	5,679.8	3,902.2	161,427.5
Longleaf Pine	**4,864.0**	**2,372.8**	**186.0**	**196.8**	**215.4**	**1,165.7**	**154.6**	**1,515.6**	10,670.9
Early Successional Habitat Development-Mgt	12.2	43.5	115.5	70.8	165.4	1,165.7	101.1	736.0	2,410.2
Restoration of Rare or Declining Natural Communities	4,788.4	2,312.3	37.0	59.0	0.0	0.0	40.0	0.0	7,236.7
Upland Wildlife Habitat Management	63.4	17.0	33.5	67.0	50.0	0.0	13.5	779.6	1,024.0
Supporting Practices	**35,548.6**	**86,491.5**	**98,111.2**	**84,904.3**	**76,495.7**	**95,342.5**	**119,531.7**	**134,077.5**	**730,503.0**
Gopher Tortoise	**12,009.9**	**68,810.3**	**74,879.2**	**48,179.6**	**47,051.8**	**55,407.8**	**72,806.5**	**81,932.1**	**461,077.2**
Brush Management	866.3	2,041.2	3,963.0	3,064.8	2,333.3	2,071.8	870.9	2,652.8	17,864.1
Forest Stand Improvement	5,653.7	7,356.4	4,567.4	4,751.0	5,436.8	5,010.7	3,823.6	6,815.9	43,415.5
Herbaceous Weed Treatment	1,224.2	2,410.2	3,875.9	3,518.1	921.2	2,465.1	3,320.8	3,417.8	21,153.3
Prescribed Burning	3,171.9	47,779.2	50,089.4	29,629.3	32,532.4	38,325.9	53,349.1	53,235.7	308,112.9
Prescribed Grazing	0.0	0.0	0.0	636.3	1,219.4	3,859.5	5,428.3	11,327.7	22,471.2
Tree/Shrub Establishment	1,093.8	9,223.3	12,383.5	6,580.1	4,608.7	3,674.8	6,013.8	4,482.2	48,060.2
Longleaf Pine	**23,538.7**	**17,681.2**	**23,232.0**	**36,724.7**	**29,443.9**	**39,934.7**	**46,725.2**	**52,145.4**	**269,425.8**
Brush Management	155.5	455.4	671.2	2,309.9	231.9	348.1	207.6	270.0	4,649.6
Forest Stand Improvement	447.5	29.0	267.9	1,019.1	830.6	406.1	1,022.3	1,414.4	5,436.9
Herbaceous Weed Treatment	240.8	487.7	1,366.6	1,226.3	1,717.1	1,968.1	3,283.6	4,682.2	14,972.4
Prescribed Burning	12,194.6	11,066.2	11,765.1	17,514.7	17,932.4	22,097.7	24,542.6	26,221.2	143,334.5
Tree/Shrub Establishment	10,500.3	5,642.9	9,161.2	14,654.7	8,731.9	15,114.7	17,669.1	19,557.6	101,032.4
Grand Total	**43,919.6**	**138,737.3**	**178,046.9**	**119,370.6**	**97,263.5**	**100,404.9**	**126,429.1**	**139,568.3**	**943,740.2**

U.S. Fish and Wildlife Service

The gopher tortoise population located west of the Tombigbee and Mobile Rivers in Alabama was federally listed as Threatened by the Service in 1987. Subsequently, the Service finalized a Recovery Plan (Service 1990, entire) which delineated actions required to recover and/or protect the species. The two primary objectives of the recovery plan were to prevent the listed population from becoming endangered and a long-term objective of delisting.

Sections 7 and 10 of the Act establish processes that allow the Service to review federal and non-federal actions that will affect species listed as endangered or threatened under the Act, and to provide exemptions to prohibitions outlined in section 9(a) of the Act. Section 7(a)(1) requires the Service to review programs administered and to utilize such programs in furtherance of the purposes of the Act. Section 7(a)(1) also requires all other federal agencies to implement programs for the conservation of listed species. Section 7(a)(2) requires that federal agencies consult with the Service to ensure that their actions are not likely to jeopardize the continued existence of listed species and are not likely to result in the destruction or adverse modification of designated critical habitat for listed species.

Section 10 of the Act allows a non-federal party to apply for and obtain a permit that authorizes the incidental take of federally listed wildlife or fish, subject to the development of a conservation plan. The Act defines incidental take as "[take that] is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity." Section 10(a)(1)(A) of the Act authorizes the Service to develop a Safe Harbor Agreement with an interested party and issue a permit to enhance the propagation or survival of a listed species. The Service must determine that the conservation measures to be implemented throughout the agreement will contribute to recovering the species by providing a net conservation benefit. Section 10(a)(1)(B) of the Act allows an applicant to apply for and obtain an incidental take permit for a listed species. Preparing a conservation plan, generally referred to as a Habitat Conservation Plan, is required for all Section 10(a)(1)(B) permits. Conservation plans developed for all section 10 incidental take permits must meet Service issuance criteria (50 CFR 17.22 and 50 CFR 17.32).

Recognizing that many species may spend at least part of their life cycle on non-federal lands, the Service implements conservation delivery tools and programs that aid in the conservation of listed and at-risk species, such as the gopher tortoise, on non-federal lands. The Cooperative Endangered Species Conservation Fund (Section 6) is a tool that provides grants to states to participate in a wide array of voluntary conservation projects for candidate, proposed, and listed species. Additionally, cooperative conservation programs such as the Safe Harbor Program and the Partners for Fish and Wildlife Program provide technical and financial assistance to private landowners and others for the conservation of wildlife and associated habitat. Partners for Fish and Wildlife Program projects implemented on private lands include landowner agreements terms ranging from 10 to 30 years depending on state and project specifics. Between 2010 and 2019, under the Partners for Fish and Wildlife Program, approximately 65,000 acres (26,305 ha) of restoration and enhancement activities were implemented in gopher tortoise habitat occurring on private lands in Alabama, Florida, Georgia, and Mississippi (Service 2020, unpaginated).

State Listing Protections

Each state within the historical range of the gopher tortoise provides some measure of protection for the species. The gopher tortoise is protected by regulation as a non-game species in Alabama, is state listed as threatened in Florida, Georgia, and Louisiana and is state listed as endangered in Mississippi and South Carolina. Gopher tortoise protections vary by state, however, laws within most states focus on prohibitions against the take, possession, export/sale, and killing of gopher tortoises. Alabama, Florida, Georgia, and Mississippi include specific prohibitions against gassing of wildlife burrows, including those of the gopher tortoise. South Carolina has prohibitions on the take of gopher tortoises and gopher tortoise burrows.

In Florida, through the Landowner Assistance Program, the FWC assists private landowners with plans to improve their wildlife habitat. In fiscal year 2017-2018, a typical planning year, this program planned beneficial management activities on 44,158 acres (17,870 ha) of gopher tortoise habitat in 34 Florida counties (FWC 2020a, p. 6). This program prepares 10-year plans for private land management activities and updates these plans on a 10-year interval. Over the next ten years, the FWC estimates that more than 440,000 acres (178,061 ha) of gopher tortoise habitat will have been managed with assistance from Landowner Assistance Program planning efforts(FWC 2020a, p.6).

3.9.2. Florida Gopher Tortoise Management Plan and Permitting Guidelines

Florida has developed a management plan and permitting guidelines to guide gopher tortoise recovery efforts. The primary goal of the Gopher Tortoise Management Plan (FWC 2007, revised 2012, entire) is to identify and conserve gopher tortoise populations through the implementation of conservation actions that include minimizing loss of tortoises, gopher tortoise population restoration and enhancement, and increasing and improving gopher tortoise habitat. While relocation activities (discussed below) are conducted in other states, Florida has also developed Gopher Tortoise Permitting Guidelines (FWC 2008, revised July 2020; entire) that direct regulatory actions, including mitigation, habitat management, and habitat acquisition objectives. Florida's regulations require that take of tortoises be authorized by a FWC permit and that the impacts be considered and mitigated.

3.9.3. Relocation, Translocation, Recipient Sites, and Headstarting

Relocation is the intentional movement of individuals to another location within its home range, or more frequently described as within the same site. Translocation describes the intentional capture and transfer of individuals (or groups of individuals) from one location to another. Gopher tortoises have been considered one of the most translocated species in the Southeast U.S. (Dodd and Seigel 1991, p. 340) and translocation is commonly used as a conservation strategy to mitigate the loss of tortoises from land slated for development. These displaced tortoises are often translocated to reestablish extirpated populations or augment existing populations (Griffith et al. 1989; p. 477). Due to its use for conservation, numerous studies have sought to evaluate the success of gopher tortoise translocation and improve its efficacy. However, tortoises are long lived, slow-growing, and are slow to reach maturity, making it difficult to determine if translocations result in viable tortoise populations without long-term monitoring.

Measures of translocation success in scientific literature include high site fidelity and survival rates as retention of tortoises on-site is imperative to establishment of stable populations. A population viability model for translocated tortoises concluded 90 percent annual retention of tortoises would be necessary to stabilize a translocated population (Siegel and Dodd 2000, p. 222). However, this model assumed retention rates were constant over time, which conflicts with findings in research studies. Emigration from recipient areas is high within the first-year post-translocation (Lohoefener and Lohmeier 1986, pp. 37-40; Burke 1989, p. 299; Diemer 1989, p. 2; Mushinsky et al. 2006, p. 366), but appears to decline over time (73 percent retention in first year following translocation; 92-100 percent retention 2-17 years post-translocation; Ashton and Burke 2007, p. 785). Apparent survival was found to be reduced the first 1-2 years post-translocation, but high in subsequent years; reduced apparent survival immediately post-translocation was primarily attributed to dispersal rather than mortality (Tuberville et al. 2008, pp. 2694-2695). High dispersal rates may be due to larger home ranges and greater long-distance movements post-translocation (Tuberville et al. 2005, p. 353; Bauder et al. 2014, p. 1449); these movements could relate to disorientation, attempts to return to their original home range, or exploration of their new environment (Bauder et al. 2014, p. 1450). Soft-release, or the temporary penning of gopher tortoises within a recipient area, is highly effective at limiting dispersal post-translocation. One study found a 76.9 percent dispersal rate when tortoises were not penned, a 38.5 percent dispersal rate when tortoises were penned for 9 months, and only an 8.3 percent dispersal rate when tortoises were penned for 12 months (Tuberville et al. 2005, p. 354).

Several considerations have been suggested to improve translocation success, such as: know and accommodate the biological constraints of the species, understand genetic factors, and minimize the risk of disease transmission (Dodd and Seigel 1991, pp. 344-346). Tortoise density and habitat condition should also be considered to ensure recipient sites provide sufficient space for foraging, reproduction, cover, and social interaction (Dodd and Seigel 1991, pp. 344-346). It has been recommended that relocations be conducted when: they are economically and logistically justified, have a high probability of success, include at least 100 individual tortoises, occur in areas of high-quality habitat, and take place where habitat management will occur after translocation (Ashton and Burke 2007, p. 786). Concerning disease transmission, it is recommended to not relocate tortoises showing clinical signs of disease and ensuring protection and management of recipient sites (Mushinsky et al. 2006, p. 369).

Studies have also sought to evaluate the impacts of translocation on body weight and habitat selection (Riedl et al. 2008, entire; Bauder et al. 2014, entire), disease risk and transmission (Hernandez et al. 2010, entire; Cozad et al. 2020, entire), translocation of tortoises to different latitudinal ranges (DeGregorio et al. 2012, entire; McKee et al. 2021, entire), mating systems (Tuberville et al. 2011, entire), social structure (Schulte 2020, entire), and interactions with resident populations (Riedl et al. 2008, entire).

While translocation is successful at removing tortoises from immediate danger due to development, there are still uncertainties about its efficacy. Additional research is needed to inform improvements to translocation methodology and may include: evaluating the efficacy and improvements to release methodology, the effect of habitat quality and size of resident populations on site fidelity of translocated animals, the relationship between cover type and quality on suitable site stocking densities, initial mortality rates post-translocation, disease risk, and long-term population demography of translocated populations (Tuberville et al. 2005, p. 356; Tuberville et al. 2008, p. 2695).

Gopher tortoise relocation and translocation practices are being implemented and included as regulatory agency guidance (Ginger 2010, personal communication; Service 2019 (84 FR 54732 54757)) in both the western and eastern portions of the range. The primary goals for recipient sites are to help prevent the loss of tortoises and retain the local or regional tortoise resource; and while habitat is lost on the development site, recipient sites can contribute to habitat conservation if sites receive long-term protection and subsequent habitat management. These sites can provide high conservation value by restocking tortoises to appropriately suitable lands where populations have previously been depleted. However, this practice could result in an overall net loss of habitat if not implemented in conjunction with acquisition and additional protection of habitat.

Florida's gopher tortoise permitting program includes the largest scale use of relocation and translocation practices in the range. When possible, FWC permits on-site relocation of tortoises to areas within the property boundaries of development sites, if an appropriate quantity and quality of habitat will be retained within the site boundary; this is part of an effort to retain the local populations of gopher tortoise in these areas. When habitat will not be retained on-site, tortoises are translocated to FWC-approved recipient sites. As of December 9, 2019, the FWC has permitted 39 long-term protected recipient sites (these sites are encumbered under a perpetual conservation easement that requires active management to ensure tortoise habitat suitability) comprising greater than 41,700 acres (16,875 ha), over 23,000 acres (9,308 ha) of which are permitted as gopher tortoise habitat. As of April 23, 2021, there is space for approximately 14,400 gopher tortoises available across long-term and short-term protected permitted recipient sites in Florida. This number fluctuates as reservations are made or released and is subject to change as new sites are permitted, recipient sites reach capacity, or when action is taken in the event that a permitted site falls out of compliance. For example, there are currently (as of April 23, 2021) greater than 20 sites in the pre-application stage or pending review by the FWC for consideration as potential recipient sites. In addition to long-term and short-term protected recipient sites, Florida also has several incidental take permitted recipient sites, such as Eglin Air Force Base (AFB) and Nokuse Plantation. To date, Eglin AFB has received over 1,200 gopher tortoises. Eglin AFB has established a goal of relocating 6,000 tortoises to the base. To continue efforts of re-establishing tortoises in the Florida Panhandle and alleviate constraints on recipient site capacity for other gopher tortoise translocation needs in Florida, Eglin AFB will accept tortoises from solar development sites under a Memorandum of Agreement (MOA) with FWC executed in 2020. Other recipient site options in Florida include restocking of public conservation lands, waif (tortoises of unknown origin) recipient sites, and research recipient sites.

Several other states are currently considering projects or have ongoing efforts to translocate tortoises, providing benefit to the species. For example, there is an ongoing effort to restock gopher tortoises on public lands where they are currently depleted in South Carolina using waif gopher tortoises (McKee et al. 2021, entire). More than 180 adult gopher tortoises from across the species' range have been translocated to the Aiken Gopher Tortoise Heritage Preserve in South Carolina; the total gopher tortoise population is approximately 300 tortoises. A 600 acre (243 ha) parcel in Mobile County, AL was purchased to conserve tortoises and serve as a recipient site for tortoises displaced by Alabama Department of Transportation sponsored projects. With implementation of appropriate management, this site has the capacity to support an estimated population of 346 tortoises (Federal Highways Administration 2010, p. 1). In Alabama, a plan will be developed for translocation and population augmentation with recommendations and protocol pertaining to donor and recipient sites.

In the western portion of the gopher tortoise's range, individual animals are typically translocated either to avoid mortality during land development activities or because they are considered waif tortoises by the state agencies and the Service (76 FR 45130). Tortoises suitable for these translocations include those brought in by the public, those that are reproductively isolated, or individuals determined to be in danger (e.g., crossing roads, burrows near road edges, etc.). At the time of capture, all waif tortoises and, for development projects, all tortoises at both the impact and relocation sites are evaluated to determine whether they have clinical signs of URTD through a physical examination and laboratory blood tests may also be completed. Tortoises that test positive for URTD antibodies are evaluated on a case-by case basis, but generally are not relocated to a URTD-negative tortoise population. Since some individual tortoises have tested seropositive and then tested seronegative upon re-testing months later (Wendland 2007, pp. 88-89), there are uncertainties about the utility of the testing protocol and whether impacts of translocation stress or seasonality play a role in affecting test results.

Headstarting, or the process of hatching and/or rearing juvenile turtles in captivity through their most vulnerable period (Spencer et al. 2017, p.1341) has shown success as a technique that could be used to boost depleted gopher tortoise populations (Holbrook et al. 2015, pp. 542-543; Tuberville et al. 2015, pp. 467-468; Quinn et al. 2018, p. 1552; Tuberville et al. 2021, p. 92). Headstarting turtles allows hatchlings to reach larger body size classes more quickly compared to their counterparts living under natural conditions, presumably making them less susceptible to predation (Heppell et al. 1996, p. 556; O’Brien et al. 2005, entire; Tuberville et al. 2021, p. 88). Natural predation rates of eggs and hatchling gopher tortoises are high (See section 3.6) and increasing survival of these life stages through headstarting or other measures could serve as a useful conservation tool. Eggs or hatchlings obtained from nests, when collected from robust populations, minimizes negative effects on donor populations (Quinn et al. 2018, p. 1554). The headstarting technique has historically garnered considerable controversy (Frazer 1992, entire; Seigel and Dodd 2000, entire; Burke 2015, entire), but there is increasing recognition of its potential role, particularly when used in concert with other management actions (Turtle Conservation Fund 2002, entire; Spencer et al. 2017, entire). Headstarting may be most beneficial to areas where gopher tortoise populations are severely depleted. However, headstarting is resource-intensive and can potentially pull limited resources away from land management activities or other conservation actions if implemented in areas with established populations or robust translocation and repatriation programs. Headstarting should be carefully considered, with specific conservation targets identified, prior to implementation.

Headstarting has only recently been explored as a management tool for the gopher tortoise. The gopher tortoise headstarting program at Camp Shelby in Forrest County, Mississippi (funded by the MS Army National Guard) has been ongoing since 2013 and is still active. It began as an experimental study to determine if tortoises could successfully be reared indoors for several years, and at what age they would reach a size that, when released, would have a high likelihood of survival (Holbrook et al. 2015, entire). These initial objectives have been met, as tortoises have successfully been reared indoors for several years with a very high (greater than 95 percent) survival rate; initial releases of 2- to 3-year old tortoises into the wild indicate that these juveniles have a much higher survival rate as well (70–80 percent versus some accounts of approximately 30 percent for wild 2- to 3-year old tortoises). Headstarted juveniles are often 2 to 3 times larger than wild cohorts. Plans for tortoises currently in the headstarting program will continue to be released into other areas within the installation where habitat has been restored and is either no longer occupied by tortoises or the tortoise population is lacking a juvenile size class. Due to the ongoing success of the Camp Shelby headstarting program, plans are now in development to expand the program into adjacent habitat located in DeSoto National Forest (M. Hinderliter 2021, Service, personal communication).

In Georgia and South Carolina, post release monitoring of head started yearling gopher tortoises opportunistically released at two protected sites has been reported (Tuberville et al. 2015, entire). Several years of the mark–recapture study revealed that head started gopher tortoises have the potential to experience post-release annual survival as high as 80 percent. A subsequent study used radiotelemetry to estimate survival and reported that 8- to 9-month head-started gopher tortoises exhibited 70 percent annual survival when predation risk during soft-release penning was mitigated (Quinn et al. 2018, entire). However, annual tortoise survivorship was observed to vary among release groups and across even small spatial scales because of variation in predation risk (Tuberville et al. 2005, p. 353; Quinn et al. 2018, p. 1548), which may confound perceived benefits of headstarting without a direct comparison to hatchlings. To account for spatial and temporal variability in survivorship and more explicitly quantify the benefits of headstarting, Tuberville et al. (2021, p. 89) released hatchling and head started yearling gopher tortoises as pairs directly into adult burrows and compared their post release movement and survival until winter dormancy. The study results indicated that yearling head started gopher tortoises experienced significantly higher survival to dormancy but exhibited similar movement patterns when compared to hatchlings released simultaneously (Tuberville et al. 2021, p. 90). Additional investigation is needed into the optimal duration of headstarting and whether longer headstarting periods confer an additional survival advantage (Tuberville et al. 2021, p. 92).

3.9.4. The Gopher Tortoise Conservation and Crediting Strategy

The Gopher Tortoise Conservation and Crediting Strategy is a conservation initiative designed to balance military mission activities and gopher tortoise conservation in Southeast installations (Service 2017, entire). The Crediting Strategy establishes the framework for determining credit for Department of Defense (DoD) conservation actions. The Crediting Strategy is an important instrument in providing for the conservation of the gopher tortoise across the candidate range and is intended to achieve a net conservation benefit to the species. The Crediting Strategy focuses on identification, prioritization, management, and protection of viable gopher tortoise populations and best remaining habitat, as well as increasing the size and/or carrying capacity of those viable populations while promoting the establishment of new, viable populations through increased connectivity or translocation and repatriation efforts (Service 2017, entire).

3.9.5. Conservation Agreements

A Candidate Conservation Agreement (revised 2018) for gopher tortoise conservation was developed as a cooperative effort among state, federal, non-governmental, and private organizations (e.g., The Longleaf Alliance, Joseph W. Jones Ecological Research Center, American Forest Foundation, etc.). The primary function of this agreement is to implement proactive gopher tortoise conservation measures across the candidate range.

In 2017, a Candidate Conservation Agreement with Assurances (CCAA) was established with the Camp Blanding Joint Training Center providing protections for approximately 17,000 acres (6,879 ha) of sandhill to be managed for the benefit of multiple at-risk species, including the gopher tortoise (Service et al. 2017a, entire).

In 2012 in Florida, FWC entered into a 30-year MOA with Mosaic Fertilizer, LLC (Mosaic) to facilitate the conservation of gopher tortoises and establish a long-term structure for tortoise relocations (implemented under the September 2012 Gopher Tortoise Permitting Guidelines). Mosaic land encompasses approximately 300,000 acres (121,405 ha) in Florida, approximately 1 percent of which are utilized in mining and reclamation operations but also includes forested, shrub, herbaceous, wetlands, upland communities; the area occupied by tortoises on Mosaic lands is unknown (FWC 2020a, p. 2). As part of this MOA, prior to mining operations, Mosaic relocates all gopher tortoises from the mine site to a certified recipient site, consistent with FWC Gopher Tortoise Permitting Guidelines (FWC 2020a, p. 2). Additionally, through this MOA, Mosaic promotes management of gopher tortoise habitat through payments to state agencies and non-governmental organizations to carry out controlled burns or other habitat management activities that benefit tortoises (FWC 2020a, p.2).

3.9.6. Conservation Strategies, Best Management Practices, and Other Conservation Initiatives and Guidelines

The Rangewide Conservation Strategy for the Gopher Tortoise was developed in 2013 by the Service to guide conservation of the gopher tortoise. Specifically, this Strategy is designed for partners, including the states within gopher tortoise range, the Service, and other public and private entities to collect and share information on gopher tortoise threats, outline highest priority conservation actions, and identify organizations best suited to undertake those conservation actions (Service 2013, entire).

In Florida, Forestry Wildlife Best Management Practices for State Imperiled Species were developed in 2014 to enhance silviculture's contribution to the conservation of wildlife and to provide guidance to landowners who chose to implement these voluntary practices (FDACS 2015, entire). As of 2020, the Florida Forest Service had received a Notice of Intent to implement conservation practices from 198 landowners on more than 3.7 million acres (1.5 million ha), ranging from small private non-industrial landowners to large working forest ownerships (FWC 2020, unpaginated). Subsequent to the Forestry Wildlife Best Management Practices, in 2015, Florida Department of Agriculture and Consumer Services and FWC collaboratively developed the Agriculture Wildlife Best Management Practices for State

Imperiled Species for other commodity groups to promote sound, agricultural land use, natural resource conservation, and reduce the potential for incidental take of State Imperiled Species (FDACS 2015, p. ii), including burrowing animals such as the gopher tortoise. As of 2021, Notice of Intent to implement conservation practices was provided by 28 landowners for approximately 425,031 acres (172,004 ha) of privately owned land (FWC 2021, p. 1). The FWC also provides recommendations to landowners annually. In fiscal year 2017-2018, the FWC recommended beneficial management and/or mitigation activities on 98 projects encompassing 29,495 acres (11,936 ha) of tortoise habitat across 40 counties (FWC 2021, p.1).

There are numerous other gopher tortoise conservation tools and guides, including the 2018 Best Conservation Practices for Gopher Tortoise Habitat on Working Forest Landscapes, that was collaboratively developed by partners including the Georgia Department of Natural Resources (GDNR) and the Service to assist in making recommendations for best conservation practices for creating and maintaining gopher tortoise habitat in the candidate portion of the range (GDNR et al. 2018, entire). GDNR developed the Forest Management Practices to Enhance Habitat for the Gopher Tortoise, which details the essentials of managing habitat for gopher tortoises including prescribed fire, timber harvest, and selective herbicide use (GDNR 2014, unpaginated) . The Georgia Gopher Tortoise Initiative is an extension of the GDNR's long-standing effort in conserving longleaf pine systems. The initiative is a collaborative effort between several public and private entities and is geared towards the protection, restoration, and long-term management of gopher tortoise habitat.

3.9.7. Conservation Lands

The conservation of multiple large, contiguous tracts of habitat is essential to the persistence of gopher tortoises. Gopher tortoise habitat occurs across a wide range of public ownerships with varying levels of management. An estimated 1.7 million acres (688,000 ha) of potential gopher tortoise habitat occurs on protected lands across a wide range of ownerships including federal, state, local government, non-governmental organizations (NGOs), and private lands (e.g., conservation easements) throughout the species' range (see Figure 4.11).

Land Acquisition and Management Planning

Land acquisition for conservation is a primary tactic in preventing habitat loss, fragmentation, and degradation. Each state within the historical range of the gopher tortoise has statutory authority to acquire land for conservation purposes. With the publishing of the 12-month finding (76 FR 45130) in 2011, all states within the historical range have made concerted efforts to protect gopher tortoise habitat via strategic land acquisition. Between 2011 and 2019, Alabama, Florida, Georgia, and South Carolina have reported fee-simple acquisition of approximately 42,000 acres (16,996 ha) of potential gopher tortoise habitat with an additional approximate 78,000 acres (31,565 ha) acquired in conservation easements (CCA 2019, pp. 52-73). Federal entities including the U.S. Air Force, the Forest Service, and the Service recorded an additional 2,740 acres (1,109 ha) of potential gopher tortoise habitat acquired and approximately 24,000 acres (9,712 ha) of conservation easements acquired (CA 2019, pp. 52-73).

Habitat improvement and management are vital factors in restoring and maintaining the structure and composition of vegetation within gopher tortoise habitat. As described in Chapter 2, over most of its range, the gopher tortoise inhabits open canopy pine ecosystems, scrub oak uplands, and flatwoods maintained by frequent growing season fire. Habitat management activities may include ecosystem restoration and enhancement, non-native and invasive plant and animal control, prescribed fire, chemical and mechanical vegetation management activities, and timber management. Habitat management occurring on public conservation lands is often accomplished via natural resource planning instruments (e.g., land management plans, comprehensive conservation plans, resource management plans, etc.).

Department of Defense

As part of the implementation of the Sikes Improvement Act (1997; 16 U.S.C. 670 et seq), the Secretaries of the military departments are required to prepare and implement Integrated Natural Resource Management Plans (INRMP) for each military installation in the United States. The INRMP must be prepared in cooperation with the Service and State fish and wildlife agencies and must reflect the mutual agreement of these parties concerning conservation, protection, and management of wildlife resources (16 U.S.C. 670a). The DoD must conserve and maintain native ecosystems, viable wildlife populations, Federal and State listed species, and habitats as vital elements of its natural resource management programs on military installations, to the extent that these requirements are consistent with the military mission (DoD Instruction 4715.3). Several installations (e.g., Eglin AFB) occur within the historical range of the gopher tortoise, providing important habitat for the species. Many of these installations specifically include gopher tortoise habitat and population management prescriptions and goals within their individual INRMPs. Most INRMPS also include species specific management for other upland species, likely benefiting gopher tortoises as well. Additionally, as part of their INRMPS, military installations across the Southeast complement state and federal laws by maintaining regulations on training restrictions in areas where rare species are found. According to an ArcGIS estimate, there is approximately 830,000 acres of gopher tortoise habitat occurring on military installations throughout the range. The condition of this habitat and the extent to which these areas are occupied by gopher tortoises is not fully understood.

U.S. Forest Service

The Forest and Rangeland Renewable Resources Planning Act (16 U.S.C. 36), as amended by the National Forest Management Act of 1976 (16 U.S.C. 1600-1614), requires that each National Forest (NF) be managed under a forest plan which is revised every 10 years. Forest plans provide an integrated framework for analyzing and approving projects and programs, including conservation of listed species. Several National Forests (e.g., Ocala NF, Desoto NF, Conecuh NF, Apalachicola NF, etc.) occur within the historical range of the gopher tortoise, providing important habitat conservation for the species. Identification and implementation of land management and conservation measures to benefit gopher tortoises vary among National Forests, but generally include habitat restoration and management objectives and maintaining buffers around gopher tortoise burrows during various forest management activities.

The Desoto NF recently completed 10 years of implementing a Collaborative Forest Landscape Restoration Program, in which they implemented longleaf pine restoration goals on approximately 374,000 acres of National Forest Land. Restoration goals included: pine thinning (30,716 acres), longleaf reestablishment (13,132 acres), prescribed burning (995,000 acres), hazardous fuel reduction and wildlife habitat improvement with herbicide (8,600 acres), non-native invasive species control (975 acres), pitcher plant bog restoration (775 acres), and road decommissioning (300 miles). Almost all of these conservation goals support gopher tortoise populations on Mississippi National Forest lands and have the potential to not only enhance but increase suitable habitat. With successful results and high support among partners, this Program was recently extended. In addition, the Desoto NF has prioritized any management treatment that contributes to improvement of habitat for federally listed species, including the gopher tortoise, as set forth in their Mission, Vision, and Operational Strategy (USFS 2020, entire).

U.S. Fish and Wildlife Service

The National Wildlife Refuge System Improvement Act of 1997 (16 U.S.C. 668dd) requires that each Refuge be managed under a Comprehensive Conservation Plan which is revised every 15 years. Additionally, this Act states that each Refuge shall be managed to, among other things, consider the needs of fish and wildlife first and to maintain the biological integrity, diversity, and environmental health of the Refuge System. Several National Wildlife Refuges (NWR) (e.g., Merritt Island NWR, Lake Wales Ridge, NWR, Lower Suwannee NWR, St. Marks NWR, etc.) occur within the historical range of the gopher tortoise, providing important habitat conservation for the species. Management activities included in NWR Comprehensive Conservation Plans that influence gopher tortoises include habitat restoration activities such as pine thinning and other mechanical vegetation management for restoring desired vegetative conditions in pine and scrub systems, and tortoise management and monitoring actions based on priorities of the refuge and available resources.

States

Through statute, the state of Florida requires that managers of lands that contain imperiled species consider the habitat needs of these species during preparation of management plans and that all land management plans include short-term and long-term goals to serve as the basis for land management activities; these goals include measurable objectives for imperiled species habitat maintenance, enhancement, restoration, or population restoration (253.034(5)). In Georgia, land management planning on state property is directed by policies contained within the Georgia Planning Act of 1989 (O.C.G.A. 12-2-28) and the Georgia Environmental Policy Act (O.C.G.A. 12-16-1). In South Carolina, the Heritage Trust Act (S.C. Code Section 51-17-80 and –90) requires a management plan, but does not require regular reviews or updates and while ongoing planning is not prescribed by state law, some timber harvest planning does occur under S.C. Code Section 50-3-510 et. seq. In Mississippi, while there are no statutes requiring resource management plans, MS Code Section 49-5-103 allows for annual appropriations for the General Fund for the management of nongame and endangered species.

3.9.9. Private Lands Conservation Efforts

Most forested land within the gopher tortoise range is privately owned. Privately owned lands account for approximately 80 percent of potential gopher tortoise habitat, of which approximately half are managed for forest production. (Greene et al. 2019, p. 201). As the human population continues to grow in the Southeast, development and related socioeconomic pressures will increasingly threaten forest resources, with effects such as forest conversion to non-forest uses and increasing fragmentation and degradation of forests. Forest loss may lead to loss of ecological function and connectivity essential for the dispersal of gopher tortoises across the landscape. With >90% of land in private ownership, couple with increasing numbers of urban and absentee landowners, forested lands within the range of the gopher tortoise are particularly susceptible to fragmentation and land-use conversion, It is important to strategically target forest-retention efforts, particularly as landscapes are subject to rapid conversion to development, and volatility in timber markets increase risk in private forestland timber production.

It is important to note, data included in our viability analysis (included in chapters 4 and 5) represents a subset of gopher tortoises likely to occur on the landscape, as the majority of data from private lands were lacking. Thus, population estimates in this SSA do not represent an assessment of all populations of gopher tortoises, but rather represent information that was provided by partners through much of the species' range. Most population estimates came from assessments of populations on lands managed for the conservation of biodiversity or natural resources.

Large Working Forest Lands

Coordinating with large working forest landowners and managers, NCASI provides technical information and scientific research needed to achieve environmental goals and principles, including species conservation. Across the entire range of the gopher tortoise, 12 large working forest ownerships in the listed range and 16 in the candidate portion of the gopher tortoise range account for over 6 million acres (2.4 million ha) (NCASI 2020, p. 3) of forest land, representing a significant land use with the potential to influence gopher tortoise resiliency in a multitude of ways across the range. While not all working forest lands include appropriate habitat conditions for gopher tortoises, approximately 2.78 million acres (1.12 million ha) of suitable soil types and 2.98 million acres (1.21 million ha) of open pine conditions are estimated to occur on private forest ownerships within the NCASI database (NCASI 2021, p. 1). Evidence of gopher tortoise occurrence from informal surveys and observations was reported by NCASI from Member Company lands in 107 counties between 1977 and 2019 (Figure 3.9). While the data reported does not cover all gopher tortoise habitat on Member Company land and does not include all lands under private forest management within range of the gopher tortoise, the information provided does reflect over 10,000 observations recorded between 2013 and 2019 (91 counties rangewide) (NCASI 2020, p. 9-11; Miller, pers. comm., 2021).

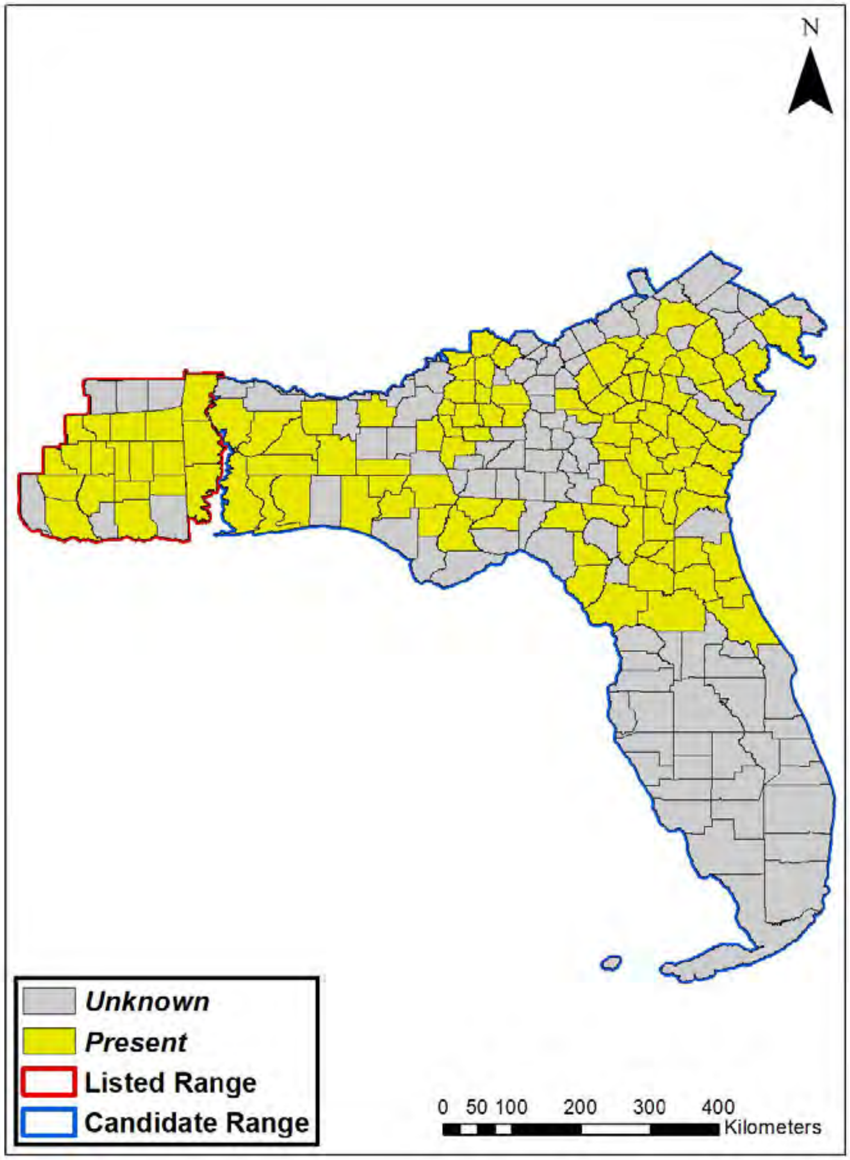

Figure 3. 9-Gopher tortoise known occurrence location (yellow) and unknown (gray) on NCASI Member Company lands. Data compiled here includes informal and formal surveys, burrow observations, presence at a stand level, and tortoise sightings. Unknown counties (gray) do not imply absence on NCASI Member Company lands as some counties do not contain Member Companies, some Member Company land in some counties may not include gopher tortoise habitat, and not all Member Company lands had survey data (NCASI 2020, p. 8).

While working to meet a range of objectives including timber production, many larger private working forests also accomplish conservation within a broad network (Figure 3.10) of collaboration with Federal, State and local government agencies, universities, and environmental non-governmental organizations (ENGOs). Forest certification is one method used to ensure forest lands are managed to provide habitat for wildlife, including gopher tortoises. Participants in forest certification programs such as the Sustainable Forestry Initiative (SFI), and Forest Stewardship Council, adhere to a set of principles that reflect a commitment to providing certain societal benefits, including conservation of biological diversity (NCASI 2020, p. 11). Certification is maintained through third party audits to demonstrate conformance with applicable standards. Standards applicable to gopher tortoise conservation include: 1) having a program to incorporate conservation of native biological diversity, including species, wildlife habitat, and ecological community types at stand and landscape scales; 2) developing criteria and implementing practices to retain stand-scale wildlife habitat elements; and 3) working individually or collaboratively to support diversity of native forest cover types and age or size classes that enhance biological diversity at the landscape scale. An estimated 13.7 million acres (5.5 million ha) within states where gopher tortoises occur are certified through SFI (SFI 2021, unpaginated), though the proportion of certified acres that occur within the range of the gopher tortoise is unknown. Additionally, the proportion of certified acres that include gopher tortoises or gopher tortoise habitat is also unknown.

Across the range of the gopher tortoise, master logger programs are available in each state. These programs include training that meets SFI program standards and in addition to increasing safety and efficiency within the profession, provides professional loggers with environmental training, Environmental training includes BMPs, the ESA, and threatened and endangered species management, including gopher tortoise. Trained master/professional loggers supervise most forest harvesting operations to meet the requirements of the SFI.

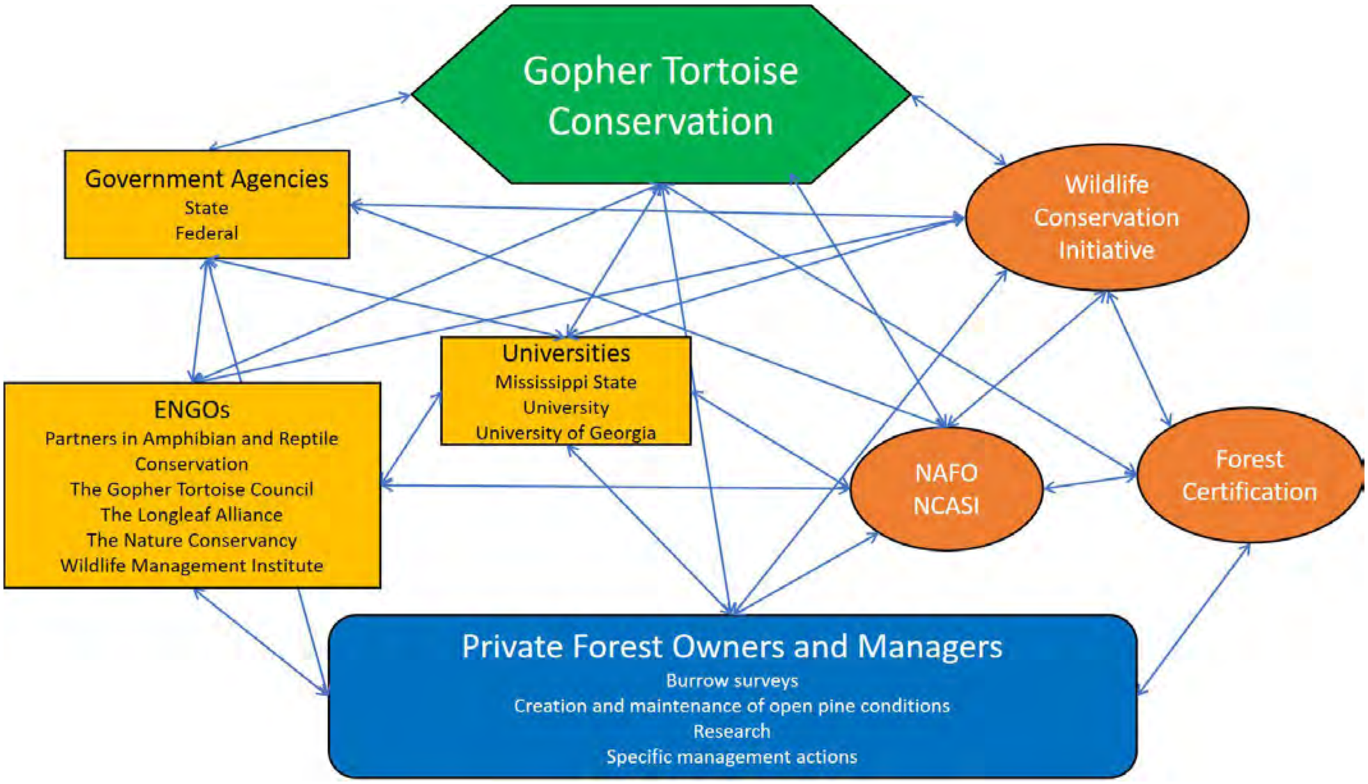

Figure 3. 2-Gopher tortoise conservation occurs through collaboration among several entities. Large private working forest owners and managers (blue) complete gopher tortoise conservation within their own organizations but also collaborate with environmental non-governmental organizations (ENGOs), government agencies, and universities (yellow). Furthermore, private forest owners and managers cooperate with each other via the National Alliance of Forest Owners, NCASI, and the Wildlife Conservation Initiative (orange) to ensure gopher tortoise conservation efforts happen throughout the species' range. Lastly, forest certification programs (orange) provide further assurances that at-risk species conservation (including gopher tortoise conservation) will continue to be a priority on private forests. Entities listed do not represent an exhaustive list of cooperators and partners. Source: NCASI

Family Forests

The largest forest landowner group in the United States is the family forest landowners, controlling 36 percent of forest lands in the country (Butler et al. 2016, p. 641) and in the south, private ownerships account for 87 percent of forest land (Oswalt 2014, p. 6). Similar to large working forest landowners, family forest landowners accomplish conservation through a broad network of conservation partners (Figure 3.11). Conservation values are important and family forest landowners rank beauty, wildlife, nature, and legacy as top reasons for owning land, and timber production as not one of the top ten reasons (Butler et al. 2016, p. 644). Working with smaller, family forest landowners, the American Forest Foundation (AFF) works to increase sustainable wood supplies on family forests while protecting and enhancing habitat for at-risk species, including the gopher tortoise. In accomplishing this objective, in 2017 the AFF has partnered with the Service's Partners for Fish and Wildlife Program to support conservation of at-risk species on private lands within the Southeast. Participating landowners work with Partners biologists to develop habitat improvement plans that meet their long-term objectives for the property, receive cost share for habitat improvement projects and commit to actively managing the project area. Consistent with the Partners program requirements, landowners enter into formal agreements with the Service and AFF for a minimum of 10 years. Since 2017, the partnership has engaged landowners with over 3,500 acres (1,416 ha) under agreement where habitat improvement projects have included approximately 2,000 acres (809 ha) of longleaf pine establishment and the introduction of prescribed fire to more than 1,400 acres (566 ha) of existing pine forests. An additional focus of this partnership is the implementation of wildlife surveys, including gopher tortoise. Since 2017, gopher tortoise surveys on participating forests have identified 762 gopher tortoises, including 2 populations that meet the MVP criteria (AFF 2021, unpaginated). As with the large working forests, family forest landowners may participate in forest certification programs such as the American Tree Farm System (ATFS). The ATFS has certified more than one million acres of private lands in each of the Southeast states and requires landowners and managers to implement BMPs, identify and protect state and federal listed species, and to protect soil and water resources. ATFS certification, as are most forest certifications, is a third-party audited certification system authorized by the Program for the Endorsement of Forest Certification (PEFC). It is unknown how many acres of ATFS certified lands occur within the gopher tortoise range, include gopher tortoise habitat, or support gopher tortoise populations.

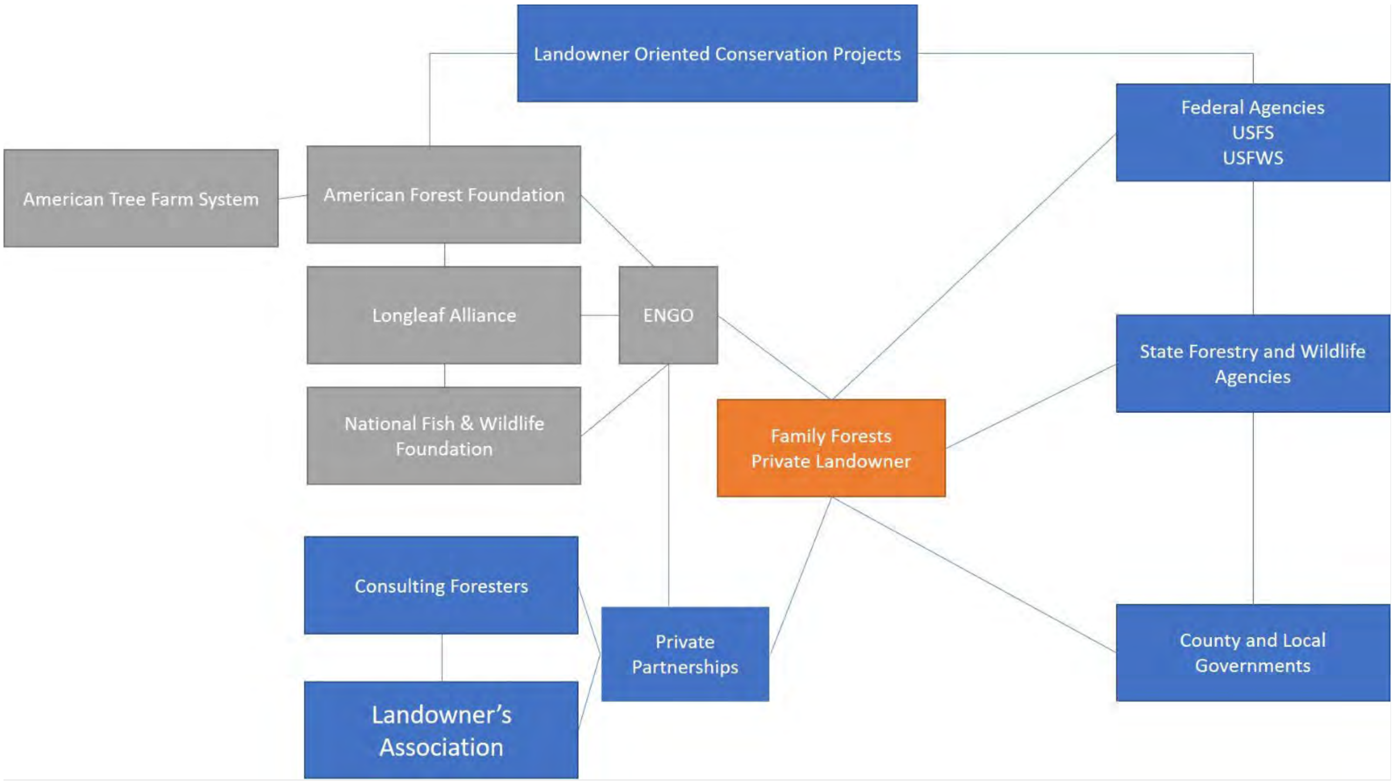

Figure 3. 11-Gopher tortoise conservation delivery network for small family forests. Entities listed are not exhaustive of all potential partners and stakeholders. Source: AFF

Additionally, The Longleaf Alliance works with private landowners and other partners across the range of the gopher tortoise to restore and maintain habitat as an essential part of their larger focus in restoring the longleaf pine ecosystem. In providing technical and financial assistance, the Longleaf Alliance in 2019, assisted landowners with the implementation of over 55,000 acres (22,258 ha) of prescribed fire within gopher tortoise habitat in addition to assistance with longleaf pine plantings, groundcover restoration, and invasive plant management efforts (SERPPAS 2020, p. 17).

Conservation Banks

Several privately-owned tracts of land are managed as mitigation/conservation areas for gopher tortoises in both Mississippi and Alabama, providing suitable habitat, protection, and habitat management. In Greene County, MS, the 1,230-acre Chickasawhay Gopher Tortoise Conservation Bank was established in 2009 to accept tortoises displaced by development within the Bank's service area and to compensate impacts to tortoises. As the only official mitigation bank for the gopher tortoise, the national mitigation banking guidelines are followed for maintaining optimal habitat, including aggressive prescribed fire and longleaf restoration programs.

In Mobile County, AL, four gopher tortoise conservation areas are managed through HCPs with the Service. These areas serve as a relocation site for tortoises impacted by utility and county construction and maintenance and are required to follow habitat plans which include restoration and management of the open-canopied, upland longleaf pine habitat used by gopher tortoises. However, they are all less than 700 acres and primarily surrounded by urban landscapes with incompatible habitat.

3.10. Summary of Factors Influencing Viability

The best available information regarding the gopher tortoise and gopher tortoise habitat indicates that habitat loss, degradation, and fragmentation (due to land use changes from urbanization), climate change, and habitat management are the most significant factors influencing gopher tortoise viability. Urbanization results in a range of impacts that either remove or degrade/fragment remaining habitat, or impact gopher tortoises directly through development. Urbanization brings road construction and expansion, which may cause direct mortality of gopher tortoises. In addition, this type of development may also create conditions beneficial to invasive species, increase predators and inadequate conditions for fire management. Temperature increases associated with long term climate change are likely to further constrain use of prescribed fire through a decrease in the number of suitable burn days. Habitat loss resulting from sea level rise associated with climate change is a risk for coastal populations of gopher tortoise. These factors are considered to have population level effects and were evaluated further in the current condition and future condition analysis.

CHAPTER 4 – POPULATION AND SPECIES NEEDS AND CURRENT CONDITION

4.1. Introduction

In this chapter, we consider the gopher tortoise's current distribution, species needs, and how the species needs influence the 3 Rs. We first define populations of the species. Next, we characterize population and habitat factors for the species in terms of the 3 Rs. Finally, we estimate the current condition of the gopher tortoise using population metrics used to characterize the 3 Rs.

Survey methodologies

We received a variety of data to assess resiliency factors for the gopher tortoise, including information from state and federal agencies, local governments, and private lands. These data represent a subset of gopher tortoises likely to occur on the landscape due to the lack of a comprehensive private lands data set. Data were collected using burrow surveys of various methodologies and included burrow surveys (comprehensive and area-constrained) both with and without burrow scoping incorporated, and line transect distance sampling (LTDS; Buckland et al. 1993, entire; Thomas et al. 2010, entire); some burrow data were submitted with unknown methodology. Comprehensive burrow surveys, sometimes called 100 percent surveys, involve a team of researchers searching a site to count the total number of gopher tortoise burrows present. Area-constrained surveys, also referred to as belt transect surveys, use a similar methodology as comprehensive surveys. However, these surveys are restricted to a transect of pre-delineated length and width, and population estimates are extrapolated site-wide based on the proportion of the site that was surveyed (Auffenberg and Franz 1982, pp. 95-96; Cox et al. 1987, p. 39). As counting burrows alone during these surveys results in unknown occupancy estimates, an occupancy rate (or correction factor), is often used to estimate population size for comprehensive and belt transect surveys (0.614, Auffenberg and Franz 1982, p. 96; 0.5, Ashton and Ashton 2008, p. 158; 0.40, Guyer et al. 2012, p. 132).

Biologists also sometimes use burrow-scope cameras in conjunction with burrow surveys to directly estimate abundance of local populations by counting individuals within burrows; this method assumes that all potentially occupied gopher tortoise burrows were detected at sites and that only a single gopher tortoise is present in a burrow. Line transect distance sampling is a survey method to derive estimates of abundance where a research team walks transects, observes gopher tortoise burrows, searches the burrow for a gopher tortoise with a burrow scope, records the precise spatial location of occupied burrows, and measures the perpendicular distance of each occupied burrow to the transect line (Smith et al. 2009a, entire). Invariably, burrows and individuals are imperfectly sampled because detection probability of burrows is less than one. However, analysis of LTDS data generates functions estimating the decay of the detection rate with increasing distance from the transect line, and this detection function can then be used to account for undetected burrows and therefore estimate the total number of occupied burrows in the search area (i.e., total population size). Because juvenile gopher tortoises have small burrows that are difficult to observe, detection of juveniles during all burrow survey types (comprehensive, belt transect, LTDS) is lower than adults; thus, surveys may underrepresent smaller size classes in the population estimates (Smith et al. 2009a, p. 356; Gaya 2019, pp.13-31).

Because data were provided by a variety of sources, contained disparate levels of data resolution, and were collected in various ways, we could not reliably determine abundance, density, habitat availability, or other metrics for all populations. All population data provided are integral to evaluating the current condition of the gopher tortoise, although different data types come with different assumptions and limitations as described below.

Spatially explicit data

The most useful data, from an analysis perspective, are those data that come from standardized and systematic surveys which result in spatially explicit burrow locations and subsequent population estimates. There are several advantages to spatially explicit data, including the ability to make more reliable estimates of populations size; use of spatial buffering to delineate populations based on species biology (see Delineating Populations section below); ability to tie site-specific factors, such as habitat and management factors, to locations of gopher tortoises; and, ability to estimate future parameters, such as probability of persistence and estimated future abundance of gopher tortoise populations.

Due to discrepancies in historical data collection, surveys have recently been performed using LTDS (Buckland et al. 1993, entire; Thomas et al. 2010, entire) when possible and applicable. This methodology is believed to be the most statistically reliable to assess accurate measurements of gopher tortoise populations (Smith et al. 2009b, p. ii). Surveys using this methodology have been done across the range of the gopher tortoise and have been providing more comprehensive data on the status of the species, at least in conservation lands where it has been mostly used. Some belt transect survey data submitted were incomplete and the proportion of habitat surveyed, and therefore the proportion of burrows or tortoises, was unknown. Also, population estimates derived from the belt transect method tend to be less accurate than LTDS; unlike LTDS, the belt transect method involves an area-constrained survey and assumes that burrows occur uniformly and independent of space. Moreover, LTDS analyses yield estimates of precision and detectability that cannot by calculated using the belt transect methodology. Some burrow data were included with unknown survey methodology. In these instances, it is likely that these data do not represent the true population sizes for these sites.

County level information

Private landowners, large and small, play a vital role in conserving habitat for fish, wildlife, and plants, highlighted by the fact that more than two-thirds of the nation's threatened and endangered species use habitat found on private land. The gopher tortoise is no different, where a large percentage of potential habitat is located on land that is privately owned. This highlights the importance of including data from private lands when assessing species viability. The vast majority of the private lands data obtained for this assessment lack a spatial component because of issues associated with confidentiality of location data; this does not preclude the utility and importance of these data in the species status assessment. To this end, we created a landowner questionnaire and utilized responses to estimate population, habitat, and management factors at a county scale to ensure privacy for respondents (Appendix A). We received 167 responses to the landowner questionnaire, with respondents owning properties covering much of the range of the gopher tortoise (Figure 4.1). Responses likely represent a small percentage of private lands that currently support gopher tortoises, particularly given the reluctance many private landowners have sharing occurrence data for at risk species. In addition to these responses, the Florida Forestry Association (FFA) sent out their own questionnaire to additional landowners in the state of Florida, with an additional 34 respondents. Although the FFA questionnaire was similar to the one found in Appendix A, a key difference was that we were not able to obtain population estimates from the 34 responses, thus are unable to estimate current resiliency for populations on these properties.

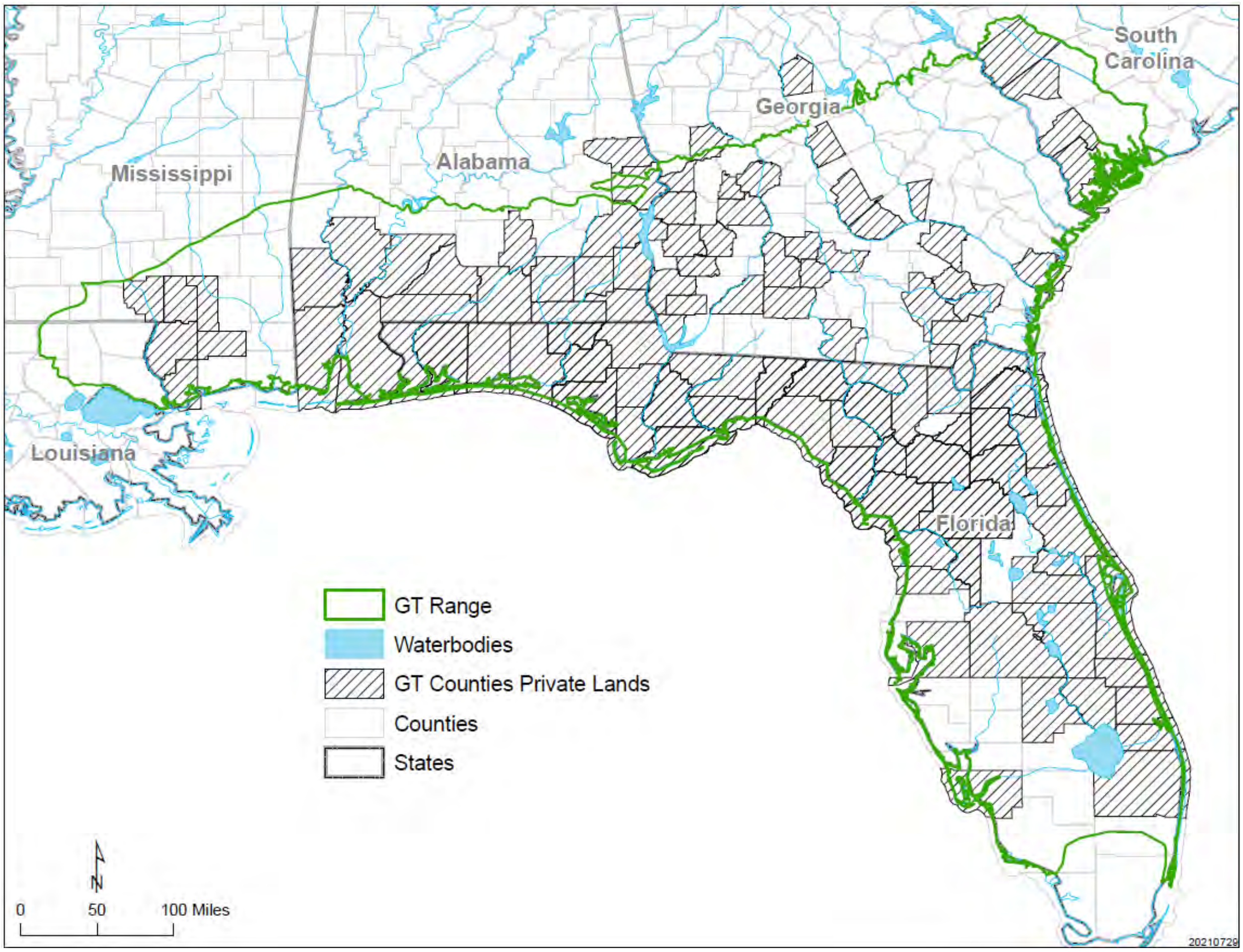

Figure 4. 1-Location of counties with responses to the private landowner questionnaire (with hatching).

Because data received from these questionnaires are not spatially explicit, there are limitations to the applicability of the data as it relates to delineation of populations, assessment of site-specific factors such as habitat quality and quantity, and management regimes, and use of abundance data in projections of future scenarios. Due to these limitations, we present results for current conditions for both types of data (spatially explicit and county level) separately. As will be discussed in Chapter 5 (Future Conditions), we only used spatially explicit data to inform the population model used to forecast future scenarios for the gopher tortoise, which introduces a degree of uncertainty into future projections, given we were only able to use a subset of populations that likely occur on the landscape.

4.2. Delineating populations

As the population is a biologically meaningful unit in an analysis of resiliency, which is then scaled up to redundancy and representation at the species scale, appropriately defining and delineating populations is a crucial step to assess species viability. Below we discuss the challenges of delineating populations for the gopher tortoise and outline our approach.

For this assessment, we defined populations for the species as contiguous areas surrounding known gopher tortoise burrows with habitat conducive to survival, movement, and inter-breeding among individuals within the area. To delineate populations, we compiled and used all records with spatially explicit information, as detailed previously. In addition to naturally occurring gopher tortoise populations, we also included long-term recipient sites in Florida and South Carolina (hereafter, recipient sites) that currently support translocated individuals. A detailed discussion of recipient sites can be found in Chapter 3 (3.9.3 Translocation, Relocation, Recipient Sites and Headstarting). We could not delineate populations for county records that were lacking coordinates, thus we placed these records at the county's centroid and summarized population and habitat factors separately.

Using spatial survey data from across the range of the gopher tortoise, we sought to operationally identify populations at two spatial scales: local populations and landscape populations (Figure 4.2). Local populations can be considered groupings of individuals discovered by demographic or spatial analysis (Smallwood 2001, entire; Goessling et al. 2021, p. 141), whereas landscape populations can refer to the assemblage of individuals found within a property or region of interest (Goessling et al. 2021, p. 141). We defined local populations as geographic aggregations of individuals that interact significantly with one another in social contexts that make reproduction significantly greater between individuals within the aggregation than with individuals outside of the aggregation (sensu Smallwood 1999). We operationally delineated local populations by identifying aggregations of individuals or burrows where individuals were clustered together within a 1,968 feet (600 m) buffer to the exclusion of other adjacent individuals or burrows. Studies of gopher tortoise populations in Alabama (Conecuh NF; C. Guyer, unpublished data), Georgia (Ft. Stewart Army Reserve; E. Hunter and D. Rostal, unpublished data), and Florida (Boyd Hill Nature Preserve; J. Goessling and G. Heinrich, unpublished data) have found that greater than 80 percent of gopher tortoise movements within and among years were less than 1,640 feet (500 m). We recognize that although gopher tortoise interactions may primarily occur within 600 meters of a burrow cluster, the extent to which a tortoise will travel and interact with other tortoises varies by population, and this is likely influenced by many factors, including demographics (sex and size class ratios), population density, whether the population is naturally occurring or a translocated population, habitat type, management, nearby urbanization, and degree of habitat fragmentation.

We selected a 1,968 feet (600 m) distance to buffer populations to encompass typical movement distances and adjacent habitat around surveyed populations that might include gopher tortoises. Because gopher tortoise habitat and demography vary across the range, the 1,968 feet (600 m) buffer represents a compromise across geography and habitat based on a thorough literature search and species expert input. We assumed that areas unsuitable for gopher tortoises were unsuitable for gopher tortoise movement or survival and considered those strict barriers when delimiting local populations. Thus, movement barriers included interstates, freeways, and expressways (HPMS 2019); major rivers and lakes (Sciencebase.org); wetlands, and highly urbanized areas as determined by visual inspection with ESRI imagery.

Local populations can be connected to other, nearby local populations by dispersal; together, connected local populations may form landscape populations. Gopher tortoises infrequently move long distances from established core home range areas, and such movements can result in permanent emigration and immigration into other populations. Local populations that are spatially proximate to other local populations might receive immigrants that bolster population size. While little quantitative information is available describing the frequency or success of immigration, one study found that 2 percent of adults emigrated from local populations each year (Ott-Eubanks et al. 2003, p.319). It is important to note that this emigration estimate was based on only 2 individuals and may underestimate true immigration. We identified instances of two or more local populations that may be connected by dispersal through gopher tortoise habitat as landscape populations.

Although the term landscape population has been used to identify areas where individuals are located within a human defined boundary (Goessling et al. 2021, p. 141), such as a property line, we define a landscape population as a series of local populations that are connected by some form of movement; individuals within a landscape population are significantly more likely to interact with other individuals within the landscape population than individuals outside of the landscape population. Gopher tortoises have been shown to move over 4,921 feet (1,500 m) throughout multiple years, with distances as large as 8,802-15,220 feet (2,683-4,639 m) (McRae et al. 1981, p.172; Diemer-Berish et al. 2012, p. 52; Guyer et al 2012, entire; Castellon et al 2018, p. entire; unpublished data from Goessling and Rostal and Hunter). We operationally delineated landscape populations by identifying local populations connected by habitat within 8,202 feet (2.5 km) buffer around each local population; habitat was considered any areas other than open water, wetlands, paved roads (interstates, freeways, and expressways), and urbanized areas. Landscape populations could comprise multiple local populations or a single local population if no other local populations were within 8,202 feet (2.5 km) buffer, or otherwise separated by a barrier to gopher tortoise movement.

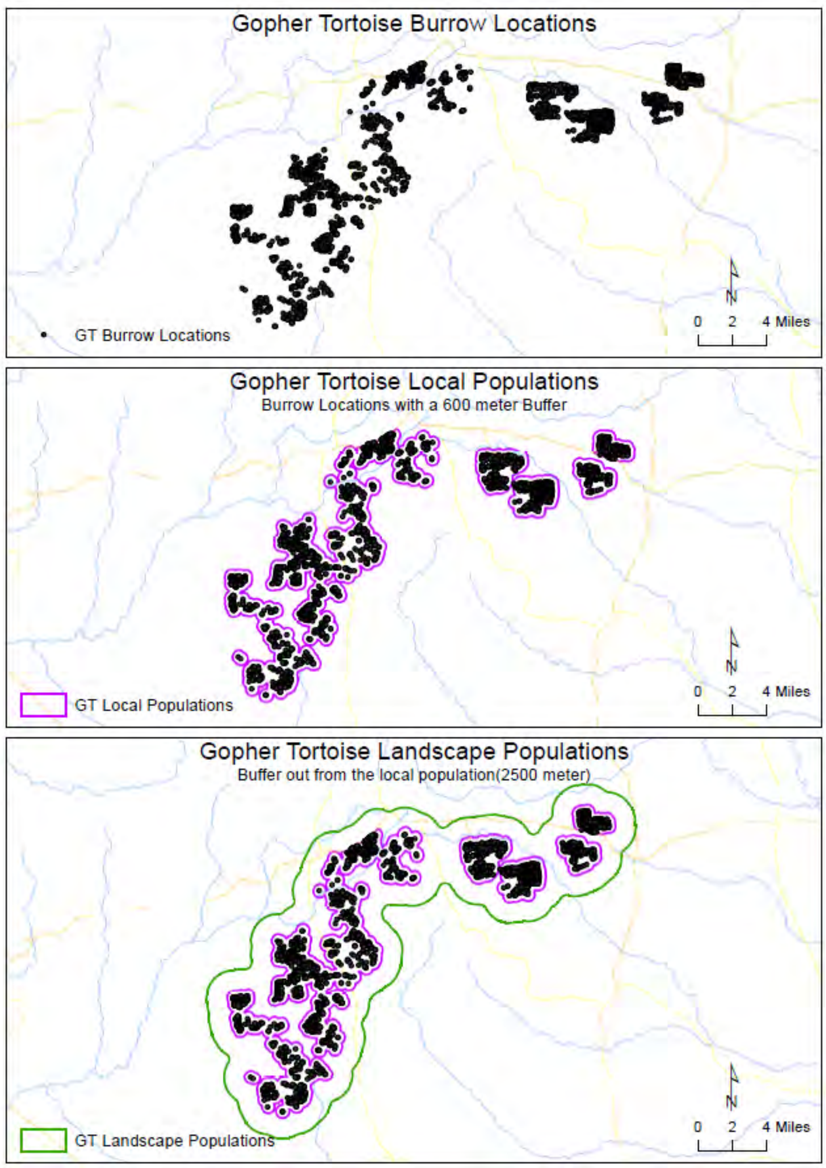

Figure 4. 2-Process for delineating local (0.37 miles/600 m buffer) and landscape populations (1.55 miles/2500 m buffer) using burrow locations for gopher tortoises.

Our process of spatially delineating local populations and landscape populations resulted in a dataset of 656 local populations from 253 landscape populations (Figure 4.3); Florida had the greatest number of local (316) and landscape populations (161), followed by Georgia (151, 63, respectively), Mississippi (99, 7), Alabama (77, 14), Louisiana (7, 5), and South Carolina (6, 4).

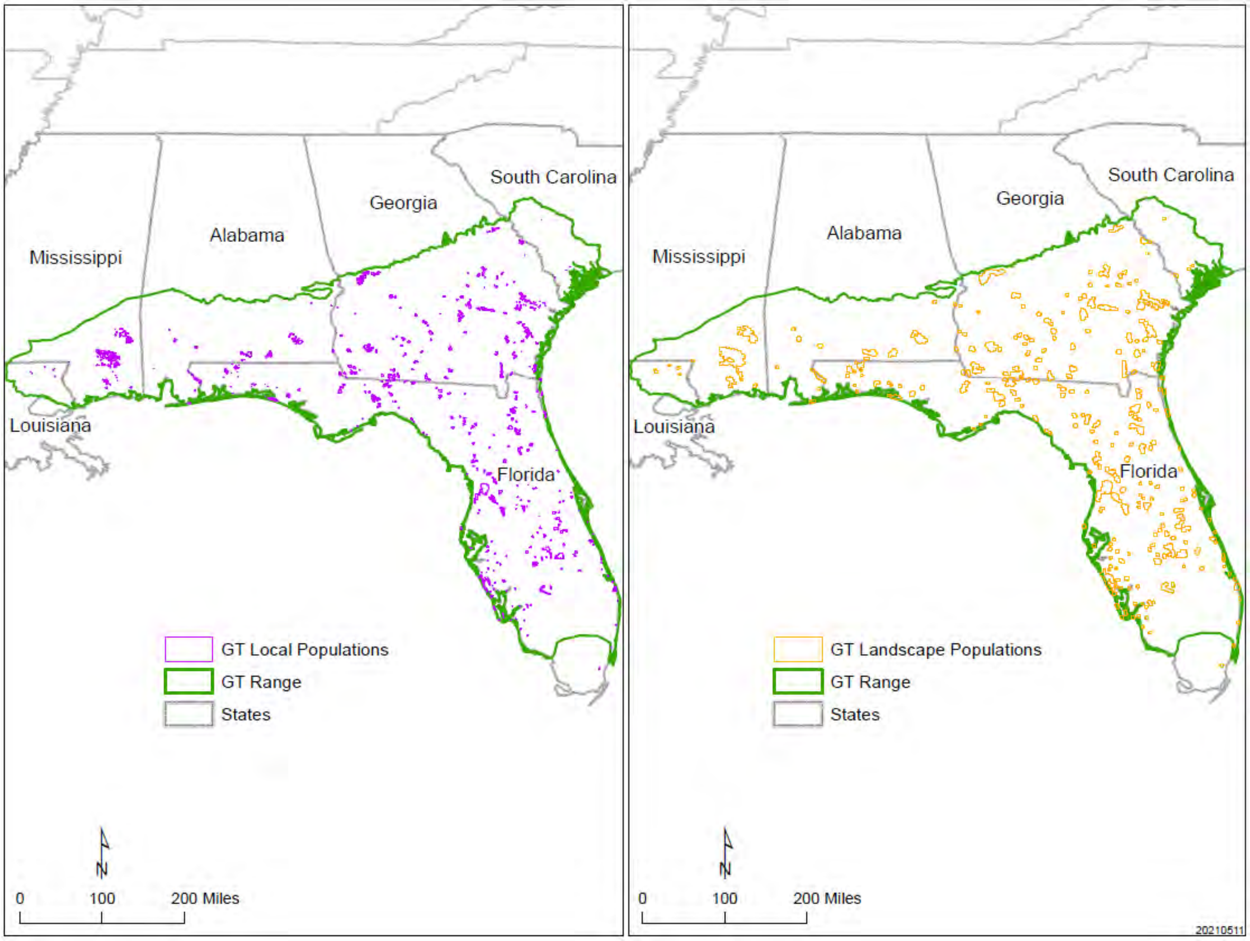

Figure 4. 3-Location of spatially delineated local populations (left panel) and landscape populations (right panel) across the range of the gopher tortoise.

4.3. Delineating representative units

Representation refers to the breadth of genetic and environmental diversity within and among populations, which influences the ability of a species to adapt to changing environmental conditions over time. Differences in life history traits, habitat features, and/or genetics across a species range often aid in the delineation of representative units, which are used to assess species representation. Representation improves with the persistence of populations spread across the range of genetic and/or ecological diversity within the species.

Drawing conclusions about genetic subdivisions and unique genetic assemblages based on available data are difficult because methodologies varied among studies, sample sizes were small in some areas, distances among samples were large in some cases, and areas covered by each study varied. While there is molecular support for recognizing the western portion of the range as genetically distinct, other research has suggested that additional structure exists at both rangewide and regional scales (Ennen et al. 2010, entire; Clostio et al. 2012, entire; Ennen et al. 2012, entire; Galliard et al. 2017, entire). A recent study investigating genetic structure at multiple scales found five genetic regions (Western, Central, West Georgia, East Georgia, and Florida), loosely delineated by biogeographical features including the Tombigbee-Mobile Rivers, Apalachicola-Chattahoochee Rivers, and transitional areas between physiographic provinces of the Coastal Plains (Figure 4.4; Galliard et al. 2017, pp. 503-507). The Tombigbee-Mobile Rivers separate the Western region from the rest of the range, which corresponds to the listed portion of the range of the species. The Apalachicola-Chattahoochee Rivers divide the Central and West Georgia regions, although there is a high degree of admixture at the border of these two regions. The rest of the genetic groups are associated with transitional zones between the Eastern Gulf, Sea Island, and Floridian physiographic province sections of the Coastal Plains, with high amounts of admixture between adjacent genetic groups (Figure 4.4; Galliard et al. 2017, pp. 503-507).

With respect to gene flow, levels of gene flow have been found to be asymmetric from central to peripheral regions, with the highest levels from the Central to Western Regions, and the lowest between the Florida and Western Georgia groups (Galliard et al. 2017, p. 509). Finally, significantly lower genetic diversity is found at the periphery of the range, with low diversity in the Western and East Georgia regions (Ennen et al. 2010; Clostio et al. 2012; Galliard et al. 2017, p. 509).

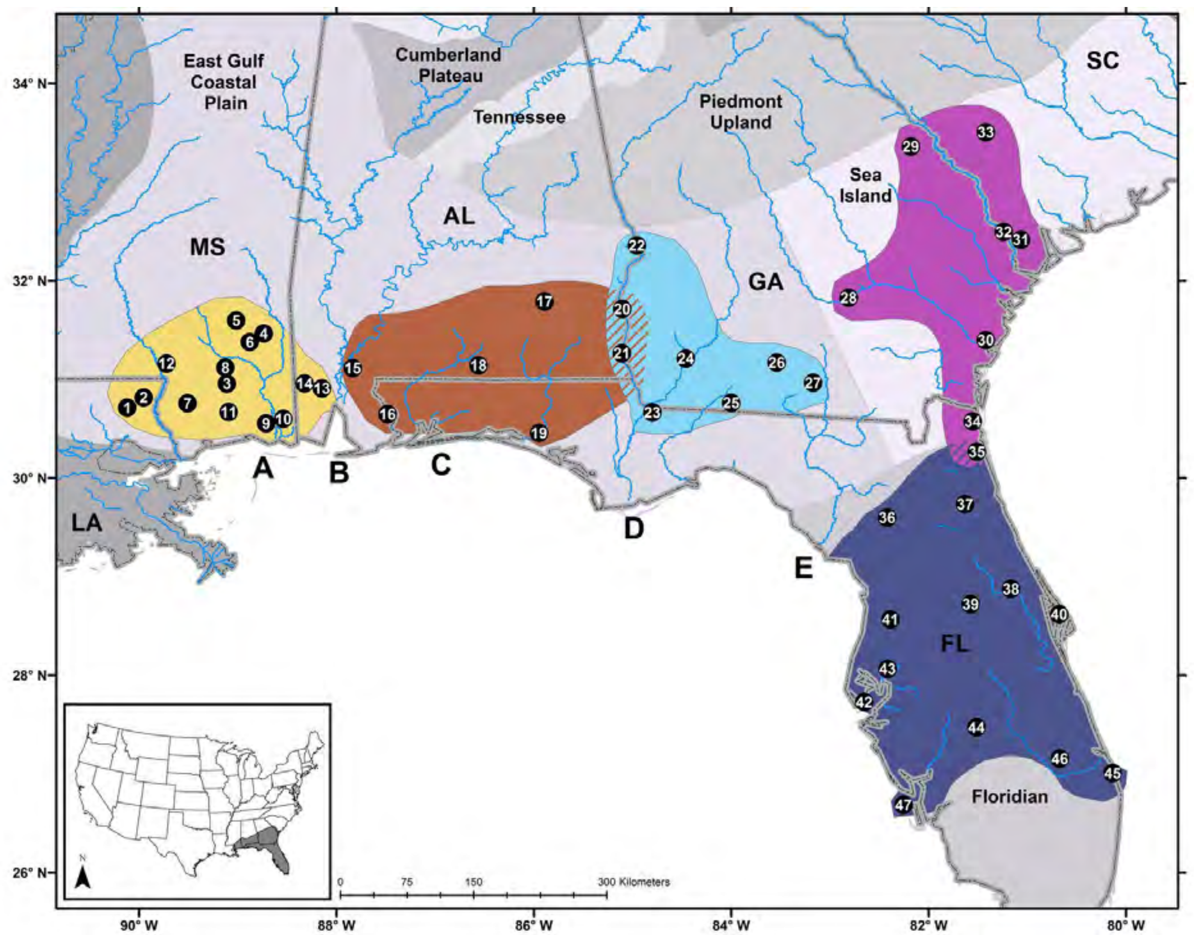

Figure 4. 4-Sampling locations and subsequent genetics units from genetics study by Galliard et al. 2017. The colored shaded areas around sampling sites represent their assignment to one of the five genetic groups (regions) as follows: yellow (Western), brown (Central), light blue (West Georgia), magenta (East Georgia), and dark blue (Florida).

For this assessment, we delineated five representative units (hereafter analysis units) based on the results of Galliard et al. (2017, entire), physiographic regions, and the input of species experts (Figure 4.5). We used the Tombigbee-Mobile Rivers and Apalachicola-Chattahoochee Rivers as boundaries between the Western (Unit 1), Central (Unit 2), and West Georgia (Unit 3) analysis units. Because of the high degree of admixture and lack of well-defined boundaries found within transitional zones of physiographic regions, we used other biogeographic barriers and expert input to delineate boundaries between West Georgia, East Georgia (Unit 4), and Florida (Unit 5) analysis units. We used U.S. Environmental Protection Agency (EPA 2013, unpaginated) Level IV ecoregions to delineate the boundaries between the two Georgia units, and the East Georgia and Florida unit. We used the Suwanee River to separate the West Georgia and Florida units, as this river represents a significant barrier to dispersal, and gene flow between these 2 units is known to be low (Galliard et al. 2017, p. 509).

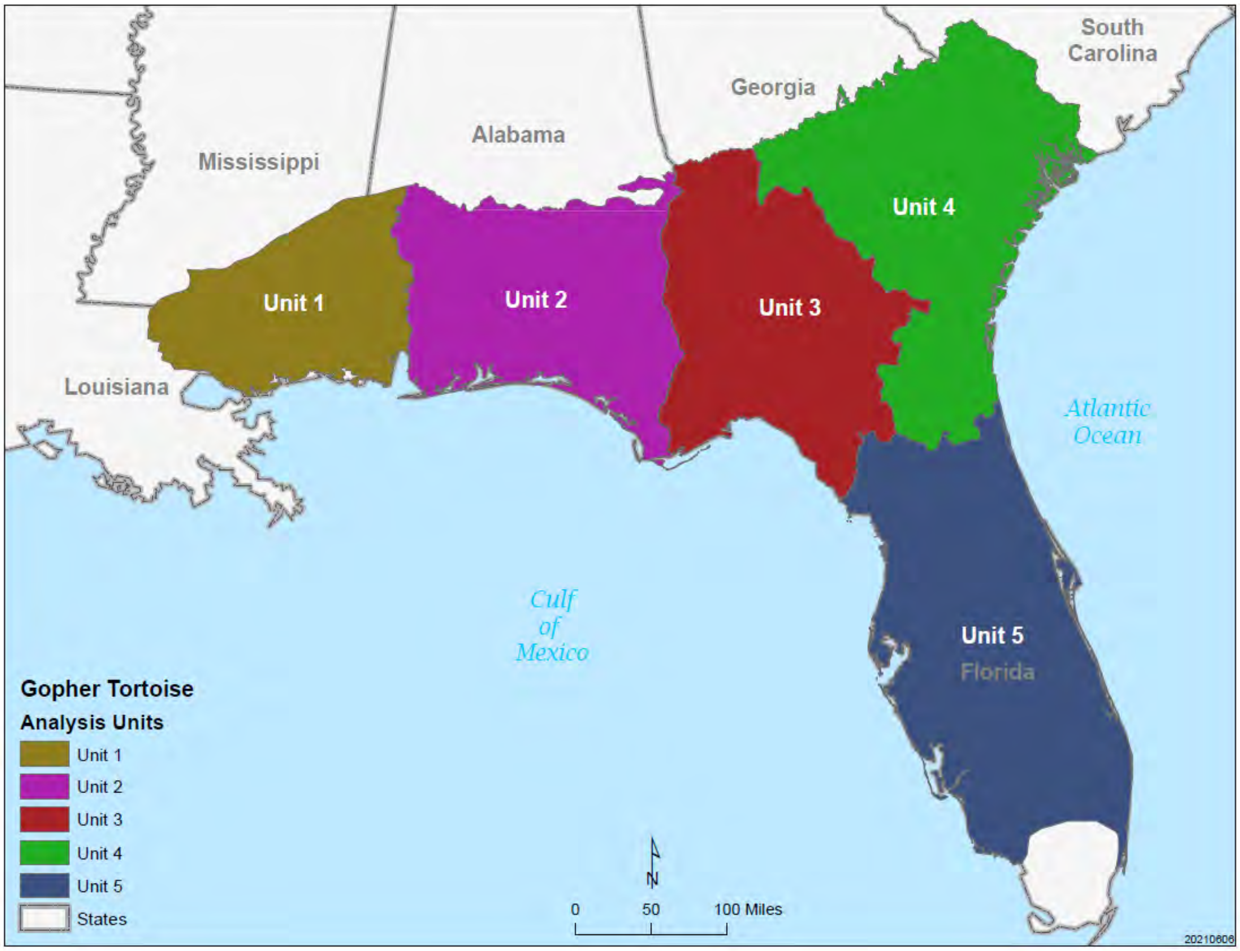

Figure 4. 5-Analysis units used as units of representation for the gopher tortoise in this Species Status Assessment. Analysis units include Western (Unit 1), Central (Unit 2), West Georgia (Unit 3), East Georgia (Unit 4), and Florida (Unit 5).

4.4. Current resiliency

Resiliency describes the ability of a species to withstand low-level stochastic events and is associated with population size, growth rate, and habitat quality. Highly resilient populations are more likely to withstand disturbances such as random fluctuations in fecundity (demographic stochasticity), variation in mean annual temperature (environmental stochasticity), or the effects of anthropogenic activities, such as local development projects. Viability denotes a species' ability to sustain populations over a determined time frame and is closely tied with population resiliency. Below, we describe population, habitat, and management factors that contribute to resiliency of gopher tortoise populations.

4.4.1. Population factors

For gopher tortoise populations to persist for a biologically meaningful timeframe, they must have an adequate number of individuals (population size), be above a particular density (population density), and have sufficient genetic exchange between local populations to maintain genetic diversity (Figure 4.6). There must also be sufficient habitat to support individual and population needs, which we discuss in the next section (Habitat and Management Factors). Population size and density are driven by a variety of underlying demographic parameters, including fecundity, sex ratio, and survival at various life history stages (egg, nest, hatchling, juvenile, and adult survival). Genetic diversity is primarily driven by rates of emigration and immigration between local populations.

It is important to note that populations of gopher tortoises experience great variation in abiotic characteristics across the species' range, and variation in abiotic characteristics influences demographic rates among populations. At southern latitudes, populations experience significantly warmer mean annual temperature, which may afford greater overall opportunity for thermoregulation, energy acquisition, and metabolism when compared to northern populations. As a result, southern populations of gopher tortoises experience faster growth rates, younger ages of sexual maturity (hereafter, maturity age), and increased clutch size (Ashton et al. 2007; Moore et al. 2009, pp. 387-392; Meshaka Jr. et al. 2019, entire).

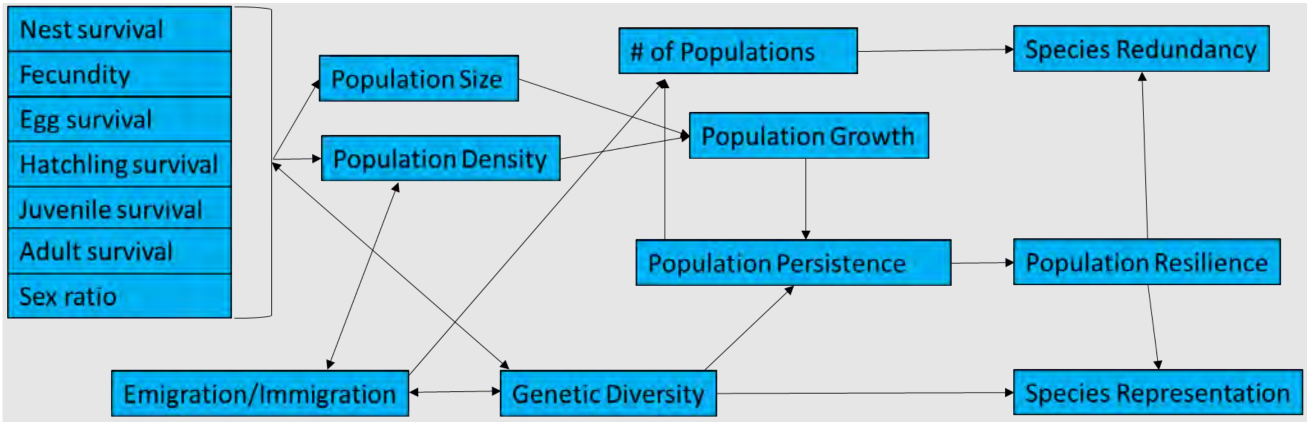

Figure 4. 6-Influence diagram depicting population factors contributing to viability of gopher tortoise.

Minimum viable population (MVP) size is a benchmark used to identify the smallest population size that will reliably persist through a biologically appropriate time frame. The purpose of establishing MVP parameters is to provide acceptable benchmarks for conservation and recovery efforts and is not to determine absolute minimum thresholds that if not met, will result in certain population demise, or that meeting targets implies viability. To reach scientific consensus on appropriate MVP parameters for the gopher tortoise, the GTC convened the Minimum Viable Population and Minimum Reserve Size Working Group in July 2013 and October 2014 (GTC 2013, 2014; entire); this working group determined an MVP includes at least 250 adult gopher tortoises. This abundance criterion was informed by population viability analyses which found populations of 250 or more individuals were most likely to withstand stochastic events and persist for 100 years (Miller et al. 2001, p. 28) or 200 years under favorable habitat conditions (Tuberville et al. 2009, p. 19). The working group also determined an MVP contains a density of no less than 0.4 gopher tortoises per hectare (approximately 0.16 gopher tortoises per acre); this criterion was based on Guyer et al. (2012, pp. 130-131) which found populations with densities below this threshold exhibited altered movement patterns that could negatively impact gene flow and viability. The working group also concluded that at least 247 acres (100 hectares) of high quality, managed habitat was required for a population to persist (McCoy and Mushinsky 2007, p. 1404; GTC 2013, pp. 2-3). Additional MVP criteria included an approximate 1:1 ratio of males to females, evidence of recruitment into the population, variability in size and age classes, and no major constraints to gopher tortoise movement (GTC 2013, pp. 2-3).

The MVP working group recognized populations of less than 250 adults as support populations with two categories, primary and secondary support. Primary support populations contain between 50-249 adult individuals, and secondary support populations are those with less than 50 adults (GTC 2014, p. 4). These support populations may persist for a long period of time under high-quality habitat conditions (Folt et al. 2021, p. 13), but are likely more vulnerable to stochastic events than MVPs (Miller et al. 2001, p. 28; GTC 2014, p. 4). Thus, viability can be evaluated as a measure of the likelihood that a species will sustain populations over time, rather than as a specific state of viable or not viable.

Because we lack consistent and reliable estimates of density, sex ratios, recruitment, dispersal, habitat, and management effort for all sites with available spatial occurrence data, we qualitatively assessed resiliency at the population level by evaluating the estimated current abundance of local populations and creating ordinal resiliency categories. Population estimates for this assessment include data on State, Federal, local government, and private lands, collected in various ways, ranging from standardized survey techniques including belt transect surveys and LTDS (Spatially Explicit), to private lands population information provided at the county level (County Level), to long-term recipient sites (Spatially Explicit). Data were provided by a variety of sources and contain disparate levels of data resolution; thus, we could not reliably determine abundance, density, or other metrics used to identify MVPs (see above) for all populations. All population data provided are integral to evaluating the current condition of the gopher tortoise. Therefore, we used a burrow conversion factor for properties that provided burrow counts and locations but did not have a corresponding abundance estimate from a LTDS survey. Although there is no single burrow conversion factor that would be appropriate for all population across the range of the species, we used a conventional burrow conversion factor of 0.4 individuals/burrow (Guyer et al. 2012, pp. 130-131) to calculate an estimated current population size based on the literature and expert input.

We used estimated abundance of adult gopher tortoises as a metric for categorical levels of resiliency: high (greater than or equal to 250), moderate (51-249), and low (less than 50). These resiliency levels align with the MVP working group’s categories for minimum viable (high resiliency), primary support (moderate resiliency), and secondary support (low resiliency) populations (GTC 2014, p. 4). Landscape populations likely provide a higher level of resiliency than local populations, assuming gopher tortoises are able to disperse at a landscape scale, although we do not quantify this explicitly in our resilience assessment. Resiliency categories for local populations are defined as follows:

- High-local population highly likely to persist through a biologically appropriate time frame.
- Moderate-local population likely to persist for a long period of time under high-quality habitat conditions, although more vulnerable to stochastic disturbances compared to highly resilient populations.
- Low-local population may persist for a long period of time under high quality habitat conditions and high levels of management, but highly vulnerable to stochastic disturbances.

Population Factors: Results

Table 4.1 and Figure 4.7 summarize the results of the resiliency analysis for spatially delineated populations of gopher tortoises. It is important to note that abundance estimates are only from spatially delineated populations (i.e., do not contain county level data or gopher tortoises that are present, but not reported), and that these estimates likely significantly underestimate the true number of gopher tortoises present across the species' range. Based on available data, there are an estimated 149,152 gopher tortoises from 656 spatially delineated local populations across the range of the species, with local abundance categories as follow: 360 low, 169 moderate, and 127 high. Most gopher tortoises are found in the eastern portion of the range with Unit 5 supporting 47 percent of the estimated rangewide population total, and Units 3 and 4 supporting 26 percent and 19 percent, respectively. Units 1 and 2 support much smaller numbers of gopher tortoises, with 2 percent and 6 percent of the estimated rangewide population total, respectively, likely driven by differences in soils, as discussed earlier in Chapter 2: Species Biology.

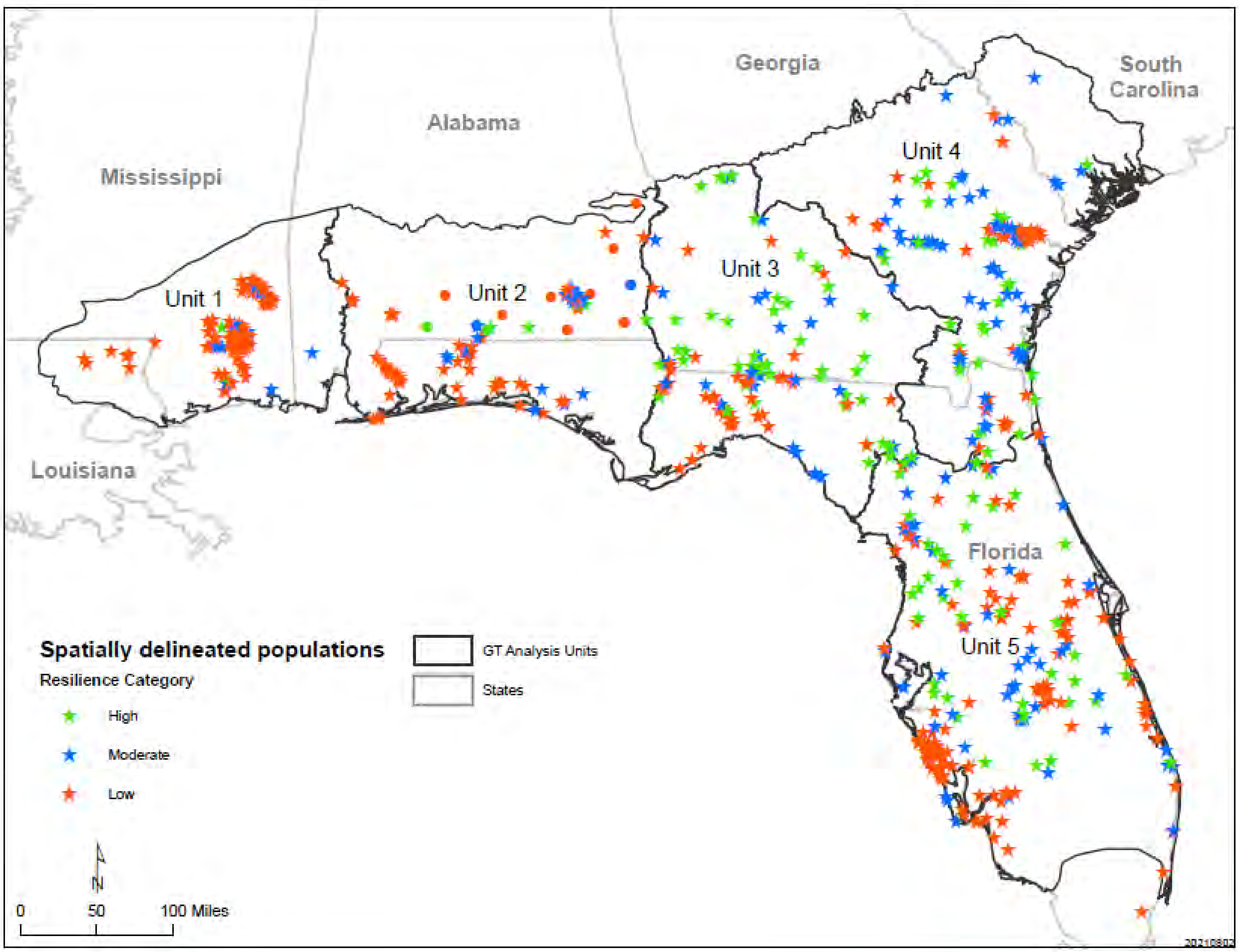

Figure 4.7-Location and associated resiliency (red = low; blue = moderate; green = high) for spatially delineated local populations of gopher tortoise.

Table 4.1-Site specific data population factors and current resiliency for spatially delineated local populations of gopher tortoise.

Analysis unit	# of burrows	# of landscape pops	# of local pops	Abundance	Current Resiliency
1	8,815	13	106	3,100	Low (94)
					Moderate (10)

					High (2)
2	5,809	30	106	8,642	Low (71) Moderate (27) High (8)
3	17,867	55	109	38,947	Low (42) Moderate (24) High (43)
4	20,216	46	124	28,408	Low (35) Moderate (58) High (31)
5	24,783	109	211	70,055	Low (118) Moderate (50) High (43)
Rangewide	**77,490**	**253**	**656**	**149,152**	**Low (360)** **Moderate (169)** **High (127)**

Table 4.2 summarizes the county location and results of the population factors we were able to obtain from the landowner questionnaire. We received responses from 167 properties across all analysis units, which represents approximately 25 percent of all data available for this report. Ninety-one (91) of these properties reported juveniles present, meaning approximately 55 percent of properties show evidence of reproduction. Although respondents only provided categories of abundance on the questionnaire, as opposed to precise abundance estimates, we provide estimates of low, moderate, and high condition classes for abundance as with the spatially delineated populations as follows: 63 low, 11 moderate, and 11 high. As with the spatially delineated populations, most of the properties classified as moderate or high abundance are in the eastern portion of the range, with the western portion supporting many populations

with low abundance. The results reported here for the landowner questionnaire do not include over 10,000 observations recorded between 2013 and 2019 (91 counties rangewide) by an informal NCASI survey (NCASI 2020, p. 9-11; Miller, pers. comm., 2021). Thus, results are assuredly an underestimate of gopher tortoise occurrences on private forests as they are derived from mostly informal surveys, do not cover all possible locations of gopher tortoises across the properties, and only includes a subset of acres under private forest management within gopher tortoise range.

Table 4. 2-County level data population factors (presence of juveniles, estimated number of burrows, and estimated abundance) derived from landowner questionnaire, organized by analysis unit.

Analysis unit	# of properties	Juveniles present?	Estimated # of burrows	Estimated abundance
1	17	Yes (7) No (10) Unknown (0)	Unknown (4)	Unknown (4)
			1-50 (13)	1-50 (13)
			50-250 (0)	50-250 (0)
			>250 (0)	>250 (0)
2	32	Yes (17) No (6) Unknown (9)	Unknown (27)	Unknown (29)
			1-50 (5)	1-50 (3)
			50-250 (0)	50-250 (0)
			>250 (0)	>250 (0)
3	48	Yes (21) No (8) Unknown (19)	Unknown (31)	Unknown (31)
			1-50 (12)	1-50 (12)
			50-250 (1)	50-250 (2)
			>250 (4)	>250 (3)
4	22	Yes (11) No (8) Unknown (3)	Unknown (2)	Unknown- (6)
			1-50 (9)	1-50 (10)
			50-250 (8)	50-250 (5)
			>250 (3)	>250 (1)
5	48	Yes (35) No (6) Unknown (7)	Unknown (12)	Unknown (12)
			1-50 (18)	1-50 (25)
			50-250 (11)	50-250 (4)
			>250 (7)	>250 (7)

4.4.2. Habitat and management factors

The Minimum Viable Population and Minimum Reserve Size Working Group discussed the influence of habitat size, quality, and management on the viability of gopher tortoise populations and concluded that the minimum reserve size to support a viable gopher tortoise population was 247 acres (100 ha), if that site is of superior quality and will be maintained at that quality (GTC 2013, p. 2). Persistence is believed to increase with habitat quality, and previous efforts involving expert workshops and habitat suitability modeling has shown that habitat suitability for gopher tortoises increases with the amount of well-drained soil, compatible land cover (e.g., evergreen forests, shrub), and fire frequency (Figure 4.8 and 4.9; Crawford et al. 2020, pp. 134-136).

Gopher tortoises may be found in a variety of vegetative community types, including upland pine systems such as sandhill and mesic flatwoods, scrub, xeric hammock, dry prairie, coastal grasslands and dunes, mixed hardwood-pine communities, and ruderal communities, with the primary determinants of gopher tortoise habitat suitability being well-drained sandy soils and the presence of an open savanna-like vegetation community. Given the gopher tortoise's affinity for open savanna conditions, maintenance of an open canopy and mid-story is the primary focus of management. Historically, frequent surface fires on the order of every 1-5 years were the primary driver that maintains savanna-like vegetation communities on most sites occupied by the gopher tortoise, although some extremely xeric sites may be maintained largely by moisture limitation. Today, this fire regime is best maintained through prescribed fire, as fragmentation of the landscape by roads and other fire barriers, and social/societal constraints (i.e., suppression efforts) prevents the spread of fire from natural lightning ignitions. Loss and alteration of gopher tortoise habitat from fire exclusion or fire suppression has a significant effect on survival of the gopher tortoise (Boglioli et al. 2000, p. 704), and increased urbanization has limited its use in many locations (Ashton and Ashton 2008, p. 78). Mechanical and chemical treatments to reduce midstory vegetation can also be effective techniques, particularly in areas with constraints to conducting prescribed fire (e.g., at wildlife urban interfaces where smoke management and liability can severely limit the ability to conduct prescribed fire).

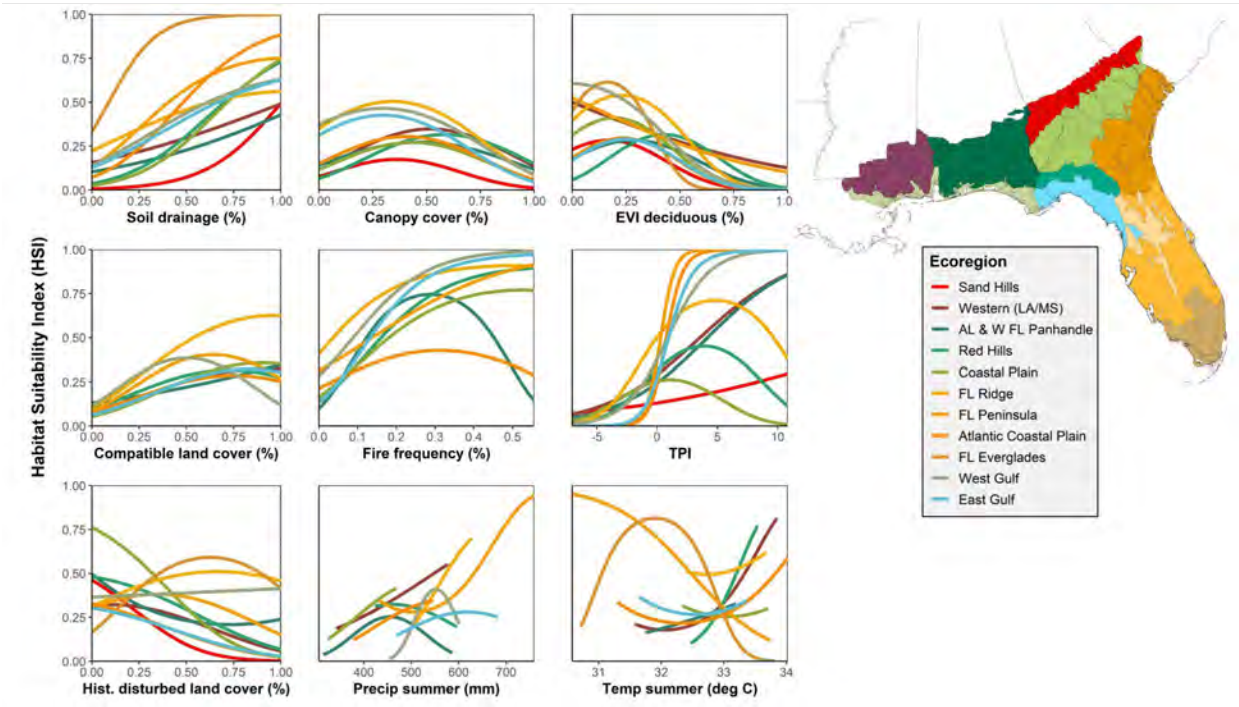

Figure 4. 8-*From Crawford et al. 2020:* Relationships from the best-fitting model between habitat suitability and environmental predictors, by ecoregion group (top right), for the gopher tortoise. Although relationships varied by ecoregion, gopher tortoise habitat suitability tended to increase with the amount of well-drained soil, compatible land cover (e.g., evergreen forests, scrub/shrub), and fire frequency.

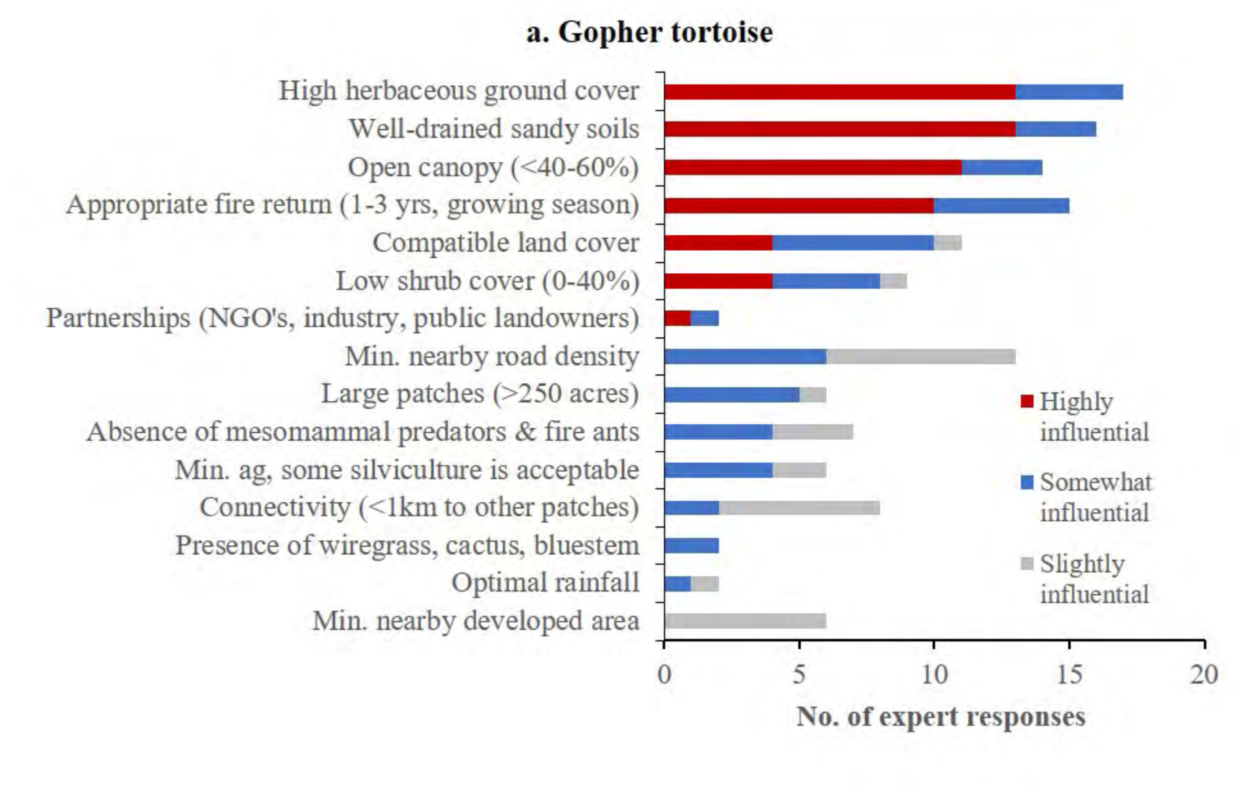

Figure 4. 9-*From Crawford et al. 2020, p. 68:* Influential environmental, landscape, and biophysical attributes for gopher tortoise habitat and presence at a site, as identified in questionnaires of 16 experts. Attributes are generally ordered from highest (top rows) to lowest (bottom rows) influence on habitat suitability and species presence. Definitions for attribute rankings: Highly – attributes must occur at a site for the species to be present; Somewhat – attributes occurring on the landscape greatly increase the likelihood of species being present, but species may occasionally use landscapes without these attributes; Slightly – attributes occurring on the landscape slightly or variably increase the likelihood of species being present, but species may use landscapes without these attributes.

Habitat Factors: Results

Because habitat data were provided by a variety of sources and contain disparate levels of data resolution, we could not reliably determine estimates of habitat within all populations across the range of the gopher tortoise. Thus, we summarize the spatially delineated populations and county level information separately, and estimates of habitat were not used to assess resiliency of gopher tortoise populations; only abundance was used to assess resiliency Estimates of occupied habitat are derived from the Habitat Suitability Index (HSI) model described below (Figure 4.10), and include all suitable habitat found within the 1,968 feet (600 m) buffers used to delineate local populations (Table 4.3). We also calculate estimates of potential habitat by calculating the amount of suitable habitat as predicted by the HSI model, which is located outside of the 1,968 feet (600 m) buffers used to delineate local populations (Table 4.3). Finally, we summarize the amount of low, medium, and high quality habitat as provided by landowners from the questionnaire described earlier (Table 4.4).

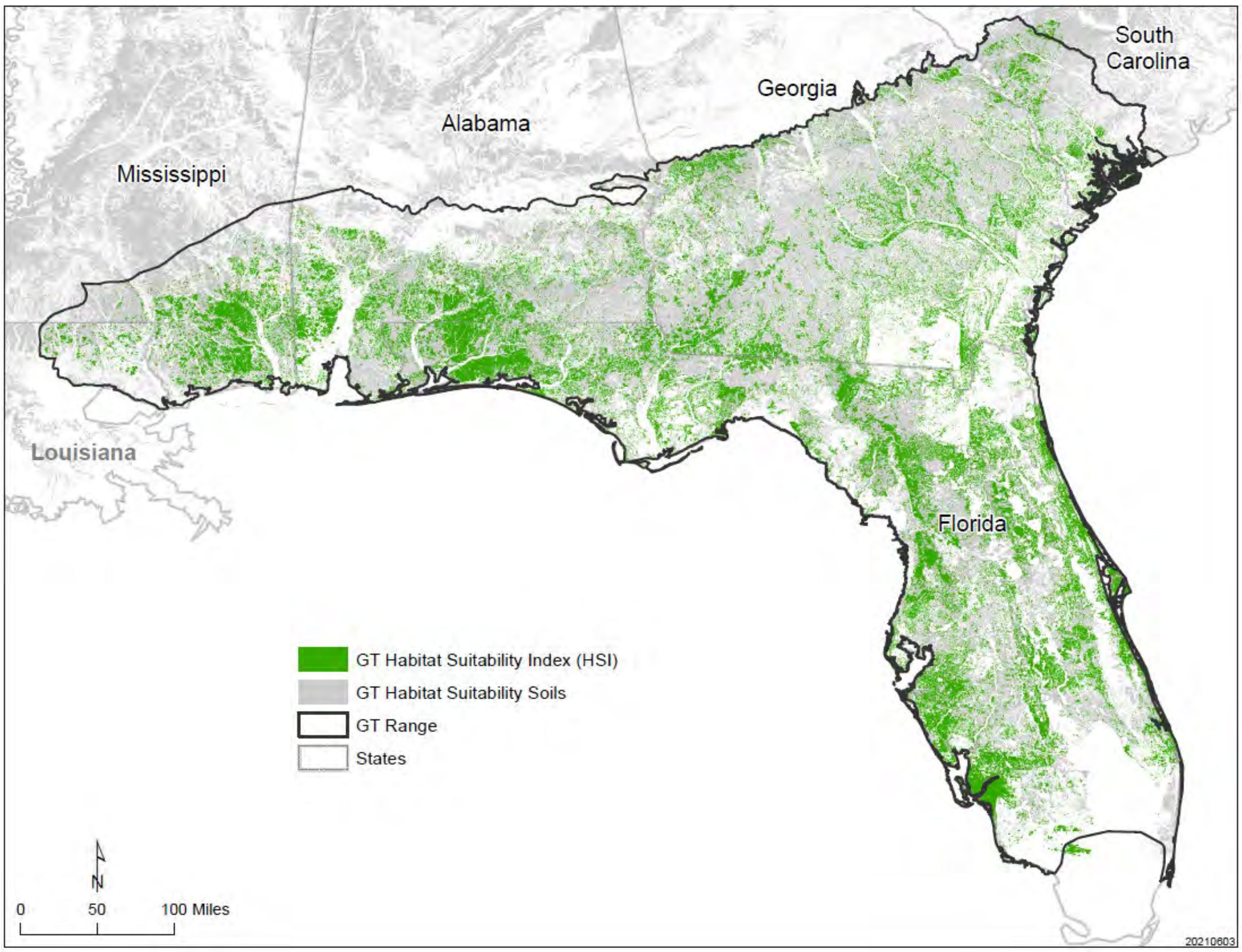

Figure 4. 10-Location of suitable habitat (green) from the HSI model (Crawford et al. 2020) and suitable soils (grey).

Table 4. 3-Estimates of known occupied habitat (habitat included within local population boundaries) and potential habitat (habitat located outside of local population boundaries), by analysis unit, as predicted by the HSI model. Total habitat is the sum of occupied and potential habitat.

Analysis Unit	Occupied Habitat	Potential Habitat	Total Habitat
1	103,582 acres	1,937,559 acres	2,041,141 acres
2	68,430 acres	3,416,877 acres	3,485,307 acres
3	220,127 acres	2,932,265 acres	3,152,392 acres
4	149,146 acres	2,768,120 acres	2,917,266 acres
5	303,627 acres	5,284,111 acres	5,587,738 acres
Rangewide Total	**844,912 acres**	**16,338,932 acres**	**17,183,844 acres**

Table 4. 4-Estimates of low, moderate, and high suitability habitat based on responses to landowner survey. Total habitat is the sum of low, moderate, and high suitability habitat.

Analysis Unit	Low Suitability Habitat	Moderate Suitability Habitat	High Suitability Habitat	Total Habitat
1	4,599 acres	10,943 acres	9,153 acres	24,695 acres
2	18,246 acres	84,004 acres	18,251 acres	120,501 acres
3	18,195 acres	21,356 acres	54,615 acres	94,167 acres
4	30,118 acres	38,131 acres	28,813 acres	97,063 acres
5	37,807 acres	33,208 acres	39,898 acres	110,914 acres
Rangewide	**108,965 acres**	**187,642 acres**	**150,730 acres**	**447,340 acres**

Management Factors: results

To assess gopher tortoise management, we used several data sets available from multiple sources and at multiple spatial scales and these data may include some overlap. First, we used the Tall Timbers Southeast fire history dataset, derived from the U.S. Geological Survey Burned Area (v2) Products (Hawbaker et al. 2020, entire) representing years 1994-2019, which allowed for estimates of acres burned (prescribed fire and wildfire) within gopher tortoise populations across multiple years. The advantages of these data are that they cover the entire range of the species and can be summarized by habitat acreage estimates for the gopher tortoise; however, we are unable to estimate other midstory management techniques such as chemical and mechanical treatments with these data. Acres burned across all units has generally increased over time, with significantly more burning occurring in Unit 5 (Table 4.5). It should be noted that we did not use any management metrics in our resiliency assessment; only abundance was used to assess population resiliency.

Table 4. 5-Acres burned (prescribed fire and wildfire), rangewide, and by analysis unit, for the years 1994-2019. Data obtained from the Tall Timbers Southeast fire history dataset.

Year	**Unit 1 fire acres**	**Unit 2 fire acres**	**Unit 3 fire acres**	**Unit 4 fire acres**	**Unit 5 fire acres**	**Total acres**
1994	17064	29580	22325	28969	41777	139716
1995	17351	23740	32089	29225	56752	159157
1996	14663	33233	68453	67842	103565	287756
1997	23548	28191	39641	47278	65203	203861
1998	22581	35007	60527	72085	99443	289644
1999	42810	76413	107046	94854	174827	495949
2000	70032	88929	134093	92035	163276	548366
2001	51095	68601	123032	102376	174164	519268
2002	45423	60584	71056	71704	104606	353374
2003	28963	43311	44151	45206	80722	242353
2004	40680	64721	85354	77782	145806	414342
2005	29955	59132	52668	61542	130292	333590
2006	89316	111019	102895	90224	249825	643279
2007	73774	90137	152646	161408	192678	670643
2008	53711	73615	104675	104038	140159	476199
2009	50212	79730	108016	93087	167332	498377
2010	38619	67389	85344	68852	129831	390035
2011	54290	101537	188435	292767	210675	847704
2012	16508	54169	68760	135385	117246	392067
2013	50671	106243	164417	106302	135898	563532
2014	69394	113388	162379	183892	218601	747655
2015	68604	105771	112364	102538	177518	566795
2016	89220	156954	193986	112830	188606	741597
2017	88513	197421	340685	331213	415134	1372965
2018	70181	149963	346703	213304	516060	1296210
2019	35795	106202	194682	161009	582368	1080058

We also used summary data for prescribed fire and other midstory maintenance activities available from America's Longleaf Restoration Initiative (ALRI) FY2019 annual report. An advantage of these data is the inclusion of management practices beyond prescribed fire, although the spatial scale of the data is the historical range of longleaf pine, thus estimates of management, include areas outside of gopher tortoise habitat. Also, gopher tortoises use a variety of pine communities, so by limiting reported management actions to longleaf stands, data reported by ALRI excludes some areas within the species range where gopher tortoises are likely present. Florida reported by far the most acres of habitat managed for longleaf by fire and other methods, with nearly 600,000 acres (242,811 ha) treated between October 2018-September 2019. Much of the management implemented by partners under the ALRI umbrella is likely to benefit gopher tortoise.

Table 4. 6-Midstory management, including acres burned and acres managed by other means (e.g., chemical and mechanical) between October 2018-Septemeber 2019, as reported by ALRI (2019).

State	Acres burned	Acres treated (other)	Total acres treated
Alabama	141,054	7,788	148,842
Florida	529,086	58,330	587,416
Georgia	133,019	503	133,522
Mississippi	52,941	3,505	56,446
Louisiana	53,716	9,135	62,851
South Carolina	64,276	5,170	69,446

Next, we summarize management practices as detailed in the gopher tortoise CCA 2021 annual report, which covers management actions implemented during FY2021 (Table 4.7). The goal of the CCA is to organize a cooperative approach to gopher tortoise management and conservation in the eastern portion of its range, and the standardized report generated by partners helps to support this approach and encourages uniform actions and reporting, integrating monitoring and research efforts, and support partner formation. Advantages of the CCA management data are they are specific to sites known to support gopher tortoises and include both prescribed fire and other beneficial practices such as chemical and mechanical treatments, and invasive species control. Unfortunately, the CCA data are limited to the eastern portion of the range, thus does not include information for the western portion.

Table 4. 7-Midstory management, including acres burned and acres managed by other means (e.g., chemical and mechanical), by agency, for FY2021, as reported by the gopher tortoise CCA report (2021). Data cover only the candidate portion of the gopher tortoise range. *Other includes Poarch Band of Creek Indians, Longleaf Alliance, Jones Center, Alabama Forestry Commission, National Park Service, and Georgia Power.

Agency	Acres burned	Acres treated (other)	Total acres restored or maintained
DoD	75,505	13,636	89,141
Forest Service	48,548	3,606	52,154
USFWS	20,362	1,639	22,001
Alabama	6,030	7,229	13,259
Florida	111,891	146,230	258,121
Georgia	33,209	2,530	35,739
South Carolina	431	100	531
Other*	98,513	3,233	101,746

Finally, Table 4.8 summarizes the results provided by respondents to the landowner questionnaire, including total acres burned on the property using prescribed fire, estimated burn frequency in years, and whether other practices beneficial to gopher tortoises are implemented on the property. A total of 228,454 acres (92,452 ha) were burned by private landowners that responded to the questionnaire, with most of this prescribed burning occurring in analysis units 3 and 5. Although there is some variance by analysis unit, many property owners are implementing prescribed fire on a 1-3 year cycle, with few landowners burning on a cycle of greater than 5 years. Finally, many landowners are implementing additional beneficial practices, including chemical and mechanical midstory treatments, invasive species control, and flagging of burrows prior to thinning of forest stands.

Table 4. 8-Results provided by respondents to the landowner questionnaire, by analysis unit, including acres burned, estimated burn frequency in years, and whether other practices beneficial to gopher tortoises are implemented on the property.

Analysis Unit	Acres burned	Burn frequency in years (# of respondents)	Other beneficial practices Y/N (# of respondents)
1	11,605	1-3 (14)	Y- (17)
		3-5 (0)	N- (0)
		>5 (1)	
2	33,562	1-3 (9)	Y- (23)
		3-5 (5)	N- (9)
		>5 (1)	
3	66,299	1-3 (14)	Y- (21)
		3-5 (7)	N- (27)
		>5 (0)	
4	12,361	1-3 (8)	Y- (17)
		3-5 (4)	N- (5)
		>5 (3)	
5	104,627	1-3 (7)	Y- (40)
		3-5 (13)	N- (8)
		>5 (11)	

4.5. Current resiliency results

Below, we summarize the results of the current condition analysis for both spatially delineated and county level local populations, by analysis unit (Table 4.9 and Figure 4.11). Current resiliency is derived from the estimated abundance at each local population (except for county level data which did not have an estimated abundance; these were labeled as unknown); although our resiliency assessment was limited to abundance within each population, habitat and management factors are also summarized for each analysis unit.

Table 4. 9-Number of local populations and current resiliency of gopher tortoise, by analysis unit; includes spatially explicit and county level data.

Analysis unit	# of local populations	Current Resiliency
1	123	Low (107)
		Moderate (10)
		High (2)
		Unknown (4)
2	138	Low (74)
		Moderate (27)
		High (8)
		Unknown (29)
3	157	Low (54)
		Moderate (26)
		High (46)
		Unknown (31)
4	146	Low (45)
		Moderate (63)
		High (32)
		Unknown (6)
5	259	Low (143)
		Moderate (54)
		High (50)
		Unknown (12)
Rangewide	**823**	**Low (423)**
		Moderate (180)
		High (138)
		Unknown (82)

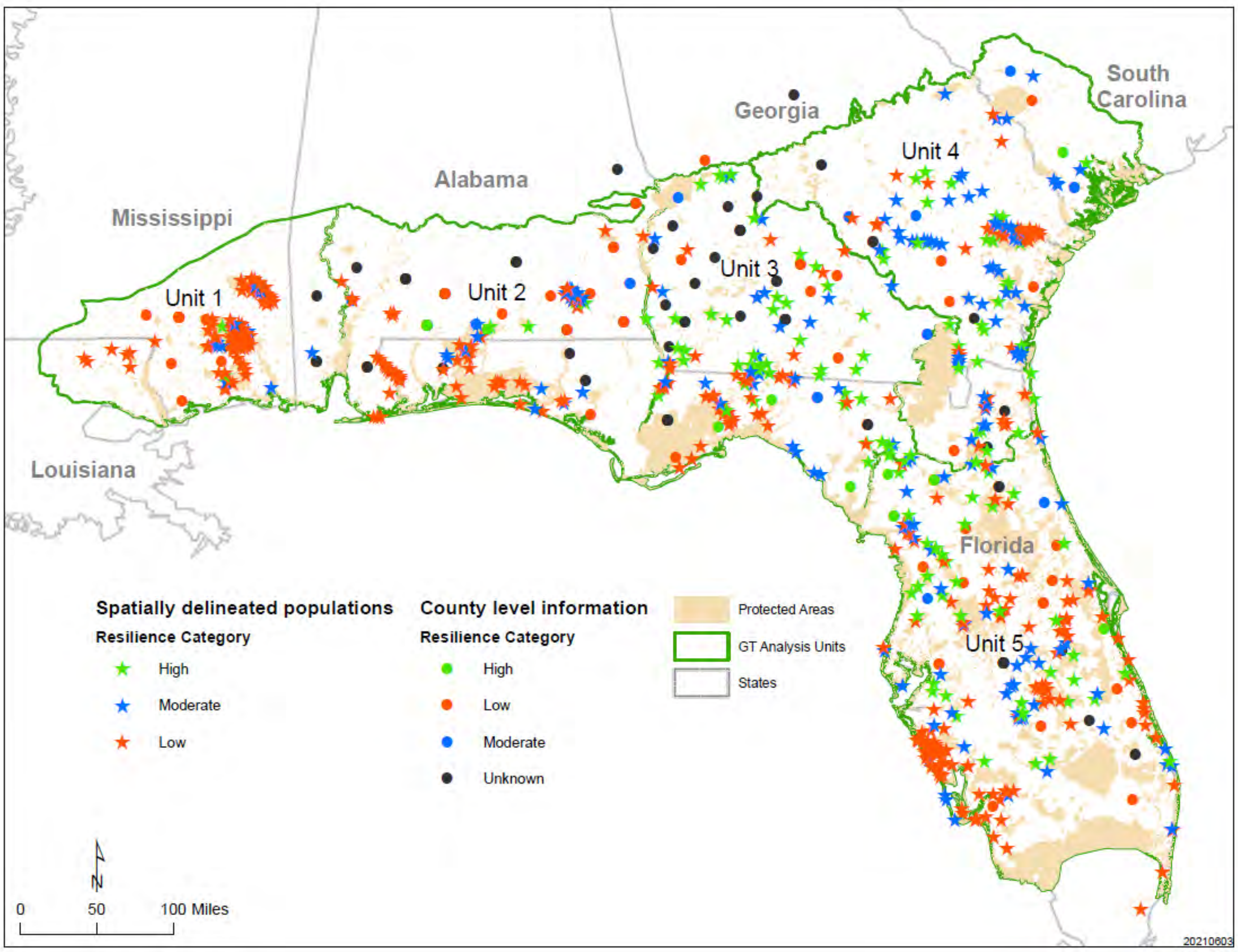

Figure 4. 11-Location of protected areas and local gopher tortoise populations with associated current resiliency, by analysis unit; includes spatially explicit and county level data.

<u>Unit 1</u>

Based on available data, analysis unit 1 is composed of many small, disconnected populations, and very few larger populations (123 local populations; 13 landscape populations), spread across private and public land. Based on current abundance, there are 107 low, 10 moderate, and 2 high resiliency populations within this unit; 4 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.12). Camp Shelby, a DoD property, is the stronghold of the unit with a local population having an estimated 1,003 individual gopher tortoises. Seventeen properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 7 properties reporting signs of reproduction.

Although over 103,000 acres (41,682 ha) of habitat are currently known to be occupied by gopher tortoises, there is nearly 2 million acres (809,371 ha) of estimated habitat where gopher tortoise occupancy is unknown and where future surveys may reveal more gopher tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that over 35,795 acres (14,485 ha) were burned within this unit in 2019, over a 2 times increase over time since 1994. Over 90 percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with all respondents reporting implementing additional beneficial practices for gopher tortoises.

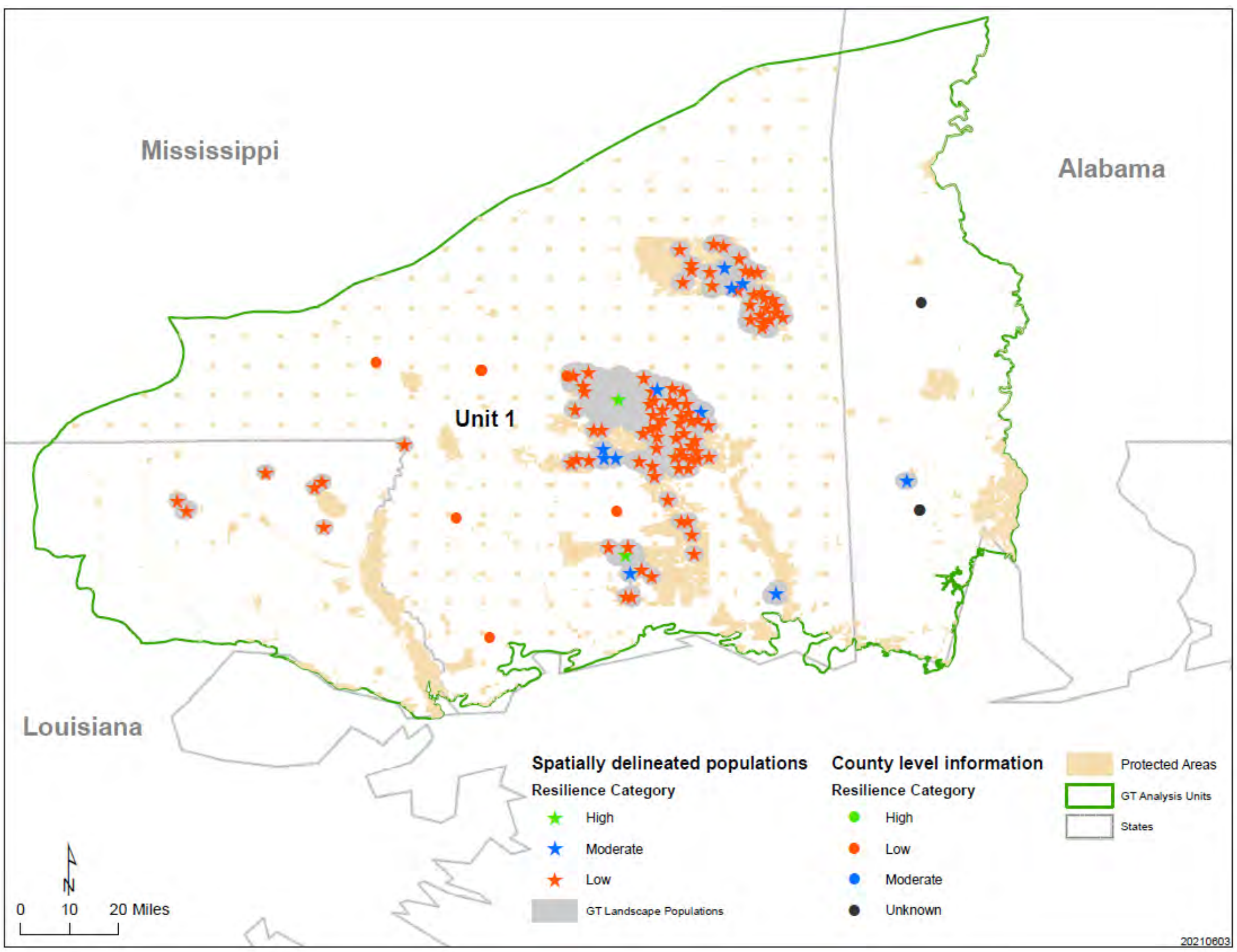

Figure 4. 12-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 1.

Unit 2

Based on available data, analysis unit 2 has 138 local populations and 30 landscape populations. Based on current abundance estimates, this unit is composed of 74 low, 27 moderate, and 8 high resiliency local populations; 29 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.13). The 8 highly resilient populations are found on Fort Rucker, Conecuh NF, Apalachee WMA, Perdido WMA, Geneva State Forest, and an unnamed private property. Thirty-two properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 17 properties reporting signs of reproduction.

Although over 68,000 acres (27,518 ha) of habitat are currently known to be occupied by gopher tortoises, there is nearly 3.4 million acres (1.37 million ha) of estimated habitat where gopher tortoise occupancy is unknown and where future surveys may reveal more tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that approximately 106,000 acres (42,896 ha) were burned in 2019, just over a 3 times increase since 1994. Sixty percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with 72 percent of respondents reporting implementing additional beneficial practices for gopher tortoises.

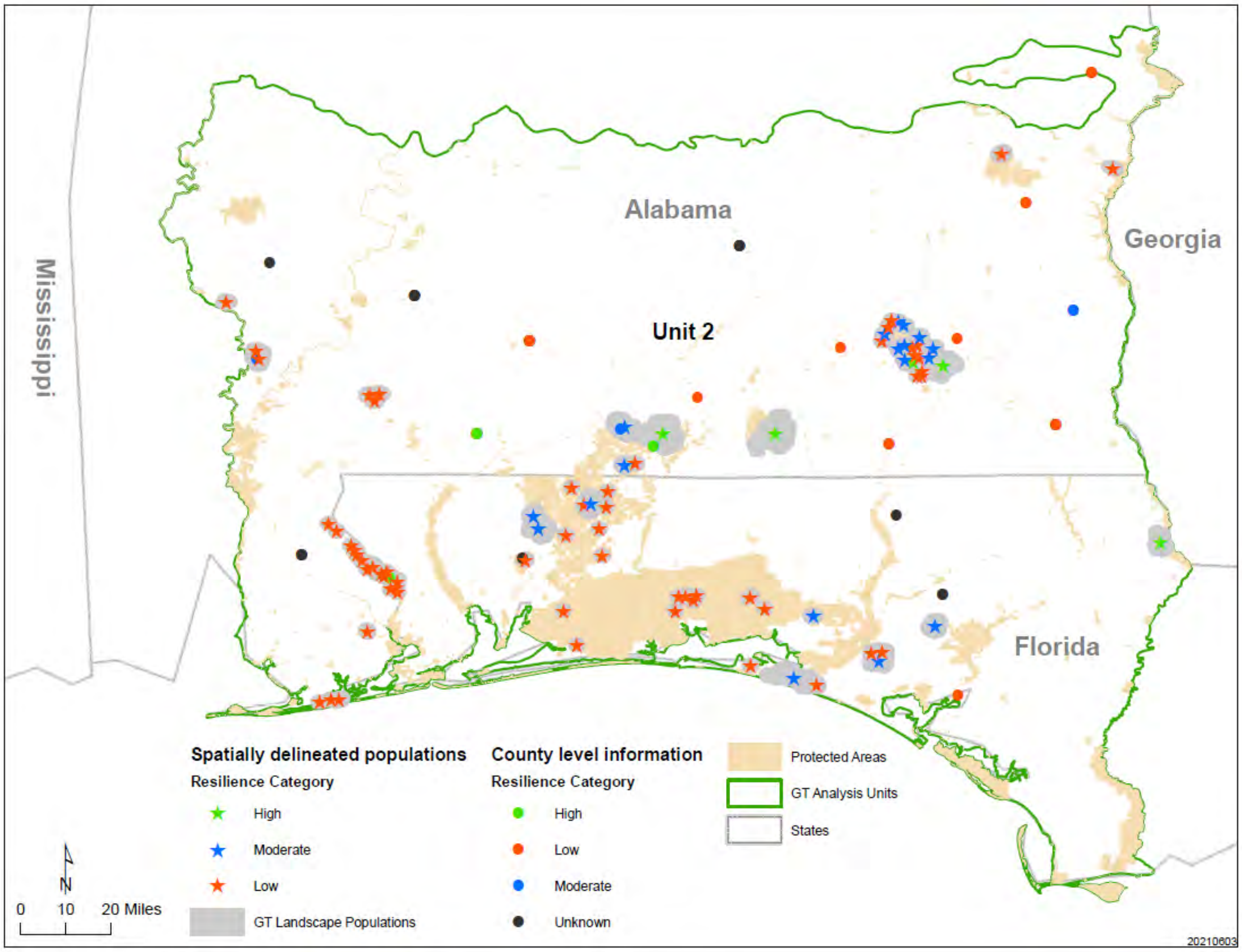

Figure 4. 13-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 2.

Unit 3

Based on available data, analysis unit 3 has 157 local populations and 55 landscape populations. Based on current abundance estimates, analysis unit 3 is composed of 54 low, 26 moderate, and 46 high resiliency populations; 31 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.14). Of the 46 highly resilient populations, 7 populations have estimates exceeding 1,000 individuals, including Twin Rivers State Forest, Chattahoochee Fall Line WMA, River Bend, Alapaha River WMA, Apalachicola NF, and the Jones Center at Ichauway. Forty-eight properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 21 properties reporting signs of reproduction.

Although over 220,000 acres (89,030 ha) of habitat are currently known to be occupied by gopher tortoises, there is over 2.9 million acres (1.17 million ha) of estimated habitat where gopher tortoise occupancy is unknown, and where future surveys may reveal more tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that over 194,000 acres (78,509 ha) were burned in 2019, almost a 10 times increase since 1994. Sixty-seven percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with 44 percent of respondents reporting implementing additional beneficial practices for gopher tortoises.

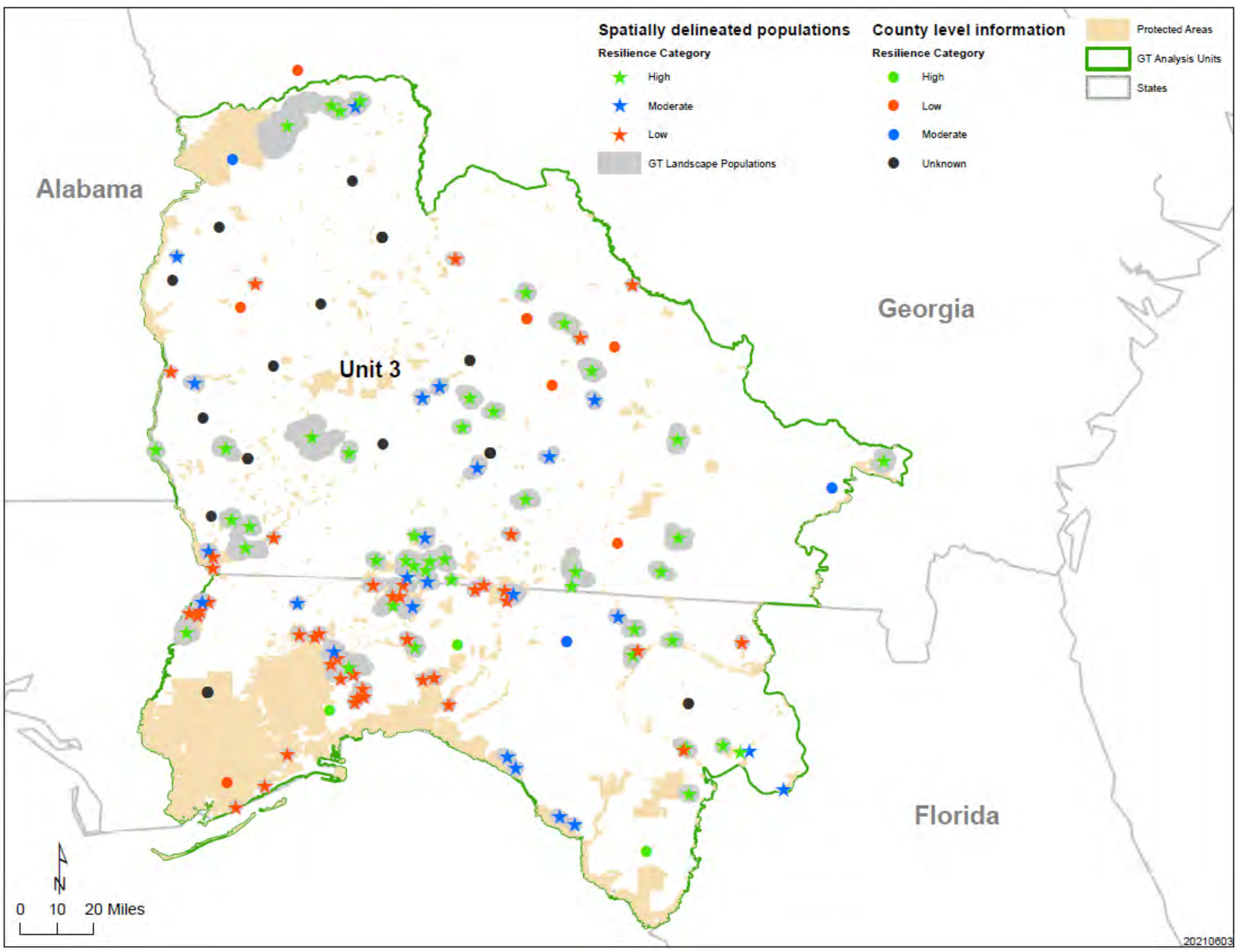

Figure 4. 14-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 3.

Unit 4

Based on available data, analysis unit 4 has 146 local populations and 46 landscape populations. Based on current abundance estimates, analysis unit 4 is composed of 45 low, 63 moderate, and 32 high resiliency populations; 6 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.15). Of the 32 highly resilient populations, 5 populations have estimates exceeding 1,000 individuals, including Ohoopee Dunes WMA, Ralph E. Simmons State Forest, Jennings State Forest, and Fort Stewart. Twenty-two properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 11 properties reporting signs of reproduction.

Although over 149,000 acres (60,298 ha) of habitat are currently known to be occupied by gopher tortoises, there is over 2.7 million acres (1.09 million ha) of estimated habitat that is currently not known to be occupied where future surveys may reveal more gopher tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that over 161,000 acres (65,154 ha) were burned in 2019, over a 7 times increase since 1994. Fifty-three percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with 77 percent of respondents reporting implementing additional beneficial practices for gopher tortoises.

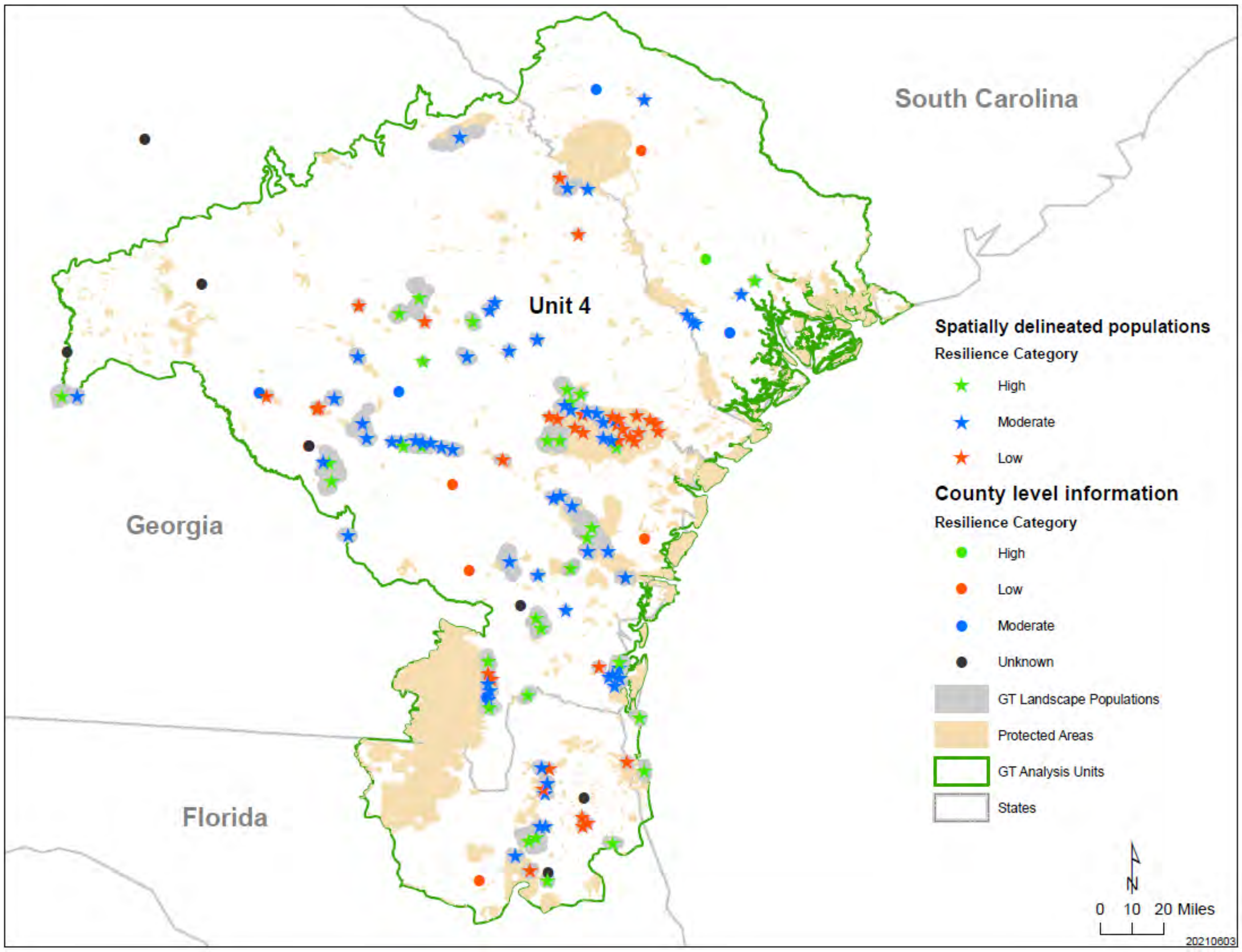

Figure 4. 15-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 4.

Unit 5

Based on available data, analysis unit 5 has 259 local populations and 109 landscape populations. Based on current abundance estimates, analysis unit 5 is composed of 143 low, 54 moderate, and 50 high resiliency populations; 12 populations have an unknown resiliency due to no population estimates being available for these properties (Figure 4.16). Of the 47 highly resilient populations, 12 populations have estimates exceeding 1,000 individuals, including Camp Blanding and Goldhead Branch State Park; Ocala NF; Chassahowitzka WMA; Ichetucknee Springs State Park; Bell Ridge Wildlife and Environmental Area; Etoniah Creek State Forest; Halpata Tastanaki and Cross Florida Greenway; Lake Louisa State Park; Kissimmee Prairie Preserve State Park; Green Swamp West Unit WMA; Withlacoochee State Forest's Citrus Tract;

and Perry Oldenburg Wildlife and Environmental Area and Withlachoochee State Forest's Croom Tract. Forty-eight properties on private land in the unit support gopher tortoise populations based on responses to the landowner survey, with 35 properties reporting signs of reproduction.

Although over 300,000 acres (121,405 ha) of habitat are currently known to be occupied by gopher tortoises, there is nearly 5.3 million acres (2.14 million ha) of estimated habitat where gopher tortoise occupancy is unknown and where future surveys may reveal more gopher tortoises to be present on the landscape. The most current estimates for prescribed fire implementation show that over 582,368 acres (235,675 ha) were burned in 2019, a nearly 14 times increase over time since 1994. Twenty-three percent of landowners who responded to the questionnaire, report implementing prescribed fire on a 1-3 year rotation, with 83 percent of respondents reporting implementing additional beneficial practices for gopher tortoises.

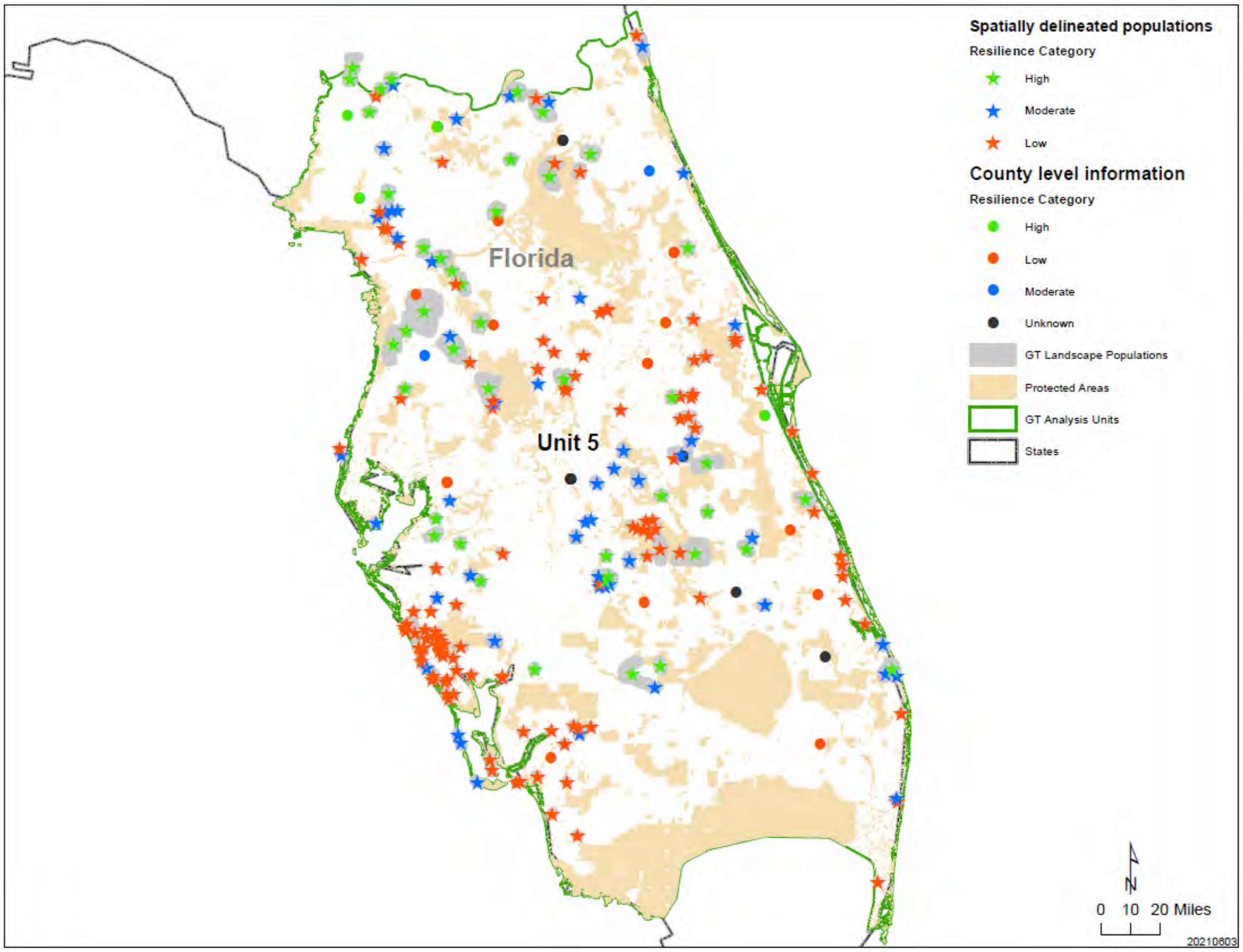

Figure 4. 16-Location and associated resiliency (red = low; blue = moderate; green = high) for local populations of gopher tortoise in analysis unit 5.

4.6. Current representation and redundancy

As described previously in this chapter, representation for this species is assessed primarily based on genetic variation across the range of the species (5 analysis units; Galliard et al. 2017, entire). We evaluated current representation by examining the number of populations and their associated resiliency within the five population analysis units across the species' range (Gaillard et al. 2017, entire). We report redundancy for gopher tortoise as the total number and resiliency of populations and their distribution within and among representative units.

Although gopher tortoises occupy vegetative communities with a variety of pine types, the species was historically associated with longleaf pine systems, which once covered an estimated 92 million acres (37.2 million ha) (Frost 1993, p. 20), but has declined significantly due to forest clearing and conversion for agriculture and development (Landers et al. 1995, p. 39). Due to loss of open pine conditions, gopher tortoise representation and redundancy have likely decreased significantly from historical levels. Currently, all five analysis units are occupied by multiple local populations, although the resiliency of these populations varies across the range (Figure 4.17). Unit 1, in the far western portion of the species range, is comprised of many small, isolated populations (although there is uncertainty in whether currently unknown populations are present on private lands which could ultimately connect these small populations into larger more resilient populations; future surveys and data from private lands would help elucidate this uncertainty), with only 10 percent of the populations having at least moderate resiliency (calculated as 100% x (moderate + high)/(total - unknown)), and only 2 populations with high resiliency, leaving portions of this unit potentially vulnerable to catastrophic events. These results are confounded by the fact that Unit 1 is the western extent of the species range, and spatial gradients in environmental factors often produce predictable patterns in which habitat quality is highest in the centers of species' ranges and becomes more unsuitable as the range edge is approached; thus, apparent lower levels of abundance seen in the western portion of the range might be driven by natural variation in climate and soils found at the edge of the species' range. Also, there are likely many populations that are unaccounted for with the limited data we had available, which if accounted for, would infer a higher degree of redundancy (i.e., more populations and greater spatial distribution).

Similarly, for Unit 2, in the western-central portion of the range, only 32 percent of the populations are of moderate or greater resiliency, but 8 populations are classified as highly resilient, potentially buffering against the potential of catastrophic events. The central (Unit 3) and eastern (Units 4 and 5) have many populations (67 percent of the total number of populations assessed), and the resiliency of many of the populations is of moderate or high condition (Unit 3 = 57 percent; Unit 4 = 68 percent; Unit 5 = 50 percent). In addition to a relatively high number of highly resilient populations within the 3 eastern analysis units, the populations are well distributed across each unit, potentially buffering against the impacts of potentially catastrophic events. The fact that there are more resilient populations in the eastern portion of the range compared to the western portion is not surprising, as the soils are not as suitable in the western portion, an important component of habitat driving habitat quality, and ultimately abundance and density.

From a rangewide perspective, although representation and redundancy have likely decreased significantly relative to the historical distribution of the species, there are still many resilient populations distributed across the range of the species, contributing to future adaptive capacity (representation), and buffering against the potential of future catastrophic events. Because the species is widely distributed across its range, it is highly unlikely any single event would put the species as a whole at risk. However, portions of analysis unit 1 are likely more vulnerable to such catastrophes given that most of the populations present in this unit are of low resiliency.

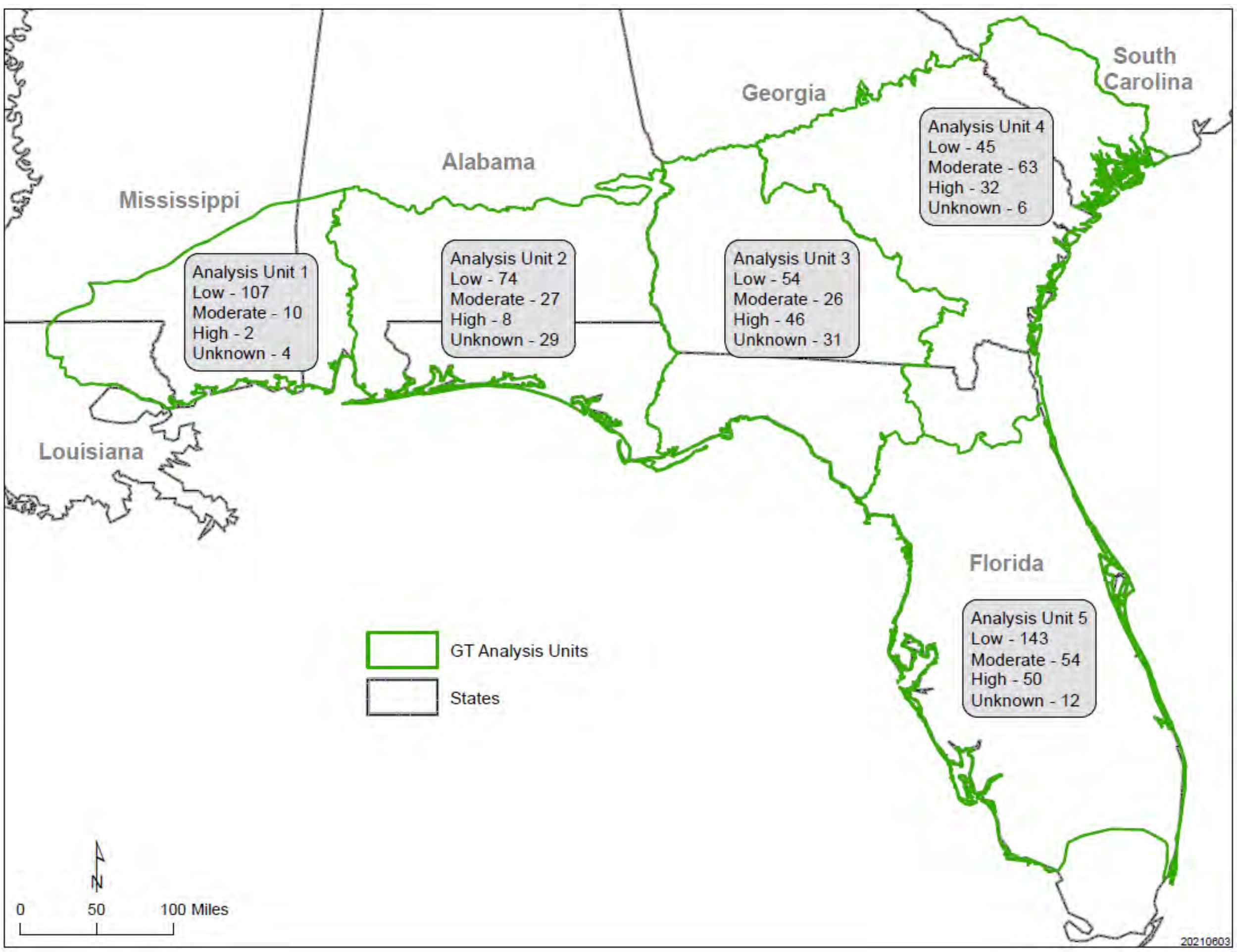

Figure 4. 17-Resiliency of gopher tortoise local populations summarized by analysis unit.

CHAPTER 5 – FUTURE CONDITIONS AND VIABILITY

We have considered what the gopher tortoise needs for viability and the current condition of those needs (Chapters 2 and 4), and we reviewed the influencing factors that are driving the current, and future conditions of the species (Chapter 3). We now consider what the species' future condition might be by projecting populations that occur on protected conservation lands. We apply our future forecasts to the concepts of resiliency, representation, and redundancy to describe the future viability of the gopher tortoise.

To assess viability for the gopher tortoise, we developed an analytical framework that integrates projections from multiple models of future anthropogenic and climatic change to project future trajectories/trends of gopher tortoise populations and identify stressors with the greatest influence on future population persistence. The modeling framework was built to support the future conditions analysis by estimating the change in population growth and persistence probability of populations while accounting for geographic variation in life history. The model links intrinsic factors (demographic vital rates) to four extrinsic anthropogenic factors that are hypothesized to threaten gopher tortoise population persistence (climate warming, sea-level rise, urbanization, and shifts in habitat management). We used published models describing extrinsic factors in the future to project gopher tortoise demographics under six future scenarios varying in threat magnitude and presence. A regression analysis of model outputs was used to identify threats that are predicted to have the greatest impact on population persistence. A detailed model description is included in Appendix B.

5.1 Models and scenarios

5.1.1. Model Structure

A population viability analysis (PVA) framework was used to predict population growth and extinction risk for the gopher tortoise. The PVA is a stage-based population model (i.e., Lefkovitch model) used to project population size and structure forward in time with simulations. For the PVA, local population demography of gopher tortoises was conceptualized in a multi-stage, female-only model, with two discrete life stages: juveniles and adults. During a given time-step, both stages had a probability of individuals surviving and staying within the stage, juveniles had a probability of maturing to become adults, and adults had a probability of reproducing and potentially recruiting individuals into the juvenile stage. Individuals that did not survive during a time-step were assumed to have either died or permanently emigrated from the population. Recruitment into the adult stage by immigration was also modeled. In the following sections of Chapter 5, we describe the methods and results of the future conditions analysis; we note that a detailed description of the model structure can be found in Appendix B.

5.1.2. Demographic parameters

We constructed a baseline population model that approximated demographic conditions experienced by gopher tortoise populations in recent decades across the species' range. However, populations of gopher tortoises experience great variation in abiotic characteristics across the species' range, and variation in abiotic characteristics influences demographic rates among populations. At more southern latitudes, populations experience significantly warmer mean annual temperature, which may afford greater overall opportunity for thermoregulation, energy acquisition, and metabolism when compared to northern populations. As a result, southern populations of gopher tortoises experience faster growth rates, younger ages of sexual maturity (hereafter, maturity age), and increased clutch size (Mushinsky et al. 1994, p. 123; Ashton et al. 2007, entire; Meshaka Jr. et al. 2019, p. 105-106). Because the goal was to predict population growth and extinction risk of populations across the species' range and predictive population models are most useful when demographic parameters are modeled specific to populations of interest (Ralls et al. 2002, entire), we extended the model to accommodate for geographic variation in demographic rates by estimating parameters specific to the geographic location of populations.

Demographic parameters used to model and project baseline population demographics of gopher tortoises are shown in Table 5.1. For parameters thought to vary substantially by abiotic features among sites, linear regression models were fit to estimate relationships between demographic rates and mean annual temperature (hereafter, MAT; degrees C) sourced from the 'WorldClim' database (Hijmans 2020, entire). If parameters were not known to vary geographically, mean values were modeled as invariant among populations. In the following subsections, we describe how parameters describing recruitment, maturity age, survival, immigration, and initial population size, were modeled.

Table 5. 1-Demographic parameters, mean estimates, and distribution shapes used to model and project baseline population demographics of gopher tortoises in conservation lands across the species' range.

Parameter	Distribution shape	Mean (SE)
Probability of breeding	Beta	0.97 (0.01)
Fecundity	Log normal	-3.54 (2.42) + 0.48 (0.12) * MAT
Nest survival	Beta	0.35 (0.10)
Probability of viable eggs	Beta	0.85 (0.05)
Probability of female	Beta	0.50 (0.04)
Hatchling survival	Beta	0.13 (0.03)
Juvenile survival	Beta	0.75 (0.06)
Adult survival	Beta	0.96 (0.03)
Maturity age	Log normal	43.52 (11.31) – 1.41 (0.53) * MAT
Juvenile abundance	Log normal	Varying by population
Adult abundance	Log normal	Varying by population
Immigration rate	Beta	0.01 (0.001)
Percent of winter days for burning	Beta	0.77 (0.05)
Percent of spring days for burning	Beta	0.80 (0.05)
Percent of summer days for burning	Beta	0.65 (0.05)
Change in winter days for burning	Beta	Varying by projection scenario
Change in spring days for burning	Beta	Varying by projection scenario
Change in summer days for burning	Beta	Varying by projection scenario
Burn probability	Beta	0.4 (0.015)
Fire effect on survival	Beta	0.96 – 0.027 (0.003) * YSB

<u>Recruitment</u>

We modeled the proportion of breeding females in a given year as 0.97; this estimate has recently been validated by two independent field studies (J. Goessling unpubl. data, 2021; E. Hunter unpubl. data, 2021). Because fecundity varies widely among populations and is likely driven by a north-to-south latitudinal gradient in temperature (Ashton et al. 2007, p. 360), we used linear regression to estimate the relationship between MAT and estimates of mean clutch size from the literature and then used regression coefficients to simulate mean values for populations, given the geographic location and MAT of a population. We modeled the proportion of nests that survive predation as 0.35 using an estimate from unmanipulated nests (Smith et al. 2013, p. 355). We modeled the probability of eggs being viable and hatching as 0.85, an average from reviews of field hatching rates (Landers et al. 1980, p. 359; Rostal and Jones 2002, p. 7). To account for males (and remove them) during projections, we assumed that sex ratios of eggs were even within populations and modeled the probability of eggs being female as 0.5. We modeled hatchling survival from nest emergence until the following survey period as 0.13 (0.04–0.34, 95 percent confidence interval [CI]), given results from a meta-analysis of hatchling survival of gopher tortoises (Perez-Heydrich et al. 2012, p. 342).

Maturity age

Age at maturity varies along a latitudinal gradient across gopher tortoise populations (Mushinsky et al. 1994, p. 123; Meshaka Jr. et al. 2019, p. 105-106). We used linear regression to estimate the relationship between MAT and maturity age estimates of females from the literature, then used regression coefficients to simulate mean maturity ages for populations, given the population's geographic location and MAT. Given a predicted maturity age for a population, we then calculated the probability that a juvenile will transition to adulthood during a given year.

Survival Rates

Survival rates are difficult to measure for gopher tortoises because individuals are long-lived, challenging to recapture, may become unavailable for resurvey by emigrating away from study populations, or may die. When individuals disappear from a study population, mark-recapture analyses are often unable to estimate whether individuals died or emigrated away. To this end, most mark-recapture studies of gopher tortoise seeking to understand survival have estimated apparent annual survival, which is the probability that individuals survived and stayed within a study area. Studies have found apparent annual survival to vary between adults and juveniles, with adults having higher survival than juveniles (Tuberville et al. 2014, p. 1155; Howell et al. 2020, p. 60; Folt et al. 2021, p. 624-625). We reviewed the literature for apparent annual survival estimates for gopher tortoises and performed a linear regression analysis testing for effects of age and MAT on survival, which confirmed that adults have greater survival than juveniles but failed to recover an effect of MAT on survival; rather, survival is likely most strongly influenced by habitat quality and management at sites (Howell et al. 2020, entire; Folt et al. 2021, p. 627;

Hunter and Rostal 2021, p. 661). We modeled adult survival as 0.96 and juvenile survival as 0.75 (Folt et al. 2021, p. 624-625), with a density-dependent limit on population growth where for each time-step when density increased above 2 females/ha, we prevented recruitment into the adult age class. Field studies have estimated tortoise density to range from 0.02–1.50 individuals/ha among northern populations (Guyer et al. 2012) and from 4.2–24.9 individuals/ha in southern Florida. We selected a threshold of 2 females/ha (i.e., 4 tortoises/ha, assuming even sex ratios) as a limit for density dependence because there is a considerable uncertainty when estimating tortoise density and 2 females/ha was a conservative intermediate estimate of maximum density among populations across the species' range.

Immigration

Gopher tortoises infrequently move long distances from established core home range areas; such movements can result in permanent emigration and immigration into other populations. We implicitly modeled losses to local populations due to emigration because the estimates of apparent annual survival accounts for individuals that emigrate from local populations. Given ongoing emigration, local populations within the same landscape population might receive immigrants that bolster population size. While little quantitative information is available describing the frequency or success of immigration, one study found that 2 percent of adults emigrated from local populations each year (Ott-Eubanks et al. 2003, p. 319). Given it is unlikely that all emigrants successfully immigrate into another population, the number of immigrants into local populations was modeled as a product of a randomly-drawn immigration rate (mean = 1 percent) multiplied by the total number of adult tortoises in adjacent populations (i.e., landscape population size) divided by the number of nearby local populations. Immigration rate was constrained during each time step so that the sum of immigration rate and survival rate could not exceed 1.

Initial population size

To estimate population growth and extinction risk of gopher tortoise populations across the species' range, we initialized the model with estimates of population size from spatially delineated populations. Population estimates were collected by a diverse partnership of cooperating State and Federal agencies, private organizations, and academic institutions. As discussed previously, only spatially explicit data were used in the future projection modelling. Because initial population sizes used in this analysis are the same dataset that were included in Chapter 4, the same assumptions and data limitations apply, including factors that may result in underrepresentation of initial population sizes and thus, future projections. It is important to note, data included in future condition modelling represents a subset of gopher tortoises likely to occur on the landscape, as data from private lands were lacking due to the absence of spatial information. Population estimates do not represent an assessment of all local populations of tortoises that exist in southeastern North America, but rather represent information that was provided by partners through much of the species' range. Most population estimates came from assessments of local populations on lands managed for the conservation of biodiversity or natural resources. Future inclusion of additional spatially explicit populations, particularly from private lands, would provide projections that better describe the species as a whole; our current model only makes projections about a subset of the species' populations.

We initialized starting population size using population estimates derived from data collected using burrow surveys and LTDS. Using spatial survey data associated with population estimates, we identified populations at two spatial scales as described in Chapter 4: local populations and landscape populations. We received some population estimates in aggregate from properties that were delineated to have two or more local populations of gopher tortoises; in these instances, we multiplied the population estimate (and confidence limits) by the area of each delineated local population and divided by the total survey area of the original survey. We assumed that population estimates being delineated into two or more local populations through this process would have even population densities and this process spread the population assessment evenly among local populations delineated by in the dataset. Some delineated local populations assessed in current conditions have less than 2 individuals; we removed these local populations from the future condition analysis.

The process of delineating local populations and landscape populations resulted in a dataset of 626 local populations that formed 244 landscape populations. We used population estimates from local populations to parameterize initial population size of adults and juveniles during simulated population projections. We assumed a 1:1 sex ratio and a 3:1 adult:juvenile ratio in populations (Folt et al. 2021, p. 626) and used the ratios to isolate and separate the female population into juvenile and adult components.

5.1.3. Modeling threats

We sought to model how predicted future changes to abiotic and biotic features may threaten future population growth and viability of gopher tortoises. We engaged scientists with expert knowledge in both gopher tortoise population biology and habitat management and identified a series of factors that experts considered to have high likelihood of influencing gopher tortoise demographics in the future (hereafter, threats). Using the list of threats, we reviewed the literature to identify research describing quantitative effects of how threats (or similar mechanisms) influence specific demographic parameters in the conceptual model for gopher tortoises. Below, we describe hypotheses for how four threats (climate warming, sea-level rise, urbanization, and climate-change effects on habitat management) may influence gopher tortoise demographics, and how we used quantitative estimates of the threats from the literature to parameterize and simulate how threats may influence future population growth and viability of gopher tortoises.

Climate warming

Climate change is predicted to drive warming temperatures and seasonal shifts in precipitation across Southeastern North America (Carter et al. 2018, entire). Of these two effects, warming temperatures may have the greater impact on gopher tortoises, because gopher tortoise demography is known to be sensitive to temperature gradients across the species' range. Specifically, maturity age and fecundity vary along a north-south latitudinal gradient, where warmer, southern populations have faster growth rates, younger maturity ages, and increased fecundity relative to cooler, northern populations (Ashton et al. 2007, p. 123; Meshaka Jr. et al. 2019, p. 105-106). As climate warming increases temperatures in the region, individuals in populations may experience more favorable conditions for growth and reproduction across the species' range. Because no studies have linked gopher tortoise growth or fecundity to interannual or interpopulation variation in precipitation, it seems less likely that climate-driven shifts in precipitation will influence gopher tortoise demography. Although the gopher tortoise exhibits temperature-dependent sex determination, we did not include this effect in the model as gopher tortoises can modify nest site selection and timing of nesting, as discussed in Chapter 3. We also did not model any potential range expansion or contraction that could occur due to long term climate change because there is no consensus or projection framework that we are aware of related to vegetative community changes and climate change projections; also, any significant expansion or contraction of the gopher tortoise range is likely to occur beyond our projection timeframe of 80 years.

We modeled how climate warming may influence gopher tortoise demography by using the estimated linear relationships of MAT with maturity age and fecundity to predict how warming temperatures experienced by populations in the future will drive concurrent changes in demography. For each population, we used historical estimates of MAT using the 'WorldClim' database (Hijmans 2020, entire) and then simulated step-wise climate-warming effects on MAT each year in the future where warming rates were parameterized by three treatments of climate warming: (1) a 1.0 °C (1.8 °F) increase in MAT over the next 80 years, (2) a 1.5 °C (2.7 °F) increase in MAT over the next 80 years, and (3) a 2.0 °C (3.6 °F) increase in MAT over the next 80 years (IPCC 2013, entire). The three scenarios (1.0 °C, 1.5 °C, and 2.0 °C) related to an optimistic prediction of RCP2.6, an intermediate prediction between RCP2.6 and RCP4.5, and a prediction for RCP4.5, respectively. Each year in the future, we used simulated changes in MAT to calculate mean maturity age and fecundity at sites. This analysis assumes that: (i) all local populations will respond homogeneously to warming temperatures, and (ii) there are no potential climatic ceilings that would limit growth and reproduction.

<u>Habitat management</u>

Prescribed fire is the most common management technique to maintain high-quality, open canopy conditions for gopher tortoises (Landers and Speake 1980, entire; Diemer 1986, p. 130; Yager et al. 2007, entire; Ashton et al. 2008, entire); however, when fire is not present in sufficient intervals or intensity to maintain open canopy conditions on the landscape, apparent survival of gopher tortoises decreases (Hunter and Rostal 2021, p. 661), potentially to levels that are insufficient for maintaining population viability (Folt et al. 2021, p. 627). However, wildlife managers tasked with maintaining high-quality habitat for gopher tortoises and other fire-dependent upland plant and animal species (Guyer and Bailey 1993,entire) may be challenged because regional climate warming may make habitat management with prescribed fire more difficult to accomplish. Managers require suitable fuel and weather conditions (e.g., relative humidity, temperature, wind speed; i.e., the ‘burn window’) to facilitate manageable fire behavior that will accomplish intended goals while limiting risk toward human communities. However, climate-change models predict the availability of burn window conditions to shift over future decades, with available conditions for fire management increasing in the winter but decreasing in the spring and summer (Kupfer et al. 2020, p. 769-770); summed together, seasonal shifts in the burn window conditions will decrease overall opportunity for management with prescribed fire. If managers become limited in the use of prescribed fire, resulting decreases in habitat quality may drive decreases in gopher tortoise survival. Alternatively, managers will need to rely on alternative tools to control midstory, such as chemical and mechanical treatments, which can be economically costly. Also, it should be noted that, although the ability to implement prescribed fire will likely be greatly constrained in the future, modelling for the southeastern United States suggests increased wildfire risk and a longer fire season, with at least a 30 percent increase from 2011 in lightning-ignited wildfire by 2060 (Vose et al. 2018, p. 239). It is possible that more frequent wildfires may help to mitigate predicted decreases in suitable burn days.

We estimated how habitat management influences gopher tortoise population growth by modeling habitat management of populations and linking the frequency of management to adult survival (see Appendix B for more information). We assumed that a baseline fire-return interval of 1-4 years (mean = 2.5 years) maintains high-quality habitat for the species (Guyette et al. 2012, p. 330; Crawford et al. 2020, p. 141) and then modeled the probability that the habitat associated with a population is burned during a given year (burn probability) as the inverse of the fire-return interval. Next, using historical baseline data describing average seasonal burn opportunity across southeastern North America (Kupfer et al. 2020, p. 769-771), we modeled the number of available burn days (i.e., days within the burn window) in winter (January–February), spring (March–May), and summer (June–July) as a product of the total days per season (59, 92, and 61 days, respectively) and the percentage of days historically available for burning (0.766, 0.800, and 0.645, respectively). We modeled four treatments for how the number of days available for prescribed fire may change in the future (Kupfer et al. 2020, p. 769-771): (1) ‘decreased fire’ - prescribed fire use will decrease consistent with climate shifts projected by

RCP4.5, (2) ‘very decreased fire’ - prescribed fire use will decrease with climate projections RCP8.5, (3) ‘increased fire’ - prescribed fire use will increase opposite of the effect projected by RCP4.5, and (4) ‘status quo’ - prescribed fire use will remain at current levels.

For each treatment, we modeled effects of climate change on the percentage of available burn days over the next 80 years using average effects from across southeastern North America (Kupfer et al. 2020, p. 769-771): 0.016 increase in winter, 0.040 decrease in spring, and 0.239 decrease in summer (‘decreased fire’ treatment); 0.030 increase in winter, 0.105 decrease in spring, and 0.436 decrease in summer (‘very decreased fire’ treatment); 0.016 decrease in winter, 0.040 increase in spring, and 0.239 increase in summer (‘increased fire’ treatment), and no effects on burn days (‘status quo’ treatment). The increased fire and status quo treatments could result if habitat managers can offset effects of climate change by benefiting from methodological advances in fire management or by using alternative methods rather than prescribed fire, such as mechanical or chemical treatments, to achieve similar management goals.

Urbanization

Human development of the landscape (i.e., urbanization) threatens terrestrial wildlife communities in the southeastern United States, including gopher tortoise populations that often rely on upland habitats that are popular sites for urban development or agriculture. While the local gopher tortoise populations we modeled are largely on conservation lands intended for wildlife conservation, urbanization threatens to surround these conservation lands, disrupt habitat connectivity, and decrease metapopulation dynamics that maintain connectivity and gene flow both among local populations and within landscape populations. Additionally, urbanization can disrupt habitat management by decreasing the ability of managers to use prescribed fire, with the caveat that managers have the alternative to implement other tools, such as mechanical and chemical treatments. We sought to model effects of urbanization pressure on gopher tortoise populations by linking urbanization projections from the SLEUTH urbanization model (Terando et al. 2014, entire) to habitat management of local populations with prescribed fire and with baseline immigration rates of gopher tortoises across landscape populations.

First, we modeled an effect of urbanization on habitat management by making burn probability a function of each population's distance to the nearest urban area. Studies have found evidence of fire exclusion/suppression in habitats within 600 m to 5 km (0.4 to 3.1 miles) of urban areas (Theobald & Romme, 2007, entire; Pickens, et al., 2017, p. 105). Therefore, we chose a moderate value of 10,498 feet (3.2 km) to capture the interaction between urbanization and fire frequency. Specifically, we assumed that local populations immediately adjacent to urban areas (distance less than 328 feet [0.1 km]) are unable to manage with prescribed fire. We also assumed management is uninfluenced for populations far from urban areas (greater than 10,498 feet [3.2 km]; no effect), and management of populations between 328-10,498 feet (0.1–3.2 km) from an urban area experience a negative effect on fire management with burn probability declining as a linear function of the population's proximity to the urban area (i.e., populations closer to urban areas experience less prescribed fire).

To model effects of urbanization on migration dynamics among local populations within landscape populations, we first estimated the total area and urbanized area within landscape populations in year 2020 using the SLEUTH model. Next, we estimated future urbanization and its effect on dispersal for gopher tortoises by estimating future urbanized areas using the SLEUTH model projections for 40, 60, and 80 years in the future. We then calculated the predicted change in proportion of habitat due to future urbanization for landscape populations. For each year greater or equal to 3 during population projections, we modeled the number of adult immigrants into local populations in each year as a function of the total number of individuals in the landscape population available for immigration to the local population during the previous year divided by the total number of local populations in the landscape population; this estimated a number of migrants from the landscape population that would be available to immigrate into a local population being modeled during a given timestep. We then multiplied the number of dispersing tortoises during a timestep by the proportion of non-urbanized habitat across the landscape, assuming that urbanized habitat prevented dispersal by causing mortality of dispersing tortoises (i.e., road mortality). Next, we assumed that the likelihood of a population is managed with prescribed fire varies by its distance to the nearest urban area. We first estimated the distance of each local population to the nearest urban area in the current conditions (i.e., year 2020) and in the future using the SLEUTH model by measuring the distance to urban area from the geometric center of local populations to the edge of the nearest neighbor urban area. We assumed that local populations immediately adjacent to urban areas (distance < 0.1 km) are unable to be managed with prescribed fire and forced burn probability to 0 for those populations; that management is uninfluenced for populations far from urban areas (> 3.2 km; no effect on burn probability); and that populations between 0.1–3.2 km from an urban area experience a negative effect on fire management where burn probability declined as a linear function of the population's proximity to urban area. We explain how we modeled urbanization in greater detail in Appendix B.

We estimated predicted effects of urbanization on local and landscape populations by modeling three treatments from the SLEUTH urbanization model that corresponded to different probability thresholds of urbanization:
(1) a 'low urbanization' treatment where future urbanization was limited to cells with urbanization probability greater or equal to 0.95,
(2) a 'moderate urbanization' treatment with urbanization predicted by probability greater or equal to 0.50, and
(3) a 'high urbanization' treatment with urbanization probability greater or equal to 0.20.
We assumed that: (i) immigration was limited to adults and that no juveniles successfully migrate among populations, and (ii) immigrants cannot survive or move through urbanized areas (e.g., due to road mortality) but can survive while moving through unurbanized areas.

<u>Sea level rise</u>

Because gopher tortoises are a terrestrial species and not suited for wetlands, sea-level rise may negatively affect gopher tortoise populations in low-lying coastal areas, such as coastal sand-dune environments (Blonder et al. 2021, p. 6-8). Projected sea-level rise scenarios provide a range of coastal inundation scenarios that vary in severity. We modeled effects of sea-level rise on gopher tortoises using three scenarios of sea-level rise predicted by the U.S. National Oceanic and Atmospheric Administration (NOAA), the 'intermediate-high', 'high', and 'extreme' scenarios, which correspond to projections from two of the most likely global emission scenarios, RCP6 and RCP8.5 (IPCC 2013, entire; NOAA 2020, entire). Local projections for the two scenarios are available from U.S. Geological Survey sea-level monitoring stations across the southeastern United States, providing estimates of sea-level rise for stations at decadal time steps in the future to year 2100.

We modeled three treatments of sea-level rise using projections from NOAA:
(1) the 'intermediate-high' scenario derived from RCP6.0, which projects approximately 6.0 feet (1.83 m) of sea-level rise over the next 80 years;
(2) the 'high' scenario which projects approximately 8.37 feet (2.55 m) of sea-level rise over the next 80 years; and,
(3) the 'extreme' scenario derived from RCP8.5, which projects approximately 10.37 feet (3.16 m) of sea-level rise over the next 80 years (NOAA 2020, entire).

We modeled sea-level rise effects on populations in two ways. First, assuming that gopher tortoise populations cannot persist when oceanic levels encroach too close upon their habitat, we simulated decreasing elevation of gopher tortoise populations due to sea-level rise. We extracted historical estimates of elevation Above Sea Level (ASL; in feet/m) using the centroid geographic coordinates of each local population using the 'WorldClim' database (Hijmans 2020, entire). Given the total predicted sea-level rise of each treatment over the next 80 years, we simulated incremental sea-level rise at each population in each year in the future and subtracted this incremental oceanic rise from the site's elevation through time. When the site elevation of populations decreased to less than 5.56 feet (2 m) ASL, we considered the populations functionally extirpated. Second, we assumed that habitat inundated by sea-level rise adjacent to local populations would decrease connectivity and dispersal dynamics of individuals among populations within landscape populations. We used spatial projections from NOAA to estimate future inundation area due to sea-level rise for each landscape population, and then modeled immigration to decline as a function of decreasing habitat available for dispersal at the landscape scale. The analysis of sea-level rise effects assumes that: (i) sea-level rise throughout the Southeast will be homogeneous and characterized by NOAA projections derived from data from Ft. Myers, Florida, (ii) populations less than 5.56 feet (2 m) ASL are unable to persist, and (iii) populations are unable to migrate away from sites because coastal areas are often heavily developed and there is no guarantee that adjacent properties would be available for entire populations to migrate.

5.1.4. Scenarios and population projection structure

To understand how gopher tortoise populations will respond to scenarios with multiple concurrent factors, we created a set of six scenarios with varying levels of threat magnitude and combination (Table 5.2). Specifically, we created three scenarios with different levels of stressors (low stressors, medium stressor, and high stressors) that experienced habitat management consistent with contemporary target management goals. We then used the medium stressor values and built three additional models that varied in habitat management treatments, ranging from 'more management' conditions to worsening ('less management') and much worse ('much less management') conditions (Table 5.2). Appendix B describes how uncertainty in future states of factors and scenarios were addressed, including geographic variation among populations, parametric uncertainty, and temporal stochasticity.

Table 5. 2-Six scenarios of future climate warming, sea-level rise, urbanization, and habitat management used to simulate population growth and extinction risk for gopher tortoises for 80 years into the future. Scenarios vary in the magnitude of threat influences on gopher tortoise demography; threat levels included three levels of climate warming (1.0, 1.5, and 2.0 degrees C increase; 1.8, 2.7, 3.6 degrees F, respectively), three levels of sea-level rise (intermediate-high [6.00 feet/1.83 m], high [8.37 feet/2.55 m], and extreme [10.37 feet/3.16 m] scenarios), three levels of urbanization scenarios predicted by the SLEUTH model (Terando et al. 2014, entire) at probability thresholds of 0.9 (conservative projection), 0.5 (moderate projection), and 0.1 (aggressive projection), and four levels of changes in habitat management (no changes, less management predicted by RCP4.5 [Kupfer et al. 2020, p. 769-770], much less management predicted by RCP8.5 [Kupfer et al. 2020, p. 769-770], and improved management [the opposite of the effect predicted by RCP4.5 in Kupfer et al. 2020, p. 769-770]).

Scenarios	Climate warming (deg C)	Sea-level rise (m)	Urbanization	Management
Low stressors	1.0	0.54 m	P = 0.95	Status quo
Medium stressors	1.5	1.83 m	P = 0.50	Status quo
High stressors	2.0	3.16 m	P = 0.20	Status quo
More management	1.5	1.83 m	P = 0.50	More

Less management	1.5	1.83 m	P = 0.50	Less
Much less management	1.5	1.83 m	P = 0.50	Much less

Little to no data exist describing gopher tortoise immigration rates (γ) in wild populations. Given uncertainty associated with this parameter, we sought to include a sensitivity analysis to understand the effects of γ on our results. We crafted three additional scenarios: a 'no immigration' scenario with γ = 0, a 'high immigration' scenario with γ = 0.02, and a 'very high immigration' scenario with γ = 0.04. We simulated these scenarios with stressor and habitat management values from the 'medium stressors' scenario with a projection interval of 80 years, and we compared the resulting immigration scenarios to the 'medium stressors' scenario results that were simulated with γ = 0.01.

To assess future redundancy, resiliency, and representation of the gopher tortoise, we used population projections to estimate changes in gopher tortoise populations in the future under each of the six scenarios (Table 5.2). We assessed redundancy by measuring predicted changes in the total number of individuals, local populations, and landscape populations in the future. We summarized population trends by estimating population growth rate as increasing (greater than 1.00), stable (equals 1.00), or decreasing (less than 1.00). We measured population growth of total population size, the number of local populations, and the number of landscape populations across the species' range during the projection interval by dividing the value from year 2020 by the model-predicted value at the end of the projection interval.

We assessed the resiliency of future populations to changing environments by estimating extinction risk. We chose 3 females as a lower threshold to approximate functional extinction because populations with fewer than three females are extremely likely to be inbred and at great risk of extirpation (Chesser et al. 1980, entire; Frankham et al. 2011, p. 466). For each population, we estimated persistence probability, and then categorized populations as 'extremely likely to persist' (persistence probability greater or equal to 0.95), 'very likely to persist' (P greater than or equal to 0.80 and less than 0.95), 'more likely than not to persist' (P greater than or equal to 0.50 and less than 0.80), and 'unlikely to persist' (i.e., extirpated; persistence probability less than 0.50). We then simulated the number of populations predicted to persist at the end of the projection. For each landscape population, we estimated resiliency by selecting the constituent focal population with the greatest persistence probability and used that value to categorize landscape population persistence and simulated landscape population survival.

We evaluated how representation is predicted to change in the future by examining how population growth of total population size (number of individual females), number of populations, and number of landscape populations will vary by the five population genetic groups of tortoises across the species' range (Gaillard et al. 2017, p. 501-504). For each scenario, we summarized the results among all populations across the species' range, but also by genetic units (five units; see Gaillard et al. 2017, p.501-504). All analyses were performed in the statistical program R (R Core Team 2018, entire). A more detailed methodological summary of the future conditions analysis is included in Appendix B.

5.2 Model results

Linear regression analysis of three demographic parameters reviewed in the literature (fecundity, maturity age, and apparent annual survival probability) found that fecundity and maturity age vary significantly by MAT across the species' range (Figure 5.1). For each 1 °C (1.8 °F) increase in MAT, we found that maturity age decreased by 1.41 years (0.18–2.62, 95 percent CI), which was a statistically significant effect (P = 0.029). For each 1 °C (1.8 °F) increase in MAT, we found that fecundity increased by 0.52 eggs per clutch (0.27–0.77, 95 percent CI), which was statistically significant (P less than 0.001). Survival probability showed no significant trend with respect to MAT.

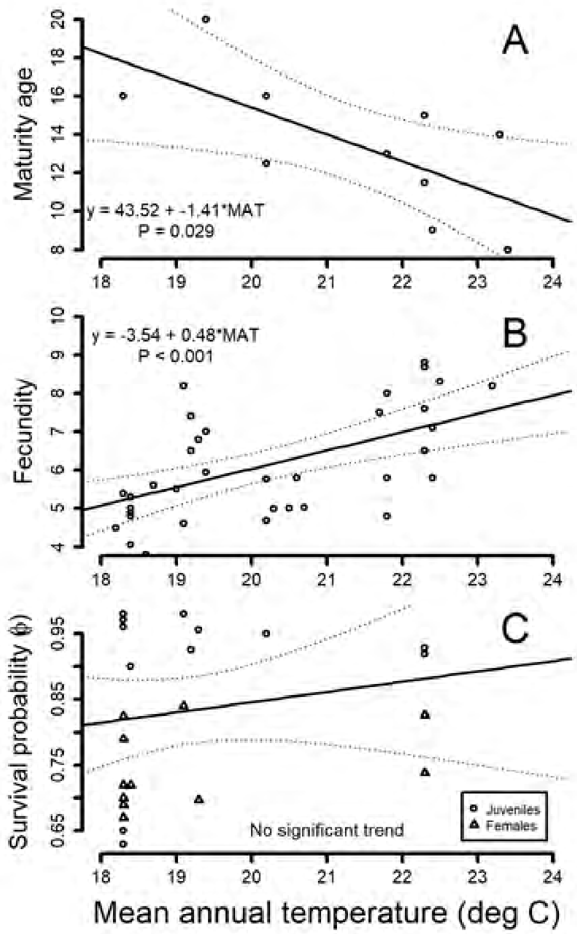

Figure 5. 1-Effect of mean annual temperature (MAT; degrees C) on (A) maturity age (MA), (B), fecundity, and (C) annual apparent survival probability of gopher tortoise (Gopherus polyphemus) populations. Geographic variation in biotic conditions (e.g., MAT) predict significant variation in maturity age and fecundity (P less than 0.05) but not in annual apparent survival probability.

We simulated population growth of 626 local populations and 244 landscape populations that were estimated to comprise approximately 70,600 individual (female) gopher tortoises. Population projections under six scenarios of future change during 40, 60, and 80-year projection intervals predicted declines in the number of gopher tortoise individuals, local populations, and landscape populations of gopher tortoises (Table 3). Relative to current levels of total population size, projections for total population size suggested declines by 2060 (λ = 0.65–0.67 among scenarios; i.e., 33–35 percent declines), 2080 (λ = 0.66–0.70 among scenarios; 30–34 percent declines), and 2100 (λ =

0.67–0.72 among scenarios; i.e., 28–33 percent declines). The six scenarios varied little in their effects on the total number of individuals, local populations, and landscape populations; but scenario effects become more magnified in each successive timestep. However, 95 percent confidence intervals for projections of future population growth overlapped with 1.00 in all scenarios and timesteps, indicating significant uncertainty in projections for each scenario at each projection interval.

Among the simulated populations, the number of local populations and landscape populations also were predicted to decline in each projection interval (Table 5.3). Declines in local populations and landscape populations were modest at the 40-year timestep (47–48 percent and 25–27 percent declines among scenarios, respectively) but were exacerbated at the 60-year (60–61 percent and 41–43 percent declines, respectively) and 80-year (68–70 percent and 53–57 percent declines, respectively) timesteps. Scenarios did not vary strongly in their effect on the predicted number of persisting local populations and landscape populations within each projection interval.

Table 5. 3-Simulated population projections for female gopher tortoises under six scenarios of future change. Columns summarize the initial number (in 2020), future predicted number, and population growth rate (λ) for the total population size, number of populations, and number of landscape populations for six scenarios projected 40, 60, and 80 years into the future. See Table 5.2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of landscape populations		
	Initial	Future	λ	Initial	Future	λ	Initial	Future	λ
Year 2060									
Low stressors	70610	47468	0.67 (0.30–1.80)	626	332	0.53 (0.51–0.55)	244	179	0.73 (0.63–0.81)
Medium stressors	70614	47630	0.67 (0.30–1.91)	626	331	0.53 (0.51–0.54)	244	183	0.75 (0.61–0.80)
High stressors	70582	45998	0.65 (0.28–1.84)	626	329	0.53 (0.51–0.55)	244	177	0.73 (0.64–0.80)
More management	70611	46646	0.66 (0.29–1.84)	626	329	0.53 (0.51–0.55)	244	178	0.73 (0.61–0.80)
Less management	70610	46826	0.66 (0.29–1.79)	626	328	0.52 (0.50–0.54)	244	180	0.74 (0.62–0.80)
Much less management	70600	46495	0.66 (0.29–1.80)	626	323	0.52 (0.50–0.54)	244	178	0.73 (0.60–0.79)
Year 2080									
Low stressors	70609	49281	0.70 (0.36–1.77)	626	249	0.40 (0.38–0.41)	244	143	0.59 (0.44–0.73)
Medium stressors	70636	48924	0.69 (0.37–1.79)	626	250	0.40 (0.38–0.41)	244	142	0.58 (0.45–0.73)
High stressors	70592	46674	0.66 (0.34–1.70)	626	246	0.39 (0.37–0.41)	244	138	0.57 (0.43–0.70)

More management	70598	49246	0.70 (0.35–1.86)	626	250	0.40 (0.38–0.42)	244	145	0.59 (0.45–0.74)
Less management	70604	48754	0.69 (0.34–1.80)	626	247	0.39 (0.38–0.41)	244	138	0.57 (0.44–0.72)
Much less management	70569	48592	0.69 (0.35–1.69)	626	243	0.39 (0.37–0.42)	244	142	0.58 (0.42–0.72)
Year 2100									
Low stressors	70614	50846	0.72 (0.37–1.77)	626	198	0.32 (0.30–0.33)	244	114	0.47 (0.36–0.62)
Medium stressors	70594	48366	0.69 (0.36–1.74)	626	196	0.31 (0.29–0.33)	244	108	0.44 (0.35–0.59)
High stressors	70578	47378	0.67 (0.35–1.70)	626	194	0.31 (0.29–0.33)	244	109	0.45 (0.33–0.60)
More management	70584	49114	0.70 (0.36–1.73)	626	196	0.31 (0.30–0.33)	244	110	0.45 (0.33–0.62)
Less management	70596	47202	0.67 (0.37–1.75)	626	193	0.31 (0.29–0.33)	244	106	0.43 (0.34–0.61)
Much less management	70608	48520	0.69 (0.37–1.67)	626	188	0.30 (0.28–0.32)	244	106	0.43 (0.34–0.59)

Categorization of populations by persistence probability revealed finer-scale variation of how scenarios varying in magnitude of stressors and management influenced persistence probability of populations (Table 5.4). Among the three projection intervals, the ‘low stressors’ scenario tended to predict higher percentages of Extremely Likely Extant populations and lower percentages of Unlikely Extant (i.e., Extirpated) populations relative to the ‘medium stressors’ and ‘high stressors’ scenarios. Similarly, the ‘more management’ scenario tended to predict higher percentages of Extremely Likely Extant populations and lower percentages of Unlikely Extant (i.e., Extirpated) populations relative to the ‘less management’ and ‘much less management’ scenarios. Figure 5.2 illustrates persistence probabilities among populations and landscape populations predicted by the ‘less management’ scenario.

Table 5. 4- Predicted population persistence probabilities categories for gopher tortoise populations in year 2100 under six future scenarios varying in the magnitude of future stressors; numbers represent number of local gopher tortoise populations, whereas numbers in parentheses represent the percentage of populations that fall into each category; persistence categories are Extremely Likely Extant (P > 95.0 percent), Very Likely Extant (P = 80.0–94.9 percent), More Likely Than Not Extant (P = 50.0–79.9 percent), and Unlikely Extant (P < 50.0 percent; i.e., extirpated). See Table 5.2 for descriptions of scenarios and their parameters.

Population persistence category	Scenario					
	Low stressors	Medium stressors	High stressors	More management	Less management	Much less management
Year 2060						
Extremely Likely Extant	104 (16.6%)	103 (16.5%)	101 (16.1%)	99 (15.8%)	102 (16.3%)	104 (16.6%)
Very Likely Extant	102 (16.3%)	97 (15.5%)	108 (17.3%)	108 (17.3%)	98 (15.7%)	91 (14.5%)
More Likely Than Not Extant	135 (21.6%)	145 (23.2%)	135 (21.6%)	134 (21.4%)	141 (22.5%)	141 (22.5%)
Unlikely Extant (i.e., Extirpated)	285 (45.5%)	281 (44.9%)	282 (45%)	285 (45.5%)	285 (45.5%)	290 (46.3%)
Year 2080						
Extremely Likely Extant	78 (12.5%)	74 (11.8%)	71 (11.3%)	79 (12.6%)	74 (11.8%)	76 (12.1%)
Very Likely Extant	35 (5.6%)	44 (7%)	41 (6.5%)	36 (5.8%)	41 (6.5%)	31 (5%)
More Likely Than Not Extant	122 (19.5%)	116 (18.5%)	117 (18.7%)	128 (20.4%)	103 (16.5%)	114 (18.2%)
Unlikely Extant (i.e., Extirpated)	391 (62.5%)	392 (62.6%)	397 (63.4%)	383 (61.2%)	408 (65.2%)	405 (64.7%)
Year 2100						
Extremely Likely Extant	76 (12.1%)	72 (11.5%)	70 (11.2%)	71 (11.3%)	70 (11.2%)	70 (11.2%)
Very Likely Extant	21 (3.4%)	20 (3.2%)	25 (4%)	24 (3.8%)	24 (3.8%)	24 (3.8%)
More Likely Than Not Extant	65 (10.4%)	62 (9.9%)	55 (8.8%)	58 (9.3%)	57 (9.1%)	54 (8.6%)
Unlikely Extant (i.e., Extirpated)	464 (74.1%)	472 (75.4%)	476 (76%)	473 (75.6%)	475 (75.9%)	478 (76.4%)

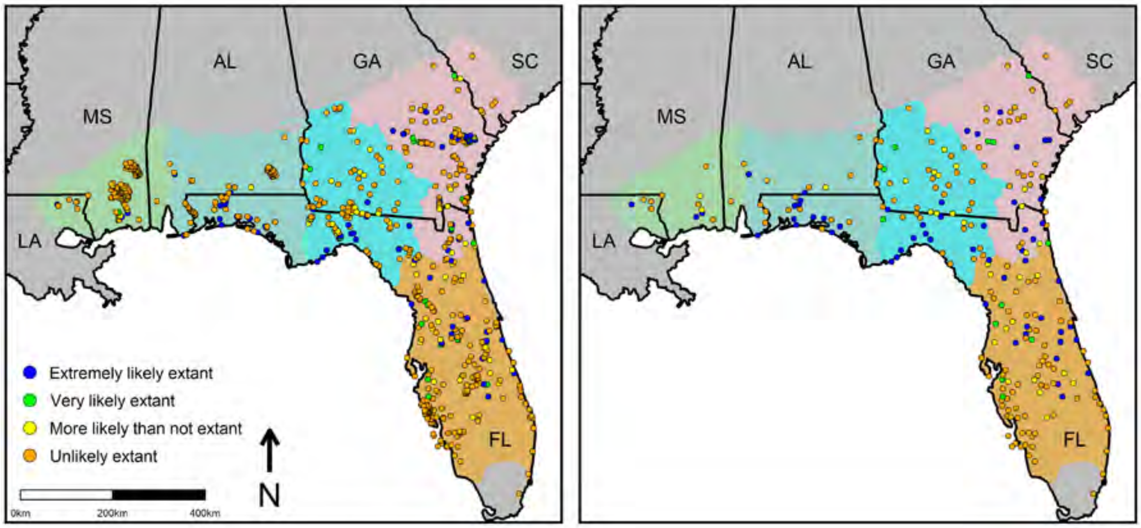

Figure 5. 2- Persistence probabilities of gopher tortoise (*Gopherus polyphemus*) local populations (left) and landscape populations (right) predicted by a future scenario of less habitat management with medium stressor (Table 2) projected 80 years into the future. Symbols are colored by persistence probability categories: Extremely Likely Extant (≥ 95.0 percent), Very Likely Extant (= 80.0–94.9 percent), More Likely Than Not Extant (= 50.0–79.9 percent), and Unlikely Extant (< 50.0 percent; i.e., extirpated). See Table 5.2 for descriptions of scenarios and their parameters.

Our analysis of representation revealed that changes in the number of individuals, local populations, and landscape populations varied by analysis unit (Figure 5.3); we provide the projections for the 80-year projection interval in Table 5.5. Among the five analysis units projected 80 years into the future, units 1, 3, and 5 were predicted to decline overall, with mean λ values ranging between 0.60–0.73, 0.47–0.49, and 0.52–0.58 among scenarios for each unit, respectively (i.e., 27–40 percent, 51–53 percent, and 42–48 percent declines, respectively); however, 95 percent CI of λ values overlapped with 1.00 in all scenarios for each of the three units, indicating uncertainty in future abundance. Unit 4 was predicted to experience more modest declines in total abundance (λ = 0.86–0.98; i.e., 2–14 percent decrease), but 95 percent CI of λ also overlapped 1.00, indicating uncertainty in predicted future abundance. Alternatively, total abundance in Unit 2 was predicted to increase substantially (λ = 2.37–2.53; i.e., 137–153 percent increase); 95 percent CI of λ exceeded 1.00, indicating a significant predicted increase.

Scenarios predicted substantial declines in the number of local populations among all units. Predicted reductions in populations were greatest in Unit 1 (λ = 0.22–0.23), Unit 2 (λ = 0.23–0.26), and Unit 5 (λ = 0.28–0.30), and slightly weaker (but still strong) in Unit 3 (λ = 0.37–0.39) and Unit 4 (λ = 0.39–0.41). The number of landscape populations was predicted to decline among all scenarios in each analysis unit, with the strongest loss of landscape populations in Unit 5 (λ = 0.36–0.41 among scenarios) and the weakest loss of landscape populations in Unit 3 (λ = 0.48–0.53 among scenarios).

Table 5. 5- Simulated population projections for gopher tortoises populations in each of the five analysis units. Six scenarios of predicted future change were projected 80 years into the future; results are summarized by the initial number, future predicted number, and population growth rate (λ) for the total population size, number of local populations, and number of landscape populations in each genetic unit. See Table 2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of landscape populations		
	Initial	Future	λ	Current	Future	λ	Initial	Future	λ
Unit 1									
Low stressors	1571	1151	0.73 (0.22–3.55)	102	23	0.23 (0.18–0.27)	13	6	0.46 (0.46–0.46)
Medium stressors	1573	1066	0.68 (0.22–3.50)	102	23	0.23 (0.18–0.27)	13	6	0.46 (0.46–0.54)
High stressors	1572	990	0.63 (0.22–3.86)	102	23	0.23 (0.18–0.26)	13	6	0.46 (0.46–0.54)
More management	1572	1066	0.68 (0.21–4.01)	102	23	0.23 (0.19–0.27)	13	6	0.46 (0.44–0.54)
Less management	1573	1026	0.65 (0.22–3.79)	102	22	0.22 (0.18–0.26)	13	6	0.46 (0.46–0.54)
Much less management	1572	947	0.60 (0.22–3.42)	102	22	0.22 (0.18–0.26)	13	6	0.46 (0.46–0.54)
Unit 2									
Low stressors	2896	7316	2.53 (1.49–4.08)	81	21	0.26 (0.21–0.30)	29	16	0.55 (0.48–0.66)
Medium stressors	2896	7022	2.42 (1.24–3.94)	81	19	0.23 (0.20–0.27)	29	15	0.52 (0.45–0.59)
High stressors	2894	6868	2.37 (1.50–4.04)	81	19	0.23 (0.20–0.28)	29	14	0.48 (0.45–0.59)
More management	2896	7086	2.45 (1.39–3.95)	81	20	0.25 (0.21–0.28)	29	15	0.52 (0.45–0.59)
Less management	2898	7007	2.42 (1.58–4.10)	81	20	0.25 (0.20–0.28)	29	15	0.52 (0.45–0.59)
Much less management	2898	7084	2.44 (1.44–3.92)	81	19	0.23 (0.20–0.27)	29	14	0.48 (0.45–0.52)
Unit 3									
Low stressors	19432	9468	0.49 (0.31–1.08)	110	42	0.38 (0.34–0.44)	55	29	0.52 (0.36–0.73)
Medium stressors	19428	9125	0.47 (0.31–1.04)	110	42	0.38 (0.34–0.44)	55	27	0.49 (0.32–0.68)
High stressors	19419	9406	0.48 (0.30–1.02)	110	42	0.38 (0.34–0.44)	55	28	0.50 (0.35–0.72)
More management	19426	9338	0.48 (0.30–1.11)	110	43	0.39 (0.35–0.45)	55	29	0.53 (0.38–0.76)
Less management	19430	9224	0.47 (0.31–1.06)	110	42	0.38 (0.33–0.43)	55	28	0.51 (0.35–0.75)

Much less management	19432	9332	0.48 (0.31–1.03)	110	41	0.37 (0.33–0.43)	55	27	0.48 (0.35–0.70)
Unit 4									
Low stressors	14032	13793	0.98 (0.55–2.20)	123	50	0.37 (0.33–0.43)	46	21	0.46 (0.35–0.65)
Medium stressors	14030	13368	0.95 (0.55–2.28)	123	50	0.39 (0.35–0.45)	46	22	0.48 (0.37–0.64)
High stressors	14040	12013	0.86 (0.42–1.98)	123	48	0.41 (0.37–0.46)	46	20	0.43 (0.35–0.62)
More management	14036	13325	0.95 (0.54–2.11)	123	51	0.40 (0.36–0.44)	46	22	0.48 (0.35–0.66)
Less management	14034	13109	0.93 (0.54–2.09)	123	49	0.41 (0.37–0.46)	46	22	0.48 (0.35–0.67)
Much less management	14039	13118	0.93 (0.56–2.11)	123	49	0.39 (0.35–0.43)	46	20	0.43 (0.36–0.63)
Unit 5									
Low stressors	32684	19120	0.58 (0.25–1.70)	210	62	0.30 (0.27–0.32)	103	41	0.40 (0.30–0.52)
Medium stressors	32666	17786	0.54 (0.24–1.65)	210	60	0.29 (0.26–0.31)	103	43	0.41 (0.27–0.53)
High stressors	32653	18102	0.55 (0.25–1.66)	210	60	0.29 (0.26–0.32)	103	39	0.38 (0.25–0.58)
More management	32655	18300	0.56 (0.24–1.64)	210	60	0.29 (0.26–0.31)	103	41	0.40 (0.26–0.57)
Less management	32662	16836	0.52 (0.23–1.71)	210	60	0.29 (0.25–0.32)	103	37	0.36 (0.27–0.54)
Much less management	32666	18038	0.55 (0.24–1.59)	210	58	0.28 (0.25–0.30)	103	40	0.38 (0.27–0.51)

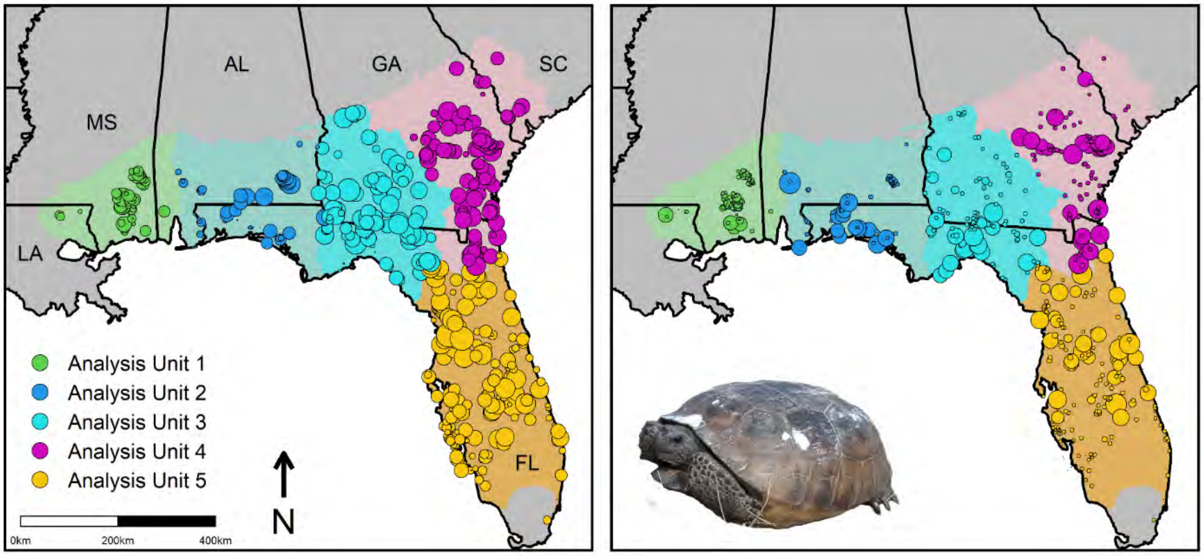

Figure 5. 3-Current (left) and future predicted abundance (right) of gopher tortoise (*Gopherus polyphemus*; right inset) populations in the southeastern United States that were modeled to predict future population growth and extinction risk for the species under scenarios of global change. Each circle represents a local population and circles are colored by analysis units. Symbol size reflects a log-transformed scale of population size; the left panel shows population size estimated during a survey during 2010–2020; the right panel shows predicted population size under a future scenario of 'medium stressors with less management' (Table 5.2). Abundance of populations during 2010–2020 was estimated from analysis of data from burrow surveys or Line Transect Distance Sampling (LTDS) at each the site within the last ten years.

We found that model projections were sensitive to input values for immigration rate (Table 5.6). The population declines predicted by the 'medium stressors' scenario were exacerbated substantially when simulated with an immigration rate of 0; conversely, elevated values for immigration produced population projections that substantially increased the total population size above initial starting population size and decreased declines in local populations and landscape populations.

Table 5. 6- Simulated population projections for gopher tortoises under scenarios varying in immigration rate (γ): no immigration (γ = 0), intermediate immigration (γ = 0.01), high immigration (γ = 0.02), and very high immigration (γ = 0.04). Columns summarize the initial number (in 2020), future predicted number, and population growth rate (λ) for the total population size, number of populations, and number of landscape populations for four scenarios projected 80 years into the future. Each scenario models stressors and management actions using input values from the 'medium stressors' scenario from Table 2, and the 'intermediate immigration' scenario has the same input values the 'medium stressors' scenario from Table 2; see Table 2 for more information about input parameters.

Scenarios	Total population size			Number of local populations			Number of landscape populations		
	Initial	Future	□	Initial	Future	□	Initial	Future	□
No immigration	70602	1566	0.02 (0.01–0.18)	626	81	0.13 (0.11–0.15)	244	46	0.19 (0.09–0.36)
Intermediate immigration	70594	48366	0.69 (0.36–1.74)	626	196	0.31 (0.29–0.33)	244	108	0.44 (0.35–0.59)
High immigration	70600	91805	1.30 (0.71–2.76)	626	247	0.39 (0.38–0.41)	244	124	0.51 (0.39–0.66)
Very high immigration	70600	151320	2.14 (1.18–4.44)	626	312	0.50 (0.48–0.52)	244	144	0.59 (0.48–0.68)

With each 50-female increase in starting population size, populations were 1.029 (1.027–1.03; 95 percent CI) times as likely to persist, which was statistically significant ($P < 0.0001$). With each 1 local population increase in landscape populations, local populations were 0.987 (0.986–0.987; 95 percent CI) times as likely to persist (i.e., 1.013 times less likely), which was statistically significant ($P < 0.0001$). For each 500-ha increase in area, populations were 1.002 (1.001–1.003; 95 percent CI) times as likely to persist, which was statistically significant ($P = 0.044$). With each 10 m increase in elevation, populations were 0.901 (0.899–0.904; 95 percent CI) times as likely to persist (i.e., 1.109 times less likely), which was statistically significant ($P < 0.0001$). For each 0.5 degree increase in latitude, populations were 1.122 (1.119–1.125; 95 percent CI) times as likely to persist, which was statistically significant ($P < 0.0001$). With each 0.01 proportional loss in landscape area due to sea-level rise, local populations were 0.57 (1.67–1.82; 95 percent CI) times as likely to persist (i.e., 1.747 times less likely), which was statistically significant ($P < 0.0001$). With each 0.1 proportional loss in landscape area due to urbanization, local populations were 0.96 (0.955–0.965; 95 percent CI) times as likely to persist (i.e., 1.042 times less likely), which was statistically significant ($P < 0.0001$). With each categorical increase in fire management (from 'very less' to 'less' to 'status quo' to 'increased'), local populations were 1.021 (1.014–1.029; 95 percent CI) times as likely to persist, which was statistically significant ($P < 0.0001$).

5.3. Summary of future conditions and viability

We synthesized literature describing gopher tortoise life history and built a predictive population model that accounted for geographic variation in demography to estimate growth of gopher tortoise populations across the species range on conservation lands. We then identified a series of influences (climate warming, sea-level rise, urbanization, and habitat management) that have been hypothesized to have significant current and future effects on gopher tortoise populations. Then, using estimates of these effects on gopher tortoise demography and/or reasonable assumptions, we linked influences to specific demographic rates and used published model projections of their prevalence in the future (Terando et al. 2014, entire; IPCC 2013, entire; Kupfer et al. 2020, entire; NOAA 2020, entire) to simulate how gopher tortoise populations will respond to future conditions across the species' range.

Using this integrative modeling framework, we simulated future resiliency, representation, and redundancy of gopher tortoise populations under six scenarios varying in the magnitude of influences at 40, 60, and 80 years in the future. Simulated growth of approximately 70,600 individuals (females) from 626 local populations and 244 landscape populations predicted future declines in the number of individuals, local populations, and landscape populations among all scenarios and projection intervals. Scenarios did not vary strongly in their effect on λ of individuals, populations, and landscape populations; no single stressor scenario or management scenario was sufficient to prevent population declines, and 95 percent confidence intervals of projections overlapped significantly among all scenarios, indicating statistical insignificance of scenario effects.

While scenarios did not have strong effects on overall trends in abundance and population redundancy, categorization of populations by persistence probabilities suggested that the ‘increased management’ and ‘low stressors’ scenarios performed better at increasing population persistence and reducing extirpation than other management and stressor scenarios. Increased habitat management promoted greater population persistence relative to decreased management scenarios because of positive effects of management on survival in local populations, which increases population growth and persistence probability of populations. While populations may experience reproductive benefits from warming temperatures in the future (i.e., positive effects with increased stressors), the ‘low stressors’ scenarios outperformed the elevated stressor scenarios because the negative effects of urbanization and sea-level rise on survival and immigration were stronger than the positive effects of warming on reproduction.

The regression analysis identified significant effects of initial abundance, number of populations per landscape population, area, elevation, urbanization, sea-level rise, and habitat management to influence persistence probabilities of local populations. For groups and agencies seeking alternatives to buffer tortoise populations from anthropogenic effects, these factors represent opportunities for management and/or conservation. We observed positive effects of initial population size, area, and fire management on population persistence. Because large areas of land support larger local populations of tortoises experience increased persistence probabilities (Fahrig and Merriam 1985, entire), management actions to conserve large tracts of land with abundant and well-connected populations on high-quality habitat might be prioritized, as well as actions to increase population size of local populations or increase the number of local populations within landscape populations (i.e., translocation and repatriation, respectively; e.g., Tuberville et al. 2008, entire; McKee et al. 2021, entire). Similarly, increased urbanization will decrease immigration and habitat management among populations, and conservation planning strategies could emphasize securing connectivity of existing local populations through strategic land acquisitions or partnerships (Ashrafzadeh et al. 2020, entire). We observed particularly strong negative effects of both sea-level rise and elevation on persistence probability. The sea-level rise effect was due in large part because we set an extinction threshold where local populations that fell to less than 2 m asl due to sea-level rise were forced to extinction. Gopher tortoise populations in low-elevation, coastal areas at risk of sea-level rise might be doomed, and future conservation actions might include assisted migration (Vitt et al. 2010, entire) to suitable areas less at risk to sea-level rise and coastal inundation (Blonder et al. 2020, entire). The effect of decreased persistence at higher elevations was likely due to increased urbanization pressure in high-elevation areas; urbanization was also predicted to have a significant negative effect on persistence of local populations, and urbanization tends to focus on upland, high-elevation habitats that are occupied by tortoise populations (Diemer 1986, entire).

The large declines in number of local populations occurred, in part, because many local populations (N = 174; 27.8%) delimited in our surveys had very few individuals to start with in the current conditions. Assuming a 3:1 adult to juvenile ratio and an even sex ratio, local populations with less than 8 individuals were functionally extirpated at the start of projections, given our quasi-extinction probability (< 3 adult females). This also likely explains the negative effect of landscape population size on population persistence we observed in our regression analysis; for example, a few extremely large landscape populations (e.g., six landscape populations contained 13–50 local populations) were dominated by local populations with <8 individuals, thus driving down mean persistence probability in the large landscape populations. This also likely explains the negative effect of landscape population size on population persistence we observed in our regression analysis; a few extremely large landscape populations (e.g., six landscape populations had 13–50 local populations) were dominated by local populations with <8 individuals, thus driving down mean persistence probability in large landscape populations.

Our analysis simulated the fate of known populations largely on protected, conservation lands that should be managed for natural resource conservation in the future. We expect populations on managed, conservation lands to be characterized by greater demographic rates and persistence probabilities relative to populations not existing on conservation lands (i.e., populations that we were unable to model in our framework). To this end, we did not project the abundance of existing populations not included in our dataset or estimate the formation of new populations outside of conservation lands. While other tortoise populations exist outside of the ones we simulated with our projection model and new tortoise populations may form due to natural dispersal and colonization dynamics, they may occur on lands lacking long-term protection from development, their demographic rates are likely reduced relative to populations on conservation lands, and we did not feel comfortable projecting those populations into the future under assumptions of land management and protection for wildlife conservation. Similarly, we could not estimate the formation of new populations outside of the sites we projected, or the migration of entire populations to new areas, because there is no guarantee that land would be available for populations to form on or migrate to.

Previous demographic models for gopher tortoises have not used immigration parameters (e.g., Tuberville et al. 2009, entire; Folt et al. 2021, entire) and modeled gopher tortoise demography as closed to immigration, perhaps due to the paucity of field estimates of immigration in wild populations. Previous models found no scenarios where populations were stable or increasing, although recent studies have documented situations where stability and population growth are achieved in the field (Folt et al. 2021, p. 624-626; Goessling et al. 2021, p. 141). This discrepancy suggests a disconnect between demographic projections that are largely influenced by apparent survival projections and actual trends occurring in populations, a discrepancy that may be resolved by incorporating immigration during projection analyses. To this end, we incorporated an immigration parameter for local populations and found projections were sensitive to inputs for this parameter. This was supported by the fact that persistence probabilities were sensitive to threats that influenced immigration rates and two scenarios of ‘no immigration’ and ‘high immigration’ produced results that strongly deviated from results of the stressor and management scenarios. Together, these lines of evidence suggest that immigration is an important parameter in gopher tortoise demography that may deserve future attention when studying gopher tortoises in the field and building models of gopher tortoise demography in the laboratory. Due to the uncertainty of true immigration rates, and the use of a small sub-set of populations used in this model relative to the true number of tortoises on the landscape, it is likely that immigration is underrepresented in this model, resulting in uncertainty in future projections.

It is important to note that we included long-term recipient sites in our population projections, although there are several assumptions that we made when including these data. While translocation is successful at removing gopher tortoises from immediate danger due to development, there are still uncertainties about its efficacy, and additional research is needed to inform improvements to translocation methodology. Gopher tortoises are long-lived, slow-growing, and are slow to reach maturity, making it difficult to determine if translocations result in viable gopher tortoise populations without long-term monitoring. Additionally, many of the recipient sites included in this analysis have not reached their permitted capacity, potentially resulting in greater uncertainty in the future condition estimates for these populations.

We modeled some parameters in our simulation exercise as invariant among populations across the species' range, largely for variables which we found lacked substantial data describing geographic variation. For example, we modeled a density-dependent limit on recruitment to the adult age class of 2.0 females/hectare and a fire-return interval of 1–4 years as necessary to create high-quality habitat for tortoises in all populations. However, tortoise populations may have different mechanisms across the species range; in Florida, populations may reach greater densities before density-dependent effects influence life history, and fire may be less important in regulating quality habitat in some areas with deep sandy soils (Hunter and Rostal 2021). More research describing geographic variation in life history, particularly how Florida populations differ from northern populations, would be useful to update and improve the utility of the model framework we used.

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APPENDIX A

Gopher Tortoise Private Landowner Questionnaire

Gopher Tortoise Data Request

To support the development of a Species Status Assessment (SSA) for the gopher tortoise, the U.S. Fish and Wildlife Service (Service) is collecting, compiling, synthesizing, and analyzing the best available science on habitat and management of the species. This form is being used to gather data and information for the gopher tortoise SSA, which will be used to inform the classification decision for the gopher tortoise. Classification decisions are based only on the best available science. Multiple groups have requested additional clarification in the type of information that the Service will need to do the evaluation for this species, and therefore, we are providing this form for you to consider. However, the Service will accept information in any format that you can provide.

Please answer the below questions to the best of your ability. If there is other important information you think we should know about your property, please feel free to provide that in the last question on the form. We appreciate your time and effort! We would appreciate your response by September 15, 2019, if possible, to ensure we have adequate time to consider the information during our status review, but we will accept information throughout the entire process. All data and information submitted to us, including names and addresses, would become part of the administrative record.

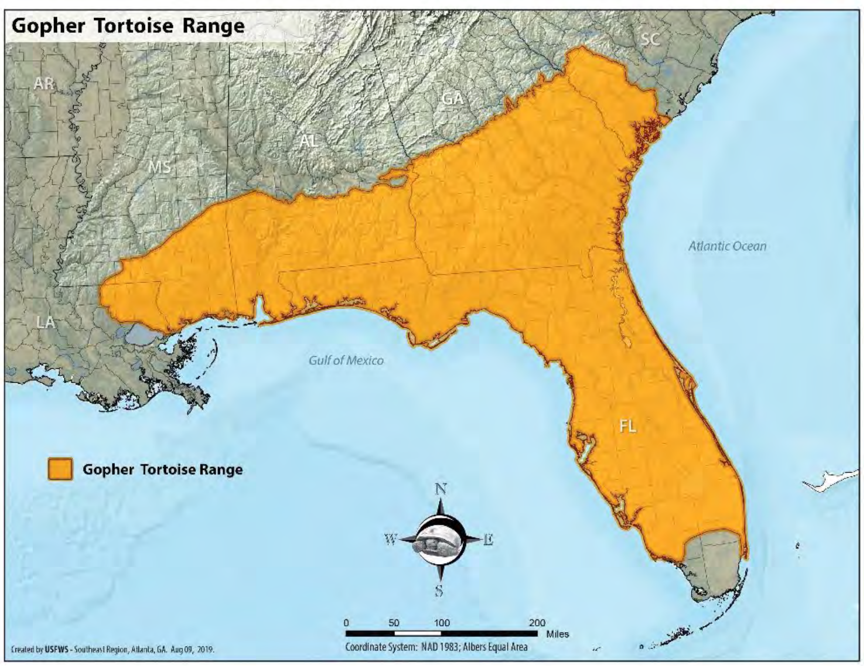
In order to avoid duplication, please submit this form only once (via internet or PDF version). If PDF version, please provide to the Service at gophertortoise@fws.gov or through your respective association to provide to the Service.

Gopher Tortoise Data Request

Basic Property Information

Please provide as much information about your property as you feel comfortable. If you would like to submit additional information or data, please do so at gophertortoise@fws.gov.

State



County (if you own property in multiple counties, please fill out separate forms for each county).

Counties with Gopher Tortoises

Alabama: *Baldwin, Choctaw, Clarke, Marengo, Mobile, Sumter, Washington, Baldwin, Barbour, Bullock, Butler, Choctaw, Clarke, Coffee, Conecuh, Covington, Crenshaw, Dale, Dallas, Escambia, Geneva, Henry, Houston, Lee, Lowndes, Macon, Marengo, Mobile, Monroe, Montgomery, Pike, Russell, Washington, Wilcox*; **Louisiana**: *Livingston, St. John the Baptist, St. Tammany, Tangipahoa, Washington*; **Mississippi**: *Clarke, Covington, Forrest, George, Greene, Hancock, Harrison, Jackson, Jasper, Jefferson Davis, Jones, Lamar, Lawrence, Marion, Pearl River, Perry, Pike, Stone, Walthall, Wayne*; **Georgia**: *Appling, Atkinson, Bacon, Baker, Ben Hill, Berrien, Bleckley, Brantley, Brooks, Bryan, Bulloch, Burke, Calhoun, Camden, Candler, Charlton, Chatham, Chattahoochee, Clay, Clinch, Coffee, Colquitt, Cook, Crawford, Crisp, Decatur, Dodge, Dooly, Dougherty, Early, Echols, Effingham, Emanuel, Evans, Glascock, Glynn, Grady, Houston, Irwin, Jeff Davis, Jefferson, Jenkins, Johnson, Lanier, Laurens, Lee, Liberty, Long, Lowndes, McDuffie, McIntosh, Macon, Marion, Miller, Mitchell, Montgomery, Muscogee, Peach, Pierce, Pulaski, Quitman, Randolph, Richmond, Schley, Screven, Seminole, Stewart, Sumter, Talbot, Tattnall, Taylor, Telfair, Terrell, Thomas, Tift, Toombs, Treutlen, Turner, Twiggs, Ware, Washington, Wayne, Webster, Wheeler, Wilcox, Wilkinson, Worth*; **Florida**: *Alachua, Baker, Bay, Bradford, Brevard, Broward, Calhoun, Charlotte, Citrus, Clay, Collier, Columbia, DeSoto, Dixie, Duval, Escambia, Flagler, Franklin, Gadsden, Gilchrist, Glades, Gulf, Hamilton, Hardee, Hendry, Hernando, Highlands, Hillsborough, Holmes, Indian River, Jackson, Jefferson, Lafayette, Lake, Lee, Leon, Levy, Liberty, Madison, Manatee, Marion, Martin, Miami-Dade, Monroe, Nassau, Okaloosa, Okeechobee, Orange, Osceola, Palm Beach, Pasco, Pinellas, Polk, Putnam, St. Johns, St. Lucie, Santa Rosa, Sarasota, Seminole, Sumter, Suwannee, Taylor, Union, Volusia, Wakulla, Walton, Washington*; **South Carolina**: *Aiken, Allendale, Barnwell, Bamberg, Colleton, Dorchester, Hampton, Jasper*

Is your property subject to a conservation easement?

○ Yes ○ No

Is your property third party certified (e.g., SFI, FSC, ATFS)?

○ Yes ○ No

Do you implement any wildlife conservation or land best management practices?

○ Yes ○ No

Gopher Tortoise Data Request

Gopher Tortoise Habitat Type Information

How many acres of potential gopher tortoise type habitat are on your property? Potential gopher tortoise habitat includes well-drained, sandy soils, and can be found in a variety of habitats such as longleaf pine forests/ sandhills, xeric oak hammocks, scrub, pine flatwoods, dry prairies, coastal dunes, and pastures. This number will be called your “GT Acres”, and can either be an exact number or a high and low estimate.

Which of the following community types best describes your GT acres? (choose all that apply)

- ☐ Pine
- ☐ Hardwood
- ☐ Mixed-pine hardwood
- ☐ Pasture/Open
- ☐ Other

We can describe gopher tortoise habitat suitability as low, moderate, or high depending on the condition of the canopy, mid-story/shrub layer, and herbaceous ground cover. Please estimate the approximate amount of your GT acres that fall in the Low suitability class as described below:

How many acres do you have that meet the Low Suitability as described below?

Description and examples of low suitability

		Metric	
Low	**Dense canopy; uniform stand condition, characterized by minimal herbaceous groundcover**	Pine Basal Area (ft²/acre)	Less than 10 or greater than 105 (ft²/acre)
		Pine Canopy Cover	Less than 10% or more than 85%
		Mid-story Cover	More than 40%
		Native Herbaceous Ground Cover	Less than 20%

Please estimate the approximate amount of your GT acres that fall in the Medium suitability class as described below:

How many acres do you have that meet the Medium Suitability as described below?

Description and examples of Medium suitability

Medium	**Fairly open canopy, with low to dense mid-story/shrub layer so only a few areas have adequate light reaching the ground to support herbaceous groundcover**	**Metric**	
		Pine Basal Area (ft^2/acre)	10 to 20 or 90 to 105
		Pine Canopy Cover	10 to 20 % or 75 to 85%
		Mid-story Cover	30 to 40%
		Native Herbaceous Ground Cover	20 to 30%

Please estimate the approximate amount of your GT acres that fall in the High suitability class as described below:

How many acres do you have that meet the High Suitability as described below?

Description and examples of high suitability

High	Open canopy; minimal shrub/mid-story layer; abundant native herbaceous groundcover	Metric	
		Pine Basal Area (ft^2/acre)	20 to 90
		Pine Canopy Cover	20 to 75%
		Mid-story Cover	Less than 30%
		Native Herbaceous Ground Cover	30 to 98%

Land Management Information

If prescribed fire is used on the GT acres, how many acres are treated with fire? [ ]

If prescribed fire is used on the GT acres, what is the prescribed burning frequency?

- ○ 1 to 3 years
- ○ 3 to 5 years
- ○ 5 to 7 years
- ○ More than 7 years
- ○ Other: [ ]

What other beneficial management practices do you use on your property? check all that apply

- ☐ Herbicide application for hardwood control
- ☐ Roller Chopping
- ☐ Mowing/Mulching
- ☐ Thinning
- ☐ Longleaf planting
- ☐ Invasive species control
- ☐ Marking/flagging burrows before thinning or disruptive practices
- ☐ Other: [ ]

On how many GT acres do you manage mid-story woody vegetation by methods other than prescribed fire (e.g. mechanical or herbicide)?

[ ]

Do you anticipate the land use, management objectives, or fire regime to change in the next 20-30 years?

- ○ Yes
- ○ No

If yes, explain how.

[ ]

Gopher Tortoise Information

Have there been gopher tortoises observed on your property in the last 5 years?

- ○ Yes
- ○ No

Has a complete survey of the property been done?

- ○ Yes
- ○ No

If Yes, what was the type of survey conducted?

- ☐ Line-transect distance sampling
- ☐ 100% survey method
- ☐ Opportunistic
- ☐ Other: __________

What is the estimated number of individual tortoises on your property?

○ 1 to 25	○ 50 to 100	○ 250 or more
○ 25 to 50	○ 100 to 250	○ Unknown

What is the estimated number of tortoise burrows on your property?

○ 1 to 25	○ 50 to 100	○ 250 or more
○ 25 to 50	○ 100 to 250	○ Unknown

Have juvenile gopher tortoises or juvenile burrows (i.e. burrow opening <5 inches) been seen on your property?

◯ Yes

◯ No

No (image NOT of a gopher tortoise burrow)

Examples of juvenile burrows. You can go here (https://www.outdooralabama.com/sites/default/files/GT%20vs%20other%20burrows%20Identification%20Guide%20Handout.pdf) for additional examples.

Anything important you think we should know about your property and conservation practices for gopher tortoises?

APPENDIX B

Gopher Tortoise Population Modelling

Predicting Population Growth of Gopher Tortoises (*Gopherus polyphemus*) under Future Scenarios of Climate Warming, Sea-level Rise, Urbanization, and Habitat Management

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Introduction

In this paper, I describe an analytical framework that integrates predictions from multiple models of future anthropogenic change to: (1) predict future population growth of an imperiled, ecologically significant species, (2) identify stressors with the greatest influence on future population persistence, and (3) support decisions about conservation and management during, for example, a Species Status Assessment for the gopher tortoise (*Gopherus polyphemus*). I reviewed the literature describing gopher tortoise life history and adapted a previously published population model for gopher tortoises (Folt et al. 2021) to estimate population growth and persistence probability of populations while accounting for geographic variation in life history. I expanded the model to link intrinsic factors (demographic vital rates) to four extrinsic anthropogenic factors that are hypothesized to threaten gopher tortoise population persistence (climate warming, sea-level rise, urbanization, and shifts in habitat management). I used published models describing predictions for extrinsic factors in the future to project gopher tortoise demographics under six future scenarios varying in threat magnitude and presence. I performed a regression analysis of model outputs to identify threats that are predicted to have the greatest impact on population persistence.

Methods

I sought to predict population growth and extinction risk for the gopher tortoise in a population viability analysis (PVA) framework. I built a stage-based population model (i.e., Lefkovitch model) (Lefkovitch 1965) and used the model to project population size and structure forward in time with simulations. For the PVA, I conceptualized local population demography of tortoises in a multi-stage, female-only model with two discrete life stages: juveniles and adults (Figure 1). During a given time-step, both stages had a probability of individuals surviving and remaining within the stage, juveniles had a probability of maturing to become adults, and adults had a probability of reproducing and potentially recruiting individuals into the juvenile stage. Individuals that did not survive during a time-step were assumed to have either died or permanently emigrated from the population. I also modeled recruitment into the adult stage by immigration (see below).

Model structure

I used the model structure to predict future abundance of populations across the range of the gopher tortoise using a first-order Markovian process in which adult abundance at time *t* was a function of adult and juvenile abundance at time *t*-1 with vital rates stochastically drawn from parameter distributions:

$$N_t^a = N_{t-1}^a \times \varphi_{t-1}^a + N_{t-1}^j \times \varphi_{t-1}^j \times \tau_{t-1} + N_{t-1}^i, \qquad (1)$$

where *N* is abundance, φ is the apparent annual survival rate, and τ is an annual transition rate from juvenile to adult (i.e., maturation) during each time step *t* (year); superscripts a, j, and i denote adults, juveniles, and immigrants, respectively.

Juvenile abundance at time *t* was a function of juvenile and hatchling abundance at time *t*-1 with vital rates similarly drawn from parameter distributions:

$$N_t^j = N_{t-1}^j \times \varphi_{t-1}^j \times (1 - \tau_{t-1}) + R_{t-1}, \quad (2)$$

where *N* is abundance, φ is survival, τ is the juvenile-adult transition rate, and R is recruitment (below) during each time step t (year).

For individuals to recruit into the juvenile stage, adult females must lay eggs that hatch into offspring and survive until the next survey period (i.e., time step). Therefore, to estimate annual recruitment by reproduction, we modeled the probability of females breeding (PB), the mean number of eggs laid per individual (fecundity; F), the probability of nests surviving predation (NS), the proportion of eggs that are viable and hatch (VE), the probability of eggs being female (PF) and the survival probability of hatchlings through the first year to the next survey period (φ^h) at time *t* (Noon and Sauer 1992). I modeled probabilities (*PB, NS, VE,* PF, φ^h) as beta-distributed random variables, and I modeled fecundity as a log-normal random variable. Together, I then modeled recruitment (R) at time *t* as a product of:

$$R_t = PB_t \times F_t \times NS_t \times VE_t \times PF \times \varphi_t^h, \quad (3)$$

where the superscript *h* denotes hatchling.

Demographic parameters

I sought to construct a baseline population model that approximated demographic conditions experienced by gopher tortoise populations in recent decades across the species' range. However, populations of gopher tortoises experience variation in abiotic characteristics across the species' range, and variation in abiotic characteristics influences demographic rates among populations. At southern latitudes, populations experience significantly warmer mean annual temperature, which may afford greater overall opportunity for thermoregulation, energy acquisition, and metabolism when compared to northern populations. As a result, southern populations of tortoises experience faster growth rates, younger ages of sexual maturity (hereafter, maturity age), and increased clutch size (Mushinsky et al. 1994, Ashton et al. 2007, Meshaka Jr. et al. 2019). Because my goal was to predict population growth and extinction risk of populations across the species' range and predictive population models are most useful when demographic parameters are modeled specific to populations of interest (Ralls et al. 2002), I extended the model to accommodate for geographic variation in demographic rates by estimating parameters specific to the geographic location of populations.

I reviewed the literature for demographic estimates from gopher tortoise populations in the wild (Appendix 1). For parameters thought to vary by abiotic features among sites, I fit linear regression models to estimate relationships between demographic rates and mean annual temperature (hereafter, MAT; degrees C) sourced from the 'WorldClim' database (Hijmans 2020). After testing whether the data met assumptions of parametric statistics, I evaluated whether regression models estimated statistically significant effects of independent variables on response variables with α = 0.05. I used observed statistically significant linear relationships between MAT and demographic rates among populations as a predictive tool to generate mean parameter estimates with error for populations in our predictive modeling framework, given georeferenced data describing MAT at sites. If parameters were not known to vary geographically, I modeled mean values as invariant among populations. In the following paragraphs, I describe how I modeled parameters describing recruitment, maturity age, survival, immigration, and initial population size, respectively; however, all stochastic parameters and the distributions used to model them are summarized in Table 1.

I modeled the proportion of breeding females (oviposition; PB) in a given year as 0.97; this estimate has recently been validated by two independent field studies (Jeffrey Goessling, Eckerd

College, personal communication; Elizabeth Hunter, personal communication). Because fecundity (F) varies widely among populations and is likely driven by a north-to-south latitudinal gradient in temperature (Ashton et al. 2007), I used linear regression to estimate the relationship between MAT and estimates of mean clutch size (F) from the literature and then used regression coefficients to simulate mean values of F for populations, given the geographic location and MAT of a population. I modeled the probability of nests that survive predation (NS) as 0.35 using an estimate from unmanipulated nests (Smith et al. 2013). I modeled the probability of eggs being viable and hatching (VE) as 0.85, an average from a review of field hatching rates (Landers et al. 1980, Rostal and Jones 2002). To account for males (and remove them) during projections, I assumed that sex ratios of eggs were even within populations and modeled the probability of eggs being female (PF) as 0.5. I modeled hatchling survival (φ^h) from nest emergence until the following survey period as 0.13 (0.04–0.34, 95% CI), given results from a meta-analysis of hatchling survival of gopher tortoises (Perez-Heydrich et al. 2012). I modeled mean values of PB, NS, VE, PF, and φ^h as invariant among populations; I modeled F as a function of MAT at local populations using regression coefficients from my analysis of literature values (Table 1). For each recruitment parameter, I modeled parameters using appropriate statistical distributions (below) and randomly estimated the parameter in each year using stochastic draws using estimates of variance associated with parameter estimates (Table 1).

Maturity age also varies along a latitudinal gradient among gopher tortoise populations (Mushinsky et al. 1994, Meshaka Jr. et al. 2019). I used linear regression to estimate the relationship between MAT and maturity age estimates of females from the literature (Table 1); I then used regression coefficients to simulate mean maturity ages for populations, given the population's geographic location and MAT. Given a predicted maturity age for a population, I then calculated the probability that a juvenile will transition to adulthood, τ, during a given year with:

$$\tau = \frac{1}{Maturity\ age - 1}. \quad (4)$$

This formula assumes that all individuals in the juvenile age class at a population have an equal probability, τ, of transitioning to the adult state (i.e., maturing), and that this probability is the inverse of the age of sexual maturity minus one, to account for one year spent as a hatchling.

Survival rates are difficult to measure for gopher tortoises because individuals are long-lived, challenging to recapture, may become unavailable for resurvey by emigrating away from study populations, or may die (e.g., Folt et al. 2021). When individuals disappear from a study population, mark-recapture analyses are often unable to estimate whether individuals died or emigrated away (Williams et al. 2002). To this end, most mark-recapture studies of gopher tortoise seeking to understand survival have estimated apparent annual survival (φ), which is the probability that individuals survived and stayed within a study area. Studies have found φ to vary between adults and juveniles, with adults having higher survival than juveniles (Tuberville et al. 2014, Howell et al. 2020, Folt et al. 2021). I reviewed the literature for apparent annual survival estimates for gopher tortoises (Appendix 1) and performed a linear regression analysis testing for effects of age and MAT on survival. This heuristic analysis confirmed that adults have greater survival than juveniles but failed to recover an effect of MAT on survival; rather, survival is likely most strongly influenced by habitat quality and management at sites (Howell et al. 2020, Folt et al. 2021, Hunter and Rostal 2021). I modeled adult survival (φ^a) as 0.96 and juvenile survival (φ^j) as 0.75, given demographic rates reported from relatively stable populations in Alabama (Folt et al. 2021). I modeled a density-dependent limit on population growth where for each time-step when density increased above 2 females/ha, I prevented recruitment into the adult age class. This was meant to simulate population conditions where juveniles may elect to disperse away from high-density conditions to other populations with lower density, while also enforcing a limit on maximum population size (i.e., carrying capacity). Field studies have estimated tortoise density to range from 0.02–1.50 individuals/ha among northern populations (Guyer et al. 2012) and from 4.2–24.9 individuals/ha in southern Florida. I selected a threshold of 2 females/ha (i.e., 4 tortoises/ha, assuming even sex ratios) as a limit for density dependence because there is a considerable uncertainty when estimating tortoise density and 2 females/ha was a conservative intermediate estimate of maximum density among populations across the species' range.

Gopher tortoises infrequently move long distances from established core home range areas; such movements can result in permanent emigration and immigration into other populations. I implicitly modeled losses to local populations due to emigration because the estimates of apparent annual survival (φ) account for mortality and permanent emigration away from local populations. Given ongoing emigration, local populations that are spatially proximate to other local populations might receive immigrants that bolster population size. While little quantitative information is available describing the frequency or success of immigration, one study found that 2% of adults emigrated from local populations each year (Ott-Eubanks et al. 2003). Given it is unlikely that all emigrants successfully immigrate into another population, I modeled the number of immigrants into local populations as a product of a randomly-drawn, beta distributed, time-varying annual immigration rate (γ; mean = 0.01) multiplied by the total number of adult tortoises in adjacent populations (i.e., landscape population size, N^m; see below) divided by the number of nearby local populations. I constrained γ during each time step such that its randomly-drawn value could never exceed $1 - \varphi^a$. Demographic parameters were modeled as random variables that accounted for both parametric uncertainty and temporal variability. We provide a full description of how the model treated uncertainty below, after describing simulation scenarios and other aspects of the model.

I sought to estimate population growth and extinction risk of tortoise populations across the species' range. To do so, I initialized the model with estimates of population size from populations on protected, conservation lands (e.g., national forests, state forests, state wildlife management areas), military installations, and some private lands across the species' range during the last ten years. Population estimates were collected by a diverse partnership of cooperating state agencies, private organizations, and academic institutions (see Acknowledgments) using burrow surveys burrow scope surveys, and lLine Transect Distance Sampling (LTDS) surveys. Population estimates do not represent an assessment of all local populations of tortoises that exist in southeastern North America, but rather represent information that was provided by partners through much of the species' range. Most population estimates came from assessments of local populations on lands managed for the conservation of biodiversity or natural resources.

I initialized starting population size using population estimates derived from data collected using burrow surveys, burrow scope surveys, and LTDS surveys. Burrow surveys involved a team of researchers searching a site to count the number of gopher tortoise burrows that were present and detected at a given site. Only burrows that were clearly identifiable as being constructed by a tortoise were counted. Because gopher tortoises often construct and/or use more than one burrow per individual, I used a published estimate of the relationship between the number of tortoises and burrows among six populations (0.4 tortoises/burrow; Guyer et al. 2012) to estimate the number of tortoises at sites from burrow count data. The burrow survey method assumes the tortoise-per-burrow estimate from Guyer et al. (2012) is generalizable to tortoise populations range-wide and that no burrows are missed during surveys; this method likely underestimates total population size, because small burrows are undetected (Gaya 2019). Burrow scope surveys used the same field survey methods as burrow surveys but included an additional step of using a burrow-scope camera to verify the presence of tortoises in burrows. Burrow scope surveys attempted to directly estimate abundance of local populations by counting individuals directly; this method assumes that all tortoise burrows were detected at sites and that only a single tortoise is present in a burrow. Burrow scope surveys also likely underestimate total population size because small burrows are difficult to detect during field surveys.

LTDS surveys are a population estimation method where a research team walks transects through habitat, observes tortoise burrows, searches the burrow for a tortoise with a burrow scope, records the spatial location of occupied tortoise burrows, and measures the perpendicular distance of each occupied burrow to the transect line. Invariably, burrows and individuals are imperfectly sampled, because detection probability of burrows is less than one. However, analysis of the LTDS survey data generates functions estimating the decay of the detection rate with increasing distance from the transect line, and this detection function can then be used to account for undetected burrows and therefore estimate the total number of occupied burrows in the search area (i.e., total population size). I note that because juvenile tortoises have small burrows that are difficult to observe, detection of juveniles during LTDS is lower than adults, and LTDS surveys may underrepresent smaller size classes in the population estimates.

Population estimates from surveys allowed us to parameterize initial population size during simulated projections of populations. However, many population estimates were measured at spatial scales that may not necessarily reflect the target unit for demographic projection models, the population, but rather express the number of individuals that exist across a larger spatial scale (e.g., a property boundary) that may functionally represent more than one local populations. Using spatial survey data associated with population estimates, I sought to operationally identify populations at two spatial scales: local populations and landscape populations. I defined local populations as geographic aggregations of individuals that interact significantly with one another in social contexts that make reproduction significantly greater between individuals within the aggregation than with individuals outside of the aggregation (*sensu* Smallwood 1999). I operationally delimited local populations by identifying aggregations of individuals or burrows where individuals were clustered together within a 600 m buffer to the exclusion of other adjacent individuals or burrows. Studies of gopher tortoise populations in Alabama (Conecuh National Forest; C. Guyer, unpublished data), Georgia (Ft. Stewart

Army Reserve; E. Hunter and D. Rostal, unpublished data), and Florida (Boyd Hill Nature Preserve; J. Goessling and G. Heinrich, unpublished data) have found that >80% of gopher tortoise movements within and among years were less than 500 m. I selected a 600 m distance to buffer populations to encompass typical movement distances and adjacent habitat around surveyed populations that might include tortoises. I assumed that unsuitable habitat for tortoises (i.e., interstates, freeways, and expressways (HPMS 2019); major rivers and lakes (Sciencebase.org); wetlands, and highly urbanized areas as determined by visual inspection with ESRI imagery)e.g., major rivers and lakes, wetlands, paved roads [interstates, freeways, and expressways], urban areas) were unsuitable for tortoise movement or survival and considered those strict barriers when delimiting local populations. Adjacent local populations connected to each other by suitable habitat through which dispersal might occur formed a landscape population. I operationally delimited landscape populations by identifying local populations connected by suitable habitat within a 2.5 km buffer around each local population or any single population that was isolated from other populations by greater than 2.5 km. I received some population estimates from properties that were delimited to have two or more local populations of tortoises; in these instances, I multiplied the population estimate (and confidence limits) by the area of each delimited local population and divided by the total survey area of the original survey. I assumed that population estimates being delimited into two or more local populations through this process would have even population densities and this process spread the population assessment evenly among local populations delimited by in the dataset.

The process of delimiting local populations and landscape populations resulted in a dataset of 626 local populations that formed 244 landscape populations; Florida had the greatest number of local (314) and landscape populations (152), followed by Georgia (151, 63, respectively), Mississippi (94, 7), Alabama (54, 14), Louisiana (7, 5), and South Carolina (6, 4). I used population estimates from local populations to parameterize initial population size of adults (N^a) and juveniles (N^j) during simulated population projections. I assumed a 1:1 sex ratio and a 3:1 adult:juvenile ratio in populations, given observations from stable local populations in Alabama (Folt et al. 2021), and used the ratios to isolate and separate the female population into juvenile and adult components.

Modeling threats

Climate warming – The world is rapidly changing in the 21st century, and numerous anthropogenic factors threaten the stability and persistence of natural ecosystems worldwide. I sought to model how predicted future changes to abiotic and biotic features in southeastern North America may threaten future population growth and viability of gopher tortoises. I met with scientists with expert knowledge in both gopher tortoise population biology and habitat management and identified a series of factors that experts considered to have high likelihood of influencing tortoise demographics in the future (hereafter, threats). Using the list of threats, I reviewed the literature to identify research describing quantitative effects of how threats (or similar mechanisms) influence specific demographic parameters in the conceptual model for tortoises. Here, I describe hypotheses for how four threats (climate warming, sea-level rise, urbanization, and climate-change effects on habitat management) may influence tortoise demographics, and how I used quantitative estimates of the threats from the literature to parameterize and simulate how threats may influence future population growth and viability of gopher tortoises.

Climate change is predicted to drive warming temperatures and seasonal shifts in precipitation across southeastern North America (Dalton and Jones 2010). Of these two effects, warming temperatures may have the greater impact on gopher tortoises, because tortoise demography is known to be sensitive to temperature gradients across the species' range. Specifically, maturity age and F vary along a north-south latitudinal gradient, where warmer, southern populations have faster growth rates, younger maturity ages, and increased fecundity relative to cooler, northern populations (Ashton et al.

2007, Meshaka Jr. et al. 2019). As climate warming increases temperatures in the region, individuals in populations may experience more favorable conditions for growth and reproduction across the species' range. Because no studies have linked tortoise growth or fecundity to interannual or interpopulation variation in precipitation, it seems less likely that climate-driven shifts in precipitation will influence tortoise demography. I modeled how climate warming may influence gopher tortoise demography by using the estimated linear relationships of MAT with maturity age and F (above) to predict how warming temperatures experienced by populations in the future will drive concurrent changes in demography. For each population, I extracted historic estimates of MAT using the 'WorldClim' database (Hijmans 2020) and then simulated step-wise climate-warming effects on MAT each year in the future where warming rates were parameterized by three treatments of climate warming: (1) a 1.0 °C increase in MAT over the next 80 years, (2) a 1.5 °C increase in MAT over the next 80 years, and (3) a 2.0 °C increase in MAT over the next 80 years (IPCC 2013). Each year in the future, I used simulated changes in MAT to calculated mean maturity age and F at sites. This analysis assumes that: (i) all local populations will respond homogeneously to warming temperatures, and (ii) there are no potential climatic ceilings that would limit growth and reproduction.

Habitat management – Through much of its range, gopher tortoises prefer upland habitat with open canopy, sparse midstory, and an understory plant community that provides diverse food sources (Aresco and Guyer 1999, Birkhead et al. 2005, McCoy et al. 2013, Bauder et al. 2014, Nussear and Tuberville 2014). Prescribed fire is the most common management technique to maintain high-quality, open habitat for gopher tortoises (Landers and Speake 1980, Diemer 1986, Yager et al. 2007, Ashton et al. 2008); however, when fire is not present in sufficient intervals or intensity to maintain open habitat on the landscape, apparent survival of gopher tortoises decreases (Hunter and Rostal 2021), potentially to levels that are insufficient for maintaining population viability (Folt et al. 2021). However, wildlife managers tasked with maintaining high-quality upland habitat for gopher tortoises and other fire-dependent upland plant and animal species (Guyer and Bailey 1993) may be challenged because regional climate warming may make habitat management with prescribed fire more difficult to accomplish. Managers require suitable fuel and weather conditions (e.g., relative humidity, temperature, wind speed; i.e., the 'burn window') to facilitate manageable fire behavior that will accomplish intended goals while limiting risk toward human communities. However, climate-change models predict the availability of burn window conditions to shift over future decades, with available conditions for fire management increasing in the winter but decreasing in the spring and summer (Kupfer et al. 2020); summed together, seasonal shifts in the burn window conditions will decrease overall opportunity for management with prescribed fire. If managers become limited in the use of prescribed fire, resulting decreases in habitat quality may drive decreases in gopher tortoise survival (Hunter and Rostal 2021). I modeled how habitat management influences gopher tortoise population growth by modeling habitat management of populations and linking the frequency of management to adult survival. I assumed that a baseline fire-return interval (FRI) of 1–4 years (mean = 2.5 years) maintains high-quality habitat for gopher tortoises (Guyette et al. 2012, Crawford et al. 2020) and then modeled the probability that a population is burned during a given year (burn probability; BP) as the inverse of the fire-return interval:

$$BP_t = \frac{1}{FRI}. \tag{5}$$

For example, an intended two-year FRI for a population would yield a BP of 0.5. Next, using historic baseline data describing average seasonal burn opportunity across southeastern North America (Kupfer et al. 2020), I modeled the number of available burn days (i.e., days within the burn window) in winter (January–February; W), spring (March–May; Sp), and summer (June–July; Su) as a product of the total days per season (59, 92, and 61 days, respectively) and the stochastically-drawn percentage of days historically available for burning (0.766, 0.800, and 0.645, respectively). I modeled four treatments for how the number of days available for prescribed fire may change in the future (Kupfer et al. 2020): (1) prescribed fire use will decrease consistent with climate shifts predicted by RCP4.5 ('decreased fire'), (2) prescribed fire use will decrease with climate predictions RCP8.5 ('very decreased fire'), (3) prescribed fire use will increase opposite of the effect predicted by RCP4.5 ('increased fire'), and (4) prescribed fire use will remain at current levels ('status quo'). For each treatment, I modeled effects of climate change on the percentage of available burn days over the next 80 years using average effects from across southeastern North America (Kupfer et al. 2020): 0.016 increase in winter, 0.040 decrease in spring, and 0.239 decrease in summer ('decreased fire' treatment); 0.030 increase in winter, 0.105 decrease in spring, and 0.436 decrease in summer ('very decreased fire' treatment); 0.016 decrease in winter, 0.040 increase in spring, and 0.239 increase in summer ('increased fire' treatment), and no effects on burn days ('status quo' treatment). The third and fourth scenarios could result if habitat managers can offset effects of climate change by benefiting from methodological advances in fire management or by using alternative methods rather than prescribed fire, such as mechanical or chemical treatments, to achieve similar management goals. We extracted all mean values and predicted effects from the text in Kupfer et al. (2020).

For the first three treatments, I used the predicted effects to model stepwise changes in the percentage of available burn days per season in each year. Assuming that changes in total burn opportunity result in changes in total burn frequency, I modeled BP in each year t as a product of the function of the inverse of FRI and predicted changes in the total number of burn days available due to climate change:

$$BP_t = \frac{1}{FRI} * \frac{W_t + Sp_t + Su_t}{W_1 + Sp_1 + Su_1}. \qquad (6)$$

where subscript 1 is the first year of the projection and t is each year ranging from 1 to the last year in the projection. For the fourth treatment, I modeled no effects of climate on the number of available burn days per year; burn probability did not vary by fixed effects through time in an attempt to simulate unvarying management ability in the future. I used estimates of BP to simulate whether a population was burned in each year. Apparent annual survival probability of female gopher tortoises is highest in the first year after a site is burned, but declines by 0.027 each year without fire (Hunter and Rostal 2021). During each year of projections, I simulated adult survival as a stochastic effect of the number of years since last burn (YSB):

$$\varphi_t^a = 0.96 - 0.027 \times YSB. \tag{7}$$

Because Hunter and Rostal (2021) only estimated the effect of year-since-burn on survival of adults up to three years since burn, I did not extrapolate this effect beyond 3 years or to juveniles. This formulation assumes that: (i) changes in the number of days available to burn result in changes in burn frequency (i.e., management is limited by available burn days), the season that a burn is performed does not influence habitat quality (but see: Aresco and Guyer 1999, Yager et al. 2007), and (iii) effects of YSB on survival from Georgia (Hunter and Rostal 2021) is generalizable to all populations of gopher tortoises.

Urbanization – Human development of the landscape (i.e., urbanization) threatens terrestrial wildlife communities in the southeastern United States, including gopher tortoise populations that often rely on upland habitats that are popular sites for urban development or agriculture. While the local tortoise populations I modeled are largely on conservation lands intended for wildlife conservation, urbanization threatens to surround these lands, disrupt habitat connectivity, and decrease metapopulation dynamics that maintain connectivity and gene flow both among local populations and within landscape populations. Additionally, urbanization can disrupt habitat management by decreasing the ability of managers to use prescribed fire. I sought to model effects of urbanization pressure on tortoise populations by linking urbanization predictions from the SLEUTH urbanization model (Clarke 2000) to habitat management of local populations with prescribed fire and with baseline immigration rates (γ) of tortoises across landscape populations. First, I modeled an effect of urbanization on habitat management by making BP a function of each population's distance to the nearest urban area ($dNUA$). Specifically, I assumed that local populations immediately adjacent to urban areas (distance < 0.1 km) are unable to manage with prescribed fire and forced BP to 0, management is uninfluenced for populations far from urban areas (> 3.2 km; no effect on BP), and management of populations between 0.1–3.2 km from an urban area experience a negative effect on fire management with BP declining as a linear function of the population's proximity to the urban area (i.e., populations closer to urban areas experience less prescribed fire). For populations between 0.1–3.2 km of an urbanized area, I added an additional term to Equation 6 to estimate BP as a consequence of $dNUA$ at time t:

$$BP_t = \frac{1}{FRI} * \frac{W_t + Sp_t + Su_t}{W_1 + Sp_1 + Su_1} * \frac{dNUA_t}{3.2}. \quad (8)$$

To model effects on urbanization on migration dynamics among local populations within landscape populations, I first estimated the total area (A; ha) and urbanized area (UA; ha) within landscape populations in year 2020 using the SLEUTH model. Assuming that tortoises cannot survive and/or move through urbanized areas but can survive and move in unurbanized areas, I estimated the initial proportion of suitable dispersal habitat (PDH_i) for tortoise dispersal in landscape populations at the start of population projections as:

$$PDH_i = \frac{A_i - UA_i}{A_i}. \quad (9)$$

I next estimated future urbanization and its effect on dispersal habitat for tortoises using the SLEUTH model predictions for 40, 60, and 80 years in the future. I estimated predicted urbanized area in the future (UA_f; ha). Similar to Equation 9, I estimated the future proportion of suitable dispersal habitat (PDH_f) around populations in the future:

$$PDH_f = \frac{A_i - UA_f}{A_i}. \quad (10)$$

I calculated the predicted change in proportion of dispersal habitat (ΔPDH) due to future urbanization for landscape populations by taking the difference between PDH_f and PDH_i. For each year $t \geq 3$ during population projections, I modeled the number of adult immigrants (N_t^i) into local populations in each year as a function of the number of individuals in the landscape population available for immigration to the local population during the previous year (N_{t-1}^{mp}), the total number of local populations in the landscape population (N^{lp}), γ_t, PDH_i, ΔPDH, and the time-step in the future:

$$N_t^i = \frac{N_{t-1}^{mp}}{N^{lp} - 1} * \gamma_t * \left[PDH_i + \Delta PDH * \frac{t}{total}\right], \quad (11)$$

where t is the year in the population projection, ranging from t_i = 1 to the total projection interval ($total$). I estimated N^{mp} at t = 1 by summing the starting population size of all local populations in the landscape population and subtracting the abundance of the focal population, because individuals from the focal population would be unavailable for immigration into their own population. I assumed that population growth of the landscape population term would change through time similarly to that of the local population being modeled in any instance; therefore, I modeled changes in N^{mp} through time as a function of changes in abundance of the local adult population size during the previous time step, $\frac{N_t^a}{N_{t-1}^a}$, during year 3 and beyond. I next estimated the distance of each local population to the nearest urban area currently and in the future using the SLEUTH model. I measured distance to urban area from the geometric center of local populations to the edge of the nearest neighbor urban area. I estimated predicted effects of urbanization on local and landscape populations by modeling three treatments from the SLEUTH urbanization model that corresponded to different probability thresholds of urbanization: (1) a low urbanization treatment where future urbanization was limited to cells with urbanization probability ≥0.95, (2) a moderate urbanization treatment with urbanization predicted by probability ≥0.50, and (3) a high urbanization treatment with urbanization probability ≥0.20. I assumed that: (i) immigration was limited to adults and that no juveniles successfully migrate among populations, and (ii) immigrants cannot survive or move through urbanized areas (e.g., due to road mortality) but survive perfectly while moving through unurbanized areas.

Sea-level rise – Warming temperatures across Earth are causing the polar ice caps to shrink, release freshwater into the oceans, and drive substantial increases in oceanic levels worldwide (hereafter, sea-level rise) (IPCC 2013). In southeastern North America, sea-level rise is predicted to influence low-lying coastal habitats by causing floods, inundation, and shifts in land-cover types (Marcy et al. 2011). Because gopher tortoises are a terrestrial species and not suited to wetland habitats, sea-level rise may negatively affect gopher tortoise populations in low-lying coastal areas, such as coastal sand-dune environments (Blonder et al. 2020). Projected sea-level rise scenarios provide a range of coastal inundation scenarios that vary in severity. I modeled effects of sea-level rise on tortoises using three scenarios of sea-level rise predicted by NOAA, the 'intermediate-high', 'high', and 'extreme' scenarios, which correspond to predictions from two of the most likely global emission scenarios, RCP6.0 and RCP8.5 (IPCC 2013, NOAA 2020). Local predictions for the two scenarios are available from USGS sea-level monitoring stations across the southeastern United States, providing estimates of sea-level rise for stations at decadal time steps in the future to year 2100. I modeled three treatments of sea-level rise using predictions from NOAA: (1) the 'intermediate-high' scenario derived from RCP6.0, which predicts ca. 1.83 m of sea-level rise over the next 80 years, (2) the 'high' scenario which predicts 2.55 m of sea-level rise over the next 80 years, and (3) the 'extreme' scenario derived from RCP8.5, which predicts 3.16 m of sea-level rise over the next 80 years (NOAA 2020). I modeled sea-level rise effects on populations in two ways. First, assuming that gopher tortoise populations cannot persist when oceanic levels encroach too close upon their habitat, I simulated decreasing elevation of tortoise populations due to sea-level rise. I extracted historic estimates of elevation above sea level (asl; in m) using the centroid geographic coordinates of each local population using the 'WorldClim' database (Hijmans 2020). Given the total predicted sea-level rise of each treatment over the next 80 years, I simulated incremental sea-level rise at each population in each year in the future and subtracted this incremental oceanic rise from the site's elevation through time. When the site elevation of populations decreased to less than 2 m asl, I considered the populations functionally extirpated and forced the population size vectors, N^j and N^a, to zero. Second, I assumed that habitat inundated by sea-level rise adjacent to local populations would decrease connectivity and dispersal dynamics of individuals among populations within landscape populations. I used spatial predictions from NOAA to estimate future inundation area due to sea-level rise for each landscape population, and then I modeled γ to decline as a function of decreasing habitat available for dispersal at the landscape scale. Assuming that tortoises cannot survive and/or move through inundated areas but can survive and move in inundated areas, I extended Equation (11) to subtract the proportion of area lost to sea-level rise (SLR) from the proportion of dispersal habitat (PDH_i) in each year:

$$N_t^i = \frac{N_{t-1}^{mp}}{N^{lp} - 1} * \gamma_t * \left[PDH_i + \Delta PDH * \frac{t}{total} - SLR * \frac{t}{total}\right], \tag{12}$$

The analysis of sea-level rise effects assumes that: (i) sea-level rise throughout southeastern North America will be homogeneous and characterized by NOAA predictions derived from data from Ft. Myers, Florida, (ii) populations less than 2 m asl are unable to persist, and (iii) populations are unable to migrate away from sites because coastal areas are often heavily developed and there is no guarantee that adjacent properties would be available for entire populations to migrate.

Population projection structure

I conceptualized and mathematically articulated different scenarios for how four factors (climate warming [3 treatments]; habitat management [4 treatments]; urbanization [3 treatments]; sea-level rise [3 treatments]) might influence future population growth of gopher tortoises. However, factors of global change are not independent; rather, most factors that I considered depend on other factors (e.g., sea-level rise is a consequence of climate warming). To understand how tortoise populations will respond to scenarios with multiple concurrent factors, I created a set of six scenarios with varying levels of threat magnitude and combination (Table 2). Specifically, I created three models with different levels of stressors (low stressors, medium stressor, and high stressors) that experienced habitat management consistent with contemporary target management goals. I then used the medium stressor values and built three additional models that varied in habitat management treatments, ranging from 'more management' conditions to worsening ('less management') and much worse ('much less management') conditions (Table 2). The three stressor models were meant to estimate the effects of uncertainty in unmanageable future stressors (climate warming, sea-level rise, urbanization), while the management models were meant to estimate the effects of uncertainty in actionable management practices (e.g., habitat management).

To encompass uncertainty in future states of risk factors and scenarios, I projected population growth for each local population under each of the six model scenarios using a stochastic projection uncertainty structure that accounted for scenario uncertainty, geographic variation among populations, parametric uncertainty, and temporal stochasticity (Figure 2). For each scenario, I parameterized certain stochastic variables specific to the scenario and then projected gopher tortoise populations across the species' range into the future. For each population, I specified mean demographic rates specific to the MAT of the population's geographic location (Table 1) and then simulated future population trajectories with 100 replicates each projected 80 years into the future. During simulations, I applied an uncertainty structure that accounted for both parametric uncertainty (among replicates) and temporal stochasticity (within replicates; McGowan et al. 2011). For each replicate, I drew mean values (and an associated error term) to model parametric uncertainty; I then modeled temporal stochasticity by drawing stochastically from the mean (given its error) during each time step within the replicate. I simulated parameters by drawing replicate-level means stochastically from either beta distributions (e.g., probabilities) with shape parameters calculated from mean and standard deviation estimates (Morris and Doak 2002), log-normal distributions (e.g., counts), or binomial distributions (e.g., probabilities simulating discrete events). I projected populations 80 years into the future because this interval overlapped with the maximum duration of future predictions of the climate, urbanization, and sea-level rise models that I used and the interval also encompassed ca. two generations of gopher tortoises (B. Folt, pers. obs.). I felt uncomfortable making predictions past 80 years into the future because of uncertainty among models and parameters.

Little to no data exist describing gopher tortoise immigration rates, γ, in wild populations. Given uncertainty associated with this parameter, I sought to include a sensitivity analysis to understand the effects of γ on our results. I crafted three additional scenarios: a ‘no immigration’ scenario with $\gamma = 0$, a ‘high immigration’ scenario with $\gamma = 0.02$, and a ‘very high immigration’ scenario with $\gamma = 0.4$. I simulated these scenarios with stressor and habitat management values from the ‘medium stressors’ scenario with a projection interval of 80 years, and I compared the resulting immigration scenarios to the ‘medium stressors’ scenario results that were simulated with $\gamma = 0.01$.

To understand redundancy, resiliency, and representation of the gopher tortoise in the future, I used the population projections to estimate future changes in tortoise populations under each of the six scenarios (Table 2). I assessed resiliency by measuring the predicted population rate of change in the total number of individuals, local populations, and landscape populations in the future relative to current conditions. I summarized population trends by estimating population growth rate (λ), a metric that describes change in population size as increasing ($\lambda > 1.00$), stable ($\lambda \sim 1.00$), or decreasing ($\lambda <$

1.00) over a projection interval; I measured population growth rate of total population size (N^{total}), the number of local populations (N^{p}), and the number of landscape populations (N^{m}) across the species' range during the projection interval. I report changes in population size (total, local, or landscape populations) with λ values or by expressing λ values as percent increases or decreases from initial current population size during the projection interval (e.g., a λ = 1.25 is a 25% increase; λ = 0.66 is a 34% reduction), and I report ranges of λ values among the six scenarios. I assessed the resiliency of future populations to changing environments by estimating extinction risk. Within populations, I evaluated extinction risk with a quasi-extinction probability (P_e), where I estimated P_e by the proportion of simulations resulting in < 3 females alive at the end of the simulation period. I chose < 3 females as a threshold to approximate functional extinction because populations with fewer than three females are extremely like to be inbred (Chesser et al. 1980, Frankham et al. 2011). For each population, I estimated persistence probability (P_p) as 1–P_e, and then I used P_p to categorize populations as 'extremely likely to persist' ($P_p \geq 0.95$), 'very likely to persist' ($0.80 \leq P_p < 0.95$), 'more likely than not to persist' ($0.50 \leq P_p < 0.80$), and 'unlikely to persist' (i.e., extirpated; $P_p < 0.50$). I then took a random draw from a Bernoulli distribution with $p = P_p$ for each population to simulate the likely number of populations predicted to persist at the end of the projection; I summarized this simulation with the median (95% CI) of 1000 replications. For each landscape population, I estimated resiliency by selecting the constituent focal population with the greatest persistence probability and used that value to categorize landscape population persistence and simulated landscape population survival by drawing from a Bernoulli distribution in the future. I evaluated how representation is predicted to change in the future by examining how population growth of total population size (number of individuals), number of populations, and number of landscape populations will vary by the five analysis units across the species' range. For each scenario, I summarized the results among all populations across the species' range, but also by analysis units (five units) and state (six states: Alabama, Florida, Georgia, Louisiana, Mississippi, South Carolina).

My demographic model for gopher tortoises included biotic, abiotic, and anthropogenic effects on demography. To understand the relative importance of how each hypothesized factor contributed to population persistence among the 626 populations modeled, I used model outputs from each scenario projected 80 years into the future and regressed P_p of populations by hypothesized fixed effects. Specifically, I built a generalized linear model where I evaluated how biotic (initial population size, number of populations per landscape population), abiotic (population area, elevation, latitude), and anthropogenic (sea-level rise, urbanization, management level) factors influenced population persistence; I fit the model with a binomial distribution to accommodate a response variable with values ranging between 0–1. To simplify the model, I treated management as a continuous variable with four values: more management (1), status quo (0), less management (-1), and much less management (-2). I evaluated statistical significance of mixed-effects model parameters using α = 0.05 and I reported the size of statistically significant effects using odds ratios.

I performed all analyses in the statistical program R (R Core Team 2018).

Results

Linear regression analysis of three demographic parameters reviewed in the literature (fecundity, maturity age, and apparent annual survival probability) found that fecundity and maturity age vary significantly by MAT across the species’ range (Figure 3). For each 1 °C increase in MAT, I found that maturity age decreased by 1.41 years (0.18–2.62, 95% CI), which was a statistically significant effect (P = 0.029). For each 1 °C increase in MAT, I found that fecundity increased by 0.48 eggs per clutch (0.24–0.72, 95% CI), which was statistically significant (P < 0.001). I used linear functions describing geographic variation in demographic rates to randomly simulated mean fecundity and age of maturity for each population during simulations, given the patterns of MAT at each population's location (Table 1).

I simulated population growth of an estimated 70,600 individual (female) gopher tortoises comprising 626 local populations and 244 landscape populations in the current conditions. Population projections under six scenarios of future change during 40, 60, and 80-year projection intervals predicted declines in the number of gopher tortoise individuals, local populations, and landscape populations of gopher tortoises (Table 3). Relative to current levels of total population size, predictions for total population size suggested declines by 2060 (λ = 0.65–0.67 among scenarios; i.e., 33–35% declines), 2080 (λ = 0.66–0.70 among scenarios; 30–34% declines), and 2100 (λ = 0.67–0.72 among scenarios; i.e., 28–33% declines). The six scenarios varied little in their effects on the total number of individuals, local populations, and landscape populations; but scenario effects become more magnified in each successive timestep. However, 95% confidence intervals (CI) for predictions of λ all overlapped with 1.00 in all scenarios and timesteps, indicating significant uncertainty in predictions for each scenario at each projection interval. Among the simulated populations, the number of local populations and landscape populations also were predicted to decline in each projection interval (Table 3). Declines in local populations and landscape populations were modest at the 40-year timestep (47–48% and 25–27% declines among scenarios, respectively) but were exacerbated at the 60-year (60–61% and 41–43% declines, respectively) and 80-year (68–70% and 53–57% declines, respectively) timesteps. Scenarios did not vary strongly in their effect on the predicted number of persisting local populations and landscape populations within each projection interval.

Categorization of populations by persistence probability revealed finer-scale variation of how scenarios varying in magnitude of stressors and management influenced persistence probability of populations (Table 4). Among the three projection intervals, the 'low stressors' scenario tended to predict higher percentages of Extremely Likely Extant populations and lower percentages of Unlikely

Extant (i.e., Extirpated) populations relative to the 'medium stressors' and 'high stressors' scenarios. Similarly, the 'more management' scenario tended to predict higher percentages of Extremely Likely Extant populations and lower percentages of Unlikely Extant (i.e., Extirpated) populations relative to the 'less management' and 'much less management' scenarios. Figure 5 illustrates persistence probabilities among populations and landscape populations predicted by the 'less management' scenario.

Changes in the number of individuals, local populations, and landscape populations varied by analysis unit and state (Appendix 2, Appendix 3). Among the five analysis units projected 80 years into the future, units 1, 3, and 5 were predicted to decline overall, with mean λ values ranging between 0.60–0.73, 0.47–0.49, and 0.52–0.58 among scenarios for each unit, respectively (i.e., 27–40%, 51–53%, and 42–48% declines, respectively); however, 95% CI of λ overlapped with 1.00 in all scenarios for each of the three units, indicating uncertainty in future abundance. Unit 4 was predicted to experience more modest declines in total abundance (λ = 0.86–0.98; i.e., 2–14% decrease), but 95% CI of λ also overlapped 1.00, indicating uncertainty in predicted future population growth. Alternatively, total abundance in Unit 2 was predicted to increase substantially (λ = 2.37–2.53; i.e., 137–153% increase); 95% CI of λ did not overlap 1.00, indicating a significant predicted increase in population size. Scenarios predicted substantial declines in the number of local populations among all units. Predicted reductions in populations were greatest in Unit 1 (λ = 0.22–0.23), Unit 2 (λ = 0.23–0.26), and Unit 5 (λ = 0.28–0.30), and slightly weaker (but still strong) in Unit 3 (λ = 0.37–0.39) and Unit 4 (λ = 0.39–0.41). The number of landscape populations was predicted to decline among all scenarios in each analysis unit, with the strongest loss of landscape populations in Unit 5 (λ = 0.36–0.41 among scenarios) and the weakest loss of landscape populations in Unit 3 (λ = 0.48–0.53 among scenarios).

Among the six states, total population size was predicted to decline in four states (Florida, Georgia, Mississippi, South Carolina) and increase in two (Alabama, Louisiana; Appendix 3; e.g., Figure 4). The number of local populations and landscape populations were predicted to decline among all scenarios for all states. In South Carolina, reductions in the number of individuals and populations were predicted to be particularly strong, where scenarios predicted substantial declines in individuals (λ = 0.03 among all scenarios; i.e., 97% declines), local populations (λ = 0.17 among all scenarios; i.e., 83% declines), and landscape populations (median λ = 0 among all scenarios; i.e., no remaining landscape populations). Similarly, Louisiana was predicted to lose all local populations and landscape populations except for one by 2100; however, growth of a single surviving population/landscape population caused the total population size to increase in the state during the projections. Similarly, Alabama was predicted to experience an 85–87% reduction in local populations (λ = 0.13–0.15 among scenarios), but predicted increases in the number of individuals in surviving populations caused predictions for the number of individuals in the state to increase substantially over the next 80 years. Mississippi was projected to lose 40–54% of total population size and 77–78% of local populations, but while maintaining 71% of its landscape populations. Predicted changes in the number of populations for Florida and Georgia were similar, with the number of local populations declining 66–68% and 61–62% among scenarios and landscape populations declining 52–55% and 52–57% among scenarios for each respective state (Appendix 3).

I found that model predictions were highly sensitive to input values for immigration rate, γ (Table 5). The population declines predicted by the 'medium stressors' scenario were exacerbated substantially when simulated with γ = 0; conversely, elevated values for γ produced population projections that substantially increased the total population size (overall λ > 1.00) and decreased declines in populations and landscape populations.

Regression analysis of how abiotic, biotic, and anthropogenic factors influenced persistence probability of local populations found support for significant effects of initial population size, number of populations per landscape population, area, elevation, latitude, sea-level rise, urbanization, and prescribed fire on persistence probability. With each 50-female increase in starting population size, populations were 1.029 (1.027–1.03; 95% CI) times as likely to persist, which was statistically significant ($P < 0.0001$). With each 1 local population increase in the landscape population, local populations were 0.987 (0.986–0.987; 95% CI) times as likely to persist (i.e., 1.013 times less likely), which was statistically significant ($P < 0.0001$). For each 500-ha increase in area, populations were 1.002 (1.001–1.003; 95% CI) times as likely to persist, which was statistically significant ($P = 0.044$). With each 10-m increase in elevation, populations were 0.901 (0.899–0.904; 95% CI) times as likely to persist (i.e., 1.109 times less likely), which was statistically significant ($P < 0.0001$). For each 0.5 degree increase in latitude, populations were 1.122 (1.119–1.125; 95% CI) times as likely to persist, which was statistically significant ($P < 0.0001$). With each 0.01 proportional loss in landscape area due to sea-level rise, local populations were 0.57 (1.67–1.82; 95% CI) times as likely to persist (i.e., 1.747 times less likely), which was statistically significant ($P < 0.0001$). With each 0.1 proportional loss in landscape area due to urbanization, local populations were 0.96 (0.955–0.965; 95% CI) times as likely to persist (i.e., 1.042 times less likely), which was statistically significant ($P < 0.0001$). With each categorical increase in fire management, local populations were 1.021 (1.014–1.029; 95% CI) times as likely to persist, which was statistically significant ($P < 0.0001$).

Discussion

I synthesized a large literature describing gopher tortoise life history and built a predictive population model that accounted for geographic variation in demography to estimate growth of populations across the species range. I then identified a series of stressors (climate warming, sea-level rise, urbanization, and habitat management) that have been hypothesized to have current and future negative effects on gopher tortoise populations; then, using estimates of stressor effects on tortoise demography and/or reasonable assumptions, I linked stressors to specific demographic rates and then used published model predictions of stressor prevalence in the future (Clarke 2000, IPCC 2013, Kupfer et al. 2020, NOAA 2020) to simulate how gopher tortoise populations will respond to plausible future conditions across the species range.

Using this integrative modeling framework, I simulated future population size, redundancy, and resiliency of gopher tortoises under six scenarios varying in the magnitude of threats at intervals of 40, 60, and 80 years in the future. Simulated growth of ca. 70,600 females from 626 local populations and 244 landscape populations predicted future declines in the number of individuals, local populations, and landscape populations among all scenarios and projection intervals. Scenarios did not vary strongly in their effect on λ of individuals, populations, and landscape populations; no single stressor scenario or management scenario was sufficient to prevent population declines, and 95% confidence intervals of predictions overlapped significantly among all scenarios, indicating statistical insignificance of scenario effects.

While scenarios did not have strong effects on overall trends in abundance and population redundancy, categorization of populations by persistence probabilities suggested that the 'increased management' and 'low stressors' scenarios performed better at increasing population persistence and reducing extirpation than other management and stressor scenarios. Increased habitat management promoted greater population persistence relative to decreased management scenarios because of positive effects of management on survival in local populations, which increases population growth and persistence probability of populations. While populations may experience reproductive benefits from warming temperatures in the future (i.e., positive effects with increased stressors), the 'low stressors' scenarios outperformed the elevated stressor scenarios because the negative effects of urbanization and sea-level rise on survival and immigration were stronger than the positive effects of warming on reproduction.

The regression analysis identified significant effects of initial abundance, number of populations per landscape population, area, elevation, urbanization, sea-level rise, and habitat management to influence persistence probabilities of local populations. For groups and agencies seeking alternatives to buffer tortoise populations from anthropogenic effects, these factors represent opportunities for management and/or conservation.

Previous demographic models for gopher tortoises have largely ignored including immigration parameters (e.g., Tuberville et al. 2009, Folt et al. 2021) and modeled tortoise demography as closed to immigration, perhaps due to the paucity of field estimates of immigration in wild populations. These models often predicted population declines, even though recent evidence was more consistent with population stability (Folt et al. 2021, Goessling et al. 2021). This discrepancy suggests a disconnect between demographic projections that are largely influenced by apparent survival projections and actual trends occurring in populations, a discrepancy that may be resolved by incorporating immigration during projection analyses. To this end, I incorporated an immigration parameter, γ, for local populations and found predictions were highly sensitive to variation in γ. This was supported by the fact that persistence probabilities were sensitive to threats that influenced immigration rates and two scenarios of 'no immigration' and 'high immigration' produced results that strongly deviated from results of the stressor and management scenarios. Together, these lines of evidence suggest that immigration is an important parameter in tortoise demography that may deserve future attention when studying tortoises in the field and building models of tortoise demography in the laboratory.

While the number of individuals, populations, and landscape populations were all expected to decline across each projection interval, overall projections suggest that extinction risk for the gopher tortoise is low in the future. Of the populations modeled here, mean predictions among scenarios for 80 years in the future suggested the presence of 47,202–50846 individuals (females) among 188–198 local populations within 106–114 landscape populations. The persistence of relatively large numbers of individuals and populations suggests resiliency of the species in the face of global change and also redundancy to buffer from future catastrophic events. The spatial distribution of populations predicted to persist in the future are distributed somewhat evenly among analysis units (e.g., Figure 5), which suggests the persistence of representation in the future as well. However, we note that the number of local populations in genetic analysis Unit 1 was the predicted decline by 27–40% among scenarios; this analysis unit includes the populations in Louisiana, Mississippi, and southwest Alabama that are currently protected federally as 'Threatened' under the ESA. The large declines in number of populations occurred, in part, because many local populations (N = 174) delimited in our surveys had very few individuals to start with in the current conditions. Assuming a 3:1 adult to juvenile ratio and an even sex ratio, local populations with less than 8 individuals were functionally extirpated at the start of projections, given our quasi-extinction probability (< 3 adult females). Thus, many local populations were doomed for extirpation from the start, because of insufficiently large population size in the current conditions. This also likely explains the negative effect of landscape population size on population persistence we observed in our regression analysis; a few extremely large landscape populations (e.g., six landscape populations had 13–50 local populations) were dominated by local populations with <8 individuals, thus driving down mean persistence probability in large landscape populations.

I sought to build a population modeling framework that accounts for important elements of population viability analyses, including clear objectives, detailed demographic data and knowledge of life history, temporal stochasticity, parametric uncertainty, density dependence, relevant extrinsic factors (i.e., threats), and sensitivity analysis, to name a few (Chaudhary and Oli 2020). However, like all models, the framework has limitations and opportunities for improvement. The model was sensitive to immigration, a parameterization that we derived largely from a single estimate of emigration (Ott-Eubanks et al. 2003). I modeled demography as an effect of predicted values of climate warming and fire management at broad spatial scales to support an impending listing decision for the species. Future models could evaluate regional variation in effects of warming and fire management for more realistic predictions of threat effects at more detailed spatial scales. The model also focused on simulating the fate of known populations and did not estimate the formation of new populations or project the abundance of existing populations not included in the dataset. Therefore, predictions for □ of local and landscape populations were constrained by an upper limit of 1 and therefore were unable to exceed this limit. My analysis provides an objective assessment of how stressors and management actions will influence future population growth, overall extinction risk of both populations and the species across landscape genetic group and by state, and how uncertainty in important input parameters (e.g., immigration) influences predictions.

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Table 1. Mean and standard error values used to estimate stochastic variables in our population projection model for gopher tortoises (*Gopherus polyphemus*) in conservation lands across the species' range. MAT = mean annual temperature (degrees C) of a population's locality; YSB = years since last burn of habitat using prescribed fire. See Appendix 1 for the full list of references used to compile parameter estimates for variables in the table.

Parameter	Distribution shape	Mean (variance)	Source
Probability of breeding	Beta	0.97 (0.01)	E. Hunter, pers. comm.
Fecundity	Log normal	-3.54 (2.42) + 0.48 (0.12) * MAT	Meshaka Jr. et al. (2019); this study
Nest survival	Beta	0.35 (0.10)	Smith et al. (2013)
Probability of viable eggs	Beta	0.85 (0.05)	Landers et al. (1980), Rostal and Jones (2002)
Probability of female	Beta	0.50 (0.04)	This study
Hatchling survival	Beta	0.13 (0.03)	Perez-Heydrich et al. (2012)
Juvenile survival	Beta	0.75 (0.06)	Appendix 1
Adult survival	Beta	0.96 (0.03)	Appendix 1
Maturity age	Log normal	43.52 (11.31) – 1.41 (0.53) * MAT	Appendix 1; this study
Juvenile abundance	Log normal	Varying by population	This study
Adult abundance	Log normal	Varying by population	This study
Immigration rate	Beta	0.01 (0.001)	Ott-Eubanks et al. (2003)
Percent of winter days for burning	Beta	0.77 (0.05)	Kupfer et al. (2020)

Percent of spring days for burning	Beta	0.80 (0.05)	
Percent of summer days for burning	Beta	0.65 (0.05)	
Change in winter days for burning	Beta	Varying by prediction scenario	
Change in spring days for burning	Beta	Varying by prediction scenario	
Change in summer days for burning	Beta	Varying by prediction scenario	
Burn probability	Beta	0.4 (0.015)	Guyette et al (2012), Crawford et al. (2020)
Fire effect on survival	Beta	0.96 – 0.027 (0.003) * YSB	Hunter and Rostal (2021)

Table 2. Six scenarios of future climate warming, sea-level rise, urbanization, and habitat management used to simulated population growth and extinction risk for gopher tortoises (*Gopherus polyphemus*) for 80 years into the future. Scenarios vary in the magnitude of threat influences on gopher tortoise demography; threat levels included three levels of climate warming (1.0, 1.5, and 2.0 degrees C increase), three levels of sea-level rise (intermediate-high [1.83 m], high [2.55 m], and extreme [3.16 m] scenarios), three levels of urbanization scenarios predicted by the SLEUTH model [Clarke 2000] at probability thresholds of 0.9 (conservative prediction), 0.5 (moderate prediction), and 0.1 (aggressive prediction), and four levels of changes in habitat management (no changes, less management predicted by RCP4.5 [Kupfer et al. 2020], much less management predicted by RCP8.5 [Kupfer et al. 2020], and improved management [the opposite of the effect predicted by RCP4.5 in Kupfer et al. 2020]).

Scenarios	Climate warming (deg C)	Sea-level rise (m)	Urbanization	Management
Low stressors	1.0	0.54 m	P = 0.95	Status quo
Medium stressors	1.5	1.83 m	P = 0.50	Status quo
High stressors	2.0	3.16 m	P = 0.20	Status quo
More management	1.5	1.83 m	P = 0.50	More
Less management	1.5	1.83 m	P = 0.50	Less
Much less management	1.5	1.83 m	P = 0.50	Much less

Table 3. Simulated population projections for female gopher tortoises under six scenarios of future change. Columns summarize the initial number (in 2020), future predicted number, and population growth rate (λ) for the total population size, number of populations, and number of landscape populations for six scenarios projected 40, 60, and 80 years into the future. See Table 2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of metapopulations		
	Initial	Future	λ	Initial	Future	λ	Initial	Future	λ
Year 2060									
Low stressors	70610	47468	0.67 (0.30–1.80)	626	332	0.53 (0.51–0.55)	244	179	0.73 (0.63–0.81)
Medium stressors	70614	47630	0.67 (0.30–1.91)	626	331	0.53 (0.51–0.54)	244	183	0.75 (0.61–0.80)
High stressors	70582	45998	0.65 (0.28–1.84)	626	329	0.53 (0.51–0.55)	244	177	0.73 (0.64–0.80)
More management	70611	46646	0.66 (0.29–1.84)	626	329	0.53 (0.51–0.55)	244	178	0.73 (0.61–0.80)
Less management	70610	46826	0.66 (0.29–1.79)	626	328	0.52 (0.50–0.54)	244	180	0.74 (0.62–0.80)
Much less management	70600	46495	0.66 (0.29–1.80)	626	323	0.52 (0.50–0.54)	244	178	0.73 (0.60–0.79)
Year 2080									
Low stressors	70609	49281	0.70 (0.36–1.77)	626	249	0.40 (0.38–0.41)	244	143	0.59 (0.44–0.73)
Medium stressors	70636	48924	0.69 (0.37–1.79)	626	250	0.40 (0.38–0.41)	244	142	0.58 (0.45–0.73)
High stressors	70592	46674	0.66 (0.34–1.70)	626	246	0.39 (0.37–0.41)	244	138	0.57 (0.43–0.70)
More management	70598	49246	0.70 (0.35–1.86)	626	250	0.40 (0.38–0.42)	244	145	0.59 (0.45–0.74)
Less management	70604	48754	0.69 (0.34–1.80)	626	247	0.39 (0.38–0.41)	244	138	0.57 (0.44–0.72)
Much less management	70569	48592	0.69 (0.35–1.69)	626	243	0.39 (0.37–0.42)	244	142	0.58 (0.42–0.72)

<u>Year 2100</u>									
Low stressors	70614	50846	0.72 (0.37–1.77)	626	198	0.32 (0.30–0.33)	244	114	0.47 (0.36–0.62)
Medium stressors	70594	48366	0.69 (0.36–1.74)	626	196	0.31 (0.29–0.33)	244	108	0.44 (0.35–0.59)
High stressors	70578	47378	0.67 (0.35–1.70)	626	194	0.31 (0.29–0.33)	244	109	0.45 (0.33–0.60)
More management	70584	49114	0.70 (0.36–1.73)	626	196	0.31 (0.30–0.33)	244	110	0.45 (0.33–0.62)
Less management	70596	47202	0.67 (0.37–1.75)	626	193	0.31 (0.29–0.33)	244	106	0.43 (0.34–0.61)
Much less management	70608	48520	0.69 (0.37–1.67)	626	188	0.30 (0.28–0.32)	244	106	0.43 (0.34–0.59)

Table 4. Predicted population persistence probabilities (P_p) categories for gopher tortoise populations in year 2100 under six future scenarios varying in the magnitude of future stressors. Persistence categories are Extremely Likely Extant (P_p > 95.0%), Very Likely Extant (P_p = 80.0–94.9%), More Likely Than Not Extant (P_p = 50.0–79.9%), and Unlikely Extant (P_p < 50.0%; i.e., extirpated). See Table 2 for descriptions of scenarios and their parameters.

Population persistence category	Scenario: Low stressors	Medium stressors	High stressors	More management	Less management	Much less management
Year 2060						
Extremely Likely Extant	104 (16.6%)	103 (16.5%)	101 (16.1%)	99 (15.8%)	102 (16.3%)	104 (16.6%)
Very Likely Extant	102 (16.3%)	97 (15.5%)	108 (17.3%)	108 (17.3%)	98 (15.7%)	91 (14.5%)
More Likely Than Not Extant	135 (21.6%)	145 (23.2%)	135 (21.6%)	134 (21.4%)	141 (22.5%)	141 (22.5%)
Unlikely Extant (i.e., Extirpated)	285 (45.5%)	281 (44.9%)	282 (45%)	285 (45.5%)	285 (45.5%)	290 (46.3%)
Year 2080						
Extremely Likely Extant	78 (12.5%)	74 (11.8%)	71 (11.3%)	79 (12.6%)	74 (11.8%)	76 (12.1%)
Very Likely Extant	35 (5.6%)	44 (7%)	41 (6.5%)	36 (5.8%)	41 (6.5%)	31 (5%)
More Likely Than Not Extant	122 (19.5%)	116 (18.5%)	117 (18.7%)	128 (20.4%)	103 (16.5%)	114 (18.2%)
Unlikely Extant (i.e., Extirpated)	391 (62.5%)	392 (62.6%)	397 (63.4%)	383 (61.2%)	408 (65.2%)	405 (64.7%)
Year 2100						
Extremely Likely Extant	76 (12.1%)	72 (11.5%)	70 (11.2%)	71 (11.3%)	70 (11.2%)	70 (11.2%)

Very Likely Extant	21 (3.4%)	20 (3.2%)	25 (4%)	24 (3.8%)	24 (3.8%)	24 (3.8%)
More Likely Than Not Extant	65 (10.4%)	62 (9.9%)	55 (8.8%)	58 (9.3%)	57 (9.1%)	54 (8.6%)
Unlikely Extant (i.e., Extirpated)	464 (74.1%)	472 (75.4%)	476 (76%)	473 (75.6%)	475 (75.9%)	478 (76.4%)

Table 5. Simulated population projections for gopher tortoises under scenarios varying in immigration rate (γ): no immigration ($\gamma =$ 0), intermediate immigration (γ = 0.01), high immigration (γ = 0.02), and very high immigration (γ = 0.04). Columns summarize the initial number (in 2020), future predicted number, and population growth rate (λ) for the total population size, number of populations, and number of metapopulations for four scenarios projected 80 years into the future. Each scenario models stressors and management actions using input values from the 'medium stressors' scenario from Table 2, and the 'intermediate immigration' scenario has the same input values the 'medium stressors' scenario from Table 2; see Table 2 for more information about input parameters.

Scenarios	Total population size			Number of local populations			Number of metapopulations		
	Initial	Future	λ	Initial	Future	λ	Initial	Future	λ
No immigration	70602	1566	0.02 (0.01–0.18)	626	81	0.13 (0.11–0.15)	244	46	0.19 (0.09–0.36)
Intermediate immigration	70594	48366	0.69 (0.36–1.74)	626	196	0.31 (0.29–0.33)	244	108	0.44 (0.35–0.59)
High immigration	70600	91805	1.30 (0.71–2.76)	626	247	0.39 (0.38–0.41)	244	124	0.51 (0.39–0.66)
Very high immigration	70600	151320	2.14 (1.18–4.44)	626	312	0.50 (0.48–0.52)	244	144	0.59 (0.48–0.68)

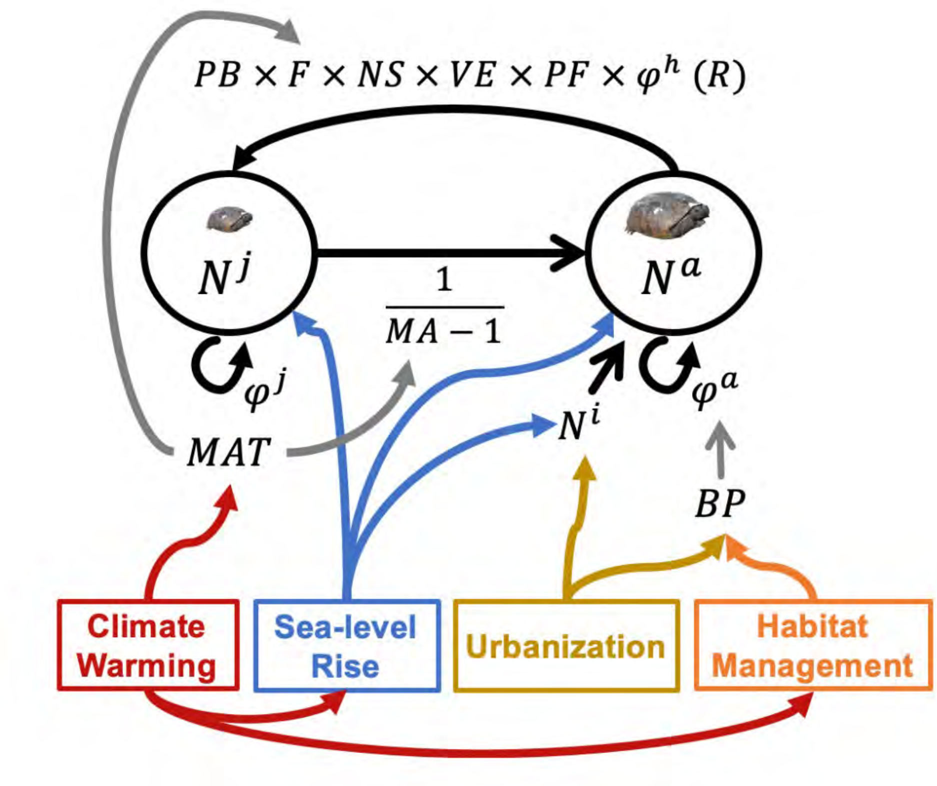


Figure 1. A conceptual model illustrating a stage-based, female-only population model (black text) used to simulate demography and project population size of the Gopher Tortoise (*Gopherus polyphemus*) into the future. Black arrows and circles indicate gopher tortoise demographic parameters (survival, growth, abundance); colored arrows and text indicate predicted threat effects on tortoise demography simulated through scenario analysis. See Table 1 for demographic variable definitions and baseline estimates; MAT = mean annual temperature (°C) and BP is burn probability with prescribed fire (see Methods). For each threat (colored box), I modeled three or four scenarios of future change in the threat magnitude (Table 2).

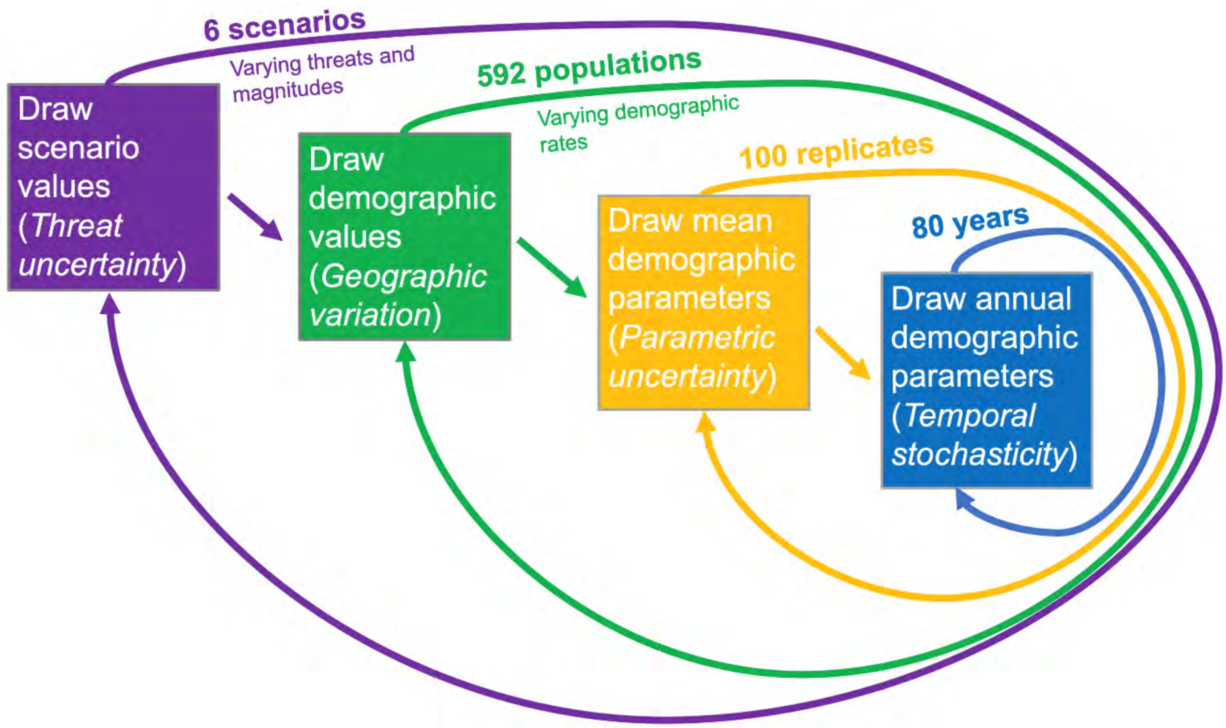


Figure 2. I used a four-loop uncertainty structure to simulate uncertainty in threats, geographic variation, parameter estimates, and temporal stochasticity of stochastic variables during population projections for gopher tortoises. For each scenario, I simulated each population using 100 replicates and projected each replicate into the future for 80 years.

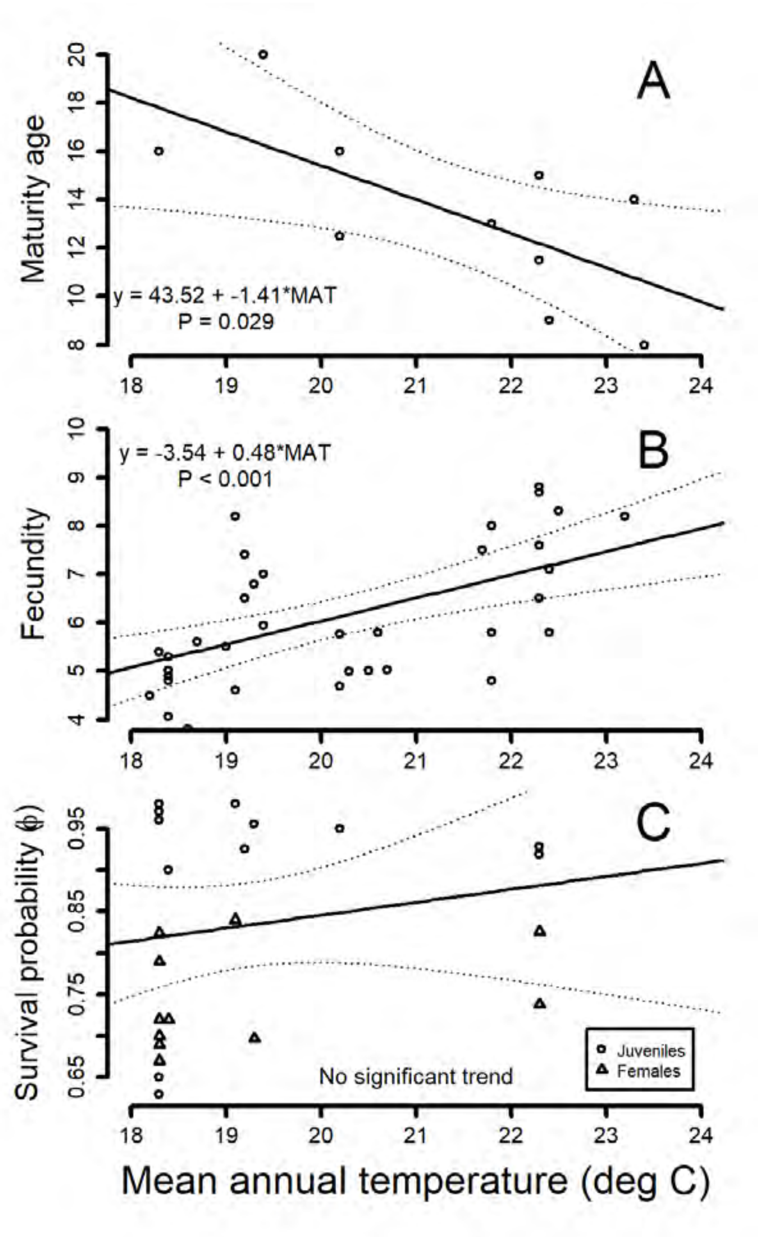


Figure 3. Effect of mean annual temperature (MAT; degrees C) on (A) maturity age (MA), (B), fecundity, and (C) annual apparent survival probability (φ) of gopher tortoise (*Gopherus polyphemus*) populations. Geographic variation in biotic conditions (e.g., MAT) predict significant variation in maturity age and fecundity (P < 0.05) but not in annual apparent survival probability (see inset text).

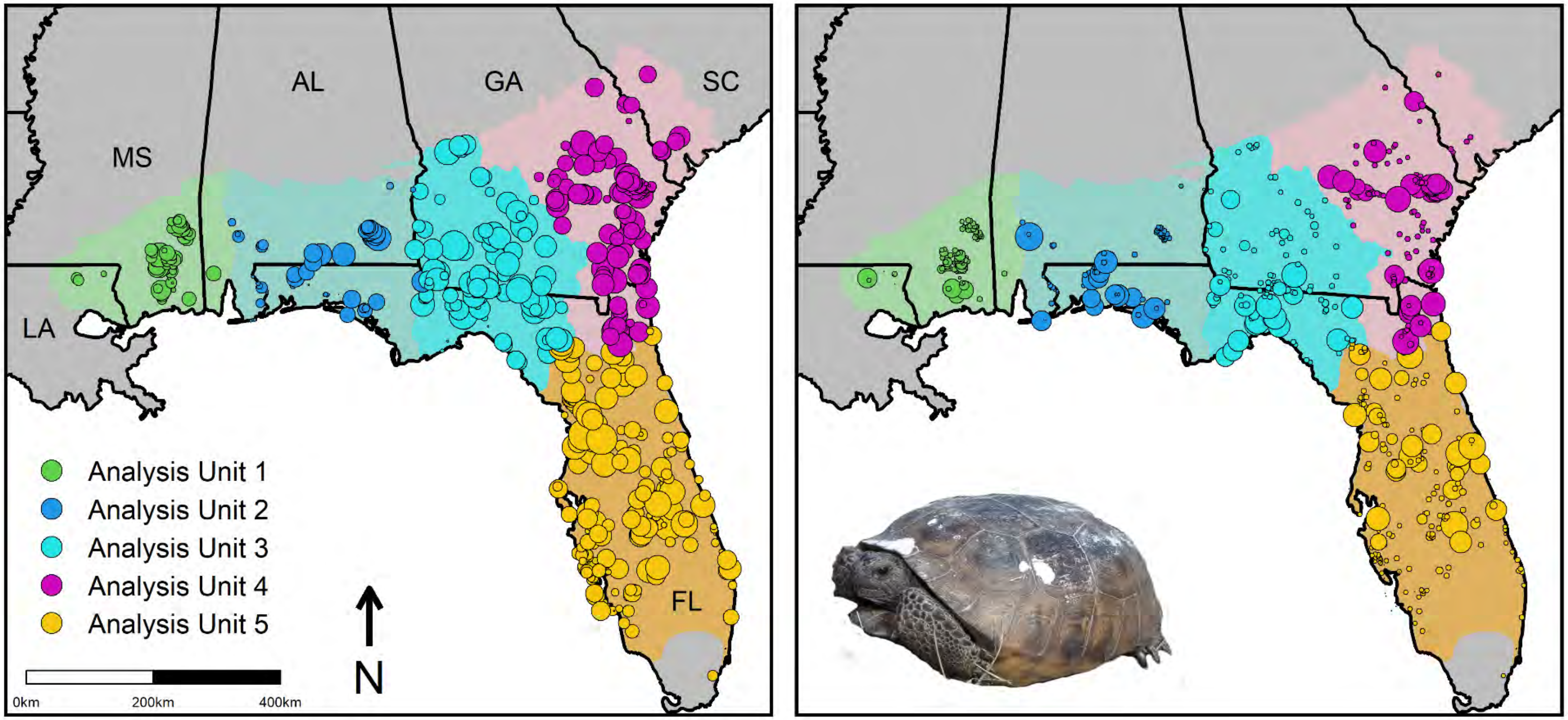


Figure 4. Current abundance (left) and predicted abundance 80 years in the future (right) of gopher tortoise (*Gopherus polyphemus*; right inset) populations in the southeastern United States that were modeled to predict future population growth and extinction risk for the species under scenarios of global change. Each circle represents a local population and circles are colored by analysis unit. Symbol size reflects a log-transformed scale of population size; the left panel shows population size estimated during a survey during 2010–2020; the right panel shows predicted population size under a future scenario of 'medium stressors with less management' (Table 2). Abundance of populations during

2010–2020 was estimated from analysis of data from burrow surveys or Line Transect Distance Sampling (LTDS) surveys at each the site within the last ten years.

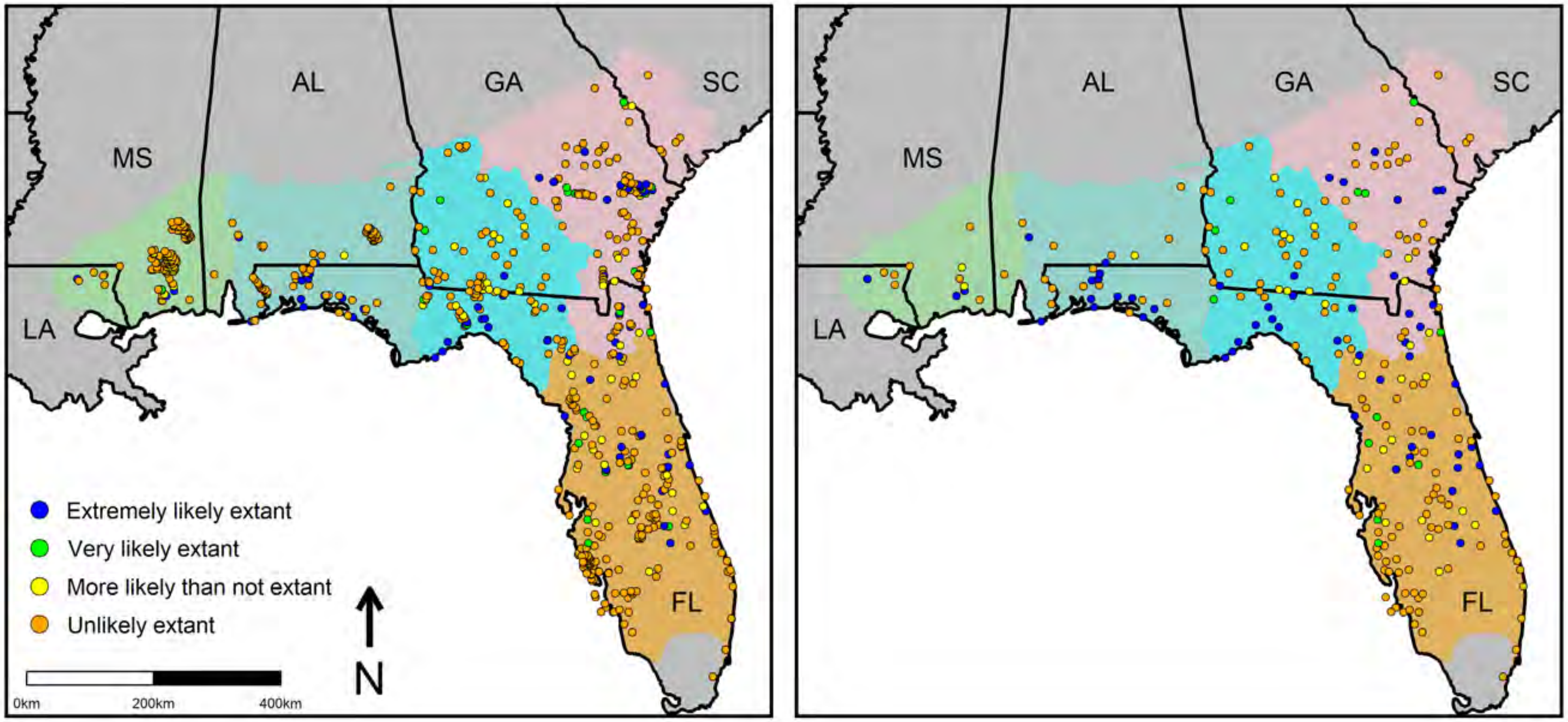


Figure 5. Persistence probabilities (P_p) of gopher tortoise (*Gopherus polyphemus*) local populations (left) and landscape populations (right) predicted by a future scenario of less habitat management with medium stressor (Table 2) projected 80 years into the future. Symbols are colored by persistence probability categories: Extremely Likely Extant (P_p > 95.0%), Very Likely Extant (P_p = 80.0–94.9%), More Likely Than Not Extant (P_p = 50.0–79.9%), and Unlikely Extant (P_p < 50.0%; i.e., extirpated). See Table 2 for descriptions of scenarios and their parameters.

Appendix 1. Demographic estimates for gopher tortoises (*Gopherus polyphemus*) identified during a literature review and used in the construction of a female-only population model. Parameters are: fecundity (F); nest survival (NS); probability of viable eggs (i.e., hatching success; VE); survival of hatchlings (φ^h), juveniles (φ^j), and adult females (φ^a); and maturity age for females (MA).

Parameter	Locality	Estimate	Reference
F	Okeeheelee County Park, FL	8.2	Ashton et al. 2007
F	Archbold Biological Station, FL	6.5	Ashton et al. 2007
F	Archbold Biological Station, FL	8.7	White et al. 2018
F	Archbold Biological Station, FL	8.1	White et al. 2018
F	South of Tampa, FL	7.6	Godley 1989
F	USF's Ecological Research Area, Tampa, FL	7.1	Mushinksy et al. 1994
F	Boyd Hill Nature Preserve, FL	8.3	Goessling and Heinrich, unpubl. data
F	North of Tampa, FL	4.8	Macdonald 1996
F	North of Tampa, FL	5.8	Small and Macdonald 2001
F	North of Tampa, FL	8.0	Small and Macdonald 2001
F	Cape Canaveral, FL	7.5	Demuth 2001
F	Gainesville, FL	5.8	Diemer-Berish et al. 2012
F	Gainesville, FL	4.7	Iverson 1980
F	Ordway Preserve, Gainesville, FL	5.8	Smith 1995
F	Jacksonville, FL	5.0	Butler and Hull 1996

F	Jacksonville, FL	5.0	Hallinan 1923
F	Branan Field Wildlife and Environmental Area, FL	5.0	Perez-Heydrich et al. 2012
F	Mobile County, AL	4.6	Marshall 1987
F	Ben's Creek WMA, LA	5.5	Smith et al. 1997
F	Silver Lake WMA, GA	7.0	Landers et al. 1980
F	The Wade Tract, GA	5.9	Radzio et al. 2017
F	Joseph W. Jones Ecological Research Center, GA	6.8	L. Smith, unpubl. Data
F	Marion County WMA, FL	5.6	Smith et al. 1997
F	Camp Shelby, MS	4.8	Epperson and Heise 2003
F	Camp Shelby, MS	5.3	J. Watkins (pers. comm.) in Butler and Hull 1996
F	Camp Shelby, MS	5.0	C. Jones and T. Mann (pers. comm.) in Butler and Hull 1996
F	Camp Shelby, MS	4.1	M. Hinderliter, unpubl. data
F	Camp Shelby, MS	4.9	J. Lee, unpubl. data
F	Fort Stewart, GA	6.5	Rostal and Jones 2002
F	St. Catherines Island, GA	8.2	Quin et al. 2016, p. 14
F	Reed Bingham State Park, GA	7.4	Quin et al. 2016, p. 14
F	Yuchi WMA, GA	6.7	Quin et al. 2016, p. 14
F	South Carolina	3.80	Wright 1982
F	George L. Smith State Park, GA	4.50	Rostal and Jones 2002
F	Alabama	4.29	Folt et al. submitted

NS	Joseph W. Jones Ecological Research Center, GA	0.35	Smith et al. 2013
VE	Archbold Biological Station, FL	0.78	White et al. 2018
VE	Ordway Preserve, Gainesville, FL	0.83	Smith 1995
VE	Jacksonville, FL	0.82	Butler and Hull 1996
VE	Branan Field Wildlife and Environmental Area, FL	0.90	Perez-Heydrich et al. 2012
VE	Silver Lake WMA, GA	0.86	Landers et al. 1980
VE	The Wade Tract, GA	0.73	Radzio et al. 2017
VE	St. Catherines Island, GA	0.90	Quin et al. 2016, p. 14
VE	Reed Bingham State Park, GA	0.93	Quin et al. 2016, p. 14
VE	Yuchi WMA, GA	0.93	Quin et al. 2016, p. 14
φ^h	Meta-analysis of three localities	0.13	Perez-Heydrich et al. 2012
φj	Archbold Biological Station, FL	0.83	Meshaka et al. 2019, p. 98
φj	Archbold Biological Station, FL	0.74	Howell et al. 2020
φj	Joseph W. Jones Ecological Research Center, GA	0.70	Tuberville et al. 2014
φj	St. Catherines Island, GA	0.84	Tuberville et al. 2008, p. 2694
φj	Conecuh National Forest, AL	0.82	Tuberville et al. 2014
φj	Conecuh National Forest, AL	0.67	Folt et al. 2021
φ^j	Conecuh National Forest, AL	0.69	Folt et al. 2021
φ^j	Conecuh National Forest, AL	0.79	Folt et al. 2021
φ^j	Conecuh National Forest, AL	0.70	Folt et al. 2021

φ^j	Conecuh National Forest, AL	0.72	Folt et al. 2021
φ^j	Conecuh National Forest, AL	0.72	Folt et al. 2021
φ^a	Archbold Biological Station, FL	0.92	Meshaka et al. 2019, p. 98
φ^a	Archbold Biological Station, FL	0.93	Howell et al. 2020
φ^a	Gainesville, FL	0.95	Ozgul et al. 2009
φ^a	Joseph W. Jones Ecological Research Center, GA	0.96	Tuberville et al. 2014
φ^a	St. Catherines Island, GA	0.98	Tuberville et al. 2008, p. 2694
φ^a	Conecuh National Forest, AL	0.98	Tuberville et al. 2014
φ^a	Conecuh National Forest, AL	0.97	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.63	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.96	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.96	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.65	Folt et al. 2021
φ^a	Conecuh National Forest, AL	0.90	Folt et al. 2021
MA	Silver Lake WMA, GA	20	Landers et al. 1982
MA	Conecuh National Forest, AL	16	Folt et al. 2021
MA	Gainesville, FL	16	Diemer and Moore 1994
MA	Gainesville, FL	12.5	Iverson 1980
MA	Tampa, FL	13	Linley 1986
MA	Tampa, FL	9	Mushinsky et al. 1994, p. 123

MA	Tampa, FL	15	Godley 1989
MA	Archbold Biological Station, FL	11.5	Meshaka et al. 2019, p. 98
MA	Jupiter, FL	8	Sano 2014
MA	Sanibel Island, FL	14	McLaughlin 1990

Appendix 2. Simulated population projections for gopher tortoises populations in each of the five genetic representation units (Gaillard et al. 2017). Six scenarios of predicted future change were projected 80 years into the future; results are summarized by the initial number, future predicted number, and population growth rate (λ) for the total population size, number of local populations, and number of metapopulations in each genetic unit. See Table 2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of metapopulations		
	Initial	Future	λ	Current	Future	λ	Initial	Future	λ
Unit 1									
Low stressors	1571	1151	0.73 (0.22–3.55)	102	23	0.23 (0.18–0.27)	13	6	0.46 (0.46–0.46)
Medium stressors	1573	1066	0.68 (0.22–3.50)	102	23	0.23 (0.18–0.27)	13	6	0.46 (0.46–0.54)
High stressors	1572	990	0.63 (0.22–3.86)	102	23	0.23 (0.18–0.26)	13	6	0.46 (0.46–0.54)
More management	1572	1066	0.68 (0.21–4.01)	102	23	0.23 (0.19–0.27)	13	6	0.46 (0.44–0.54)
Less management	1573	1026	0.65 (0.22–3.79)	102	22	0.22 (0.18–0.26)	13	6	0.46 (0.46–0.54)
Much less management	1572	947	0.60 (0.22–3.42)	102	22	0.22 (0.18–0.26)	13	6	0.46 (0.46–0.54)
Unit 2									
Low stressors	2896	7316	2.53 (1.49–4.08)	81	21	0.26 (0.21–0.30)	29	16	0.55 (0.48–0.66)
Medium stressors	2896	7022	2.42 (1.24–3.94)	81	19	0.23 (0.20–0.27)	29	15	0.52 (0.45–0.59)
High stressors	2894	6868	2.37 (1.50–4.04)	81	19	0.23 (0.20–0.28)	29	14	0.48 (0.45–0.59)
More management	2896	7086	2.45 (1.39–3.95)	81	20	0.25 (0.21–0.28)	29	15	0.52 (0.45–0.59)
Less management	2898	7007	2.42 (1.58–4.10)	81	20	0.25 (0.20–0.28)	29	15	0.52 (0.45–0.59)

Much less management	2898	7084	2.44 (1.44–3.92)	81	19	0.23 (0.20–0.27)	29	14	0.48 (0.45–0.52)
Unit 3									
Low stressors	19432	9468	0.49 (0.31–1.08)	110	42	0.38 (0.34–0.44)	55	29	0.52 (0.36–0.73)
Medium stressors	19428	9125	0.47 (0.31–1.04)	110	42	0.38 (0.34–0.44)	55	27	0.49 (0.32–0.68)
High stressors	19419	9406	0.48 (0.30–1.02)	110	42	0.38 (0.34–0.44)	55	28	0.50 (0.35–0.72)
More management	19426	9338	0.48 (0.30–1.11)	110	43	0.39 (0.35–0.45)	55	29	0.53 (0.38–0.76)
Less management	19430	9224	0.47 (0.31–1.06)	110	42	0.38 (0.33–0.43)	55	28	0.51 (0.35–0.75)
Much less management	19432	9332	0.48 (0.31–1.03)	110	41	0.37 (0.33–0.43)	55	27	0.48 (0.35–0.70)
Unit 4									
Low stressors	14032	13793	0.98 (0.55–2.20)	123	50	0.37 (0.33–0.43)	46	21	0.46 (0.35–0.65)
Medium stressors	14030	13368	0.95 (0.55–2.28)	123	50	0.39 (0.35–0.45)	46	22	0.48 (0.37–0.64)
High stressors	14040	12013	0.86 (0.42–1.98)	123	48	0.41 (0.37–0.46)	46	20	0.43 (0.35–0.62)
More management	14036	13325	0.95 (0.54–2.11)	123	51	0.40 (0.36–0.44)	46	22	0.48 (0.35–0.66)
Less management	14034	13109	0.93 (0.54–2.09)	123	49	0.41 (0.37–0.46)	46	22	0.48 (0.35–0.67)
Much less management	14039	13118	0.93 (0.56–2.11)	123	49	0.39 (0.35–0.43)	46	20	0.43 (0.36–0.63)
Unit 5									
Low stressors	32684	19120	0.58 (0.25–1.70)	210	62	0.30 (0.27–0.32)	103	41	0.40 (0.30–0.52)
Medium stressors	32666	17786	0.54 (0.24–1.65)	210	60	0.29 (0.26–0.31)	103	43	0.41 (0.27–0.53)

High stressors	32653	18102	0.55 (0.25–1.66)	210	60	0.29 (0.26–0.32)	103	39	0.38 (0.25–0.58)
More management	32655	18300	0.56 (0.24–1.64)	210	60	0.29 (0.26–0.31)	103	41	0.40 (0.26–0.57)
Less management	32662	16836	0.52 (0.23–1.71)	210	60	0.29 (0.25–0.32)	103	37	0.36 (0.27–0.54)
Much less management	32666	18038	0.55 (0.24–1.59)	210	58	0.28 (0.25–0.30)	103	40	0.38 (0.27–0.51)

Appendix 3. Simulated population projections for gopher tortoises in each of the six states within which the gopher tortoise occurs. Six scenarios of predicted future change were projected 80 years into the future; results are summarized by the initial number, future predicted number, and population growth rate (λ) for the total population size, number of local populations, and number of metapopulations in each state. See Table 2 for descriptions of scenarios and parameters.

Scenarios	Total population size			Number of local populations			Number of metapopulations		
	Initial	Future	λ	Initial	Future	λ	Initial	Future	λ
Alabama									
Low stressors	2318	3638	1.57 (0.98–2.49)	54	7	0.13 (0.09–0.19)	14	6	0.43 (0.29–0.43)
Medium stressors	2318	3709	1.60 (0.81–2.51)	54	7	0.13 (0.09–0.19)	14	5	0.36 (0.29–0.43)
High stressors	2316	3642	1.57 (1.13–2.70)	54	7	0.13 (0.09–0.19)	14	6	0.39 (0.29–0.43)
More management	2318	3752	1.62 (0.96–2.54)	54	8	0.15 (0.09–0.19)	14	6	0.43 (0.29–0.43)
Less management	2320	3633	1.57 (1.18–2.71)	54	7	0.13 (0.09–0.19)	14	5	0.36 (0.29–0.43)
Much less management	2320	3737	1.61 (1.02–2.53)	54	7	0.13 (0.07–0.17)	14	5	0.36 (0.29–0.43)
Florida									
Low stressors	44037	34536	0.78 (0.40–1.95)	314	108	0.34 (0.32–0.37)	152	74	0.48 (0.38–0.62)
Medium stressors	44022	32286	0.73 (0.39–1.87)	314	105	0.33 (0.31–0.36)	152	69	0.45 (0.36–0.59)
High stressors	44004	31798	0.72 (0.38–1.83)	314	103	0.33 (0.31–0.35)	152	70	0.46 (0.35–0.62)
More management	44009	33094	0.75 (0.39–1.90)	314	106	0.34 (0.31–0.36)	152	70	0.46 (0.34–0.63)

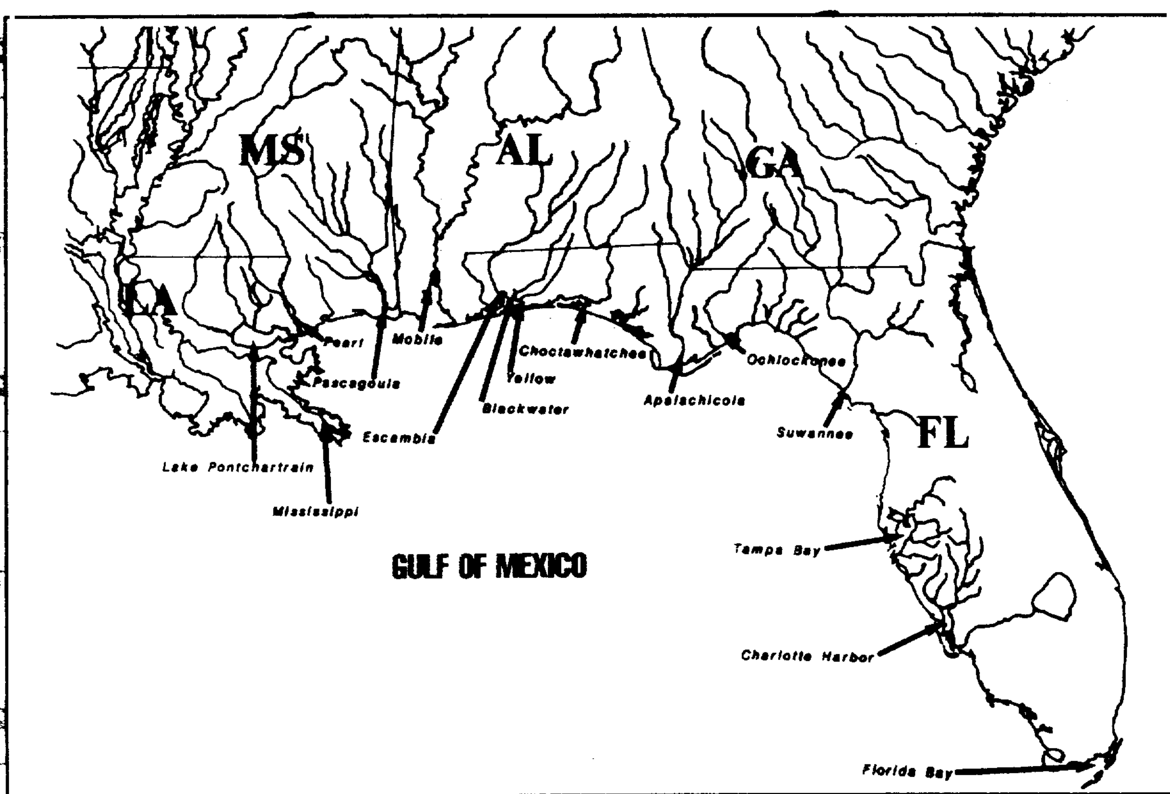
Less management	44020	31470	0.71 (0.38–1.91)	314	105	0.33 (0.31–0.36)	152	71	0.47 (0.36–0.61)
Much less management	44022	32924	0.75 (0.40–1.83)	314	102	0.32 (0.30–0.35)	152	68	0.45 (0.34–0.59)
<u>Georgia</u>									
Low stressors	22183	11510	0.52 (0.28–1.23)	151	59	0.39 (0.34–0.43)	63	27	0.43 (0.35–0.65)
Medium stressors	22176	11290	0.51 (0.27–1.32)	151	59	0.39 (0.35–0.43)	63	27	0.43 (0.32–0.63)
High stressors	22181	10934	0.49 (0.22–1.21)	151	58	0.38 (0.34–0.42)	63	30	0.48 (0.32–0.59)
More management	22180	11186	0.50 (0.27–1.21)	151	59	0.39 (0.35–0.44)	63	27	0.43 (0.33–0.63)
Less management	22178	11060	0.50 (0.27–1.22)	151	57	0.38 (0.33–0.42)	63	28	0.44 (0.33–0.63)
Much less management	22188	10897	0.49 (0.27–1.18)	151	57	0.38 (0.34–0.42)	63	27	0.43 (0.32–0.60)
<u>Louisiana</u>									
Low stressors	24	246	10.25 (8.00–14.29)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
Medium stressors	24	244	10.17 (7.88–13.79)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
High stressors	24	242	10.08 (7.71–14.21)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
More management	24	248	10.33 (7.63–14.83)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
Less management	24	244	10.17 (8.08–15.63)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.40)
Much less management	24	246	10.25 (8.21–15.42)	7	1	0.14 (0.14–0.29)	5	1	0.20 (0.20–0.20)
<u>Mississippi</u>									
Low stressors	1514	902	0.60 (0.10–3.45)	94	22	0.23 (0.18–0.28)	7	5	0.71 (0.71–0.71)

Medium stressors	1516	820	0.54 (0.10–3.41)	94	22	0.23 (0.18–0.28)	7	5	0.71 (0.71–0.71)
High stressors	1515	746	0.49 (0.10–3.77)	94	21	0.22 (0.18–0.28)	7	5	0.71 (0.71–0.71)
More management	1515	816	0.54 (0.10–3.92)	94	22	0.23 (0.19–0.29)	7	5	0.71 (0.57–0.71)
Less management	1516	780	0.51 (0.10–3.69)	94	21	0.22 (0.18–0.28)	7	5	0.71 (0.71–0.71)
Much less management	1516	698	0.46 (0.10–3.30)	94	21	0.22 (0.17–0.27)	7	5	0.71 (0.71–0.71)
South Carolina									
Low stressors	538	16	0.03 (0.02–0.15)	6	1	0.17 (0–0.50)	4	0	0 (0–0.50)
Medium stressors	538	17	0.03 (0.02–0.14)	6	1	0.17 (0–0.50)	4	0	0 (0–1.00)
High stressors	538	16	0.03 (0.02–0.16)	6	1	0.17 (0–0.50)	4	0	0 (0–0.75)
More management	538	18	0.03 (0.02–0.17)	6	1	0.17 (0–0.50)	4	1	0.25 (0–0.75)
Less management	538	16	0.03 (0.02–0.18)	6	1	0.17 (0–0.50)	4	1	0.25 (0–1.00)
Much less management	538	17	0.03 (0.02–0.16)	6	1	0.17 (0–0.50)	4	0	0 (0–0.75)

Appendix C-2 Gulf Sturgeon Recovery/Management Plan

GULF STURGEON

RECOVERY/MANAGEMENT PLAN



GULF STURGEON
(*Acipenser oxyrinchus desotoi*)

RECOVERY/MANAGEMENT PLAN

Prepared by

The Gulf Sturgeon Recovery/Management Task Team

for

Southeast Region
U.S. Fish and Wildlife Service
Atlanta, Georgia

and

Gulf States Marine Fisheries Commission
Ocean Springs, Mississippi

and

National Marine Fisheries Service
Washington, D.C.

Approved: Noreen K. Clough Date: 9/22/95
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Edwin J. Conklin
Chairman, Gulf States Marine Fisheries Commission

Approved: Rolland A. Schmitten Date: SEP 15 1995
Rolland A. Schmitten
Assistant Administrator for Fisheries, National Marine Fisheries Service

DISCLAIMER PAGE

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect listed species. Plans are published by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service, sometimes prepared with the assistance of recovery teams, contractors, state agencies, and others. Objectives will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not necessarily represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than the U.S. Fish and Wildlife Service and the National Marine Fisheries Service. They represent the official position of the U.S. Fish and Wildlife Service and the National Marine Fisheries Service only after they have been signed by the Regional Director of the Fish and Wildlife Service and the Assistant Director for Fisheries of the National Marine Fisheries Service as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

LITERATURE CITATIONS

Literature citations should read as follows:

U.S. Fish and Wildlife Service and Gulf States Marine Fisheries Commission. 1995. Gulf Sturgeon Recovery Plan. Atlanta, Georgia. 170 pp.

Additional copies of this plan may be purchased from:

Fish and Wildlife Reference Service:

5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814
Telephone: 301/492-6403
or 1-800-582-3421

Fee for recovery plans vary, depending upon the number of pages.

ACKNOWLEDGEMENTS

The Gulf sturgeon would not have received federal protection without the dedication and persistence of a few individuals who raised our consciousness of the plight of this prehistoric species. Alan Huff completed the first life history of Gulf sturgeon and has since been influential in shaping recovery and restoration efforts. Dr. Archie Carr realized the magnificence of this subspecies, initiating sturgeon studies on the Apalachicola and Suwannee rivers. Each of his sons helped him through the years, the last being Stephen, who has continued the studies after Dr. Carr's death. Stephen's work has resulted in a long-term commitment to the subspecies. The Carrs were funded in their efforts by The Florida Phipps Foundation founded by Mr. John H. (Ben) Phipps. The Foundation continues to support Stephen Carr's work. Mr. Jim Barkuloo, while with the U.S. Fish and Wildlife Service (FWS), was instrumental in persuading the FWS to list the species. Dr. Michael Bentzien completed the tedious procedural work to list the subspecies and has continued to support the team's efforts in preparing the Recovery Plan. The Gulf States of Louisiana, Mississippi, Alabama, and Florida provided protection for the Gulf sturgeon before the subspecies was listed, by prohibiting take of "sturgeon." The states continue to provide protection through implementation of surveys and studies on the Gulf sturgeon so that management decisions can be based on scientific data.

Current Species Status: The current population levels of Gulf sturgeon in rivers other than the Suwannee and Apalachicola are unknown, but are thought to be reduced from historic levels. Historically, the subspecies occurred in most major rivers from the Mississippi River to the Suwannee River, and marine waters of the central and eastern Gulf of Mexico to Florida Bay.

Habitat Requirements and Limiting Factors: The Gulf sturgeon is an anadromous fish which migrates from salt water into large coastal rivers to spawn and spend the warm months. The majority of its life is spent in fresh water. Major population limiting factors are thought to include barriers (dams) to historical spawning habitats, loss of habitat, poor water quality, and overfishing.

Recovery Objectives: The short-term recovery objective is to prevent further reduction of existing wild populations of Gulf sturgeon. The long-term recovery objective is to establish population levels that would allow delisting of the Gulf sturgeon in discrete management units. Gulf sturgeon in discrete management units could be delisted by 2023, if the required criteria are met. Following delisting, a long-term fishery management objective is to establish self-sustaining populations that could withstand directed fishing pressure within discrete management units.

Recovery Criteria: The short-term recovery objective will be considered achieved for a management unit when the catch-per-unit-effort (CPUE) during monitoring is not declining from the baseline level over a 3 to 5-year period. This objective will apply to all management units within the range of the subspecies. Management units will be defined using an ecosystem approach based on river drainages, but may also incorporate genetic affinities among populations in different river drainages. Baselines will be determined by fishery independent CPUE levels.

The long-term recovery objective will be considered achieved for a management unit when the population is demonstrated to be self-sustaining and efforts are underway to restore lost or degraded habitat. A self-sustaining population is one in which the average rate of natural recruitment is at least equal to the average mortality rate in a 12-year period. While this objective will be sought for all management units, it is recognized that it may not be achievable for all management units. The long-term fishery management objective will be considered attained for a given management unit when a sustainable yield can be achieved while maintaining a stable population through natural recruitment. Note that the objective is not necessarily the opening of a management unit to fishing, but rather the development of a population that can sustain a fishery. Opening a population to fishing will be at the discretion of state(s) within whose jurisdiction(s) the management unit occurs. As with the long-term recovery objective, this objective may not be achievable for all management units, but will be sought for all units.

Priority 1 Recovery Tasks:

1. Develop and implement standardized population sampling and monitoring techniques (1.3.1).

2. Develop and implement regulatory framework to eliminate introductions of non-indigenous stock or other sturgeon species (2.5.3).

3. Reduce or eliminate incidental mortality (2.1.2).

4. Restore the benefits of natural riverine habitats (2.4.5).

5. Utilize existing authorities to protect habitat and where inadequate, recommend new laws and regulations (2.3.1).

Costs ($000's) of Priority 1 Tasks:

Year	Action 1	Action 2	Action 3	Action 4*	Action 5
FY 1	59	0	125	26	29
FY 2	73	25	125	48	29
FY 3	114	0	125	48	29
FY 4	108	0	75	31	29
FY 5	108	0	25	0	0

Cost of No. 1 Priority Actions: $1,231,000

* Actual restoration costs undetermined

Total Cost of Recovery: $8,413,000

Date of Recovery: Delisting should be initiated by 2023, for management units where recovery criteria have been met.

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PREFACE

The U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) jointly listed the Gulf sturgeon as threatened under the authority of the Endangered Species Act of 1973, as amended (ESA).

The FWS prepared a Report on the Conservation Status of the Gulf of Mexico Sturgeon *Acipenser oxyrhinchus desotoi* in 1988 as a precursor to the listing process. The Gulf States Marine Fisheries Commission (GSMFC) began an initiative in late 1990 to draft a fishery management plan for the Gulf sturgeon. The drafting team (ad hoc subcommittee of the GSMFC Technical Coordinating Committee, Anadromous Fish Subcommittee), on October 1, 1991, in response to the listing, took action to draft a management/recovery plan. This plan meets the requirements of a fisheries management plan as originally begun by the GSMFC, as well as the requirements associated with an Endangered Species Act recovery plan. The plan incorporates the format that has become standard in federal endangered and threatened species recovery plans in recent years. The FWS published a "Framework for the Management and Conservation of Paddlefish and Sturgeon Species in the United States" in March 1993. This document resulted from a workshop sponsored by the FWS that was attended by representatives of other federal agencies, the states, the private aquaculture community, and academia in January 1992. This recovery plan is consistent with the framework document, and in essence, steps down the recommendations and strategies contained therein.

The plan is intended to serve as a guide that delineates and schedules those actions believed necessary to restore the Gulf sturgeon as a viable self-sustaining element of its ecosystem. Some of the tasks described in the plan are ongoing by the FWS, GSMFC, NBS, and the states of Louisiana, Mississippi, Alabama, and Florida. The inclusion of these ongoing tasks represents an awareness of their importance, and offers support for their continuation. Because of this ongoing research on the subspecies, the plan incorporates personal communications and unpublished data.

LIST OF ABBREVIATIONS

ADCNR	Alabama Department of Conservation and Natural Resources
AGS	Alabama Geological Survey
ANSTF	Aquatic Nuisance Species Task Force
CCC	Caribbean Conservation Corporation
CES	Cooperative Extension Service
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
COE	U.S. Army Corps of Engineers
CWA	Clean Water Act
CZM	Office of Coastal Zone Management
EIRP	Environmental Impact Research Program
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act
FDEP	Florida Department of Environmental Protection
FDNR	Florida Department of Natural Resources
FERC	Federal Energy Regulatory Commission
FGFC	Florida Game and Fresh Water Fish Commission
FRTES	Fisheries Resources Trace Elements Survey
FSBC	Florida State Board of Conservation
FWS	United States Fish and Wildlife Service
GCRL	Gulf Coast Research Laboratory
GSMFC	Gulf States Marine Fisheries Commission
GSRMA	Gulf States Resource Management Agencies (TX,LA,MS,AL,FL)
LDWF	Louisiana Department of Wildlife and Fisheries
MDWFP	Mississippi Department of Wildlife, Fisheries, and Parks
MMS	Minerals Management Service
NBS\BSC	National Biological Service, Southeastern Biological Science Center
NCSU	North Carolina Cooperative Research Unit, North Carolina State University
NGO	Nongovernmental organizations
NMFS	National Marine Fisheries Service
NRCS	Natural Resources Conservation Service (formerly SCS)
OCS	Outer Continental Shelf
SCS	Soil Conservation Service
TED	Turtle Excluder Device
USGS	United States Geological Survey
WES	Waterways Experiment Station
WSRFC	Warm Springs Regional Fisheries Center

LIST OF SYMBOLS

m	meter
mm	millimeter
cm	centimeter
kg	kilogram
km	kilometers
in	inches
ft	feet
mi	mile
lb	pound
hr	hour
°F	degrees Fahrenheit
°C	degrees Centigrade
ft/s	feet per second
m/s	meters per second
m^3/s	cubic meters per second
r	correlation coefficient
SD	standard deviation
TL	total length
FL	fork length
P	probability
hectare	not abbreviated
acre	not abbreviated

I. INTRODUCTION

NOMENCLATURE

The scientific name for Atlantic sturgeon is *Acipenser oxyrinchus* Mitchill. This species consists of two geographically disjunct subspecies: the Gulf sturgeon, *Acipenser oxyrinchus desotoi*, which inhabits the Gulf of Mexico watersheds, and the Atlantic coast subspecies, *Acipenser oxyrinchus oxyrinchus*.

Gilbert (1992) discovered that the species name of the Atlantic sturgeon has been "...misspelled for over one hundred years..." as *oxyrhynchus* rather than *oxyrinchus*. Consequently, based on the rules of zoological nomenclature, *oxyrinchus* is used throughout this plan.

Other colloquial names, in addition to Gulf sturgeon, are: Gulf of Mexico sturgeon, Atlantic sturgeon, common sturgeon and sea sturgeon.

TAXONOMY

Class: Osteichthyes
  Order: Acipenseriformes
    Family: Acipenseridae
      Genus: Acipenser
        Species: oxyrinchus
          Subspecies: desotoi

Type Specimens

The holotype was collected from the mouth of Singing River (West Pascagoula River) in Mississippi Sound off Gautier, Mississippi and is housed in the U.S. National Museum of Natural History, Washington, DC. The paratype was collected with the holotype and is deposited in the Chicago Natural History Museum (Vladykov 1955).

Current Taxonomic Treatment

The Gulf sturgeon is a member of the family Acipenseridae which inhabits the Atlantic, Gulf, Pacific and certain freshwaters of the United States (Ginsburg 1952). The family includes five members of the genus *Acipenser*, and three members of the genus *Scaphirhynchus*.

Other sturgeon likely to be found in the same waters with Gulf sturgeon include the pallid sturgeon, *Scaphirhynchus albus*, the shovelnose sturgeon, *S. platorynchus*, and Alabama sturgeon *S. suttkusi* (Rafinesque 1820; Forbes and Richardson 1908; Williams and Clemmer 1991). *Scaphirhynchus* are freshwater sturgeon that are native to the Mississippi and Mobile River systems. They formerly occurred in the upper Rio Grande River in New Mexico, but have not been recorded since 1874 (Lee et al., 1980). The fish are characterized by a flattened shovelshaped snout and are easily distinguished from Gulf sturgeon. *Acipenser oxyrinchus desotoi* is the only anadromous sturgeon occurring in the Gulf of Mexico.

Based on morphometrics, Wooley (1985) concluded that *A. o. desotoi* is a valid subspecies. Bowen and Avise (1990) analyzed the genetic structure of Atlantic and Gulf sturgeon using mitochondrial DNA (mtDNA) restriction fragment length polymorphism analysis, and postulated that relatively recent genetic contact had occurred between the two regions because of several shared mtDNA clones and clonal arrays. However, Ong et al. (manuscript submitted) used direct sequence analysis of the mtDNA control region and found three fixed nucleotide site differences between *A. oxyrinchus* from the Atlantic and Gulf coasts. They concluded that subspecific divisions are warranted for *A. oxyrinchus*, based on fixed genetic differences between the forms, their allopatric distributions, and their morphometric and life history differences. Ong et al. also postulated that their data, and those of Bowen and Avise (1990), indicate that the reproductive isolation between *A. o. desotoi* and *A. o. oxyrinchus* occurred because of climatic fluctuations in the Pleistocene in conjunction with related changes in the size of the Florida peninsula. Further, they noted that even if the two subspecies occasionally mix in ocean waters, the finding of fixed genetic differences between them suggests that homing fidelity is high in *A. oxyrinchus*.

STATUS

The U.S. Fish and Wildlife Service (FWS) and National Marine Fisheries Service (NMFS) designated the Gulf sturgeon to be a threatened subspecies, pursuant to the Endangered Species Act of 1973, as amended (ESA). The listing became official on September 30, 1991. As part of the listing, a special rule was promulgated to allow taking of the subspecies for educational purposes, scientific purposes, the enhancement of propagation or survival of the subspecies, zoological exhibition, and other conservation purposes consistent with the ESA. The special rule will allow conservation and recovery activities for Gulf sturgeon to be accomplished without a federal permit, provided the activities are in compliance with applicable state laws (FWS 1991a).

DESCRIPTION

Gulf sturgeon are anadromous fish with a sub-cylindrical body imbedded with bony plates or scutes. The snout is greatly extended and bladelike with four fleshy barbels in front of the mouth, which is protractile on the lower surface of the head. The upper lobe of the tail is longer than the lower lobe (Figure 1). The subspecies is light brown to dark brown in color and pale underneath (Vladykov 1955; Vladykov and Greeley 1963).

Characteristics common to both subspecies, *A. o. oxyrinchus* and *A. o. desotoi* are: Scutes strongly developed in longitudinal rows; 7 to 13 (average 9.8) dorsal shields; 24 to 35 (average 28.7) lateral shields behind dorsal fin in pairs; elongated fulcrum at base of lower caudal lobe decidedly longer than base of anal fin; head elongate; snout longer than postorbital distance in individuals up to 95.0 cm (38.0 in), but shorter than postorbital distance in older specimens (Vladykov and Greeley 1963).

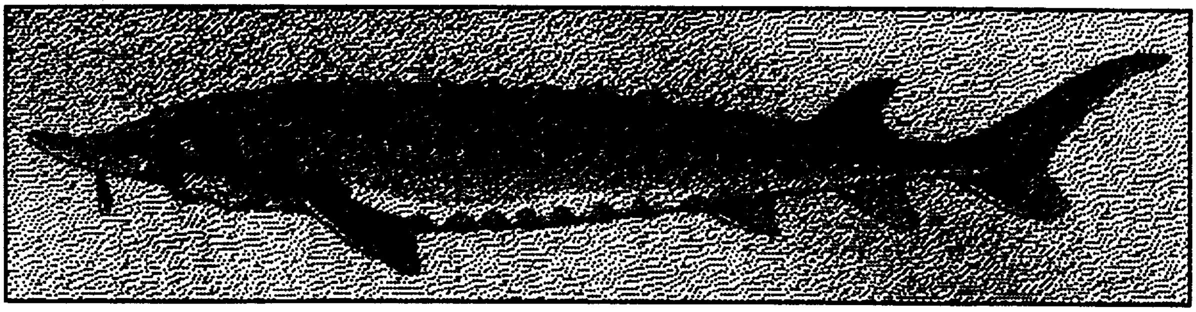

Figure 1: Gulf sturgeon *Acipenser oxyrinchus desotoi* (from Bigelow et al., 1963)

The most significant morphological characteristic to distinguish *A. o. oxyrinchus* from *A. o. desotoi* is the length of the spleen. Wooley (1985) found *A. o. desotoi* specimens had a mean spleen length versus fork length measurement of 12.3% (range 7.9 to 15.8%, SD 2.5, r = 0.212). *Acipenser o. oxyrinchus* specimens had a mean spleen length versus fork length (FL) measurement of 5.7% (range 2.8 to 8.3%, SD 1.8, r = 0.121) for a statistically significant difference ($P \leq 0.05$) and minimal overlap. He concluded that Gulf sturgeon and Atlantic sturgeon populations are allopatric and are sufficiently discrete to be considered distinct stocks for sturgeon population management.

POPULATION SIZE AND DISTRIBUTION

According to Wooley and Crateau (1985) Gulf sturgeon occurred in most major river systems from the Mississippi River to the Suwannee River, Florida and in marine waters of the Central and Eastern Gulf of Mexico south to Florida Bay (Figure 2). Comparison of historic information and current data indicates that Gulf sturgeon populations are reduced from historic levels (Barkuloo 1988). At present, Gulf sturgeon population estimates are unknown throughout its range; however, estimates have been completed for the Apalachicola and Suwannee rivers.

Extant Occurrences of Gulf Sturgeon

Offshore

A Gulf sturgeon was caught on hook and line in 1965 by Dianne Cox, a FWS employee. The 45.7-cm (18-in) Gulf sturgeon was caught in the Gulf of Mexico, 1.6 to 3.2 km (1 to 2 mi) east of Galveston Island in 6.1 m (20 ft) of water (Reynolds 1993).

The incidental catch of Gulf sturgeon in the industrial bottomfish (petfood) fishery in the north-central Gulf of Mexico from 1959 to 1963 was reported by Roithmayr (1965), based on the documentation of one juvenile specimen. The bottomfish fishery worked an area between Point au Fer, Louisiana and Perdido Bay, Florida from shore to 55 m (180 ft).

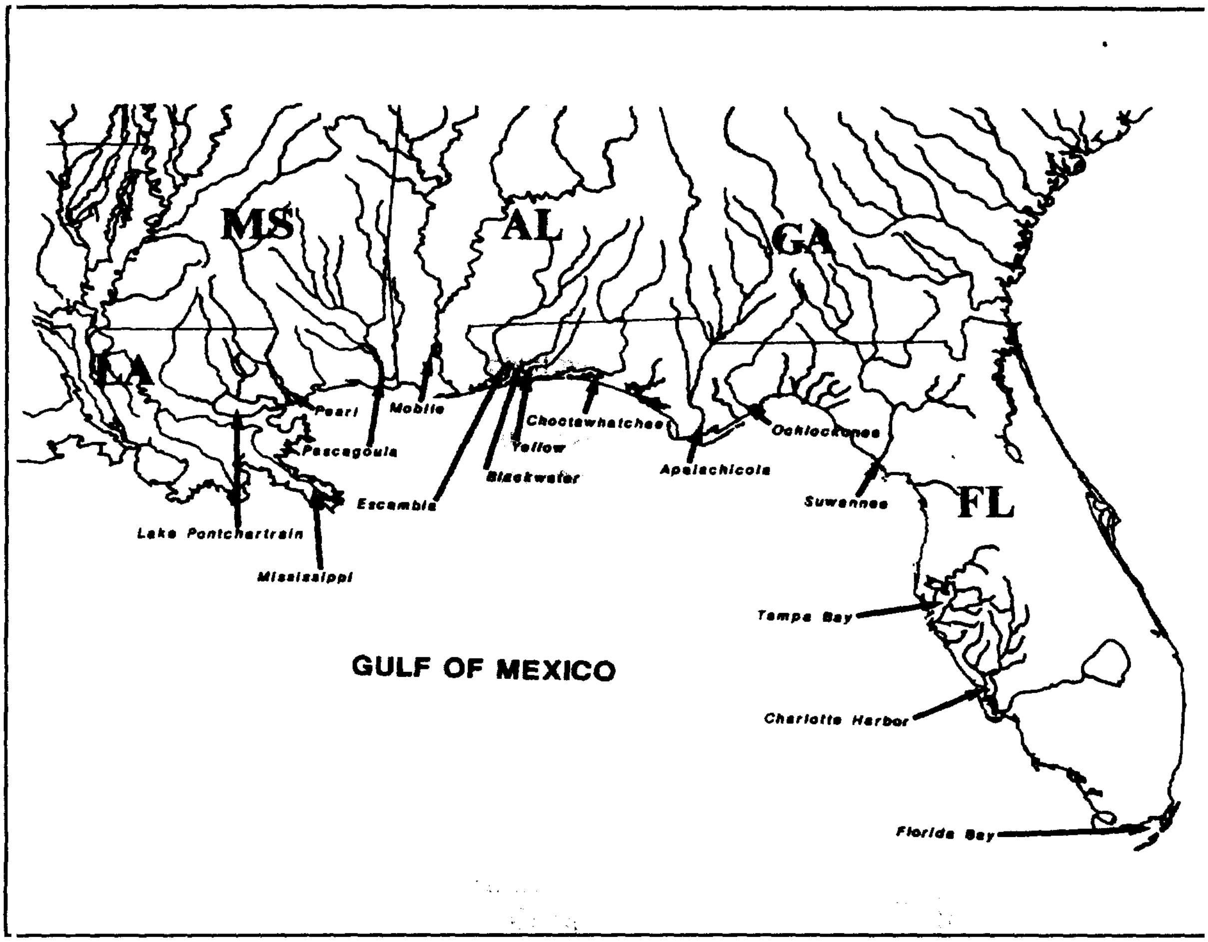

Figure 2: Range of the Gulf Sturgeon

Mermantau River Basin

Mermantau River: The Louisiana Department of Wildlife and Fisheries (1979) reported that an Atlantic sturgeon was caught by a Mr. Hugh Mhire in an otter trawl while shrimping in the Gulf off the mouth of the Mermentau River, Cameron Parish. This specimen was probably a Gulf sturgeon.

Mississippi River Basin

A photograph of a "sea" sturgeon captured at the mouth of the Mississippi River was shown in Fishes and Fishing in Louisiana (1965). Reynolds (1993) reported that a sturgeon measuring 282 cm (111.0 in) and weighing 228.2 kg (503.0 lb) was caught at the mouth of the Mississippi River at Cow Horn Reef in September of 1936.

Mississippi River: A Gulf sturgeon was caught by a commercial fisherman in the auxiliary outflow channel between river km 500.3 (river mi 311.0) of the Mississippi River and river km

16.09 (river mi 10.0) of the Red River on March 28, 1994 (G. Constant, personal communication). The Gulf sturgeon weighed 28.8 kg (63.5 lb) and was 151.2 cm (59.5 in) length and was caught in a 1.2 m (4.0 ft) hoop net.

Lake Pontchartrain Basin

Lake Pontchartrain/Lake Borgne/Rigolets: The Louisiana Department of Wildlife and Fisheries (LDWF) collected twelve Gulf sturgeon weighing 0.22 to 9 kg (0.5 to 19.8 lb) April through June of 1993 (H. Rogillio, personal communication). During a study from January 1990 to March 1993, LDWF collected and tagged 19 Gulf sturgeon weighing 0.25 to 14.5 kg (0.6 to 32.0 lb) from Lake Pontchartrain, Lake Borgne, and the Rigolets (Rogillio 1993). Commercial and sport fishermen incidentally caught 177 Gulf sturgeon measuring up to 220.0 cm (86.6 in) in length and weighing from 1.0 to 68.0 kg (2.2 to 149.9 lb) from Lake Pontchartrain from October 1991 to September 1992 (Rogillio 1993). Reynolds (1993) reported that sturgeon measuring up to 220.0 cm (86.6 in) in length and weighing up to 117.3 kg (258.0 lb) were incidentally caught by shrimp trawlers, netters and recreational anglers from 1989 to 1993 in Lake Pontchartrain. A specimen weighing 53.6 kg (118 lbs) was caught by a hook-and-line fisherman in 1986 (Sentry News 1986). Davis et al. (1970) reported that sturgeon were collected from Lake Ponchartrain during an anadromous fish survey from 1966 to 1969.

Tchefuncte River: Commercial gillnetters incidentally caught 15 Gulf sturgeon weighing from 1.0 to 18.0 kg (2.2 to 39.7 lb) between February and March 1991 in the mouth of the river (H. Rogillio, personal communication). Davis et al. (1970) reported that Gulf sturgeon were collected in trammel nets from the Tchefuncte River during an anadromous fish survey conducted from 1966 to 1969.

Tickfaw River: Davis et al. (1970) reported the collection of sturgeon in trammel nets from the Tickfaw River during an anadromous fish survey from 1966 to 1969.

Tangipahoa River: Davis et al. (1970) reported that sturgeon were collected in trammel nets from the Tangipahoa River during an anadromous fish survey from 1966 to 1969.

Amite River: Davis et al. (1970) reported catch of a sturgeon by a commercial fisherman from the Amite River. Identification of the fish was confirmed by the fisheries biologists with the Louisiana Wild Life (sic) and Fisheries Commission who were conducting an anadromous fish survey.

Pearl River: Esher and Bradshaw (1988) and Bradshaw (personal communication) gill netted a Gulf sturgeon in May 1988 in the lower Pearl River. Sixty-three Gulf sturgeon ranging from juvenile to subadult size were collected from river mile 20 of the Pearl River in 1985 (F. Petzold, personal communication). A 72.7 kg (160.3 lb) female Gulf sturgeon was caught just south of Jackson, Mississippi in 1984 by Miranda and Jackson (1987). The FWS donated a Gulf sturgeon caught by a commercial fisherman in the Pearl River at Monticello to the Mississippi Museum of Natural Science Fish Collection

(MMNS 20206) in 1982 (C. Knight, personal communication; W. McDearman, personal communication). The MDWFP measured and photographed a 119.0 kg (263.0 lb) Gulf sturgeon, 2.2 m (7.25 ft) in length taken by a commercial fisherman below the Ross Barnett Reservoir spillway in 1976 (W. McDearman, personal communication). McDearman and Stewart (personal communication) also note that in the Pearl River between Georgetown and Monticello, Mississippi, there is an area where 2 to 3 Gulf sturgeon are routinely reported by commercial fisherman every 4 to 5 years. In 1971 a Gulf sturgeon from the Pearl River was examined as part of a parasite study (N. Jordan, personal communication). Davis et al. (1970) reported the catch of Gulf sturgeon in hoop nets from the Pearl River at Highway 90 during an anadromous fish survey from 1966 to 1969. The Gulf sturgeon ranged in size from 15.2 cm (6.0 in) to 187.9 cm (74.0 in).

Middle Pearl River: Two Gulf sturgeon were collected in the Middle West Pearl River, St. Tammy Parish, Louisiana, one on March 1, 1995, and the other on March 2, 1995, by the U.S. Army Corps of Engineers, Waterways Experiment Station (WES). The Gulf sturgeon were collected in gill nets and the first sturgeon caught weighed 0.28 kg (0.62 lb) and measured 36.2 cm (14.3 in) in total length. The second Gulf sturgeon weighed 0.28 kg (0.62 lb) and measured 43.5 cm (17.1 in) in total length. Both fish were tagged with Peterson discs and released (M. Chan, personal communication).

Louisiana Department of Wildlife and Fisheries personnel collected 77 Gulf sturgeon from the west Middle Pearl River in 1994 (H. Rogillio, personal communication). The fish ranged in length from 45.7 to 165.1 cm (18 to 65 in). The majority of the fish (84 percent) ranged in length from 74.0 to 114.3 cm (29 to 45 in). The LDWF also collected 14 Gulf sturgeon weighing 1.5 to 14.5 kg (3.3 to 32 lb) in the Middle and west Middle Pearl River from June 1992 through June 1993 (H. Rogillio, personal communication). Two of those specimens were tagged with radio tags. The LDWF also collected 13 Gulf sturgeon weighing 0.27 to 4.3 kg (0.6 to 9.5 lb) in the Middle Pearl River (Drumhole) from April to May 1992 (Rogillio 1993). Commercial fishermen caught one Gulf sturgeon weighing 45.0 kg (99.2 lb) in the Middle Pearl River in February 1991.

Bogue Chitto: Three Gulf sturgeon were also captured by LDWF in the Bogue Chitto River below the Bogue Chitto sill in 1993. The Gulf sturgeon weighed from 2.9 to 4.5 kg (6.5 to 14.5 lb) (H. Rogillio, personal communication).

East Pearl River: Biologists with the FWS gill netted a Gulf sturgeon from the Mikes River, a tributary to the East Pearl River during a fishery survey in the spring of 1992. The fish was 0.7 m (2.3 ft) in length (P. Douglas, personal communication). Davis et al. (1970) reported that one sturgeon was collected in a trammel net from the East Pearl River on November 1, 1968 during an anadromous fish survey conducted from 1966 to 1969.

West Pearl River: Commercial fishermen caught five Gulf sturgeon weighing from 0.1 to 0.3 kg (0.22 to 0.66 lb) in the West Pearl River in October 1990 (H. Rogillio, personal communication).

Mississippi Sound

Bradshaw (personal communication) reported three tag returns from Gulf sturgeon that were incidentally caught by shrimpers working in Mississippi Sound during the fall of 1985. Bradshaw originally collected these Gulf sturgeon from river km 32 (river mi 20) on the Pearl River earlier in 1985. He also noted finding three dead Gulf sturgeon incidentally caught by gillnetters in the western part of the Sound and revived another Gulf sturgeon a gillnetter had caught "on" Horn Island in 1989. Five Gulf sturgeon from Mississippi Sound near Horn Island were examined as part of a parasite study (N. Jordan, personal communication). Of the five sturgeon, one was examined in each of the years 1973, 1976, and 1977, and two in 1982. One Gulf sturgeon [Gulf Coast Research Laboratory (GCRL) #1711] was incidentally caught in a shrimp trawl off the east end of Deer Island in Mississippi Sound in November 1966 in approximately 5.5 m (18 ft) of water. The Gulf sturgeon had a total length (TL) of 75.2 cm (29.6 in). Near this same location J.Y. Christmas (personal communication) reported catching one Gulf sturgeon (GCRL #28) with a TL of 55.2 cm (21.7 in) while sampling with a shrimp trawl in March 1960.

Biloxi Bay

One Gulf sturgeon was incidentally caught in a shrimp trawl in Biloxi Bay off Marsh Point on November 19, 1960 (GCRL #337). The fish was 55.5 cm (22.0 in) TL.

Pascagoula River Basin

Pascagoula Bay: Shepard (personal communication) caught two Gulf sturgeon at the mouth of Bayou LaMotte during the winters of 1991 and 1992 while gillnetting for the J.L. Scott Marine Education Center (GCRL). Reynolds (1993) reported commercial fishermen collecting Gulf sturgeon in and near the mouth of the Pascagoula River in the late 1980's and early 1990's. Shepard (personal communication) reports catching nine Gulf sturgeon from the mouth of the West Pascagoula River while gillnetting from 1983 to 1984. All but one of the sturgeon were caught at the mouth of Bayou LaMotte. The ninth fish was captured near the Sandalwood Canal. One Gulf sturgeon from the mouth of the Pascagoula River was examined in 1970 as part of as part of a parasite study conducted by GCRL (N. Jordan, personal communication).

Pascagoula River: Murphy and Skaines (1994) reported collection of seven Gulf sturgeon in the lower three miles of the Pascagoula River from April to June 1993. Two were radio tagged and released. The fish ranged in length from 46.4 to 111.8 cm (18.3 to 44.0 in) and from 0.8 to 10.4 kg (1.8 to 22.9 lb) in weight. Miranda and Jackson (1987), collected a 78.2 cm (30.8 in) Gulf sturgeon in June 1987 during 30 net-nights from the river. Three Gulf sturgeon were examined from the Pascagoula River as part of a parasite study conducted by GCRL. One was examined in 1978, the second in 1982 and the third in 1984 (N. Jordan, personal communication).

Chickasawhay River: Miranda and Jackson (1987) reported a catch of a 56.7 kg (125.0 lb) Gulf sturgeon in 1985 from the Chickasawhay River, which is a tributary of the Pascagoula River.

Leaf River: Murphy and Skaines (1994) reported that one of two fish radio-tagged from the lower Pascagoula River in May 1993 was located twice in September of that year. The last documented location of the fish was in the Leaf River three miles downstream from McLain, Mississippi approximately 123.8 km (77.0 mi) from its site of capture.

West Pascagoula River: Two Gulf sturgeon from the West Pascagoula River were examined in 1973 and 1979 as part of a parasite study conducted by GCRL (N. Jordan, personal communication). In December 16, 1964, a Gulf sturgeon (GCRL #4501) was collected by T.D. McIlwain in Big Lake off the West Pascagoula River. The sturgeon weighed 0.24 g (0.52 lb) and was 45.6 cm (18.0 in) TL. The water temperature was 13.9°C (57.0°F) with a salinity of 1.1 ppt.

Mobile River Basin

Mobile Bay: A live Gulf sturgeon was picked up on the shoreline of Bayou LaBatre by a fisherman on March 8, 1993 (F. Parauka, personal communication). The fish was 127 cm (50 in) long and weighed 12.5 kg (27.5 lb). The fish was held for observation at the Dauphin Island Sealab until a FWS biologist measured, weighed, radio-tagged, and collected genetic tissue samples and released it into Mobile Bay a day later. Efforts to locate the sturgeon again were unsuccessful. In July 1972 approximately one hundred Gulf sturgeon were observed at the mouth of the Blakeley River in eastern Mobile Bay feeding in shallow water (Vittor 1972). The sturgeon were approximately .91 m (3 ft) in length.

Mobile River: A Gulf sturgeon about 150 cm (59.1 in) long was sighted in the Mobile River near the head of Mobile Bay on October 3, 1992 by an Alabama Department of Conservation and Natural Resources (ADCNR) Marine Resources Division employee. There is a mounted specimen of a juvenile Gulf sturgeon at the Roussos Restaurant in Mobile, Alabama (J. Roussos, personal communication). The specimen is approximately 45.7 to 50.8 cm (18 to 20 in) TL and was collected in 1985 or 1986. The specimen was caught in a shrimp trawl in the Mobile River, presumably at the north end of Mobile Bay.

Tensaw River: The ADCNR reported that a commercial fisherman incidentally caught a 180 cm (70.9 in) Gulf sturgeon in the mouth of the Tensaw River in September 1991 (W. Tucker, personal communication). M. Mettee (personal communication) reported a 180 cm (70.9 in) Gulf sturgeon was incidentally netted and released in the Tensaw River in April 1986 by a commercial fisherman.

Blakeley River: Commercial gillnetters incidentally caught Gulf sturgeon in the Blakely River during the fall from 1989 to 1991.

Tombigbee River: A specimen caught in June 1987 upstream of Coffeeville on the Tombigbee River was verified by an Alabama Geological Survey (AGS) biologist as *Acipenser* (M. Mettee, personal communication). In 1977 a Gulf sturgeon from the Tombigbee River was examined as part of a parasite study (N. Jordan, personal communication). Incidental catches of Gulf sturgeon still occur annually from the Tombigbee River in the remaining riverine habitat below Coffeeville dam (J. Duffy, personal communication).

Alabama River: Incidental catches of Gulf sturgeon still occur annually from the Alabama River in the remaining riverine habitat below Claiborne dam (J. Duffy, personal communication).

Pensacola Bay Basin

Pensacola Bay: A 56.0 cm (22.0 in) TL Gulf sturgeon was collected in Pensacola Bay on January 20, 1978 (Collection No. 10319, Florida Department of Environmental Protection, FDNR).

Escambia River: Two Gulf sturgeon were collected, tagged and released in the Escambia River about 1.6 km (1.0 mi) downstream of highway 184 bridge in September 1994 by the FWS (F. Parauka, personal communication). The fish weighed 15.5 and 20.7 kg (34.0 and 45.5 lb). Incidental catches of Gulf sturgeon have been reported for the Escambia River (G. Bass, personal communication). Recreational anglers reported that prior to 1980 they would see as many as 10 Gulf sturgeon jumping in the river but now it is rare to see even one fish jump during a fishing trip (Reynolds 1993). Prior to a Florida law prohibiting sturgeon fishing in 1984, a limited commercial fishery existed on that river (National Marine Fisheries Service 1987).

Conecuh River: Annual sightings are reported from the Conecuh River in south central Alabama (J. Duffy, personal communication).

Blackwater River: Three Gulf sturgeon were collected in the Blackwater River during a Florida Game and Fresh Water Fish Commission (FGFC) striped bass netting project in March 1991. The fish weighed from 5.0 to 12.0 kg (11.0 to 26.5 lb) (FGFC, unpublished data).

Yellow River: Eighteen Gulf sturgeon were collected, tagged and released in the Yellow River below Boiling Lake in July 1993 by the FWS (F. Parauka, personal communication). The fish weighed from 5.8 to 63.6 kg (12.7 to 140.0 lb). Gulf sturgeon were collected in the Yellow River during a 1961 to 1962 survey by FGFC (1964). Commercial landings were occasionally reported prior to the 1984 fishing prohibition (J. Barkuloo, personal communication).

Choctawhatchee Bay Basin

Santa Rosa Sound: The U.S. Environmental Protection Agency (EPA) reported a 23 kg (50 lb) Gulf sturgeon washed up on the beach in Santa Rosa Sound near Navarre, Florida in 1988 (F. Parauka, personal communication).

Choctawhatchee Bay: Four Gulf sturgeon were collected by FDEP biologists on April 27, 1993 from Jolly Bay at the eastern end of Choctawhatchee Bay. The sturgeon ranged in length from 41.2 to 81.9 cm (16.22 to 32.2 in).

Choctawhatchee River: Fifty adult and subadult Gulf sturgeon were collected, tagged and released at the mouth of the Choctawhatchee River in April 1994 by the North Carolina Cooperative Research Unit, North Carolina State University (NCSU) and the FWS (Potak et al. 1995). Twenty-five of the fish were equipped with radio tags. The fish weighed from 2.5 to 72.7 kg (5.5 to 160.3 lb) and ranged in length from 73.8 to 192.0 cm (29.1 to 75.6 in). Twenty-seven Gulf sturgeon were captured, tagged, and released in the Choctawhatchee River between Howell Bluff and Rocky Landing in 1988, 1990, and 1991 by the FWS (FWS 1988, 1990, 1991b). The fish weighed from 4.5 to 52.3 kg (9.9 to 115.3 lb). In addition, a 0.13 kg (0.29 lb) specimen caught by an angler downstream from Caryville, Florida in 1991 was tagged and released by the FWS (FWS 1991b). Three Gulf sturgeon weighing from 17.0 to 26.0 kg (37.5 to 57.3 lb) were collected in the upper Choctawhatchee River below its confluence with Pea River at Geneva, Alabama in August 1991 by the FWS (FWS, unpublished data). Annual sightings are reported from the Choctawhatchee River in south central Alabama (J. Duffy, personal communication).

> **Pea River:** Three Gulf sturgeon 91.0 to 213.0 cm (35.8 to 83.9 in) in length were collected by the AGS during March 1992 about 1.0 to 3.0 km (0.62 to 1.86 mi) in the Pea River above its confluence with the Choctawhatchee River (M. Mettee, personal communication). Annual sightings are reported from the Pea River in south central Alabama (J. Duffy, personal communication).

Apalachicola, Chattahoochee, Flint River Basin

Apalachicola Bay: A 34.0 kg (74.8 lb) Gulf sturgeon was caught by a commercial fisherman in a shrimp trawl in Apalachicola Bay in November 1989 (F. Parauka, personal communication). The fish was taken to the Apalachicola National Estuarine Reserve for observation and was later tagged and released at the point of capture by the FWS. A 34.5 kg (76.0 lb) Gulf sturgeon was captured, tagged and released in Apalachicola Bay, south of Hwy 98 bridge in March 1988. Also, in March 1987, a 34.0 kg (74.6 lb) Gulf sturgeon was captured, tagged and released in Apalachicola Bay, north of Hwy 98 bridge (F. Parauka, personal communication). Incidental captures by commercial shrimpers and gill net fishermen in Apalachicola Bay were noted by Wooley and Crateau (1985) and reported by Swift et al. (1977).

Apalachicola River: The FWS Panama City, Florida Field Office has monitored the Apalachicola River Gulf sturgeon population since 1979. Three-hundred and fifty Gulf sturgeon were collected below Jim Woodruff Lock and Dam (JWLD), tagged and recaptured from May through September, 1981 through 1993. The number of fish staying below the dam in the summer was estimated using a modified Schnabel method. Fish smaller than 45.0 cm (17.7 in) TL were excluded because of sampling bias caused by net selectivity. Since 1984, the estimated annual number of fish ranged from 96 to 131 with a mean of 115 (FWS 1990, 1991b, 1992). A 145 cm (57.1 in) FL specimen was captured by FDEP (FSBC 640008) on October 28, 1970 in the river. The FGFC (1964) collected Gulf sturgeon during their anadromous fish survey conducted from 1954 to 1964.

A report of the U.S. Commission on Fish and Fisheries (1902) indicated the Apalachicola River provided the largest and most economically important commercial sturgeon fishery in Florida in 1901. Archie Carr (personal communication) noted that 32 families commercially fished for Gulf sturgeon in the mid-1940's. A commercial fishery continued until the late 1970's with only a few families. Sport fishing for Gulf sturgeon in the spring, and to a lesser extent in the fall, in some of the deeper holes in the Apalachicola River below the JWLD produced fish up to 73 kg (160.9 lb) and 2.3 m (7.5 ft) long (Tallahassee Democrat 1958, 1963, 1969).

Brothers River: Archie Carr (1978 and personal communication) began studying Gulf sturgeon in the Apalachicola River in 1975 and caught only eight sturgeon in 23 days of set-netting in Brothers Creek.

Flint River: Swift et al. (1977) noted a report of a 209 kg (460.8 lb) specimen from the Flint River near Albany, Georgia before 1950, prior to the completion of JWLD in 1957.

Ochlockonee River Basin

Ochlockonee River: Four Gulf sturgeon weighing from 2.0 to 4.0 kg (4.4 to 8.8 lb) were collected in the lower Ochlockonee River at the mouth of Womack Creek in June 1991 (FWS/Panama City and National Biological Survey/Southeastern Biological Service Center-Gainesville (NBS/SBSC-G), unpublished data). Gulf sturgeon were commercially fished in the vicinity of Hitchcock Lake in Wakulla County (Swift et al., 1977; Florida Outdoors 1959). The fish were shipped to the town of Apalachicola for processing and sale to the New York City area. Commercial landings comparable to the Apalachicola River fishery were noted in 1901 (U.S. Commission on Fish and Fisheries 1902). However, most commercial fishing for Gulf sturgeon in the river ended in the early 1970's (F. Parauka, personal communication).

Suwannee River Basin

Suwannee River: The Suwannee River appears to support the most viable Gulf sturgeon population among the coastal rivers of the Gulf of Mexico (Huff 1975). The Caribbean Conservation Corporation (CCC) has captured, marked, and released 1,670 spring migrating Gulf sturgeon at the river mouth since 1986. Based on the recapture of marked fish, the annual estimated population size ranged between 2,250 to 3,300 for Gulf sturgeon averaging about 18 kg (39.7 lb) (Carr and Rago, unpublished data). An ongoing complementary study by the NBS/BSC-G (unpublished data) has captured, marked, and released about 1,500 subadults, most of which were less than 15 kg (33.1 lb), throughout the river from March 1988 through March 1992. This river supported a limited commercial Gulf sturgeon fishery from 1899 (U.S. Commission on Fish and Fisheries 1902) until 1984 when the State of Florida prohibited harvest and possession.

Tampa Bay Basin

Tampa Bay: A commercial netter incidentally caught and released a Gulf sturgeon 56.4 cm (1.8 ft) in length, one mile west of Redington Beach near St. Petersburg in December 1992 (Reynolds 1993). Before this time, the most recent Gulf sturgeon catch reported from Tampa Bay was a 144 cm (56.7 in) FL female weighing 25.8 kg (56.9 lb), collected on December 11, 1987 near Pinellas Point (FDEP fish collection records, no collection number). Tampa Bay was the location of the first recorded significant sturgeon fishery on the Gulf of Mexico coast, lasting only three years (U.S. Commission on Fish and Fisheries 1902). The fishery began in 1886-1887 with a catch of 1,500 fish yielding 2,268 kg (5,000 lb) of roe. Two thousand fish and 2,858 kg (6,300 lb) of roe were marketed in 1887-1888. The fishery ended after the 1888-1889 season when only seven sturgeon were caught. Sturgeon catches have been reported sporadically since 1890.

Charlotte Harbor Basin

Charlotte Harbor: A 3.0 kg (6.6 lb) Gulf sturgeon was captured by a commercial mackerel net fisherman near the mouth of Charlotte Harbor on January 29, 1992 (R. Ruiz-Carus, personal communication). The sturgeon was caught on a sand bar near Boca Grande Pass, 2.4 to 3.0 m (7.9 to 9.8 ft) in depth. While specific information was given for this fish, the fishermen related that two or three sturgeon of the same size were released alive from the same net set near Boca Grande Pass. Two other specimens have been reported from Charlotte Harbor (University of Florida/Florida State Museum (UF/FSM) 35332; FSBC 18077), one of which is a 24.3 kg (53.6 lb) specimen now mounted at the Florida Marine Research Institute, FDEP, St. Petersburg, Florida.

BIOLOGICAL CHARACTERISTICS

<u>Habitat</u>

Gulf sturgeon are classified as anadromous, with immature and mature fish participating in freshwater migrations (Huff 1975; Carr 1983; Wooley and Crateau 1985; S. Carr, unpublished data; J. Clugston, unpublished data). Anecdotal information, gillnetting, and biotelemetry have shown that subadults and adults spend eight to nine months each year in rivers and three to four of the coolest months in estuaries or Gulf waters. It appears that Gulf sturgeon less than two years old remain in riverine habitats and estuarine areas throughout the year. Many Gulf sturgeon in the Suwannee River spend summer months near the mouths of springs and cool-water rivers (Foster 1993; S. Carr, unpublished data). The substrate of much of the Suwannee River is sand and limerock, especially in those areas near springs and spring runs.

Wooley and Crateau (1985) reported that Gulf sturgeon in the Apalachicola River utilized the area immediately downstream from JWLD from May through September. The area occupied consisted of the tailrace and spillway basin of JWLD and a large scour hole below the lock. During high flow periods in the late spring when water was passing through open water control gates at JWLD, Gulf sturgeon would congregate in the turbulent flow, often suspended just below the water surface. During the summer, Gulf sturgeon concentrated in the large scour hole below the lock and in the area of the dam spillway basin. This area represented the deepest available water within 25 km (15.5 mi) down-river of the JWLD. Mean total distance moved by Gulf sturgeon during this time was only 0.4 km (0.25 mi). In all cases Gulf sturgeon did not move more than 0.8 km (0.5 mi) from May through September. The area consisted of sand and gravel substrate, water depths ranged from 6.0 to 12.0 m (19.7 to 39.4 ft) with a mean depth of 8.4 m (27.6 ft) and velocities ranged from 60.0 to 90.0 cm/s (2.0 to 3.0 ft/s) with a mean velocity of 64.1 cm/s (2.1 ft/s). Because of the scarcity of historical biological data pertaining to the Gulf sturgeon in the Apalachicola River it is impossible to ascertain whether the area observed as a summer congregation area represents specific historic habitat. It may be the best alternative habitat type available to Gulf sturgeon whose migration upstream was blocked by the construction of JWLD in 1957.

The U.S. Army Corps of Engineers (COE) conducted surveys in this area in November 1991 and October 1992, to characterize flows associated with a strong cross current at the lock approach. In November 1991, velocities were measured at a depth 0.06 and 0.24 m (0.2 and 0.8 ft) of the water column, with velocities ranging from 0.19 to 0.67 m/s (0.61 to 2.19 ft/s) during normal powerhouse generation (two turbines on line with trash gate open). The follow-up survey in October 1992 included an additional measurement within the large scour hole below the lock at a depth within 0.6 m (2 ft) of the bottom. Velocities ranged from 0.08 to 0.92 m/s (0.25 to 3.01 ft/s) for normal powerhouse generation (with or without the trash gate open; with velocities at the bottom of the scour hole ranging from 0.11 to 0.37 m/s (0.36 to 1.2 ft/s) (COE 1993; COE 1994).

The Brothers River, a tributary entering the lower Apalachicola River at river km 19.3 (river mi 12.0) appears to be a staging area for Gulf sturgeon leaving the river (Odenkirk 1989). This was a favorite location for commercial Gulf sturgeon netting in past years (J. Fichera, personal communication). The Brothers River is a sluggish river with deep holes, swampy banks, and a sand and rock bottom. Wooley and Crateau (1985) characterized the habitat as having a mean depth of 11.0 m (36.1 ft), water depths ranged from 8.0 to 18.0 m (26.2 to 59.0 ft) and velocities ranged from 0.58 to 0.75 m/s (1.9 to 2.46 ft/s) with a mean velocity of .60 m/s (1.97 ft/s).

Swift et al. (1977) reported that local fishermen believed that Gulf sturgeon spawning occurred in June in the deeper holes and "lakes" along the rivers. Swift also reported that Gulf sturgeon were caught by sport fisherman from deep holes in the Apalachicola River below Jim Woodruff Dam during the spring and fall in the late 1950's to the late 1960's.

The WES reported the river conditions during collection of two Gulf sturgeon from the west Middle Pearl River on March 1, 1995. The conditions for at the surface and in 7.62 m (25 ft) of water were: temperature of 15.3°C (59.6°F) and 15.3°C (59.5°F); conductivity of 68 μmho's/cm; dissolved oxygen of 9.09 and 8.80 mg/l; pH of 6.64 and 6.57; and turbidity at the surface of 32 NTU (M. Chan, personal communication).

Bradshaw (personal communication) noted that 62 of 63 of the Gulf sturgeon collected from the East Pearl River at river km 32.2 (river mi 20) in 1985 were from one location, a deep, 12.2 m (40 ft) hole. He also reported that another Gulf sturgeon was captured at the same location in 1988.

Swift et al. (1977) noted that young Gulf sturgeon were reportedly captured in shrimp trawls in Apalachicola Bay. Muddy, soft bottom substrates, the dominant habitat of the Bay, comprise about 78% of the open water zone (Livingston 1984). Wooley and Crateau (1985) reported one Gulf sturgeon was captured 3.2 km (2.0 mi) from the mouth of Apalachicola River in the Bay in approximately 2 m (6.6 ft) depth over a mud substrate. Several Gulf sturgeon were collected from Gulf waters adjacent to Apalachicola Bay (Wooley and Crateau 1985). One Gulf sturgeon was caught 1.2 km (.75 mi) south of Cape St. George in 6 m (19.7 ft) of water and another Gulf sturgeon was captured 1.6 km (1.0 mi) south of Cape San Blas in 15 m (49.2 ft) of water. Limited stomach analyses from Suwannee and Apalachicola River Gulf sturgeon indicate that mud and sand bottoms and seagrass communities are probably important marine habitats for Gulf sturgeon (Mason and Clugston 1993).

Migration and Movement

The movements of Gulf sturgeon in the Apalachicola, Suwannee, Pearl, and Choctawhatchee rivers have been and are being monitored by ultrasonic and radio telemetry and by conventional fish sampling gear (Foster 1993; Carr 1983; Wooley and Crateau 1985; Odenkirk 1989; Rogillio 1993; Clugston et al., in press; Potak et al. 1995; S. Carr, unpublished data; Odenkirk et al., unpublished manuscript; F. Parauka, personal communication; H. Rogillio, personal communication). In general, subadult and adult Gulf sturgeon began to migrate into rivers from the Gulf of Mexico as river temperatures increased to about 16 to 23°C (60.8 to 75.0°F). They continued to immigrate through early May, but most arrive when temperatures reach 21°C. Gulf sturgeon have been collected as far upstream as river km 221 (river mi 137.3) in the Suwannee River. In the Suwannee River, most radio-tracked Gulf sturgeon appeared to settle into four 3.0 to 15.0 km (1.9 to 9.3 mi) long reaches of the river during the summer (Foster 1993). Upstream migration in the Apalachicola River is blocked at river km 171 (river mi 106.3) by the JWLD. Nearly all radio-tracked Gulf sturgeon remained in the dam tailrace during the summer (Wooley and Crateau 1985; Odenkirk 1989).

Wooley and Crateau (1985) reported that of 99 Gulf sturgeon tagged below JWLD, Apalachicola River, 6 were incidentally captured by shrimp trawlers during the fall season in Apalachicola Bay and the adjacent Gulf of Mexico. Bradshaw (personal communication) notes three Gulf sturgeon he collected and tagged in 1985 from the East Pearl River at river km 32.2 (river mi 20) that were incidentally caught by shrimpers in Mississippi Sound in the fall of that year. One Gulf sturgeon, a 53.0 cm (20.9 in) FL individual, was caught near the west tip of Cat Island, a distance of 64.6 km (40 mi) from the release point on the river.

Subadult and adult Gulf sturgeon in the Suwannee and Apalachicola Rivers generally began downstream migration in late September and October. Wooley and Crateau (1985) found that the Gulf sturgeon at the JWLD began their downstream migration in late fall when the temperature dropped to 23°C (73.4°F). Most return to the estuary or the Gulf of Mexico by mid-November to early December. In the Suwannee River, young Gulf sturgeon from about 0.3 to 2.5 kg (0.7 to 5.5 lb) remained at the river mouth during the winter and spring and were the only Gulf sturgeon captured during December, January and early February over a three year period from late 1987 to 1991 (Clugston et al. 1995). Based on mark-recapture data, these young fish did not appear to venture far into the Gulf of Mexico. Tagging (J. Clugston, unpublished data) and other life history studies (Huff 1975) found small Gulf sturgeon at river distributaries indicating that they were spawned in the Suwannee River.

Radio telemetry studies on the Choctawhatchee River conducted by NCSU in the summer of 1994, found that 25 tagged Gulf sturgeon did not distribute themselves uniformly throughout the river and did not occupy the deepest or coolest water available (Potak et al. 1995). Most fish were concentrated in relatively shallow straight stretches of the river. Of the 25 fish, 23 remained within two primary summer holding areas in the middle to lower river. They were found outside the main channel, where water velocities were less than the maximum available. Most of the fish were in water depths of 1.5 to 3.0 m (4.9 to 9.9 ft) and substrates were silt or clay.

Tagging and radio telemetry studies conducted by the LDWF during 1993 and 1994 showed subadult and adult Gulf sturgeon frequented or moved between specific areas from May through September. The most southern site is known as the Drum Hole on the west Middle Pearl River to the upper and lower Fridays Ditch on the west Middle Pearl River. Telemetry data showed movement of fish between Fridays Ditch to the West Pearl River at Powerline and Yellow Lake. Movement was also observed from Gulf sturgeon tagged from the Boque Chitto River below the sill at the canal and Lake Pontchartrain at Bayou Lacombe (H. Rogillio, personal communication).

Three sonic-tagged Gulf sturgeon were tracked into saline water and monitored in Apalachicola Bay for one to four hours in late October 1987. In November 1989, a Gulf sturgeon was monitored in Apalachicola Bay for 72 hours and tracked for 30.0 km (18.6 mi) (FWS 1988, 1989). Four Gulf sturgeon were similarly tracked in late October 1991 outside the Suwannee River and remained for about a week in water depths of 3.0 m (9.8 ft) and 5.0 km (3.1 mi) offshore in an area of mud bottom (Carr, unpublished data).

Gulf sturgeon tagging studies in the Apalachicola and Suwannee rivers demonstrate the high probability of recapture in the same river in which the fish were tagged. Between 1986 to 1992, approximately 3,750 Gulf sturgeon were tagged in the Suwannee River, and of nearly 700 recaptures, all but two were recovered in the Suwannee River. Those two recaptures occurred in the Apalachicola River and offshore near Tarpon Springs, Florida. From 1981 to 1993, a total of 350 Gulf sturgeon were tagged in the Apalachicola River. Of those, 160 were recaptured in the Apalachicola River, while six individuals were recaptured in the East Pass of the Suwannee River (S. Carr, unpublished data) and one was recaptured in the Ochlockonee River (F. Parauka, personal communication). Of those six individuals recaptured in the Suwannee River, three were recaptured the following year in the East Pass. Radio-tracking further suggests that individuals return to the same area of the river inhabited the previous summer (Foster 1993; Carr, unpublished data; FWS/Panama City, unpublished data).

Small Gulf sturgeon were noted to move southward along the western Florida coast to Florida Bay during the winters of 1957, 1959, and 1962 (D. Robins in personal communication to Wooley and Crateau 1985). Several sturgeon, estimated at 60 cm (23.6 in) FL, were also collected in fish traps in Government Cut, Miami, Florida during the winters of 1957, 1959, and 1962 (D. Robins, personal communication). Vladykov examined one of the specimens internally and determined it to be *A. o. desotoi*. These occurrences may have been in response to unusually low winter temperatures.

Stocks

Stabile et al. (unpublished manuscript) used RFLP analysis of mitochondrial DNA (mtDNA) of Gulf sturgeon collected from six geographically disjunct drainages along the Gulf of Mexico. The river systems included the Suwannee, Apalachicola, Ochlockonee, Blackwater, and Choctawhatchee rivers in Florida and the Pearl River in Louisiana/Mississippi. Their preliminary data analysis indicates that there are significant differences among Gulf sturgeon stocks. They found the most notable difference existed between the Choctawhatchee River samples and samples from other Gulf of Mexico rivers. In addition, the results indicated a break between the Apalachicola/Suwannee river populations and populations to the west of the Apalachicola River. Further, their data suggest that Gulf sturgeon display region-specific affinities and may exhibit river-specific fidelity.

Stabile et al. (unpublished manuscript) also indicated population-level polymorphisms using direct sequence analysis in sturgeon from the Gulf coast rivers. They found that Gulf sturgeon analyzed from the Pearl River exhibited haplotypes that were different from all other Gulf coast samples. Polymorphisms at other sites indicated possibly useful markers for discriminating sturgeon from the Choctawhatchee and Yellow rivers. No significant differences of mtDNA haplotypes were found among Gulf sturgeon from the eastern Gulf coast. However, these results are considered tentative because of the small sample size.

Food Habits

In the Suwannee River, stomachs of Gulf sturgeon 38 to 188 cm (15.0 to 74.0 in) FL caught in commercial gill nets 10.0 m (32.8 ft), 24.5 cm (9.4 in) stretch fished in the lower river in East Pass contained digested aquatic plant material interspersed with crab hard parts (probably blue crab, *Callinectes sapidus*). The relative abundance of crab parts was greater in stomachs of migrants entering the river in spring and usually absent from those exiting in fall (Huff 1975). Gammaridean amphipods were primarily found in smaller schooled Gulf sturgeon <82.0 cm (32.3 in) caught with trammel nets in shallow water 1.0 to 2.0 m (3.3 to 6.6 ft) in depth over a sand bank at the river's mouth (Alligator Pass). These prey species are associated with sandy substrates. Other food items included isopods (*Cyathura burbanki*), midge larvae, mud shrimp (Callianassidae), one eel (*Moringua* sp.), and unidentifiable animal or vegetable matter. Huff concluded that these small Gulf sturgeon occupied a different habitat than larger Gulf sturgeon harvested in the gill net fishery.

Mason and Clugston (1993) studied the food habits of Gulf sturgeon on the Suwannee River from 1988 to 1990. In the spring, immigrating subadult and adult Gulf sturgeon collected from the river mouth contained gammarid, haustoriid, and other amphipods, polychaete and oligochaete annelids, lancelets, and brachiopods. However, once in fresh water, these Gulf sturgeon did not eat as evidenced by the presence of only a greenish-tinged mucus in their guts during June through October. Stephen Carr (unpublished data) found in the Suwannee River that immigrating, sexually mature Gulf sturgeon were mainly empty of food; however, of food items present, brachiopods and mud shrimp dominated. By contrast, a 13.6 kg (30.0 lb) Gulf sturgeon was captured by bait trawlers on Red Bank Reef three miles from the mouth of the Suwannee River in spring 1986. Its stomach contained six species of lugworm, two species of clam, five species of crustacea, an echinoderm (sand dollar), an unidentifiable marine worm and two dozen lancelets (S. Carr, unpublished data). Mason and Clugston (1993) found that small Gulf sturgeon (0.5 to 4.0 kg) (1.1 to 8.8 lb) collected at the river mouth during the winter and early spring contained amphipod and isopod crustaceans, oligochaetes, polychaetes, and chironomid and ceratopogonid larvae. Although the guts of these young Gulf sturgeon contained small amounts of food as they migrated upstream to about river km 55 (river mi 34), they too contained only a detrital mass and were essentially empty in the freshwater reaches during the summer and fall. It remains unclear why most subadult and adult Gulf sturgeon feed for three to four months in a marine environment and enter fresh water where they do not feed for the following eight or nine months.

Growth

Huff (1975) used cross sections of pectoral fin rays to estimate the age of 631 Gulf sturgeon collected from the Suwannee River. Because back calculation using fin ray sections was not possible, mean fork lengths for fish ages 1 through 17 were calculated (Figure 3). Mean fork length at age 1 was approximately 35.0 cm (13.8 in) and increased to approximately 145.0 cm (57.1 in) at age 17.

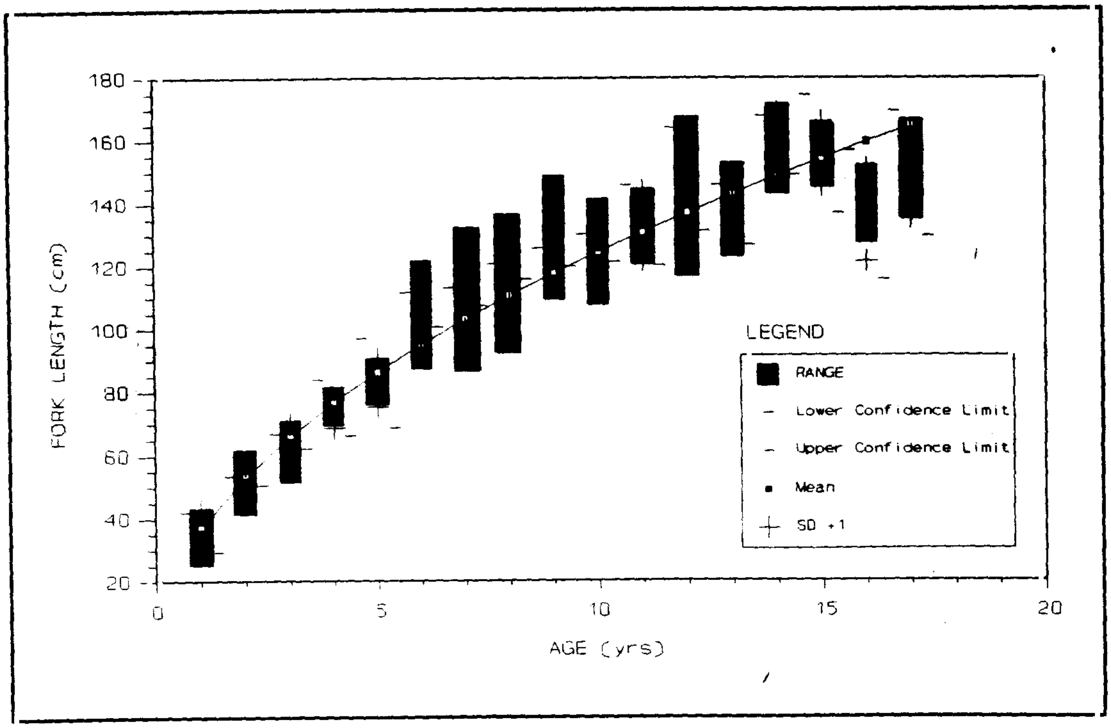

Figure 3: Length-range diagram and regression line,
Gulf sturgeon age groups 1 to 17, from 1972 to 1973 (Huff 1975)

Cross sections of pectoral fin rays were also used to estimate the age of 76 Gulf sturgeon collected from the Apalachicola River, Florida from 1982 to 1990 (Jenkins, unpublished manuscript). Fish ranged from 2 to 28 years old with lengths and weights ranging from 47.0 to 227.0 cm (18.5 to 89.4 in) and 0.2 to 90.7 kg (0.4 to 200.0 lb). Fin rays from four fish exhibited possible spawning belts. Average growth was 24.0 cm (9.4 in) per year for fish two to five years old, and 8.0 cm (3.1 in) per year to the age of eight. Fish marked and later recaptured exhibited similar large growth variations which may be the result of sexual dimorphism. The time of annulus formation was in the late summer and fall, which is a period of weight loss according to mark-recapture studies.

Carr (1983) found that on the average, marked Gulf sturgeon from the Suwannee River gained 30% of body weight in one year. He also noted that little or no growth was seen when recapture occurred during the same season and a little weight was lost by some. Wooley and Crateau (1985) noted that Gulf sturgeon 80.0 to 114.0 cm (31.5 to 44.9 in) FL tagged in early summer in the Apalachicola River below JWLD and subsequently recaptured in the same area in July and September exhibited weight losses of 4% to 15% or 0.5 to 2.3 kg (1.1 to 5.1 lb). Gulf sturgeon from 75.5 to 101.0 cm (29.7 to 39.8 in) FL tagged in September and recaptured the following year between May and September, after spending the winter period feeding in Apalachicola Bay and/or the Gulf of Mexico, showed weight gains of 35% to 137% or 4.3 to 10.2 kg (9.5 to 22.5 lb). These growth rates are considered normal for young Gulf sturgeon.

The recapture of 229 marked fish provided an opportunity to calculate seasonal growth rates of Gulf sturgeon in the Suwannee River (Clugston et al. 1995). It appears that Gulf sturgeon gain weight only during the winter and spring while in marine or estuarine waters and lose weight during the eight to nine month period while in fresh water. In general, Gulf sturgeon weighing between 7.0 kg (15.4 lb) and 27.0 kg (59.5 lb) grew about 11.0 cm (4.3 in) and gained 2.0 to 3.0 kg (4.4 to 6.6 lb) per year. In nearly all cases, however, fish that were marked and recaptured during the same summer lost weight. Those recaptures that spanned the three or four months that most fish were in the Gulf of Mexico increased in weight. Likewise, the young fish collected at the mouth of the river during the winter and spring and recaptured during the same period increased in weight. Lengths and weights were monitored for two Gulf sturgeon hatched and reared for 17 months under laboratory conditions (Mason et al., 1992). In the first year these fish grew to 71.9 cm (28.3 in) and 63.4 cm (25.0 in) in total length and to weights of 1.9 kg (4.2 lb) and 1.4 kg (3.1 lb). After 17 months they grew to 84.6 cm (33.3 in) and 78.7 cm (31.0 in) and to 3.1 kg (6.7 lb) and 2.7 kg (6.0 lb). These two fish received special treatment, and their growth in the laboratory may not represent growth of wild fish. Nevertheless, the data represent the first measured growth of young Gulf sturgeon and provide insight into the species' growth potential.

Reproduction

Timing, location and habitat requirements for Gulf sturgeon spawning are not well documented. Most subadult and adult Gulf sturgeon ascend coastal rivers from the Gulf of Mexico from mid-February through April when some adults are sexually mature and in ripe condition. Studies conducted on the Apalachicola River resulted in the only known collection of wild Gulf sturgeon larvae. Two larvae were collected at river km 168 (river mi 104.2); one on May 11, 1977 (Wooley et al., 1982) and one on May 1, 1987 (Foster et al., 1988). At the time of the 1977 collection, the surface water temperature was 23.9°C (75.0°F), water depth 4.2 m (13.78 ft), flow 365.0 m^3/s (12,888.0 ft^3/s), and velocity of .67 m/s (2.2 ft/s). During the 1987 collection the surface water temperature was 21.6°C (70.9°F), water depth 4.2 m (13.8 ft), flow 437.0 m^3/s (15430.0 ft^3/s), velocity not measured. The larva collected in 1977 was estimated to be 1 to 2 days old while the other larva was estimated to be a few hours old. A third larva was collected on April 3, 1987 at river km 18.7 (river mi 11.6) at a water temperature of 16.1°C (61.0°F), water depth 7.9 m (25.9 ft), flow not measured, and velocity .96 m/s (3.2 ft/s). The larva was estimated to be about 1 to 1.5 days old (FWS 1988).

Huff (1975) spent considerable time using anchored plankton nets to collect Gulf sturgeon eggs and larvae in the Suwannee River but was unsuccessful. However, two Gulf sturgeon eggs were collected in the river on April 22, 1993 (Marchant and Shutters, unpublished manuscript). The eggs were collected in water depths of 5.5 m and 7.3 m (18.0 ft and 24.0 ft) and water temperature 18.3°C (65.0°F) at river km 215 (river mi 134.2), just downstream of the confluence of the Alapaha River. Additional eggs were collected during late March and April 1994 at river km 201 to 221 (river mi 124.9 to 137.3) when water temperatures ranged from 18.8°C to 20.1°C (65.8°F to 68.2°F)(Smith and Clugston, unpublished manuscript). From 1988 through 1992, Gulf sturgeon investigations were conducted throughout the Suwannee River using plankton nets, small-mesh trap nets, trawls and gill nets, and electrofishing equipment. The smallest Gulf sturgeon collected was a 30.6 cm (12.0 in) specimen weighing 85.0 g (0.2 lb) at river km 215.0 (river mi 133.6) on December 3, 1991 (Clugston et al. 1995).

Stephen Carr and F. Tatman (unpublished data) found that 15 ultrasonic-tagged gravid females were associated with springs between river kms 32.0 and 145.0 (river mi 19.9 and 90.1) in the Suwannee River. The bottom habitats surrounding the springs consist mainly of rock. Their consistent association with these springs has led to Carr's speculation that spawning occurs in these areas.

Remnant reproductive populations may still occur in many small and large rivers draining into the Gulf where Gulf sturgeon have historically ranged. Infrequent anecdotal reports and incidental captures of small Gulf sturgeon indicate that reproduction is occurring in tributary rivers. Small Gulf sturgeon are closely associated with the river basin where they were spawned (river-specific affinity). This has been demonstrated in the Suwannee River and Apalachicola River/Bay distributaries, by the occurrence of similar size Gulf sturgeon in similar depths, and on similar substrate. Any analogous occurrence of small Gulf sturgeon suggests that a reproducing population remains nearby.

Spawning Age

Huff (1975) found that sexually mature females ranged in age from 8 to 17 years and sexually mature males from 7 to 21 years in the Suwannee River. The youngest ripe female specimen and the oldest immature female were age 12. The youngest ripe male specimen was 9 years old and the oldest immature male was age 10. Jenkins (unpublished manuscript) estimated a ripe male captured from the Suwannee River in 1990 to be six to seven years old.

Fecundity

Chapman et al. (1993) reported that three mature Gulf sturgeon had 458,080, 274,680, and 475,000 eggs and were estimated to have an average fecundity of 20,652 eggs/kg (9,366 eggs/lb). Smith et al. (1980) estimated that Atlantic sturgeon weighing 50.0 and 100.0 kg (110.2 and 220.5 lb) would yield over 400,000 and 1,000,000 eggs, respectively.

Gulf sturgeon eggs are demersal and adhesive (Vladykov 1963; Huff 1975; Parauka et al., 1991; Chapman et al., 1993). The eggs are globular and vary in color from gray to brown to black. Smith et al. (1980) reported that Atlantic sturgeon eggs ranged in size from 2.5 to 3.0 mm (0.10 to 0.12 in) in diameter. Parauka et al., (1991) found that eggs from Gulf sturgeon averaged 2.10 and 2.20 mm (0.08 to 0.09 in) in diameter.

Reproduction in Hatcheries

Hormone-induced ovulation and spawning of Gulf sturgeon was accomplished in 1989 at a portable hatchery located on the Suwannee River and at the Welaka National Fish Hatchery in

Florida (Parauka et al., 1991). The project was a joint effort involving the FWS, CCC, and University of California, Davis. The initial spawning produced 5,000 fry for fishery research. In 1990, 1991, and 1992, the University of Florida, the FWS, and CCC again successfully induced spawning and produced about 60,000 fry for fish culture programs. Hatching time for the artificially spawned Gulf sturgeon eggs ranged from 85.5 hr at 18.4°C (65.1°F) to 54.4 hr at about 23.0°C (73.4°F) (Figure 4) (Parauka et al., 1991). Also, at temperatures ranging from 15.6 to 17.2°C (60.1 to 63.0°F) and 19.5 to 21.0°C (67.1 to 69.8°F), eggs hatched in 95 and 65 to 70 hr, respectively (FWS 1991b). Chapman et al. (1993) reported that artificially spawned Gulf sturgeon eggs incubated at 20°C (68°F) hatched in 3.5 days. Hatching time for Atlantic sturgeon eggs has been reported to be 94 hr at 20.0°C (68.0°F) (Dean 1893), 121 to 140 hr at 16.0 to 19.0°C (60.8 to 66.2°F) (Smith et al., 1980) and 168 hr at 17.8°C (64.0°F) (Vladykov and Greeley 1963). One-hour-old Gulf sturgeon larvae, hatched under artificial conditions on the Suwannee River in 1989, ranged in length from 0.66 to 0.71 cm (0.26 to 0.28 in) with a mean length of 0.69 cm (0.27 in) (Parauka et al., 1991). Hatching success ranged from 5 to 10%.

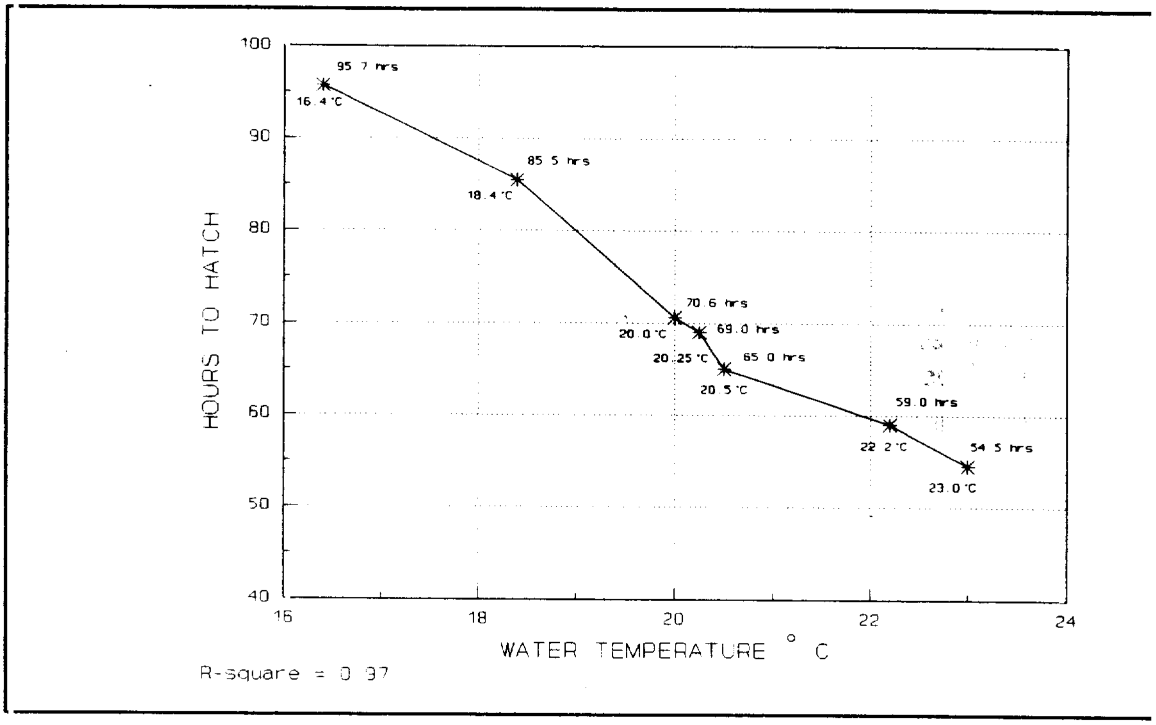

Figure 4: Gulf sturgeon egg incubation periods
at different mean water temperature (F. Parauka et al., 1991; FWS 1991b).

Predator/Prey Relationships

Van Den Avyle (1984) noted there was little written regarding competitors and predators of sturgeon. He pointed out that many fish species live in the same waters as sturgeon and that there is the possibility for competition with other bottom dwelling species. In fresh water, benthic feeders could compete with young sturgeon or feed directly on eggs and larvae. Competition with Gulf sturgeon for food or space in the marine environment is unknown. Scott and Crossman (1973) speculated that the sturgeon's "size and protective plates protect it from most predaceous fishes and its habitat and secretiveness from other predators."

Parasites and Disease

Fish lice *Argulus stizostethi*, an ectoparasitic copepod, have occasionally been observed on the opercula and gill filaments and in the gut of Gulf sturgeon collected in fresh and estuarine water. The numbers noted were not significant (Mason and Clugston 1993; F. Parauka, personal communication). Endoparasites, such as nematodes, trematodes, and leeches were noted in the guts of Gulf sturgeon (Mason and Clugston 1993). Five species of helminth parasites and one parasitic arthropod have been identified in Atlantic sturgeon from the St. Johns River, New Brunswick (Appey and Dadswell 1978). No detrimental effects from these parasites were noted in these studies.

The shovelnose sturgeon serves as host for glochidia of three mussel species. Rates of glochidial infestation on fish gills are typically low, but thought not to be detrimental to the host (R.S. Butler, personal communication). Huff (1975) reported tumor-like growths on several Gulf sturgeon ovaries from the Suwannee River. Macroscopic tumors were found from 7.5% of gill-netted females in Fall 1972, 3.5% of females in Spring 1973, and 4.6% of females in Fall 1973. Examination of this material revealed two types of growth (Harshbarger 1975). One was a perifollicular pseudocyst (surrounding follicles) filled with proteinaceous fluid often containing viable oocytes. The other type was a parafollicular serous cyst (a true separate fluid-filled cyst) containing denser proteinaceous fluid. Both types are considered subclinical, having little or no effect on adjacent organs, general ovarian development, fecundity, or spawning behavior. Microscopic slides (RTLA nos. 979 and 980) containing this material were accessioned by the Registry of Tumors in Lower Animals, Smithsonian Institution (Huff 1975). Moser and Ross (1993) reported the capture of six Atlantic sturgeon from the Brunswick River, North Carolina from June to September 1991 and in April 1992. Three of the specimen were in poor condition with abnormalities characterized by deformed mouths, lesions of the ventral buccal region and/or lesions around the eye. Oral, buccal, and ventral lesions or ulterations are common signs of poor water quality. Veterinarians examined another sturgeon from the Brunswick River that died without external evidence of disease and found the liver and heart tissues to be in poor condition.

FACTORS CONTRIBUTING TO THE DECLINE AND IMPEDIMENTS TO RECOVERY

Many members of the family Acipenseridae, including Gulf sturgeon, virtually disappeared throughout their ranges at the turn of the 20th century. Their decline was likely caused by over-exploitation and exacerbated by damming of rivers and other forms of habitat destruction and water quality deterioration, among other factors (Birstein 1993; Huff 1975; Barkuloo 1988; McDowall 1988; Smith and Clugston, unpublished manuscript).

Exploitation

The Gulf sturgeon was heavily fished because of the high value of its eggs used to produce caviar and its flesh for smoking (Carr 1983; J. Barkuloo, personal communication). Sturgeon also provided isinglass, a semi-transparent gelatin prepared from the swim bladder and used in jellies, wine and beer clarification, special cements, and glues. Directed commercial fishing contributed to the depletion of sturgeon populations. Aperiodic commercial landing statistics are available from 1887 to 1985 for Gulf sturgeon (Huff 1975; Futch 1984; Barkuloo 1988). Commercial landings data for the Suwannee River are available for 1981 to 1984 (Tatman, unpublished data). These records show that the only consistent fisheries for Gulf sturgeon occurred in west Florida. There was a directed fishery in Alabama, while there is no record of a directed commercial fishery in Mississippi, only incidental catches. Davis et al., (1970) notes a minor commercial fishery for Gulf sturgeon in the Lake Pontchartrain and its tributaries during the late 1960's.

Recreational and subsistence fishing may have contributed to population declines. A "snatch-hook" recreational fishery was popular on the Apalachicola River, Florida, during the late 1950's to 1960's (Burgess 1963; Swift et al., 1977) and continued until 1984 when the State of Florida enacted protective measures.

Incidental Catch

Incidental catch of Gulf sturgeon in other fisheries has been documented (Wooley and Crateau 1985; D. Mowbray, personal communication; H. Rogillio, personal communication). Incidental captures by commercial shrimpers and gill net fishermen in Apalachicola Bay were noted by Wooley and Crateau (1985) and reported by Swift et al. (1977). Such catches have also occurred in Mobile Bay, Tampa Bay, and Charlotte Harbor (J. Roussos, personal communication; FDEP, unpublished data). The FWS caught a small Gulf sturgeon in St. Andrew Bay while gill-net collecting for seatrout for contaminant analysis in 1986 (M. Brim, personal communication). Gulf sturgeon are occasionally caught in Gulf coast rivers on set-hooks targeting catfish (J. Duffy, personal communication). Captures of young Gulf sturgeon have been reported in blue crab traps in the Suwannee River estuary (F. Tatman, personal communication). The incidental catch of Gulf sturgeon in the industrial bottomfish (petfood) fishery in the north-central Gulf of Mexico from 1959 to 1963 was reported by Roithmayr (1965). The bottomfish fishery worked an area between Point au Fer, Louisiana and Perdido Bay, Florida from shore to water depths of about 55 m (180 ft). Hastings (1983) and Moser and Ross (1993) report capture and disruption of spawning migrations of shortnose and Atlantic sturgeon in commercial gill nets targeted for shad in the Cape Fear River, North Carolina.

The LDWF records indicate 177 Gulf sturgeon were incidentally captured and reported by commercial fishermen in southeastern Louisiana during 1992 (H. Rogillio, personal communication). Forty-four of these Gulf sturgeon were delivered to the LDWF field office or held until LDWF employees could secure them. Specimens were generally held in captivity for 1 to 7 days by the fishermen. These sturgeon were then measured, weighed, tagged and released by departmental personnel. Seventy-six Gulf sturgeon were captured in trawls, 10 in wing nets, and 91 in gill nets. A mortality of less than 1% was noted. This percentage is based on 177 Gulf sturgeon incidentally captured by commercial fishermen and 51 Gulf sturgeon captured by LDWF personnel during a Gulf sturgeon status survey.

Bradshaw (personal communication) reported three tag returns from Gulf sturgeon he collected in early 1985 which were incidentally caught by shrimpers in Mississippi Sound during the fall of that year. He also noted finding three dead Gulf sturgeon incidentally caught by gillnetters in the western part of the Sound and revived another Gulf sturgeon a gillnetter had caught "on" Horn Island in 1989.

Entrainment of *Acipenser guldenstadti* and *A. stellatus* larvae during dredging operations has been assessed by Veshchev (1982) in the lower Volga River, Russia. He concluded that hydraulic dredging operations caused significant mortality of sturgeon larvae in the Caspian basin.

Hastings (1983) reported anecdotal accounts of adult sturgeon being expelled from dredge spoil pipes while conducting a study on shortnose sturgeon on the Atlantic coast. Whether the "adult sturgeon" was an Atlantic or shortnose sturgeon was not indicated in the report.

Habitat Reduction and Degradation

Gulf sturgeon have evolved within Gulf coast drainages that exhibit seasonal patterns of high and low flows, temperature regimes, sedimentation, and other physical factors. Provision of these essential life requirements are part of and dependent on a fully functioning ecosystem.

Dams have limited sturgeon access to migration routes and historic spawning areas (Boschung 1976; Murawski and Pacheco 1977; Wooley and Crateau 1985; McDowall 1988) (Table 1). While sturgeon are able to pass some water control structures, low-head dams, or sills during high water, these structures can create barriers that preclude normal migration. An example of complete migration restriction occurred in the St. Andrew Bay system, Bay County, Florida. A newspaper account from 1895 reports sturgeon were caught at the head of North Bay in upper St. Andrew Bay (Womack 1991). The account notes that an average of three sturgeon a day were caught and 90.7 kg (200 lb) of fish had been smoked and on sale for $0.10 per lb. The FGFC collected four Gulf sturgeon 173.0 to 201.5 cm (68.1 to 79.3 in) in length from Bear Creek, a tributary to Econfina Creek which drains into North Bay, in May of 1961. A dam was placed across North Bay in 1962 preventing anadromous fish migration, and no reports of Gulf sturgeon from above the dam have been reported since that time. Not only was migration to the creeks cutoff, but approximately 2024 hectares (5,000 acres) of estuarine habitat was converted into a fresh water lake.

Another example of complete restriction to Gulf sturgeon migration is the JWLD on the Apalachicola River. Swift et al. (1977) noted a report of a Gulf sturgeon from the Flint River near Albany, Georgia prior to 1950. Huff (1975) noted Gulf sturgeon migrated 322 km

Table 1: Examples of reduction in available river habitat due to dam, water control structure, or sill construction.

River/Watershed	Total River Length	Location of Impediment	Percent Habitat Remaining
St. Andrew Bay Drainage Bear Creek, Lower Econfina Creek, upper North Bay (now known as Deer Point Lake)	11 km (6.8 mi)	Deer Point Dam County Rd 2321	0%
Apalachicola, Chattahoochee, Flint River Basin (to the fall line)	790 km (491 mi)	JWLD river km 172 (river mi 107)	22%
Mobile Bay Drainage Basin Alabama River	1691 km (1051 mi)	Claiborne Dam river km 130 (river mi 81)	8%
Tombigbee River	988 km (614 mi)	Coffeeville Dam river km 121 (river mi 75)	12%
Pearl River	772 km (480 mi)	Ross Barnett Dam (RBD) river km 486 (river mi 302)	63%
During low water conditions		Pools Bluff Sill river km 78.3 (river mi 48.7)	10%
Bogue Chitto River (during low water conditions)	217 km (135 mi)	Boque Chitto Sill river km 6.4 (river mi 4)	3%
Amite River	274 km (170 mi)	control weir river km 40.7 (river mi 25.3)	15%

(200 mi) upstream in the Apalachicola-Chattahoochee-Flint river system before the dam construction in 1957. There are numerous anecdotal reports of Gulf sturgeon in the Flint and Chattahoochee rivers prior to construction of JWLD (Swift et al. 1977). In spite of many tagging studies conducted on the Apalachicola River, no tags have been returned as a result of Gulf sturgeon moving upstream of JWLD, nor does evidence exist that the Gulf sturgeon passes though the lock system (A. Carr, personal communication; U.S. Fish and Wildlife Service, personal communication). The COE (1978) acknowledged that the dam on the Apalachicola River adversely affect Gulf sturgeon by impeding upstream migration.

An example of barriers that limit movement is found in the Pearl River basin above the Pools Bluff and Bogue Chitto Sills. Gulf sturgeon have been reported to be incidentally collected above the Pools Bluff Sill as far north as the Ross Barnett Reservoir spillway as late as 1984 (J. Stewart, personal communication; R. Jones, personal communication; W. McDearman, personal communication; R. Bowker, personal communication). Based on gauge data (COE, personal communication), the duration of water depths allowing passage of Gulf sturgeon over the sills is limited at the Bogue Chitto Sill and less restrictive at the Pools Bluff Sill (Table 2). It appears Gulf sturgeon movement above the sills is also possible through cutoffs that have developed since the construction of the Pearl River navigation canal (H. Poitevint, personal communication). However, Gulf sturgeon migration is entirely prevented above Jackson, Mississippi by the Ross Barnett Dam at river km 515 (river mi 320). Jones (personal communication) reports that Gulf sturgeon were historically found above this area. He notes the capture of a 154.2 kg (340 lb) female Gulf sturgeon 2.3 m (7.5 ft) from the river 32 km (20 mi) north of Jackson in 1942.

Navigation activities including dam construction, dredging, dredged material, and other maintenance actions could adversely affect Gulf sturgeon habitats depending on the location and timing of the activity. Elimination of deep holes and alterations of rock substrates result in loss of habitat for the Gulf sturgeon in the Apalachicola River (Carr 1983; Wooley and Crateau 1985). At Rock Bluff, river km 148.8 (river mi 92.5), this deep, rocky area frequently used by Gulf sturgeon was filled with dredged spoil material drifting downstream from a within bank disposal site at river km 150 (river mi 93) during routine maintenance dredging. This caused Gulf sturgeon to cease use of this area as a regular habitat (Carr 1983, J. Barkuloo, personal communication). The within bank disposal site is no longer used. Essential habitats of young-of-the-year Gulf sturgeon are unknown, so the impacts of dredging on early life stage habitats of Gulf sturgeon are difficult to assess.

Table 2: Duration Data on Lower Pearl River Sills (COE, personal communication).

Depth Over Sill (m)	Percent Equaled or Exceeded	
	Pools Bluff Sill[1]	Bogue Chitto Sill[2]
.3 m (1.0 ft)	100	90
.61 m (2.0 ft)	70	25
.9 m (3.0 ft)	48	10
1.2 m (4.0 ft)	35	-
1.5 m (5.0 ft)	28	-
1.8 m (6.0 ft)	24	-
2.1 m (7.0 ft)	18	-

[1]Duration based on gauge data for Pearl River at Bogulusa, Louisiana
[2]Duration based on gauge data for Bogue Chitto River at Sun, Louisiana

The entrenchment of the Apalachicola River's streambed due to the trapping of sediments in Lake Seminole, has been attributed to the construction of JWLD (COE 1986). The effects entrenchment occurred in the upper third of the river from the base of the dam to the vicinity of Blountstown, Florida. The streambed elevation lowering was also exacerbated by deepening rock sills, cutting out river bends, and repeated dredging to maintain the channel. This has resulted in elimination of some habitats that had been available to Gulf sturgeon during the summer months prior to the construction of JWLD and navigation channels. For example, as a result of streambed degradation, access to spring-fed tributary creeks has been reduced during low water periods. A cooperative effort by the COE and FGFC removed sedimentation and debris from a midstream spring below the JWLD, navigation km 170.6 (navigation mi 106.0) in January 1994. In addition, the COE obtained environmental clearances and unertook habitat restoration action by the removal of sediments at the mouth of Blue Spring Run, navigation 157.7 (river mi 98.0) in May, 1994.

Cool water habitats are thought to be important to Gulf sturgeon during the summer. Cool-water habitats in streams can be significantly reduced or even eliminated by decreased groundwater levels (Lynn Torak, personal communication). Springs emanating from the streambed originate in the groundwater-flow system and are regulated by relative differences in stream stage, spring-discharge elevation, and groundwater level. Decreased groundwater levels in the vicinity of streams, caused by pumping or climatic variation, can reduce springflow that provides cool-water habitats for the Gulf sturgeon during summer months. Pumping or climate-induced groundwater-level declines can reduce the groundwater component of streamflow (baseflow) in addition to and in the absence of springs. For example, a study in the Albany, Georgia area by Torak et al. (1993) indicates that about 74% of water pumped from the Upper Floridan aquifer in November 1985, approximately 79 million gallons a day, would have discharged to the Flint River under predevelopment conditions. The Flint River is generally unregulated and has a major spring-fed flow component that, in comparison with the Chattahoochee River, contributes the larger share of flow to the Apalachicola River during low-flow periods. The Chattahoochee River is a regulated stream that derives its flow predominantly from surface runoff. Consequently, the Chattahoochee River contributes the major portion of flow to the Apalachicola River during mean- to high-water events. Base-flow of the Flint River has been reduced since the early 1970s, mainly from groundwater and surface water irrigation withdrawals (Leitman et al. 1993). The analysis by Leitman et al. (1993) indicates that the Flint River's percent contribution to the Apalachicola River decreases, instead of increasing as would be expected as the flow in the Apalachicola River decreases. Several springs and spring runs along the upper Apalachicola and Flint Rivers have already exhibited greatly reduced flow or have ceased flowing during periods of drought. If these cool water habitats are important and are reduced in size or eliminated at critical periods of summer, Gulf sturgeon could be subjected to increased environmental stress.

Contaminants may also contribute to population declines. Experiments have shown that DDT and its derivatives and toxaphene are toxic to fish in minute quantities (Johnson and Finley 1980; White et al. 1983). Twelve Gulf sturgeon were collected from the Apalachicola, Suwannee, Choctawhatchee rivers, Ochlockonee Bay and the Gulf of Mexico near Cape San Blas, Florida, at various times between 1985 to 1991. This specimens were analyzed for pesticides and heavy metals (Bateman and Brim 1994). The Gulf sturgeon ranged in size from 1.8 to 49.0 kg (4.0 to 108.0 lb). Concentrations of arsenic, mercury, DDT metabolites, toxaphene, polycyclic aromatic hydrocarbons, and aliphatic hydrocarbons high enough to warrant concern were detected in individual fish. Specific sources of contamination were not identified. Suwannee River Gulf sturgeon had higher concentrations of arsenic in liver samples than Apalachicola River fish. However, Apalachicola River Gulf sturgeon had higher liver mercury concentrations. Organochlorine pesticides were also highest in fish from the Apalachicola River.

Organochlorines enter the environment as pesticides or industrial waste products. Use of most of these compounds has been prohibited because of effects on nontarget species and suspected carcinogenicity in humans and wildlife. Effects include reproductive failure, reduced survival of young, or physiological alterations which can affect the ability of the fish to withstand stress (White et al. 1983). Levels of DDT and derivative compounds in the samples were found at low concentrations in all Gulf sturgeon tissues, however, DDD and/or DDE was detected in 84% of the samples (Bateman and Brim 1994). In addition, amounts detected in reproductive tissue, while relatively low (range non-detect to 4.02 ppm), could affect Gulf sturgeon reproduction because DDT compounds are known to be estrogenic (Fox 1992). Like DDT, toxaphene is persistent in the environment and biomagnifies through the food chain. Toxaphene was the most heavily used insecticide after prohibition of DDT in the 1970s. Toxaphene was detected in four fish, all from the Apalachicola River. The level of toxaphene in the roe of one specimen was 14.00 ppm wet weight and exceeded the Food and Drug Administration (FDA) action level of 5.00 ppm for fish for human consumption. The highest level in muscle tissue (0.48 ppm) fell below the FDA action level for human consumption (Bateman and Brim 1994). Toxaphene is more toxic to fishes than DDT compounds (Johnson and Finley 1980) and has been shown to impair reproduction, reduce growth in adults and juveniles, and alter collagen formation in fry, resulting in "broken back syndrome" (Mayer and Mehrle 1977).

Polycyclic aromatic hydrocarbons (PAH), primarily from petroleum products, are known to be carcinogenic, cocarcinogenic and tumorigenic. Concentrations found in the ovarian tissue sample (total PAH 410 ppb; Apalachicola River) and eggs (total PAH 409 and 815 ppb; Suwannee River) could adversely affect development and survival of some percentage of eggs, larval, and juvenile fish (Bateman and Brim 1994). Aliphatic hydrocarbons are components of oils, fuels, and other petroleum products. Two or more aliphatic compounds were detected in all tissue samples of the Gulf sturgeon. Hall and Coon (1988) stated that it is likely that any animal with demonstrated petroleum hydrocarbon residues in the tissues has suffered effects of the pollutant (Bateman and Brim 1994).

Arsenic is used in herbicides, insecticides, and fungicides and can be toxic to fish in certain metabolic forms. The metal was detected in 92% of the Gulf sturgeon samples, however the metabolic form was not identified. The arsenic concentrations detected in all of the muscle tissue samples were greater than the FDA action limit of 0.50 ppm for swine muscle tissue (Bateman and Brim 1994).

Mercury, predominantly found as methylmercury in fish fillets, is highly toxic and was detected in 87% of the Gulf sturgeon samples. The mercury concentrations in muscle tissue were well below the Florida limited consumption advisory (0.50 ppm) and the FDA consumptive use action level (1.00 ppm) but, almost all tissue samples exceeded the predator protection limit of 0.10 ppm recommended by Eisler (1987) for the protection of fish-eating birds. However, the mercury levels of the Gulf sturgeon in the study were well below those reported by Armstrong (1979) for other fish species, to cause either chronic inability to catch food, rolling from side to side or acute toxicity.

Cadmium, a known teratogen, carcinogen, and probable mutagen was detected in 42% of the Gulf sturgeon samples. The concentrations were in the low to normal range for muscle and liver tissue when compared to fish species in the Fisheries Resources Trace Elements Survey (FRTES) of the NMFS (Bateman and Brim 1994). Low levels of lead were detected in 8%.

<u>Culture and Accidental or Intentional Introductions</u>

Where viable wild populations exist or sturgeon possibly can be reintroduced, the potential harm from incidental or accidental introduction of non-endemic species is a threat to the genetic integrity and biodiversity of entire ecosystems. The likelihood of these introductions increases dramatically where imports and culture of exotic species is allowed or facilitated, and even where laws or regulations exist which prohibit release of non-endemic species. Accidental releases from culture facilities and intentional releases by aquarists tiring of their hobby is a frequent occurrence. Schwartz (1972, 1981) identifies bibliographic citations of hybrid combinations between species of sturgeons (Acipenseridae). Therefore, an introduction, for example, of white sturgeon from the Pacific coast into Gulf river systems could potentially do great harm to Gulf sturgeon stocks.

An introduction has already occurred in Alabama. A white sturgeon, 50.1 cm (1.6 ft) TL, was caught by a commercial fisherman on a trotline in Lake Weiss, about 2.4 km (1.5 mi) south of Cedar Bluff, Alabama in 1989 (M. Pierson, personal communication). Lake Weiss is part of the upper Coosa River system flowing through Georgia and Alabama. In 1992 a white sturgeon, 96.0 cm (3.15 ft) TL, was caught by a fisherman in the Coosa River east of Birmingham (Sun Herald 1992). This sturgeon was caught about 100 km (62.1 mi) downstream from the 1989 capture. The white sturgeon is thought to have been accidentally released from a private fish hatchery located adjacent to the Coosa River in Georgia. The State of Georgia confiscated the white sturgeon from the hatchery in 1990.

A controversial fishery management problem revolves around the issue of hatchery stocks' adversely affect wild stocks. Hatchery technology has been employed for salmon in the Pacific Northwest for well over thirty years, but salmon stocks in many river systems have recently experienced significant declines. Biologists and many opponents of the hatchery programs attribute these declines on loss of genetic diversity caused by hatchery programs. Proponents of hatcheries argue that the basis of the problem is failure to protect habitat, manage water resources, control harvest, and prevent environmental contamination, among other factors.

These problems and failures may continue to contribute to reductions in stocks of Gulf sturgeon. The problems are readily evident and appropriate actions should be taken to correct them before or in conjuction with introduction of hatchery stock.

Other

Finally, life history characteristics of Gulf sturgeon may complicate and protract recovery efforts. Gulf sturgeon cannot establish a breeding population rapidly because of the long period they require to achieve sexual maturity. Further, Gulf sturgeon appear to be river-specific spawners, although immature Gulf sturgeon occasionally exhibit plasticity in movement or occurrence among Gulf basin rivers. Therefore natural repopulation may be non-existent or very low by Gulf sturgeon migrating from other rivers.

Fishery Management Jurisdiction, Laws, and Policies

The take of Gulf sturgeon is prohibited in the state waters of Louisiana, Mississippi, Alabama, and Florida. Section 6(a) of the ESA provides for extended cooperation with states for the purpose of conserving threatened and endangered species. The Departments of the Interior and Commerce may enter into cooperative agreements with a state, provided the state has an established program for the conservation of a listed species. The agreements authorize the states to implement the authorities and actions of the ESA relative to listed species recovery. Specifically, the states are authorized (1) to conduct investigations to determine the status and requirements for survival of resident species of fish and wildlife (this may include candidate species for listing), and (2) to establish programs, including acquisition of land or aquatic habitat or interests for the conservation of fish and wildlife. Federal funding is also provided to states under the agreements to implement the approved programs. All four of the above mentioned states have entered into Section 6 agreements with the FWS. More detailed descriptions of pertinent agencies, laws, and regulations are provided in Appendix A.

CONSERVATION ACCOMPLISHMENTS

Caribbean Conservation Corporation/Phipps Florida Foundation

1. Initiated tagging of Gulf sturgeon in 1975, using monel tags, in the Apalachicola and Suwannee Rivers which resulted in evidence of home-river fidelity, yearly growth rates, in-river weight loss, and an estimate of population size.

2. Initiated telemetry studies of Gulf sturgeon in 1976, providing evidence of the importance of the Floridian Aquifer to Gulf sturgeon ecology and in-river site fixity.

3. Initiated consultations which resulted in prohibition of take of Gulf sturgeon in the State of Florida.

Gulf States Marine Fisheries Commission

1. Initiated a Gulf sturgeon interjurisdictional fishery management plan in 1990 which evolved into the Gulf Sturgeon Recovery Plan.

National Biological Service, Southeastern Biological Science Center, (BSC-G formerly U.S. Fish and Wildlife Service), Gainesville, Florida

1. Since 1987 conducted comprehensive population and life history studies of Gulf sturgeon in the middle and lower Suwannee River, Florida, in cooperation with the CCC.

2. Facilitated survival and abundance estimates for Gulf sturgeon in the Suwannee River by FWS Resource Analysis Branch using CCC long-term data.

4. Developing relational database on physical, chemical, and biological characteristics of the Suwannee River for use with geographic information system (GIS) software.

5. Evaluating habitat characteristics in areas Gulf sturgeon are known to occupy during the summer months.

6. Conducted studies on movement of hatchery reared Gulf sturgeon released into the Suwannee River.

7. Conducted feasibility study for offshore sonic tracking of Gulf sturgeon.

8. Initiated field sampling in Tampa Bay and the Waccasassa, Steinhatchee, and Ochlockonee rivers to determine presence of Gulf sturgeon and evaluate existing habitat.

9. Provided an analysis of food habits of subadult and adult Gulf sturgeon in the Suwannee River.

10. Provided an assessment of the water quality of the Suwannee River and impacts of natural and human-induced disturbances on the food resources of the Gulf sturgeon.

11. Instituted and maintained a voucher specimen reference collection of Gulf sturgeon foods and provided expert assistance in identification of food organisms.

12. Devised and tested methods for culture of key foods used to rear Gulf sturgeon; amphipod crustaceans, brandling worm, West-African nightcrawler, blackworm, and tubificid oligochaetes.

13. Participated in first artificial spawning of the Gulf sturgeon at a temporary streamside facility in 1989-1991 and in 1992-1993 at the NBS\BSC.

14. Provided the first documented growth of Gulf sturgeon fed natural foods in a laboratory from fry stage to 17 months.

15. Conducted food preference study on cultured juvenile Gulf sturgeon comparing survivorship and growth between live and commercially prepared foods.

16. Identified critical thermal maximum and preferred temperature for cultured juvenile Gulf sturgeon.

17. Conducted investigations into plasma osmotic and metabolic responses to a wide range of experimental salinities.

18. Evaluating the retention rate of passive integrated transponders (PIT tags) and coded wire tags in cultured Gulf sturgeon.

<u>State of Alabama</u>

Alabama Department of Conservation and Natural Resources

1. Established a regulation in 1972 prohibiting all take of sturgeon within the jurisdiction of the State of Alabama.

2. Conducted literature search and field survey in 1991 and 1992 to determine historic and current status of Gulf sturgeon and possible reasons for apparent decline.

3. Conducted sampling of juvenile Gulf sturgeon on the Alabama River from 1990-1992.

4. Conducted feasibility work in 1992 regarding the use of ADCNR's Claude Peteet Mariculture Center in Gulf Shores, Alabama, as a Gulf sturgeon hatchery for the Mobile system.

Alabama Geological Survey

1. Conducted Gulf sturgeon sampling in the Alabama, Mobile, Conecuh, and Choctawhatchee river systems.

<u>State of Florida</u>

Florida Department of Environmental Protection (formerly Florida Department of Natural Resources

1. Conducted an anadromous fish survey, including Gulf sturgeon, in 1970-1971.

2. Completed the first life history study of Gulf sturgeon in the Suwannee River, Florida from 1972-1973.

3. Conducted a status review of Gulf sturgeon in Florida waters in 1984, and recommended prohibition of all take of the species within the jurisdiction of the State of Florida.

Florida Game and Fresh Water Fish Commission

1. Completed F10-R Anadromous Fish Study from 1964-1967.

2. In 1987 listed the Atlantic sturgeon as a Species of Special Concern in: Official list of endangered and potentially endangered fauna and flora in Florida. Florida Game and Fresh Water Fish Commission. 19 pp.

3. In conjuction with the COE, Mobile District, removed sedimentation and debris from a midstream spring below the JWLD on the Apalachicola River, navigation km 170.6 (navigation mi 106.0), to restore important thermal refuge habitat for the Gulf sturgeon and other anadromous species in January 1994.

Florida Marine Fisheries Commission

1. Established a regulation in 1984 prohibiting all take of sturgeon within the jurisdiction of the State of Florida.

University of Florida

1. Artificial propagation of Gulf sturgeon 1991-1995.

State of Mississippi

Gulf Coast Research Laboratory

1. Distributed Gulf sturgeon posters at boat ramps and other appropriate locations during 1992 in order to acquire information and reports on Gulf sturgeon sightings.

Mississippi Department of Wildlife, Fisheries, and Parks

1. Established a regulation in 1974 prohibiting all take of sturgeon within the jurisdiction of the State of Mississippi.

2. Listed the sturgeon as an endangered species in 1974.

3. Conducted Gulf sturgeon investigation and documentation in the Pascagoula River during 1993.

Mississippi State University

1. Documented Gulf sturgeon presence in the lower Pearl River in 1985 and 1988.

2. Documented incidental catches of Gulf sturgeon in Mississippi in 1989.

3. Investigated and documented Gulf sturgeon in the Pascagoula River in 1993.

State of Louisiana

Louisiana Department of Wildlife and Fisheries

1. Initiated a survey in 1990 to assess the status of Gulf sturgeon in Louisiana waters.

2. Initiated a radio-tracking project in 1992 on Gulf sturgeon in the Pearl River drainage and continuing into 1994.

3. Established a computerized data base in 1991 on all pallid and Gulf sturgeon sightings and captures in Louisiana and continues to be updated as needed.

4. Conducted Gulf sturgeon tagging using T-bar and monel tags beginning in 1992 and ongoing in 1994.

5. Collected blood and tissue samples for genetic analysis beginning in 1991 and ongoing in 1994.

6. Established a regulation in 1990 prohibiting all take of sturgeon within the jurisdiction of the State of Louisiana.

State of Texas

Texas Parks and Wildlife Department

1. Conducted sampling for sturgeon in the Rio Grande in 1992 - 1993.

2. Documented historic distribution of sturgeon in Texas.

U.S. Army Corps of Engineers, Mobile District, Mobile, Alabama

1. Restored access into Battle Bend Cutoff on the Apalachicola River, approximate river km 46.3 (river mi 28.8) in 1987.

2. Conducted flow/velocity studies below the JWLD to document velocities in Gulf sturgeon habitat areas during low flow conditions during November 1991 and October 1992, as

part of a Biological Assessment associated with the Jim Woodruff Powerhouse Major Rehabilitation Evaluation Report.

3. In conjuction with the FGFC, removed sedimentation and debris from a midstream spring below the JWLD on the Apalachicola River, navigation km 170.6 (navigation mi 106.0), to restore important thermal refuge habitat for the Gulf sturgeon and other anadromous species in January 1994.

4. Obtained environmental clearances and undertook action to restore habitat for the Gulf sturgeon and other anadromous species by removal of sediments at the mouth of Blue Spring Run, Apalachicola River, navigation km 157.7 (river mi 98.0) in March 1994, under the Department of the Army/National Oceanic and Atmospheric Administration Cooperative Agreement to Create and Restore Fish Habitat.

5. Initiated Anadromous Fish Hatchery Reconnaissance Study in 1987.

6. During January 1994, the COE proposed that the Waterways Experiment Station (WES) consider in the FY 1995 Environmental Impact Research Program (EIRP) a proposal to document issues affecting the protection of sturgeon related to O&M activities in North American rivers. This proposal was submitted because of similar concerns expressed by other COE divisions and districts that operation and maintenance (O&M) projects may impact sturgeon populations. It is also proposed to quantify responses of sturgeon to broad ranges of relevant physical conditions so that risk from O&M activities can be predicted. Districts will be surveyed for specific issues on sturgeon and the scope of problems will be defined. The District has been informed from COE headquarters that funds are available for WES to initiate efforts in FY 1995.

U.S. Army Corps of Engineers, Vicksburg District, Vicksburg, Mississippi

1. Funded a study conducted by WES on Gulf sturgeon in the Pearl River during 1994 and 1995.

U.S. Fish and Wildlife Service

Fisheries Resources Office, Panama City Field Office, Florida

1. First documented in-river habitat usage of Gulf sturgeon in 1977.

2. First documented Gulf sturgeon spawning in the Apalachicola River, Florida in 1977.

3. Investigated methods of externally marking Gulf sturgeon beginning in 1981.

4. Documented the movement of Gulf sturgeon in the Apalachicola River using radio and sonic telemetry devices beginning in 1982.

5. Estimated the Gulf sturgeon population size in the Apalachicola River below JWLD beginning in 1983.

6. Reviewed and validated the morphometric characteristics used in the taxanomic separation of Gulf and Atlantic sturgeon in 1985.

7. Developed field techniques and equipment which aided in the handling of Gulf sturgeon in 1985.

8. Investigated the age structure of Gulf sturgeon in the Apalachicola River by utilizing cross-sections from pectoral fin rays beginning in 1986.

9. Initiated artificial propagation of Gulf sturgeon in 1989.

10. Collected samples for and funded genetic studies on Gulf sturgeon throughout their range beginning in 1990.

11. Collected samples for and funded contaminant tissue analyses of Gulf sturgeon from the Apalachicola and Suwannee rivers, Florida beginning in 1990.

12. Initiated a program through news releases and information posters to document Gulf sturgeon sightings (past and present) from Tampa Bay, Florida to the Mississippi River in 1992.

13. Funded development of a dual radio-sonic telemetry tag in 1992.

14. Compiled and maintained a directory/data base of sturgeon and paddlefish researchers beginning in 1992.

17. Produced a report entitled Gulf Sturgeon Sightings, Historic and Recent - a Summary of Public Responses in 1993.

18. Conducted field investigations to develop a population model for the Gulf sturgeon and to delineate riverine habitat requirements in 1993 and 1994, in cooperation with the NBS, North Carolina Cooperative Fish and Wildlife Research Unit.

Ecological Services, Panama City, Florida

1. Funded preparation of an information report on the Gulf sturgeon, entitled: Gulf of Mexico Sturgeon, *Acipenser oxyrhynchus* (Vladykov), Information. 1980. Unpublished. 15 pp. J.L. Hollowell.

2. Completed a document entitled: Report on the Conservation Status of the Gulf of Mexico Sturgeon *Acipenser oxyrhynchus desotoi* in 1988.

3. **Prepared report entitled, <u>Reconnaissance Report on the Feasibility of Constructing an Anadromous Fish Hatchery Apalachicola River, Florida</u> for the COE, Mobile District in 1989.**

4. **Initiated the proposal to list the Gulf sturgeon under the ESA.**

5. Coordinated development of Gulf Sturgeon Management/Recovery Plan from 1992 to 1995.

Ecological Services, Jacksonville, Florida

1. Prepared the listing package to list the Gulf sturgeon as a threatened species under the ESA (listed September 30, 1991 in conjuction with the Department of Commerce-NOAA).

Ecological Services, Jackson, Mississippi

1. Produced a Mobile River Basin Aquatic Ecosystem Recovery Plan in 1995.

Warm Springs Regional Fisheries Center, Georgia

1. Developed Gulf sturgeon artificial feeding program in 1989.

Welaka National Fish Hatchery, Florida

1. Hormone induced spawning of Gulf sturgeon beginning in 1989.

2. Developed Gulf sturgeon artificial feeding program in 1989.

Gulf Coast Fisheries Coordination Office, Ocean Springs, Mississippi

1. Participated as a technical advisor in development of the Gulf sturgeon Management/Recovery Plan from 1992 to 1995

<u>Memorandum of Understanding (MOU) on Implementation of the Endangered Species Act.</u>

Fourteen federal agencies including the COE, NMFS, FWS, NPS, DOD, MMS, CG and EPA signed the MOU in September of 1994. The purpose of the MOU was to establish a general framework for cooperation and participation among the agencies in accordance with responsibilities under the ESA. The agencies are to work together along with appropriate involvement of the public, states, Indian Tribal governments, and local governments, to achieve the common goal of conserving species listed as threatened or endangered under the ESA by protecting and managing their populations and the ecosystems upon which those populations depend. The cooperating federal agencies involved in recovery of the Gulf sturgeon will now be able to work closer together under the umbrella of this MOU.

II. RECOVERY AND FISHERY MANAGEMENT

OBJECTIVES AND CRITERIA

Objectives constitute those results that are desired to be attained through implementation of the Recovery Plan. Criteria are those factors that define how attaining the objective will be pursued, and what will constitute sucess.

1. <u>Short-term Objective</u>: The short-term recovery objective is to prevent further reduction of existing wild populations of Gulf sturgeon within the range of the subspecies. This objective will apply to all management units within the range of the subspecies. Ongoing recovery actions will continue and additional actions will be initiated as needed.

   <u>Criteria</u>:

   A. Management units will be defined using an ecosystem approach based on river drainages. This approach may also incorporate genetic affinities among populations in different river drainages.

   B. A baseline population index for each management unit will be determined by fishery independent catch-per-unit-effort (CPUE) levels.

   C. Change from the baseline level will be determined by fishery independent CPUE over a three to five year period. This time frame will be sufficient to detect a problem and to provide trend information. The data will be assessed annually.

   D. The short-term objective will be considered achieved for a management unit when the CPUE is not declining (within statistically valid limits) from the baseline level.

2. <u>Long-term Objective A</u>: The long-term recovery objective is to establish population levels that would allow delisting of the Gulf sturgeon by management units. Management units could be delisted by 2023 if the required criteria are met. While this objective will be sought for all management units, it is recognized that it may not be achievable for all management units.

   <u>Criteria:</u>

   A. The timeframe for delisting is based on known life history characteristics including longevity, late maturation, and spawning periodicity.

   B. A self-sustaining population is one in which the average rate of natural recruitment is at least equal to the average mortality rate over a 12-year period (which is the approximate age at maturity for a female Gulf sturgeon).

C. This objective will be considered achieved for a management unit when the population is demonstrated to be self-sustaining and efforts are underway to restore lost or degraded habitat.

3. Long-term Objective B: This is a long-term fishery management objective to establish, following delisting, a self-sustaining population that could withstand directed fishing pressure within management units. Note that the objective is not necessarily the opening of a management unit to fishing, but rather, the development of a population that can sustain a fishery. Opening a population to fishing will be at the discretion of state(s) within whose jurisdiction(s) the management unit occurs. As with Long-term Objective A, this objective may not be achievable for all management units, but will be sought for all units.

Criteria:

A. All criteria for delisting must be met.

B. This objective will be considered attained for a given management unit when a sustainable yield can be achieved while maintaining a stable population through natural recruitment.

C. Particular emphasis will be placed on the management unit that encompasses the Suwannee River, Florida, which historically supported the most recent stable fishery for the subspecies.

These objectives and criteria are preliminary. After better identification of population status and evaluation of the adequacy of the habitat to support self-sustaining populations, these objectives and criteria may be revised. The criteria stated above will be more quantitatively defined through identification of management units and through population assessments in those individual management units.

OUTLINE FOR RECOVERY ACTIONS ADDRESSING THREATS

Recovery Outline Narrative

1.0 Determine essential ecosystems, identify essential habitats, assess population status, and refine life history investigations in management unit rivers.

As an initial step to enhance the long-term recovery of populations of Gulf sturgeon, collection of basic biological information is essential. Without a clear understanding of life history requirements, recovery efforts are severely hampered. Presently, lack of information in the marine environment and sparse information in the riverine environment make it difficult to adequately census populations or to implement appropriate recovery actions. Studies to provide this information should be conducted as soon as possible.

1.1 Identify essential habitats important to each life stage in river basin and contiguous estuarine and neritic waters.

Investigations are needed to locate and describe the micro- and macrohabitat characteristics critical for recovery and maintenance of the Gulf sturgeon. Radio and ultrasonic tracking studies of juveniles and adults will help determine movements and habitat utilization over time. Emphasis should be placed on tracking Gulf sturgeon in the estuarine and marine environment where it is believed that most feeding and growth occurs, and where the least information is available. Spawning areas and larval and post-larval movements and distribution within rivers must be determined. When a sufficient number of animals has been monitored and distributions identified, habitat characterization studies can be used to better define essential habitat requirements. Significant ecosystems for the recovery of the Gulf sturgeon will be identified once essential habitats are defined in riverine, estuarine, and marine environments

1.1.1 Conduct and refine field investigations to locate important spawning, feeding, and developmental habitats.

Gulf sturgeon have been successfully tracked with radio and ultrasonic transmitters in riverine systems. These studies have been limited to a very few locations, and usually for a short time spans. Multi-year tracking studies in the estuarine and marine environment have never been accomplished. Knowledge of spawning areas, developmental habitat requirements and feeding requirements are essential to the recovery of Gulf sturgeon in all river basins across the range of the species. Tracking studies appear to be the best way to initially locate important habitat. Technological advances in telemetry should facilitate long-term tracking studies to provide the needed information. The FWS and NBS should expand their efforts to identify and inventory essential habitats of Gulf sturgeon. The Gulf states resource management agencies should continue or initiate studies to identify essential habitats in their respective states. The CCC should continue their multi-year monitoring program on the Suwannee River. New field work by other researchers such as universities and non-government organizations (NGOs) should incorporate this research need into their plans. The NMFS should work with FWS and NBS to identify marine habitats used by adult Gulf sturgeon during winter migration. The MMS should seek funding to obtain this information because of the potential for impacts to the Gulf sturgeon from outer continental shelf oil and gas operations and other non-energy mineral mining activities.

1.1.2 Characterize riverine, estuarine, and neritic areas that provide essential habitat.

When areas of utilization have been delineated (Task 1.1.1), characterization of these habitats should be conducted. Characteristics of the areas regarding particular life history requirements of Gulf sturgeon at various life stages must be determined. Among the parameters that may be important include substrate, depth, instream flow, current, pH, temperature, turbidity, and food availability. The Gulf states resource management agencies, FWS, NMFS, NBS, CCC, NGOs, and universities should refine their studies or surveys to provide these data.

1.2 Conduct life history studies on the biological and ecological requirements of little known or inadequately sampled life stages.

Because of the difficulty in collecting eggs, larvae, and adequate numbers of Gulf sturgeon less than a year old, essentially nothing is known about requirements of these life stages in the wild. Year-class strength is established during these stages, and water temperature, salinity, flow, turbidity, and other factors affect survival rates. As outlined in Task 1.1, intensive field investigations must be initiated to locate and characterize habitats used by early life stages. Likewise laboratory studies on wild and cultured Gulf sturgeon must be conducted to evaluate habitat requirements and tolerances. The University of Florida, NBS, and FWS should expand ongoing investigations into the biology and ecology of Gulf sturgeon. Non-fatal sampling techniques to examine stomach contents need to be determined. Diet studies of fish captured in estuaries should be expanded. Diet of Gulf sturgeon captured offshore (neritic environments) should also be evaluated, not only to assess food preferences, but also to determine habitat use.

It is known that subadult and adult Gulf sturgeon spend winters feeding in estuarine and marine waters. Little is known about specific areas and habitat requirements. Ultrasonic techniques should be improved and studies conducted to document marine habitats frequented by Gulf sturgeon. Identified habitats must be described by depth, water quality, substrate, and food availability. The FWS and NBS should continue ongoing marine habitat investigations of Gulf sturgeon. The NMFS should initiate marine habitat investigations of Gulf sturgeon.

1.3 Survey, monitor, and model populations.

Intensive field investigations have concentrated on Gulf sturgeon life history in the Suwannee and Apalachicola rivers in Florida. Additionally, long-term monitoring of Gulf sturgeon in these systems has resulted in reliable population estimates with which population models are being developed. Outside these systems, few studies have been conducted on the Gulf sturgeon. Information such as distribution, relative abundance, age structure and other biological information should be compiled to identify baseline population status and identify index monitoring sites to evaluate success of recovery and management programs.

1.3.1 Develop and implement standardized population sampling and monitoring techniques.

The assessment of Gulf sturgeon populations Gulfwide are essential to develop and evaluate recovery and management efforts. Standardized programs to address size, age and sex composition, and stock size must be developed so that the condition of each stock can be evaluated over time and compared with those in other river systems. Government agencies, NGOs, and universities investigating Gulf sturgeon should participate in a coordinated effort to develop standardized sampling and monitoring techniques and conduct appropriate programs. Standard operating procedures will facilitate application of statistical data set comparisons between various Gulf coast river systems. In addition, fishery management/recovery decisions could be more accurately formulated with uniform data collection and reporting procedures. The FWS should take the lead in coordinating, preparing and distributing a standardized sampling and monitoring protocol document. The Gulf states resource management agencies should evaluate the status of populations of Gulf sturgeon in their streams and coastal waters. The FWS and NBS in conjunction with other researchers should verify current aging techniques for Gulf sturgeon.

1.3.2 Develop population models.

Modeling is needed to better assess fishery restoration and management options. Capture-recapture models can estimate survival, abundance and recruitment of Gulf sturgeon. Population models should be developed to forecast the future condition of Gulf sturgeon populations and provide estimates on potential rates of recovery. Appropriate models will also help identify future research needs. The FWS and NBS should continue to take the lead in formulating peer accepted population models for the Gulf sturgeon.

1.4 Continue experimental culture of Gulf sturgeon.

Successful artificial propagation of Gulf sturgeon was first accomplished in 1989. Additional work is still needed to refine culture techniques, develop handling and holding procedures for fry and broodstock, maintaining genetic diversity of broodstock, research nutritional requirements and initiate fish health management. In addition, research is needed to document the optimum chemical and physical parameters necessary for maintaining growth and survival of Gulf sturgeon under artificial and natural conditions.

1.4.1 Continue culture of Gulf sturgeon.

State, federal, and NGOs should continue to develop culture techniques for Gulf sturgeon in accordance with the Gulf Sturgeon Hatchery Guidelines, Hatchery Manual for White Sturgeon protocols addressed in the Gulf Sturgeon Recovery Plan, and state and federal laws and regulations. Efforts should be directed towards filling data gaps (i.e. hormone dosages and types, incubation temperatures, egg de-adhesion methods, broodstock reproductive staging, elimination of stress related to capture, handling, and holding, among other factors).

1.4.2 Identify the physical, chemical and biological parameters necessary to maintain growth, health and survival of Gulf sturgeon reared under artificial conditions.

Studies are needed to determine the optimum water quality conditions necessary to maintain growth and survival of fry and fingerlings. In addition, nutritional requirements and artificial feeding methods need to be identified. Research is required to document carrying capacity for various fish rearing facilities, and hauling densities of fry and fingerlings. The FWS, researchers, and universities should continue to implement additional studies to address this need. Also, the FWS should take the lead in providing updated information on artificial propagation of Gulf sturgeon.

1.4.3 Identify and test internal and external markers or techniques useful for differentiation of wild and hatchery-produced Gulf sturgeon.

The identification of non-genetic internal and external markers to differentiate between wild and hatchery-produced Gulf sturgeon is important in the development and regulation of hatchery programs. Unique markers (i.e. PIT tags, coded wire tags, and chemical marking) could allow investigators, law enforcement officers, and others to distinguish hatchery-reared fish from wild stocks. In addition, these markers or techniques may be used in selective enhancement programs and provide a means to evaluate introductions. The FWS and other researchers should continue to investigate and develop useful internal and external markers or techniques.

1.5 Identify genetic characteristics of wild and hatchery-reared Gulf sturgeon.

Research is needed to determine whether or not significant genetic differences exist among Gulf sturgeon from throughout the range of the subspecies. Determining whether genetic differences exist among populations is essential to ensure successful recovery and management of the subspecies. Genetically distinct management units may be identified and could affect reintroduction and/or population augmentation.

1.5.1 Conduct a Gulfwide genetic assessment to determine geographically distinct management units.

Determination of the genetic structure for Gulf sturgeon is essential in formulating future management decisions for the subspecies. It is important that sound restoration efforts of Gulf sturgeon address the genetic structure of the subspecies in order to identify and maintain genetic integrity and diversity. Mitochondrial DNA analysis of Gulf sturgeon should be continued with emphasis placed on obtaining Gulf sturgeon tissues and/or blood from the following river systems:

1. Pascagoula River, Mississippi.
2. Mobile and Alabama rivers, Alabama.
3. Ochlocknee River, Florida.
4. Escambia River, Florida.

A genetic tissue bank should be established and curated where state or federal agencies deposit tissue or blood for genetic analysis. The Gulf states resource management agencies, universities, NGOs, NBS, FWS, and other Gulf sturgeon researchers should establish tissue collection protocol and insure that tissue samples are collected whenever possible.

1.5.2 Assess the potential to develop genetic markers to differentiate wild and hatchery-produced Gulf sturgeon.

The development of genetic markers for differentiating between wild and hatchery produced Gulf sturgeon may be important in the development and regulation of hatchery programs. A unique genetic marker could allow investigators, law enforcement officers, and others to distinguish hatchery reared fish from wild stocks. In addition, hatchery stocks possessing a different genetic mark from wild fish may be used in selective enhancement programs and provide a means to evaluate their introductions. The FWS and NMFS should continue to investigate the potential of viable genetic markers.

2.0 Protect individuals, populations, and their habitats.

In efforts to recover listed species, protection is the most obvious initial step. By virtue of their endangered or threatened status, species may not be able to sustain continuing losses of individuals, and steps should be taken immediately to eliminate any known preventable take. Initial measures to protect individuals, populations, and their habitats can be strengthened or reduced as new information is collected.

2.1 Reduce or eliminate unauthorized take.

Under the ESA, take means "to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct." "Harm" in the definition of "take" in the ESA means an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavior patterns which include, but are not limited to, breeding, feeding, or sheltering. "Harm" in the definition means an act which actually kills or injures wildlife. Such act may include significant habitat modification or degradation where it actually kills or injures wildlife by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. In the case of the Gulf sturgeon, the immediate concern is with lethal or injurious take by non-directed fisheries. Directed fisheries for listed species are prohibited by virtue of the listing. However, a number of fisheries targeting other species use fishing gear that take Gulf sturgeon.

2.1.1 Increase effectiveness and enforcement of state and federal take prohibitions.

Directed take of the Gulf sturgeon is prohibited under the ESA and laws or regulations of Louisiana, Mississippi, Alabama, and Florida. All states within the geographic distribution of the Gulf sturgeon have cooperative agreements with the FWS that require enforcement of federal endangered species laws. Both federal and state officials are empowered to enforce prohibitions on the take of Gulf sturgeon. Appropriate steps should be taken to support and enhance enforcement activities related to restoration and protection of Gulf sturgeon. The Gulf states resource management agencies should evaluate their enforcement programs and if needed, implement appropriate enhancements or actions. The FWS and NMFS should insure that during ESA section 7 consultations, incidental take is stipulated to provide full protection of the species.

On July 1, 1975, the Atlantic sturgeon (*Acipenser oxyrinchus*, including the Gulf sturgeon) was included in Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The effect of this listing is that CITES permits are required before international shipment may occur.

2.1.2 Reduce or eliminate incidental mortality.

Incidental catch and mortality of Gulf sturgeon is a difficult or cryptic problem to address because it requires a knowledge of effort and catch composition in a variety of different fisheries. Gear types used in many fisheries are capable of capturing Gulf sturgeon, and it is essential that the magnitude of the problem in each fishery is known before effective steps can be taken to reduce or eliminate mortality. A limited observer program may be needed to evaluate the amount/extent of incidental take or mortality in some fisheries and navigation-related and other activities. When problem fisheries or other activities have been identified, gear or equipment modifications, seasonal restrictions, limited gear or equipment deployment times, and other measures may be employed to reduce mortality of Gulf sturgeon and allow the affected fisheries or other activities to continue to operate.

If incidental take is found to be related to any fishery, the NMFS and the Gulf states should promulgate adequate regulations that protect the Gulf sturgeon from such incidental take. The NMFS should also evaluate Turtle Excluder Devices (TEDs) in commercial shrimp nets to determine if they are effective in allowing Gulf sturgeon to escape from trawls. If they are not effective, funding should be sought to investigate the appropriate gear technology. The NMFS should also fund an observer program, enforcement of regulations, and other necessary actions which reduce or eliminate incidental take of Gulf sturgeon during fishing operations.

In addition, the NMFS and FWS in cooperation with the responsible federal agency should develop methodologies that would cause Gulf sturgeon to avoid areas during navigation-related (includes O&M) activities, Clean Water Act (CWA) Sections 10 and 404, or other construction activities. The NMFS and FWS should assure that the objective of ESA section 7 consultation is to reduce or eliminate incidental take during such activities. As an example, section 7 consultation for a dredging project may result in the COE permitting the activity to occur only during seasons when Gulf sturgeon are not present in the action area.

2.2 Identify and eliminate known or potentially harmful chemical contaminants, and water quantity and water quality problems which could impede recovery of Gulf sturgeon.

Chemical contaminants, water quantity, and water quality factors may have contributed to the decline or are limiting the recovery of Gulf sturgeon. These factors include pesticides (organochlorines), metals (lead, mercury, etc.), industrial byproducts, temperature, pH, suspended solids, dissolved oxygen, water depth, and water velocity. Review of existing data and information is necessary to refine or identify the chemical and water quality and quantity requirements of Gulf sturgeon.

An information search for each management unit or coastal habitat area regarding potential types of chemical contaminant loading, including chemicals from point sources, agriculture, silviculture, industrial activities and urbanization, should be conducted. Existing chemical contaminant field evaluation reports (water, sediment or biota studies) should be examined and the information utilized to make decisions related to field sampling and chemical analysis. Field sampling of water, sediments, and sentinel and/or surrogate species should be conducted, as necessary, to fill critical information gaps. State agencies in Louisiana, Mississippi, Alabama, and Florida, with assistance from the Environmental Protection Agency (EPA) and FWS should collect existing information and provide an assessment report with recommendations. The FWS should provide coordination between the federal and state agencies as needed, compile state reports, and identify a consensus priority listing of chemical contaminant sources that may have impacts on Gulf sturgeon in the river systems. The EPA "Priority Pollutants" for each management unit or habitat area should be assessed by chemical analyses for Gulf sturgeon and other benthic species. The FWS and EPA, using the compiled contaminant data, should prepare the list and conduct necessary analyses.

2.2.1 Identify potentially harmful chemical contaminants and water quality and quantity changes associated with surface water restrictions.

A comprehensive inventory of river basins with existing surface water restrictions is needed to document physical and biological impacts that may negatively affect recovery and management of Gulf sturgeon. The GSMFC, FWS, and COE should coordinate preparation of this inventory with GSMFC taking the lead for final product completion.

2.2.2 Identify and eliminate potentially harmful point and non-point sources of chemical contaminants.

Significant point sources and high-impact non-point source areas of contaminant introductions should be identified. Appropriate actions to reduce or eliminate the contaminants should be taken. With the results of 2.2.1, EPA and state agencies in Louisiana, Mississippi, Alabama, and Florida should take actions to enforce existing regulations or promulgate new ones.

2.2.3 Assess selected contaminant levels in Gulf sturgeon from management units.

Gulf sturgeon tissue analyses should be conducted to evaluate selected chemical contaminants. Appropriate actions should be taken to reduce or eliminate contaminant sources. The EPA should take the lead in efforts to reduce or eliminate identified contaminant sources through their regulatory authorities. The EPA could also assist state agencies in Louisiana, Mississippi, Alabama, and Florida in enforcement of state regulations. During the Triennial Review of state water criteria, EPA should ensure that the states have incorporated adequate water quality standards to protect the Gulf sturgeon and its benthic habitat.

Routine, standardized inspections should be conducted on all incidental catches of Gulf sturgeon (alive or dead) for the presence of gross lesions, tumors or other abnormalities to focus evaluation on chemical contaminants.

Histopathological examinations of liver tissue for cases of incidental Gulf sturgeon mortalities should be conducted to detect the presence of cellular abnormalities or carcinogenic cells.

Chemical analyses of selected tissues should be conducted from incidental mortalities of Gulf sturgeon. The FWS should take the lead in developing protocol to collect samples, conduct training if necessary, process samples for analyses, and prepare summaries of results. Wherever possible, Gulf state resource management agencies should conduct similar analyses.

Appropriate surrogate species should be utilized to better define bio-accumulation of contaminants in particular river basins. An extrapolation formula for estimating potential chemical contaminant impacts to Gulf sturgeon should be developed. The FWS and EPA should lead the efforts to identify appropriate surrogate species, conduct bio-accumulation studies, and develop an extrapolation formula. Appropriate peer review should be conducted during formula development.

2.2.4 Identify and eliminate known and potential impacts to water quantity and quality associated with existing and proposed developments, agricultural uses, and water diversions in management units.

Domestic and industrial effluent, rural and urban run-off, and inter- and intra-water diversions affect the clarity, pH, biological oxygen demand, nutrient and contaminant composition, temperature, sediment loads, and seasonal quantity of river waters. A comprehensive inventory of known or potential problem areas associated with these factors is needed. Once identified, actions to reduce or eliminate problems and promote wise land use should be taken. With the results of 2.2.1, EPA and Gulf states resource management agencies should take actions to enforce existing regulations or promulgate new ones.

Water quality and sediment factors resulting from point and nonpoint sources may negatively affect Gulf sturgeon habitat. Examples include total dissolved solids, suspended solids, turbidity, siltation, pH, temperature, and changes in sediment types. Studies to assess the effect of river water and sediment quality should be conducted to determine the habitat suitability for Gulf sturgeon.

2.2.5 Assess the relationship between groundwater pumping and reduction of groundwater flows into management units, and quantify loss of riverine habitat related to reduced groundwater in-flows.

Groundwater diversions which affect flows into management unit rivers should be identified. The loss of riverine groundwater flows attributed to diversions should be quantified and its effect on Gulf sturgeon evaluated. The U. S. Geological Survey (USGS) should take the lead in implementing appropriate studies including modelling. The Tri-State Study for the Alabama-Tallapoosa-Coosa and Apalachicola-Chattahoochee-Flint river basins funded by the COE and Alabama, Georgia, and Florida should incorporate an effort to provide a preliminary assessment of the effects of groundwater pumping into the groundwater scope of work plan.

2.2.6 Conduct studies to determine the effects of known chemical contaminants in water from management unit rivers on Gulf sturgeon or a surrogate species.

After identification of priority contaminants, physiological and behavioral responses of Gulf sturgeon life stages to long-term exposures to such chemicals should be determined. In particular, newly fertilized eggs, Gulf sturgeon larvae, and juvenile Gulf sturgeon should be tested. The EPA should work with the FWS to conduct bioassays of water from the management unit rivers to determine effects on Gulf sturgeon.

2.3 Develop a regulatory and/or incentive framework to ensure that essential habitats, streamflow, and groundwater in-flows are protected.

Where existing laws and regulations are inadequate to meet recovery objectives, appropriate state and federal agencies should propose new incentives, laws, and/or regulations.

2.3.1 Utilize existing authorities to protect habitat and, where inadequate, recommend new incentives, laws, and regulations.

The ESA provides for the protection and recovery of the Gulf sturgeon and its habitats. Likewise individual Gulf states have regulations and laws for that purpose. Adequate funding levels must be provided to enforce existing protection measures and laws. Federal and state natural resource law enforcement programs are understaffed and underbudgeted to adequately enforce laws protecting the Gulf sturgeon and its habitats. Even with adequate funding, existing authorities may be inadequate to fully protect the Gulf sturgeon and its habitats. Adoption of new incentives, laws or regulations may be necessary to ensure the recovery of the species. Protection measures should be based on the biological requirements of the subspecies and not political boundaries. The FWS should ensure protection of the Gulf sturgeon through the ESA section 7 consultation process with other federal agencies including the COE (federal projects, Section 10/404 permits), MMS (OCS oil and gas lease sales), EPA (National Pollutant Discharge Elimination System permits, Triennial Review).

2.3.2 Identify, protect and/or acquire appropriate land or aquatic habitats on an ecosystem approach.

Habitat components of the Gulf sturgeon which provide essential life requirements should be considered as part of and dependent on a fully functioning ecosystem . These ecosystems should be protected and/or acquired. The Gulf states resource management agencies, FWS, and NMFS should seek appropriate avenues of funding and take action to acquire, manage, and protect identified significant habitats or their ecosystems as appropriate.

For example, spawning habitats should receive maximum protection from disturbance. In order to protect specific habitats, the ecosystem where it occurs also requires protection. Thus, protection of spawning habitats of the Apalachicola River would include the upper 20 km (12.4 mi) of the river and its surrounding basin components. Another example includes the maintenance of habitats such as the springs that occur in the Suwannee River. To protect these springs, it is essential to maintain other ecosystem components including upstream water quality, groundwater flows and quality, and adjacent floodplains.

2.4 Restore, enhance, and provide access to essential habitats.

Gulf sturgeon have evolved within Gulf coast drainages exhibiting seasonal patterns of high and low flows, temperature regimes, sedimentation, and other physical factors which historically may have been much different than those which exist today. The restoration and enhancement of some river and stream habitats, particularly benthic habitat, within the historical range of the Gulf sturgeon may be necessary before its recovery is successful. Within some drainages, man's alterations (mainstem dams, low-head diversions) may be preventing Gulf sturgeon from gaining access to important habitats essential to some aspect of its life history. If such structures are identified as impeding migration or preventing access to critical habitats, action should be taken to restore the natural hydrography or provide a viable bypass route around the structure.

2.4.1 Identify dam and lock sites that offer the greatest feasibility for successful restoration of and to essential habitats (i. e., up-river spawning areas).

Mainstem and low-head diversion dams that are known to be impeding potentially viable Gulf sturgeon populations from reaching historically essential habitats need to be identified. The extent of important habitat types upstream from such structures (e.g., potential spawning sites and summer refugia) should be evaluated.

The GSMFC should take the lead in identifying these sites throughout the Gulf states and preparing summary and recommendations. Federal and non-federal permitted dams should be identified. The COE, FERC, and entities such as the Pearl River Valley Water Supply District should investigate ways of mitigating impacts of federal and private water resource projects or permitted activities on Gulf sturgeon populations.

2.4.2 Evaluate, design, and provide means for Gulf sturgeon to bypass migration restrictions within essential habitats.

The structures preventing upstream migrations to essential habitats should be modified or removed to allow for Gulf sturgeon passage. Specific modifications will depend on the type of obstruction, river hydrology and the importance of the habitat to the recovery of the species in that particular ecosystem. Studies regarding Gulf sturgeon behavior may be required to assist in development and design of fish passages. Modifications which provide for both up- and downstream travel by large and small fish need be considered.

First, an assessment of existing modifications should be conducted. The assessment should consider the effectiveness of the modification for use by other migratory species such as shad and striped bass. Designs should be solicited from engineering and environmental consultants. Passage structures which show promise must be evaluated to document the relative degree of usage by Gulf sturgeon. The NMFS, COE, NBS, FWS, and Federal Energy Regulatory Commission (FERC) should investigate the use of potential passage structures and initiate action or studies to assess the structure's effectiveness for Gulf sturgeon passage.

2.4.3 Operate and/or modify dams to restore the benefits of historical flow patterns and processes of sedimentation.

The operating schedules of the dams need to be evaluated to determine if water releases are benefiting the life history requirements of the Gulf sturgeon. The operations of existing structures found to be detrimental to the life cycle of Gulf sturgeon should be evaluated to determine if modifications to approximate historical flow and sedimentation patterns are possible. The COE and FERC in coordination with the GSMFC, Gulf states resource management agencies, FWS, and NMFS should identify potential modifications to and/or operations of dams and initiate action or studies to assess the feasibility for implementation.

2.4.4 Identify potential modifications to specific navigation projects to minimize impacts which alter riverine habitats or modify thermal or substrate characteristics of those habitats.

Navigation projects that have altered or modified the thermal characteristics or natural substrates of rivers should be evaluated to determine if modifications to approximate historical conditions are possible. The COE should assist the FWS in its efforts to define and protect Gulf sturgeon spawning and other essential habitats in federal project areas. The COE should study, seek funding, implement or take appropriate remedial actions to rectify navigation projects where feasible.

2.4.5 Restore the benefits of natural riverine habitats.

Dams and channel modifications have reduced habitat diversity within the range of the Gulf sturgeon. Diversity of riverine habitat (e.g., main channel, side channel, backwater and braided channel) promotes a corresponding faunal diversity. The Gulf sturgeon evolved in natural riverine settings where such diversity was prevalent. Gulf sturgeon survival could be expected to be compromised if the benefits of riverine habitat diversity are not restored. The FWS should work with the COE to identify ways to restore and protect natural river habitat diversity.

2.4.6 Seek optimum consistency between the purposes of federal and state authorized reservoirs, flood control projects, navigation projects, hydropower projects, and federal and state mandated restorations of fish populations.

Many water projects, such as hydropower and flood control dams and navigation activities, are authorized by state and federal governments for their respective purposes. Also, there are many state and federal programs authorized to restore declining fish populations. Examples include species listed under the ESA, anadromous fisheries addressed under the Anadromous Fish Conservation Act, and coastal fisheries addressed under the Interjurisdictional Fisheries Act and the Magnuson Fisheries Conservation and Management Act.

All government authorized and proposed projects and mandates should be reviewed in order to evaluate the potential to achieve recovery of Gulf sturgeon. The GSMFC should facilitate a multi-agency effort to identify project mandates and prepare a summary and recommendation report in partnership with the appropriate state and federal agencies. Recommendations should be forwarded to each of the States of Louisiana, Mississippi, Alabama, and Florida's State legislature and congressional delegation.

2.5 Maintain genetic integrity and diversity of wild and hatchery-reared stocks.

Major conservation issues that must be addressed by this recovery program relative to health of stocks, genetic conservation of stocks and displacement of stocks. A major concern in any stock restoration and enhancement program is the potential impact of introduced fish on existing wild stocks. This impact can affect wild stocks by a variety of mechanisms:

1. Disease and parasite transfer.
2. Behavioral and ecological interference.
3. Genetic consequences of interbreeding, reduction in gene flow, introduction of strains susceptible to disease.

Problems resulting from failure to protect habitat, to control fishing pressure, to ensure correct management of water resources, to control environmental contamination, and to effectively manage other parameters have contributed to reductions in stocks of Gulf sturgeon. These problems are readily evident and appropriate actions can be taken to correct them. At this point, the potential adverse effects of initiating a stocking program are unknown. The potential effects of initiating any stocking program should be evaluated. An experimental hatchery and strictly limited release program to the wild is prudent until such time as stocking has been thoroughly evaluated.

2.5.1 Evaluate the need to stock hatchery-produced Gulf sturgeon considering habitat suitability and current population status.

An assessment of whether stocking hatchery-produced fish will benefit the overall recovery of the Gulf sturgeon is paramount to the future development of Gulf sturgeon hatchery programs. An evaluation of whether the rivers to be stocked have suitable habitat to support the stocked fish, natural reproduction, and any progeny should be conducted. The recovery of the subspecies cannot be based on a "put and take" Gulf sturgeon fishery. Government agencies, NGOs, and universities investigating Gulf sturgeon should conduct an evaluation of each river system that is under consideration for stocking on the ability of the system, at its current status, to support the stocked fish and assure that natural reproduction can occur. Only ongoing improvements to the river systems should be included in the analyses. Each of the Gulf states resources management agencies should evaluate the river systems in their states. The FWS should take the lead in coordinating the assessment and preparing a summary finding report. No stocking should be conducted without approval by appropriate state agencies.

If it is determined that there is a need for stocking, the stocking should be secondary to other recovery efforts that identify essential habitats and emphasize habitat restoration. The COE should continue to work with the FWS in efforts to construct a permanent hatchery on the Apalachicola River to help in the restoration and maintenance of the Apalachicola River Gulf sturgeon population if it is determined that stocking is necessary for recovery of the subspecies.

2.5.2 Develop policy and guidelines for hatchery and culture operations related to stocking.

Raising hatchery produced fish to a size large enough to overcome lack of suitable habitat increases survival. Also, at larger sizes, these fish can be tagged and recovered, enabling assessment of the efficacy or success of the stocking effort. Peer review and evaluation of a particular stocking effort should be included in any proposal to release hatchery-reared Gulf sturgeon. Gulf states resource management agencies, GSMFC, FWS, NMFS, NGOs, universities, and other involved researchers should prepare a hatchery and culture operations plan relating to stocking policy/guidelines. The FWS should take the lead in coordinating, seeking peer review, and completing the document.

2.5.3 Develop and implement a regulatory framework to eliminate accidental and intentional introductions of non-indigenous stock or other sturgeon species.

Release of hatchery-reared fish without a program of monitoring does not fulfill government's role as a steward of renewable natural resources. Monitoring and systematic assessment of stocks will assist in determining the impact of accidental and intentional releases of non-indigenous stock or other sturgeon species. This recovery plan recognizes that it is irresponsible to intentionally release fish without review or concurrence from the recovery team or coordinator, and therefore undocumented intentional releases should not occur. In the case of federal agencies who undertake actions that may affect a listed species (stock introductions), consultation with FWS and/or NMFS is required under section 7 of the ESA.

At a minimum, the recommendations of the Aquatic Nuisance Species Task Force (ANSTF) which was established under the Nonindigenous Aquatic Nuisance Prevention and Control Act of 1990 should be conducted. The task force developed recommendations regarding direct introductions and indirect, accidental release from public and private sector facilities. All State agencies within the subspecies' range and GSMFC, FWS, NBS, NMFS, NGOs, universities, and other involved researchers should prepare a consensus policy regarding introduction of non-indigenous sturgeon stocks into the range of Gulf sturgeon in accordance with the options or actions identified by the ANSTF to reduce risks and adverse consequences associated with introductions. States should implement necessary actions for promulgating regulations consistent with the policy.

3.0 Coordinate and facilitate exchange of information on Gulf sturgeon conservation and recovery activities.

Any research and/or management activities on fish species which transcend jurisdictional boundaries must be coordinated. Management and recovery actions must be consistent across the range of the subspecies in order to be effective. Gulf sturgeon recovery efforts will be enhanced by the coordination of activities and exchange of information regarding the biology and management of all sturgeon species.

3.1 Coordinate research and recovery actions.

Coordination activities involving state and federal resource management agencies, NGOs, and universities with an interest in the Gulf sturgeon should be conducted at least every two years. Such coordination will provide for studies and management plans which will reduce duplication of effort, enhance cooperation, and optimize agency manpower and funding. The FWS and GSMFC should take the lead in conducting the coordination activities.

3.2 Develop an effective communication program or network for obtaining and disseminating information on recovery actions and research results.

All recovery participants including state and federal agencies, NGOs, and universities working on Gulf sturgeon are strongly urged to publish research findings in technical publications. Unpublished reports (gray literature), bibliographies, and available data on Gulf sturgeon should be compiled and published or otherwise made available to all participants. Acquiring, disseminating, and maintaining information regarding Gulf sturgeon recovery activities should be centralized. The FWS should take the lead in collecting and centralizing information regarding Gulf sturgeon recovery activities.

In order to ensure effective communication among the various entities involved in Gulf sturgeon research, recovery and management, a newsletter should be developed and disseminated on a regular basis. This newsletter would provide all interested parties with the most up-to-date information regarding progress toward achieving the goals of the Recovery Plan. The FWS should take the lead in preparing, printing, and disseminating the newsletter and coordinating with other existing sturgeon newsletters.

3.3 Develop a non-scientific constituency and public information program directed toward enhancing recovery actions.

In order for Gulf sturgeon recovery actions to be successful, the general public must be aware of such actions and understand the need for them. An information and education program must be developed to inform the public of the causes of the decline of Gulf sturgeon, to increase the public's awareness, understanding, and involvement in Gulf sturgeon recovery efforts and to promote wise use of land in watersheds. Educational materials such as brochures, newspaper and magazine articles, publications, posters, and slide and television presentations, among others, must be produced and disseminated to target audiences, such as commercial and recreational fishermen, boaters, and civic organizations. The Gulf states resource management agencies, FWS, NBS, and NMFS should seek funding for the development of educational material for dissemination to the public. The FWS or GSMFC should take the lead in coordinating this effort providing a centralized location for storage of information if necessary.

4.0 Implement recovery program.

Existing budgets of involved agencies and other parties are not capable of fully funding the Gulf sturgeon recovery plan. Competition for funding under the ESA is intense, partly due to the low level of appropriations to the program and the increasing number of listed species. In order to assure that actions which would result in recovery of the Gulf sturgeon are implemented, funding for activities must be secured and a designated lead recovery office must be identified. Involvement of NGOs, and universities should be solicited.

4.1 Designate and fund a Gulf sturgeon recovery lead office.

Funding to support a FWS recovery lead office must be identified to coordinate a multi-agency, multi-disciplinary recovery implementation committee. The lead office should document all research, recovery, and management information and plans. Work would be combined with other FWS duties. The lead office should be in a location which facilitates coordination with all Gulf sturgeon activities. The lead office should be funded until the Gulf sturgeon is considered recovered according to the Recovery Plan.

4.2 Seek funding for Gulf sturgeon recovery activities.

The recovery lead office, with support from involved agencies, NGOs, universities, and the public should seek to bring high visibility to the need for funding of Gulf sturgeon recovery activities. Funding strategies to acquire Congressional appropriations and other funding sources should be developed. The recovery lead office should facilitate this effort and coordinate a unified funding package for Gulf sturgeon recovery activities in the southeast.

4.3 Implement projects or actions which will achieve recovery plan objectives.

Based on the recovery plan, a series of specific projects will be identified which could bring about improvements in the habitat or stock condition of Gulf sturgeon in specific river systems throughout the range of the species. Projects should be submitted to the appropriate agencies or funding sources for consideration. The Gulf states resource management agencies should be given first opportunity to implement the identified projects, through joint efforts with FWS, NBS, NMFS, universities, NGOs, or other interested researchers.

4.4 Develop and implement a program to monitor population levels and habitat conditions of known populations in the management units as well as newly discovered, introduced, or expanding populations.

The status of the subspecies and its ecosystems should be monitored to assess any progress toward recovery while recovery actions are ongoing and following completion of actions. A standardized assessment program should be designed by a multi-agency group coordinated by the recovery lead office and the GSMFC. The Gulf states resource management agencies, federal agencies, universities, NGOs, and other researchers should conduct an annual assessment of the management unit population levels in their area of responsibility or as appropriate. The recovery lead office should maintain, collate, and review the assessments preferably on an annual basis but at least every two years. This information should be summarized for distribution and used in the Congressionally required biennial species status reports.

5.0 Monitor recovery program.

A recovery plan benefits a species only if it is implemented. The plan and its implementation must be strong enough to provide adequate guidance to species managers but be flexible enough so that it may be changed or revised to recover the species. In addition, the FWS and NMFS are required by Congress to track the status of all listed species and the implementation of recovery plans, financial expenditures for each species or clusters of species, and status of recovered species.

5.1 Assess overall success of the recovery program and recommend action.

The recovery program must be evaluated periodically to determine if it is making progress in achieving recovery objectives and to recommend future actions. These actions could include changes in recovery objectives, continuing or increasing protection, implementing new measures, revising recovery plans and recommending delisting. The recovery program should be preferably evaluated annually but at least biennially. The recovery lead office should be responsible for collection of the required information and preparation of the Congressional reports. As part of this effort, the lead office should prepare standardized reporting forms so that the affected parties can easily provide the necessary information. Reporting requirements should continue for five years after the delisting of the Gulf sturgeon.

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III. IMPLEMENTATION SCHEDULE

The Implementation Schedule indicates task priorities, task numbers, task descriptions, duration of tasks, potential or participating parties, and lastly, estimated costs (Table 3). These tasks, when accomplished, will bring about the recovery objectives for the Gulf sturgeon as discussed in Part II of this plan.

Parties with authority, responsibility, or expressed interest to implement a specific recovery task are identified in the Implementation Schedule. When more than one party has been identified, the proposed lead party is indicated by an asterisk (*). The listing of a party in the Implementation Schedule does not imply a requirement or that prior approval has been given by that party to participate or expend funds. However, parties willing to participate will benefit by being able to show in their own budget submittals that their funding request is for a recovery task which has been identified in an approved recovery plan and is therefore part of the overall coordinated effort to recover the Gulf sturgeon. Also, Section 7(a)(1) of the ESA directs all federal agencies to utilize their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of threatened and endangered species.

Following are definitions to column headings and keys to abbreviations and acronyms used in the Implementation Schedule:

Task Number & Task: Recovery tasks as numbered in the recovery outline. Refer to the Narrative for task descriptions.

Priority Number: All priority 1 tasks are listed first, followed by priority 2 and priority 3 tasks.

Priority 1 - All actions that must be taken to prevent extinction or to prevent the subspecies from declining irreversibly in the foreseeable future.

Priority 2 - All actions that must be taken to prevent a significant decline in subspecies population/habitat quality, or some other significant negative impact short of extinction.

Priority 3 - All other actions necessary to provide for full recovery (or reclassification) of the species.

Task Duration: Years to complete the corresponding task. Study designs can incorporate more than one task, which can reduce the time needed for task completion.

Underway - Task already being implemented.

Continuing - Task necessary until recovery.

Responsible or Participating Party: Federal or state government agencies or universities (party) with the responsibility and/or capability to fund or carry out the corresponding recovery task.

FWS Region - FWS Regions (only states in the Gulf sturgeons's range are listed)
- 2 - Albuquerque (Texas)
- 4 - Atlanta (LA, MS, AL, FL)

FWS Program - Division or program of the FWS
- FF- Fisheries
- FRO- Fisheries Resources Office
- ES- Ecological Services
- LE- Law Enforcement
- WNFH- Welaka National Fish Hatchery
- WSRFC- Warm Springs Regional Fisheries Center
- GCFCO- Gulf Coast Fisheries Coordination Office

Other Federal Agencies
- COE - U.S. Army Corps of Engineers
- EPA - U.S. Environmental Protection Agency
- MMS - Minerals Management Service
- NMFS - National Marine Fisheries Service
- FERC - Federal Energy Regulatory Coummission
- NBS - National Biological Service/Southestern Biological Science Center Gainesville, FL
- NRCS - Natural Resources Conservation Service

State Agencies
- GSRMA - Gulf States Resource Management Agencies
  - Louisiana Department of Wildlife and Fisheries
  - Mississippi Department of Wildlife, Fisheries, and Parks
  - Alabama Department of Conservation and Natural Resources
  - Florida Department of Environmental Protection
  - Texas Parks and Wildlife Department
- CES - Cooperative Extension Service (all GSRMA)

Other Parties
- GSMFC - Gulf States Marine Fisheries Commission
- CCC - Caribbean Conservation Corporation
- UF - University of Florida

Cost Estimates: Estimated fiscal year cost, in thousands of dollars, to complete the corresponding task. The costs associated with a task or party represent the estimated dollar amount to complete the task and are not necessarily the fiscal responsibility of the associated party.

Study designs can incorporate more than one task, which when combined can reduce the cost from when tasks are conducted separately. Cost for implementing "continuing" recovery tasks are in excess of what is displayed for the five years in the schedule.

Comments: Additional information if appropriate.

TABLE 3. IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

Priority	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY: FWS Region	RESPONSIBLE PARTY: FWS Program	RESPONSIBLE PARTY: OTHER	ESTIMATED FISCAL YEAR COSTS ($000): FY 1 FWS	FY 1 Other	FY 2 FWS	FY 2 Other	FY 3 FWS	FY 3 Other	FY 4 FWS	FY 4 Other	FY 5 FWS	FY 5 Other	COMMENTS
1	1.3.1	Develop and implement standardized population sampling and monitoring techniques	underway	4	FF* FRO-PC	NBS* GSRMA COE	1 6	30 20 2	1 20	30 20 2	7 40	30 32 5	1 40	30 32 5	1 40	30 32 5	Tasks 1.1.1, 1.3.1, 2.5.1, and 1.5.1 can be conducted concurrently
1	2.5.3	Develop and implement a regulatory framework to eliminate acidental and intentional introductions of non-indigenous stock or other sturgeon species	1	4	FF FRO-PC* ES-PC GCFCO	NBS* GSRMA GSMFC UF			5 8 2 2	2 4 1 1							Some of this effort will be dependent on the outcome of 2.5.1
1	2.1.2	Reduce or eliminate incidental mortality	underway continuing	4	FRO-PC* ES	GSMFC* GSRMA NMFS	15	15 20 75	15	15 20 75	15	15 20 75		75		25	Majority of funding for fish excluder devices & sampling protocols
1	2.4.5	Restore the benefits of natural riverine habitats	underway continuing	4	ES FRO-PC GCFCO	NBS COE GSRMA	2 2 2	2 10 8	10 2 2	2 20 12	10 2 2	2 20 12	20 5 3	3			Wk funded under existing programs. Actual restoration costs undetermined.
1	2.3.1	Utilize existing authorities to protect habitat and where inadequate, recommend new incentives, laws, and regulations	underway continuing	4	ES* GCFCO	EPA* COE GSRMA GSMFC	5 3	5 5 8 3	5 3	5 5 8 3	5 3	5 5 8 3	5 3	5 5 8 3			Section 7 consultation conducted with existing program funds
2	2.1.1	Increase effectiveness and enforcement of state and federal take prohibitions	continuing	4	LE FF* ES*	NMFS* GSRMA*	75	75 180	75	75 180	75	75 180	75	75 180	75	75 180	Sec 7 consultation will be conducted under existing programs. Add. monitoring or law personnel may be necessary
2	1.1.1	Conduct and refine field investigations to locate important spawning, feeding, and developmental habitats	underway continuing	4	FF FRO-PC* GCFCO	NBS* GSRMA COE CCC UF	1 5 1	20 60 5 10 1	1 58 1	20 60 5 10 1	1 70 2	20 80 5 10 2	1 70 2	20 80 5 12 2	1 70 5	20 80 5 12 5	Tasks 1.1.1, 1.3.1, 2.5.1, and 1.5.1 can be conducted concurrently

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY			ESTIMATED FISCAL YEAR COSTS ($000)										COMMENTS
				FWS		OTHER	FY 1		FY 2		FY 3		FY 4		FY 5		
				Region	Program		FWS	Other	FWS	Other	FWS	Other	FWS	Other	FWS	Other	
2	1.1.2	Characterize riverine, estuarine, and neritic areas that provide essential habitat	underway continuing	4	FRO-PC*	NBS* CCC GSRMA COE	5	15 2 28 5	20	15 2 28 5	70	15 3 40 5	70	15 3 40 5	10	15 3 40 5	Tasks 1.1.1 and 1.1.2 can be conducted concurrently
2	1.2	Conduct life history studies on the biological and ecological requirements of little known or inadequately sampled life stages	underway continuing	4	FRO-PC*	NBS* CCC GSRMA	5	25 2 28	20	25 2 28	20	25 3 40	40	25 3 40	40	25 3 40	Tasks 1.1.1 and 1.1.2, and 1.2 can be conducted concurrently
2	2.2.1	Identify potentially harmful chemical contaminants and water quality and quantity changes associated with surface water restrictions	3	4	ES-PC*	EPA GSRMA	25	10 40	15	10 100	75						Cost and time to complete year 2 efforts will be dependent on information collection in year 1.
2	2.2.2	Identify and eliminate potentially harmful point and non-point sources of chemical contaminants	4	4	ES-PC	EPA* GSRMA NRCS			20	10 28	25	15 40	25		25		
2	2.4.6	Seek optimum consistency between the purposes of federal and state authorized reservoirs, flood control, navigation, and hydropower projects and federal and state mandated restorations of fish populations	continuing	4	ES GCFCO	GSMFC* FERC COE NMFS				10		5		5		5	Most agency related wk., funded under existing programs

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY: FWS Region	RESPONSIBLE PARTY: FWS Program	RESPONSIBLE PARTY: OTHER	FY 1 FWS	FY 1 Other	FY 2 FWS	FY 2 Other	FY 3 FWS	FY 3 Other	FY 4 FWS	FY 4 Other	FY 5 FWS	FY 5 Other	COMMENTS
2	2.4.1	Identify dam and lock sites that offer the greatest feasibility for successful restoration of and to essential habitats	1	4	ES-PC FRO-PC	GSMFC* COE GSRMA			5 2	15 10 20							
2	2.4.4	Identify potential modifications to specific navigation projects to minimize impacts which alter riverine habitats or modify thermal or substrate characteristics of those habitats.	underway continuing	4	ES FRO-PC GCFCO	FERC* COE* NMFS GSRMA GSMFC	5 5 5	10 10 2 8 5	5 5 5	10 10 2 8 5	2 2 2	5 5 2 4 2					Some funding under existing programs. Proj. mod. costs undetermined and may require Congress. author. & non-federal sponsor
2	4.3	Implement projects or actions which will achieve recovery plan objectives	underway continuing	4	FF FRO-PC	GSRMA* NGOs											Individual project funding ID elsewhere in schedule
2	4.2	Seek funding for Gulf sturgeon recovery activities	underway continuing	4	ES* GCFCO	NBS GSMFC GSRMA											Funded under existing programs
2	2.2.4	Identify and eliminate known and potential impacts to water quantity and quality associated with existing and proposed developments, agricultural uses, and water diversions in management units	continuing	4	ES	NBS EPA* GSRMA NRCS	2	2 2 8	10	5 20 8	75	5 20 8	75	5 20	75	20	Amount of effort will be determined by outcome of task 2.2.1
2	2.2.5	Assess the relationship between groundwater pumping and reduction of groundwater flows into management units, and quantify loss of riverine habitat related to reduced groundwater in-flows	2	4	ES	USGS* GADNR						252		125			Mostly funded under the Tri-state Comp Study- AL,GA,FL

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE																	
PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY			ESTIMATED FISCAL YEAR COSTS ($000)										COMMENTS
				FWS		OTHER	FY 1		FY 2		FY 3		FY 4		FY 5		
				Region	Program		FWS	Other	FWS	Other	FWS	Other	FWS	Other	FWS	Other	
3	2.5.1	Evaluate the need to stock hatchery-produced Gulf sturgeon considering habitat suitablity and current population status	underway	4	FF FRO-PC ES-PC GCFCO	NBS GSRMA	1 1 1 1	5 8	1 3 1 1	10 8	1 5 2 1	10 4	1 10 2 1	10 4	1 10 2 1	10 13	Tasks 1.1.1, 1.3.1, 2.5.1, and 1.5.1 can be conducted concurrently
3	1.5.1	Conduct a Gulfwide genetic assessment to determine geographically distinct management units	underway	4	FF* FRO-PC GCFCO	NBS GSRMA NGOs	15 8 2	1 3 1	15 48 1	1 100 1							Majority of samples and analyses completed 1995. Will continue to completion.
3	2.2.3	Assess selected contaminant levels in Gulf sturgeon from management units	underway continuing	4	FF* ES*	EPA* GSRMA	15		30	10 20	30	10 20	10	5 20			Study on adult fish across FL panhandle completed 1994. Study on juvenile fish, Suwannee River completed 1996.
3	1.3.2	Develop population models	underway continuing	4	FF FRO-PC	NBS NMFS GSRMA NGOs	5 15	15 2 8 2	5 5	15 2 8 2	20						
3	4.1	Designate and fund a Gulf sturgeon recovery lead office	continuing	4	ES* FF		7 3		7 3		7 3		7 3		7 3	7 3	Majority of funding provided under other recovery actions
3	1.4.1	Continue culture of Gulf sturgeon	underway	4	WNFH WSRFC* FRO-PC	NBS LDWF ADNCR UF	3 2 1	2 3 3 5	23 25 10	2 3 3 5	23 25 10	2 5 5 5	23 25 10	2 5 5 10	23 25 10	2 5 5 10	

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE

PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY: FWS Region	RESPONSIBLE PARTY: FWS Program	RESPONSIBLE PARTY: OTHER	ESTIMATED FISCAL YEAR COSTS ($000): FY 1 FWS	FY 1 Other	FY 2 FWS	FY 2 Other	FY 3 FWS	FY 3 Other	FY 4 FWS	FY 4 Other	FY 5 FWS	FY 5 Other	COMMENTS
3	2.2.6	Conduct studies to determine the effects of known chemical contaminants in water from management units on Gulf sturgeon or a surrogate species	4	4	ES-PC* WNFH WSRFC	EPA NBS			75 5	10 5	75 5	10 5	75		75		WNFH & NBS may provide specimens for the studies
3	2.4.3	Operate and/or modify dams to restore the benefits of historical flow patterns and processes of sedimentation	underway continuing	4	ES FRO-PC GCFCO	FERC* COE* NMFS GSMFC											Some funding under existing programs. Project mod. costs underterm. May require Congress. authority & non-federal sponsor.
3	2.3.2	Identify, protect, and/or acquire appropriate land or aquatic habitats on an ecosystem approach	underway continuing	4	FF FRO-PC ES-PC* GCFCO RW	NBS NMFS GSRMA NGOs											ID conducted with other studies. Land acquis. & water rights costs undeterminable.
3	2.4.2	Evaluate, design, and provide means for Gulf sturgeon to bypass migration restrictions to essential habitats	continuing	4	ES FF	FERC* COE* NMFS				10 10		25 25		25 25		25 25	FWS & NMFS funded under exist. progs. Studies conducted or infrastructure funded by COE & FERC. May req. Congress. auth. & non-fed sponsor.
3	3.1	Coordinate research and recovery actions	continuing	4	ES* FF GCFCO	NBS GSMFC*	5	5	10 5 5	2 15	5	5	10 5 5	2 15	5	5	Funding for biennial workshops
3	2.5.2	Develop policy and guidelines for hatchery and culture operations related to stocking	2	4	FF FRO-PC* ES-PC GCFCO	NBS* GSRMA GSMFC UF			5 5 2 2	2 4 1 1					5 10 5 5	2 4 2 15	Conducting this effort will be dependent on the outcome of 2.5.1
3	3.2	Develop an effective communication program or network to obtain and disseminate information on recovery actions and research results	continuing	4	ES*	GSMFC CES			5	5 2	5	5 2	5	5 2	5	5 2	Funding for producing and distributing quarterly newsletters

TABLE 3. (continued). IMPLEMENTATION SCHEDULE FOR GULF STURGEON RECOVERY ACTIONS

GULF STURGEON RECOVERY IMPLEMENTATION SCHEDULE																		
PRIORITY	TASK #	TASK DESCRIPTION	TASK DURATION (YEARS)	RESPONSIBLE PARTY			ESTIMATED FISCAL YEAR COSTS ($000)											COMMENTS
				FWS		OTHER	FY 1		FY 2		FY 3		FY 4		FY 5			
				Region	Program		FWS	Other	FWS	Other	FWS	Other	FWS	Other	FWS	Other		
3	3.3	Develop a non-scientific constituency and public information program directed toward enhancing recovery actions	underway continuing	4	FF* ES* GCFCO CES	GSMFC* NMFS GSRMA			5 5 8	10 5	5 5 8	10 5	5 5 8	5	2 2 8	5		
3	1.5.2	Assess the potential to develop genetic markers to differentiate wild and hatchery-produced Gulf sturgeon	ongoing	4	FF* ES	NMFS UF			25 25	10 10	25 25	10 10						Funding this task dependent on task 1.4.3 decision
3	1.4.2	Identify physical, chemical and biological parameters necessary to maintain growth, health, and survival of fish reared under artificial conditions	underway continuing	4	WNFH WSRFC*	NBS UF LDWF ADNCR	5 5	10 5 3 3	5 20	10 5 3 3	10 20	10 8 5 5	10 20	10 8 5 5	10 20	10 10 5 5		Continuation of this effort dependent on the outcome of 2.5.1.
3	1.4.3	ID and test non-genetic internal and external markers or techniques to differentiate wild and hatchery-produced Gulf sturgeon	2	4	FF FRO-PC*	NBS CCC GSRMA			25 5	5 2 4	25 5	5 2 4						Funding this task dependent on task 1.4.3 decision
3	4.4	Develop and implement a program to monitor levels and habitat conditions of known populations in the management units as well as newly discovered, introduced, or expanding populations	continuing	4	ES* FRO-PC	NBS CCC GSRMA	1 5	5 5 20	5 5	5 5 20	1 5	5 5 20	5 5	5 5 20	1 5	5 5 20		
3	5.1	Assess overall success of the recovery program and recommend action	continuing	4	ES*		2		2		2		2		2			

APPENDIX A

FISHERY MANAGEMENT JURISDICTIONS, LAWS AND POLICIES AFFECTING THE GULF STURGEON

APPENDIX A

FISHERY MANAGEMENT JURISDICTIONS, LAWS AND POLICIES AFFECTING THE STOCKS:

Gulf sturgeon may utilize both fresh water and marine habitats at different times of the year. Excursions into the territorial waters (Exclusive Economic Zone) of the United States may occur. This factor in its biology, together with its range, subject the subspecies to the regulatory jurisdictions of the federal government as well as the States of Alabama, Louisiana, Mississippi and Florida. Numerous state and federal legislative and regulatory actions may affect the stocks. The following is a partial list of some of the more important agencies and regulations that affect the Gulf sturgeon and its habitat. State agencies should be consulted for specific and current state laws and regulations.

Federal Management Institutions. Although some recreational and subsistence harvests of Gulf sturgeon have occurred at times, the primary fishery for the sturgeon has been commercial. Because Gulf sturgeon fisheries have occurred primarily in state waters, federal agencies historically have not directly managed the stocks; though, the federal government has maintained commercial fishery landing records on the subspecies for about the past 100 years. Nonetheless, a variety of federal agencies, through their administration of laws, regulations and policies, may influence Gulf sturgeon stocks.

<u>Regional Fishery Management Councils</u>. With the passage of the Magnuson Fishery Conservation and Management Act (MFCMA), the federal government assumed responsibility for fishery management within the Exclusive Economic Zone (EEZ). The EEZ is contiguous to the territorial sea, with an inner boundary at the outer boundary of each coastal state. The outer boundary continues out 200 miles. Management of the EEZ is to be based on fishery management plans developed by regional fishery management councils. Each council prepares plans, with respect to each fishery requiring management, within its geographical area of authority and amends such plans as necessary. Plans are implemented as federal regulation through the Department of Commerce (DOC).

Among the guidelines, under which the councils must operate, are standards which state that, to the extent practicable, an individual stock of fish shall be managed as a unit throughout its range and that management shall, where practicable, promote efficiency, minimize costs and avoid unnecessary duplication (MFCMA Section 301a).

The Gulf of Mexico Fishery Management Council has not developed, nor is it considering, a management plan for the Gulf sturgeon. Furthermore, no significant fishery for the subspecies exists in the EEZ of the U.S. Gulf of Mexico.

Department of Commerce, National Oceanic and Atmospheric Administration (NOAA).

National Marine Fisheries Service. The Secretary of Commerce, acting through the NMFS, has the ultimate authority to approve or disapprove all fishery management plans prepared by regional fishery management councils. Where a council fails to develop a plan, or to correct an unacceptable plan, the Secretary may do so. The NMFS also collects data and statistics on fisheries and fishermen, performs research, and conducts management authorized by international treaties. The NMFS has the authority to enforce the Magnuson Act and the Lacey Act and is the federal trustee for living and nonliving natural resources in coastal and marine areas under United States jurisdiction pursuant to the Endangered Species Act, Section 107(f) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or "Superfund"), Section 311(f)(5) of the Clean Water Act (CWA), Executive Order 12580 of January 23, 1987, and Subpart G of the National Oil and Hazardous Substances Pollution Contingency Plan.

The NMFS exercises no management jurisdiction of the Gulf sturgeon, other than permitting scientific or incidental take under the Endangered Species Act and enforcement. The NMFS conducts some research and data collection programs and comments on all projects that affect marine fishery habitat under the Fish and Wildlife Coordination Act and Section 10 of the Rivers and Harbors Act.

The NMFS has entered into a Cooperative Agrrement with the Department of the Army to Restore and Create Fish Habitat. Under this agreement, the NMFS and the COE coordinate efforts to identify federal projects that could be modified to enhance fish habitat.

Office of Ocean and Coastal Resource Management (OCRM). The OCRM asserts its authority through the National Marine Sanctuaries Program pursuant to Title III of the Marine Protection, Research, and Sanctuaries Act (MPRSA). The OCRM Estuarine Sanctuary Program has designated Looe Key in Monroe County, Rookery Bay in Collier County, the Apalachicola River and Bay in Franklin County, Florida, and Weeks Bay in Baldwin County, Alabama, as estuarine sanctuaries.

The OCRM may influence fishery management for Gulf sturgeon indirectly through administration of the Coastal Zone Management Program and by setting standards and approving funding for state coastal zone management programs. Some states in the Gulf utilize a portion of these monies in their habitat protection and enhancement programs including reef maintenance and enhancement.

Department of the Interior (DOI).

National Park Service (NPS). The NPS under the DOI may regulate fishing activities within national park boundaries. Such regulations may affect Gulf sturgeon within specific parks. The NPS has authority to protect fishes and fish habitat primarily through the establishment of coastal and nearshore national parks and national monuments. Everglades National Park in Florida and the Mississippi District of Gulf Islands National Seashore are two examples of national park areas where Gulf sturgeon may occur.

U.S. Fish and Wildlife Service. The authority of the FWS to affect the management of the Gulf sturgeon is based primarily on the Endangered Species Act and the Fish and Wildlife Coordination Act. The FWS is the lead agency in developing the recovery plan for the subspecies under the Endangered Species Act. Under the Fish and Wildlife Coordination Act, the FWS, in conjunction with the NMFS, reviews and comments on proposals to alter habitat. Dam construction, drainage projects, channel alteration, wetlands filling and marine construction are projects that can potentially affect the Gulf sturgeon. Further, the FWS may seek mitigation of fishery resource impairment due to federal water-related development. The FWS has the responsibility to focus efforts on nationally significant fishery resources. The FWS also facilitates restoration by rebuilding certain major, economically valuable, anadromous, endangered, threatened, and interjurisdictional (managed by two or more states) fishery resources to full, self-sustainable productivity. Because the Gulf sturgeon is a threatened and an anadromous species, the FWS has conducted studies on various aspects of the subspecies' biology.

Gulf sturgeon occur in the aquatic portions (riverine, estuarine, marine) of national wildlife refuges (NWR) such as Pine Island NWR, Island Bay NWR, Passage Key NWR, Pinellas NWR, Chassahowitzka NWR,Cedar Keys NWR, Lower Suwannee NWR, St. Marks NWR, St. Vincent NWR, Florida, Bon Secour NWR, Alabama, Bogue Chitto NWR, Louisiana and Mississippi, and Delta NWR, Breton Island NWR, Bayou Sauvage NWR, Lacassine NWR, Louisiana. Fish and wildlife populations and their harvest within refuges are usually managed by the respective state which the refuge is located. Special use permits are required for commercial fishing on national wildlife refuges.

National Biological Service. The National Biological Service (NBS) is the Department of Interior's newest bureau. The NBS was created November 11, 1993, by consolidating the biological research, inventory, monitoring, and information transfer programs of seven Interior bureaus: FWS, NPS, MMS, USGS, Bureau of Land Management, Bureau of Reclaimation, and Office of Surface Mining. The Southeastern Biological Service Center (Center), Gainesville, Florida, of NBS was formerly a research center for FWS. The Center has conducted research on Gulf sturgeon since 1987 and will continue work in this area as requested by FWS and other agencies.

Environmental Protection Agency. The EPA, through its administration of the Clean Water Act, National Pollutant Discharge Elimination System (NPDES), may provide protection to Gulf sturgeon habitat. Applications for permits to discharge pollutants may be disapproved or conditioned to protect fresh and estuarine aquatic resources.

U.S. Department of the Army, Corps of Engineers. Gulf sturgeon habitat may be influenced by the COE's regulatory responsibilities pursuant to the Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act. Under these laws, the COE may authorize proposals to dredge, fill and construct in navigable waters (Section 10) or to discharge dredged or fill material into wetland areas and waters of the United States (Section 404). Such proposals could affect Gulf sturgeon habitat. The COE is also responsible for planning, construction and maintenance of dams, navigation channels and other projects that may affect Gulf sturgeon habitat.

Treaties and Other International Agreements. There are no treaties or other international agreements that affect the Gulf sturgeon. No foreign fishing applications for Gulf sturgeon harvest have been submitted to the United States government.

Federal Laws, Regulations and Policies. The following Federal laws, regulations and policies may directly and indirectly influence the habitat, populations and ultimately the management of the Gulf sturgeon.

Anadromous Fish Conservation Act (AFCA). The AFCA authorizes the Secretary of the Interior to initiate cooperative programs with the states to conserve, develop and enhance the nation's anadromous fisheries. The Act authorizes construction, installation, maintenance and operation of structures to improve or facilitate feeding, spawning and free migration of anadromous fish.

Coastal Zone Management Act and Estuarine Areas Act. Congress passed policy on values of estuaries and coastal areas through these Acts. Comprehensive planning programs to be carried out at the state level, were established to enhance, protect, and utilize coastal resources. Federal activities must comply with the individual state programs. Habitat may be protected by planning and regulating development damage to sensitive coastal habitats.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). This act is also referred to as the "Superfund". It can provide funding for "clean-up" of important habitat areas affected by oil spills or other distinct pollution discharge events.

Endangered Species Act (ESA). The ESA provides for the protection of habitat necessary for the continued existence of species listed as threatened or endangered. Section 7 of the ESA requires consultation with the FWS or NMFS by a federal agency if an action authorized, funded or carried out by such agency may affect a listed species or its critical habitat (a legal, area-specific designation). Section 7 also prohibits any federal action that would jeopardize the continued existence of a listed species or its critical habitat. Section 9 of the ESA prohibits any person or entity from "taking" a listed species without a proper permit from the FWS or NMFS. Under the ESA, taking may include harassment or habitat degradation if such would interfere with feeding, reproduction or other essential life functions. The ESA also requires preparation of a recovery plan for each listed species outlining actions needed to allow the particular species to reach a population level at which it may be delisted.

Federal Power Act (FPA). The FPA regulates the construction and operation of hydroelectric power plants through a system of licenses and permits issued by the federal Energy Regulatory Commission (FERC) (formerly Federal Power Commission). The FWS, NMFS, state agencies and others may review proposed licenses and make recommendations with respect to the needs of instream flow for fish and wildlife downstream of dams as well as the impacts that reservoir establishment may have on fish and wildlife upstream of the dams. The Act also provides for construction of fish passage facilities during dam or diversion construction. Dams are likely major factors affecting anadromous fish populations in some Gulf streams.

Federal Water Pollution Control Act (FWPCA). Also called the "Clean Water Act", the FWPCA provides for the protection of water quality at the federal level. The law also provides for assessment of injury, destruction, or loss of natural resources caused by discharge of pollutants.

Of major significance is Section 404 of the Clean Water Act (CWA), which prohibits the discharge of dredged or fill material into navigable waters without a permit. Navigable waters are defined under the CWA to include all waters of the United States, including the territorial seas and wetlands adjacent to such waters. The permit program is administered by the COE. The Environmental Protection Agency (EPA) may approve delegation of Section 404 permit authority for certain waters (not including traditional navigable waters) to a state agency; however, it retains the authority to prohibit or deny a proposed discharge under Section 404(c) of the CWA. Recent attempts to revise Section 404 or change the legal definition of wetlands may affect the utility of the CWA in wetlands protection. Although of limited applicability to anadromous fish restoration, Section 404 may be important in protecting certain types of coastal habitats or in protecting water quality in certain streams. It may also be a consideration in approval of certain types of restoration projects.

The FWPCA also authorized programs to remove or limit the entry of various types of pollutants into the nation's waters. A point source permit system was established by the EPA and is now being administered at the state level in most states. This system, referred to as the National Pollutant Discharge Elimination System (NPDES), sets specific limits on discharge of various types of pollutants from point source outfalls. A non-point source control program focuses primarily on the reduction of agricultural siltation and chemical pollution resulting from rain runoff into the nation's streams. This control effort currently relies on the use of land management practices to reduce surface runoff through programs administered primarily by the Department of Agriculture.

Both chemical contamination and siltation may be major factors limiting populations of anadromous Gulf fish species. Efforts to achieve anadromous fish restoration in key river drainages should be aimed at assuring compliance with established point and non-point source reduction programs in these basins.

Federal Water Project Recreation Act. This Act requires that consideration be given to fish and wildlife enhancement in federal water projects.

Fish and Wildlife Act of 1956. This act provides assistance to states in the form of law enforcement training and cooperative law enforcement agreements. It also allows for disposal of property abandoned or forfeited in conjunction with convictions. Some equipment may be transferred to states. The act prohibits airborne hunting and fishing activities.

Fish and Wildlife Coordination Act (FWCA). The Fish and Wildlife Coordination Act (FWCA) is the primary law providing for consideration of fish and wildlife habitat values in conjunction with federal water development activities. Under this law the Secretaries of Interior and Commerce may investigate, report and advise on the effects federal water development projects may have on fish and wildlife habitat. Such reports and recommendations, which require concurrence of the state(s) involved, must accompany the construction agency's request for congressional authorization, although, the construction agency is not bound by the recommendations. Construction agencies may transfer funds to the FWS or NMFS to investigate and report on specific projects.

The FWCA also applies to water-related activities proposed by other organizations or individuals if those activities require a federal permit or license. The FWS and NMFS may review the proposed permit action and recommend to the permitting agencies to avoid or mitigate any potential adverse effects on fish and wildlife habitat.

Fish Restoration and Management Projects Act of 1950. Under this act, the DOI is authorized to provide funds to state fish and game agencies for fish restoration and management projects. Funds for protection of threatened fish communities that are located within state waters could be made available under the act.

Food and Agriculture Act of 1962. This Act established a Resource Conservation and Development Program for regionally-sponsored flood control and drainage projects that receive financial and technical assistance from the Soil Conservation Service. Though not as active a program as it once was, activities under this program may have relevance, both positive and negative, to anadromous fish habitat protection, restoration or enhancement.

Lacey Act of 1981, as amended. The Lacey Act prohibits import, export and interstate transport of illegally-taken fish and wildlife. As such, the Act provides for federal prosecution for violations of state fish and wildlife laws. The potential for federal convictions under this Act, with its more stringent penalties, has probably reduced interstate transport of illegally-possessed Gulf sturgeon.

Magnuson Fishery Conservation and Management Act. This Act provides for the conservation of habitats throughout the ranges of anadromous species within the Exclusive Economic Zone (EEZ). It mandates the preparation of fishery management plans for important fishery resources and sets national standards to be met by such plans. Each plan attempts to define, establish and maintain the optimum yield for a given fishery.

Marine Plastic Research and Control Act of 1987 and MARPOL Annex V. MARPOL Annex V is a product of the International Convention for the Prevention of Pollution from Ships, 1973/78. Regulations under this Act prohibit ocean discharge of plastics from ships; restrict discharge of other types of floating ship's garbage (packaging and dunnage) for up to 25 nautical miles from any land; restrict discharge of victual and other recomposable waste up to 12 nautical miles from land; and require ports and terminals to provide garbage reception facilities. The MPRCA of 1987 and 33 CFR, Part 151, Subpart A, implement MARPOL V in the United States.

Marine Protection, Research and Sanctuaries Act of 1972 (MPRSA), Titles I and III and the Shore Protection Act of 1988 (SPA). The MPRSA protects fish habitat through establishment and maintenance of marine sanctuaries. This Act and the SPA regulate ocean transportation and dumping of dredged materials, sewage sludge and other materials. Criteria for issuing permits include considering the effects dumping has on the marine environment, ecological systems and fisheries resources. Permits are issued by the Corps of Engineers.

National Environmental Policy Act (NEPA). The NEPA requires an environmental review process of all federal actions. This includes preparation of an environmental impact statement for major federal actions that may affect the quality of the human environment. Less rigorous environmental assessments are reviewed for most other actions while some actions are categorically excluded from formal review. These reviews provide an opportunity for the agency and the public to comment, on projects that may impact fish and wildlife habitat.

Oil Pollution Act. This Act provides a degree of protection to coastal fisheries habitat by regulating discharge of oil from United States registry ships. Under the Act, tankers cannot discharge oil within 50 nautical miles of land, and other ships must discharge as far as practicable from land.

Outer Continental Shelf (OCS) Lands Act Amendments of 1979. These Amendments provide for assessments of the effects oil and gas exploration, development and production have on biological resources. The law also provides a channel for comments on federal approval of leasing OCS areas for exploration and development. Oil and gas leasing activities could be of concern for coastal anadromous fish habitat and offshore winter habitat of the Gulf sturgeon.

River and Harbor Act of 1899. Section 10 of the River and Harbor Act requires a permit from the U.S. Army Corps of Engineers (COE) to place structures in navigable waters of the United States or modify a navigable stream by excavation or filling activities.

Water Resources Development Acts (WRDA). These legislative actions authorize the COE to study and/or construct individual water resource projects. Prior to 1974 such acts were known as the "Flood Control Act of (year)", the "River and Harbor Act of (year)" or commonly called the "Omnibus Bill." Beginning in 1974 these laws have been referred to as the "WRDA of (year)". Numerous projects may be authorized under these Acts in any given year. Under the FWCA, "Wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs . . ." and the FWS, NMFS and state fish and wildlife agencies may review, comment and make recommendations to the COE regarding these projects' impacts on fish and wildlife resources. These comments may address the avoidance, mitigation or compensation for habitat damages.

Of particular relevance to anadromous fish habitat restoration or enhancement is the WRDA of 1986. This Act authorized the COE to study and construct environmental enhancement projects in conjunction with existing federal water projects.

STATE MANAGEMENT INSTITUTIONS, LAWS, REGULATIONS AND POLICIES.

State management institutions, laws and regulations for the Gulf sturgeon are relatively consistent among the four Gulf States within the species' range. Each state delegates substantial authority to its administrative agencies for establishing management regulations. Brief narrative descriptions are presented below for each state institution. Important state laws, regulations and policies are also summarized. **To the greatest extent possible, these requirements are current to the date of publication.**

FLORIDA

Administrative Organization.

Florida Marine Fisheries Commission
2540 Executive Center Circle West, Suite 106
Tallahassee, FL 32301
Telephone: (904) 487-0554

The Florida Marine Fisheries Commission, a seven-member board appointed by the governor and confirmed by the senate, was created by the Florida legislature in 1983. This commission was delegated rule-making authority over marine life in the following areas of concern: gear specification; prohibited gear; bag limits; size limits; species that may not be sold; protected species; closed areas; seasons; quality control codes with the exception of specific exemptions for shellfish; and special considerations relating to oyster and clam relaying. All rules passed by the commission require approval by the governor and cabinet. The commission does not have authority over endangered species, license fees, penalty provisions or over regulation of fishing gear in residential saltwater canals.

Florida Department of Environmental Protection (FDEP)
Division of Marine Resources
3900 Commonwealth Boulevard
Tallahassee, Florida 32303
Telephone: (904) 488-6058

This agency is charged with the administration, supervision, development and conservation of marine natural resources in Florida. The Florida Department of Natural Resources was the predecessor marine resources agency until its merger with the Florida Department of Environmental Regulation July 1, 1993. The agency is headed by the Governor and Cabinet. The governor and cabinet serve as the seven-member board that approves or disapproves all rules and regulations promulgated by the FDEP. The administrative head of the FDEP is the Department Secretary. Within the FDEP the Division of Marine Resources, through Section 370.02(2), Florida Statutes, is empowered to conduct research directed toward management of marine and anadromous fisheries in the interest of all people of Florida. The Division of Law Enforcement is responsible for enforcement of all marine resource related laws and all rules and regulations of the department. The Division of Marine Resources has the responsibility of overseeing the management and research efforts on the Gulf sturgeon including issuance of collecting permits for the subspecies.

Florida Game and Fresh Water Fish Commission.
Division of Wildlife
620 South Merdian Street
Tallahassee, Florida 32399
Contact: Mr. Don A. Wood, Endangered Species Coordinator
Telephone: (904) 488-3831

This agency is charged with the administration, supervision, development and conservation of wildlife and fresh water aquatic life in Florida. The FGFC is a constitutionally autonomous agency and is overseen by a governor appointed five-member board. The administrative head of the FGFC is the executive director. Within the FGFC the Division of Wildlife Resources, in accordance with the Florida Endangered and Threatened Species Act of 1977, Section 372.072, Florida Statutes, and the Wildlife Code of the State of Florida, Title 39, Florida Administrative Code, Article IV, Sec. 9, Florida Constitution, is responsible for research and management of listed fresh water and upland species. These efforts include the administrative designation of all wildlife species (including marine and estuarine species), issuance of collection permits, and various types of research of listed upland and fresh water aquatic wildlife species. The Gulf sturgeon was listed as a species of special concern by the FGFC in 1987.

Florida has habitat protection and permitting programs and a federally-approved Coastal Zone Management (CZM) program.

Legislative Authorization. Chapter 370 of the Florida Statutes Annotated contains law regulating coastal fisheries. The legislature passes statutes for the management of fisheries resources as well as specific laws which are applicable within individual counties.

Reciprocal Agreement and Limited Entry Provisions. Not applicable, since any take of Gulf sturgeon is illegal in Florida.

Commercial Landings Data Reporting Requirements. Not applicable since all take of Gulf sturgeon is illegal in Florida.

Penalties for Violations. Penalties for violations of Florida statutes and regulations are prescribed in Section 370.021, Florida Statutes. Upon the arrest and conviction for violation of any of the regulations or laws, the license holder shall show just cause why his saltwater license should not be suspended or revoked.

Annual License Fees. Not applicable, since all take of Gulf sturgeon is illegal in Florida.

Laws and Regulations. It is illegal to take *Acipenser oxyrinchus* by any means statewide according to Rule No. 46-15.01 (1984) of the Florida Marine Fisheries Commission. (Most federal and state agencies have used the specific name *A. oxyrinchus* instead of the subspecific name *A. o. desotoi*.

ALABAMA

Administrative Organization.

Alabama Department of Conservation and Natural Resources (ADCNR)
Alabama Marine Resources Division (AMRD)
P.O. Box 189
Dauphin Island, Alabama 36528
Telephone: (205) 861-2882

Management authority of fishery resources in Alabama is held by the Commissioner of the Department of Conservation and Natural Resources. The Commissioner may promulgate rules or regulations designed for the protection, propagation and conservation of all seafood. He may prescribe the manner of taking, times when fishing may occur and designate areas where fish may or may not be caught; however, all regulations are to be directed toward the best interest of the seafood industry.[5]

Most regulations are promulgated through the Administrative Procedures Act approved by the Alabama Legislature in 1983; however, bag limits and seasons are not subject to this Act. The Administrative Procedures Act outlines a series of events that must precede the enactment of any regulations other than those of an emergency nature. Among this series of events are (a) the advertisement of the intent of the regulation, (b) a public hearing for the regulation, (c) a 35-day waiting period following the pubic hearing to address comments from the hearing and (d) a final review of the regulation by a joint house and senate review committee.

Alabama also has the Alabama Conservation Advisory Board (ACAB) that is endowed with the responsibility to provide advice on policies of the ADCNR. The board consists of the governor, the ADCNR commissioner and ten board members.

The AMRD has responsibility for enforcing state laws and regulations, for conducting marine biological research and for serving as the administrative arm of the commissioner with respect to marine resources. The division recommends regulations to the commissioner.

Alabama has a habitat protection and permitting program and a federally approved CZM program.

Legislative Authorization. Chapters 2 and 12 of Title 9, Code of Alabama, contain statutes that concern marine fisheries.

Reciprocal Agreement and Limited Entry Provisions. Not applicable since all take of Gulf sturgeon is illegal in Alabama.

Commercial Landings Data Reporting Requirements. Not applicable since all take of Gulf sturgeon is illegal in Alabama.

Penalties for Violations. Take of Gulf sturgeon is illegal in Alabama, any take is considered a Class C misdemeanor and punishable by fines up to $500.00 and three months in jail.

Annual License Fees. Not applicable since all take of Gulf sturgeon is illegal in Alabama.

Laws and Regulations. It is currently illegal to take Gulf sturgeon in freshwater or coastal waters in Alabama. Alabama has no official State list of threatened and endangered species. *Acipenser oxyrinchus* is considered a threatened species by the Symposium on Endangered and Threatened Plants and Animals of Alabama (Boshung 1976).

MISSISSIPPI

Administrative Organization.

Mississippi Department of Wildlife, Fisheries and Parks (MDWFP)
Bureau of Marine Resources (BMR)
2620 Beach Boulevard
Biloxi, Mississippi 39531
Telephone: (601) 385-5860

The MDWFP administers coastal fisheries and habitat protection programs through the BMR. Authority to promulgate regulations and policies is vested in the Mississippi Commission on Wildlife, Fisheries and Parks, the controlling body of the MDWFP. The commission consists of five members appointed by the governor. The commission has full power to "manage, control, supervise and direct any matters pertaining to all saltwater aquatic life not otherwise delegated to another agency" (Mississippi Code Annotated 49-15-11).

Mississippi has a habitat protection and permitting program and a federally approved CZM program.

Legislative Authority. Chapter 49-15 of the Mississippi Code of 1972 (Annotated) contains provisions for the management of marine fisheries resources.

Reciprocal Agreement and Limited Entry Provisions. Not applicable since it is illegal to take Gulf sturgeon anywhere in the State of Mississippi.

Commercial Landings Data Reporting Requirements. Not applicable since it is illegal to take Gulf sturgeon anywhere in the State of Mississippi.

Penalties for Violations. Any person, firm or corporation violating any of the provisions of Chapter 49-15 or any ordinance duly adopted by the commission, unless otherwise specifically provided for herein, shall, on conviction, be fined not less than $100, nor more than $500, for the first offense, unless the first offense is committed during a closed season, in which case the fine shall be not less than $500, nor more than $1,000; and not less than $500, nor more than $1,000, for the second offense when such offense is committed within a period of 3 years from the first offense; and not less than $2,000 nor more than $4,000, or imprisonment in the county jail for a period not exceeding 30 days for any third or subsequent offense when such offense is committed within a period of 3 years from the first offense and also upon conviction of such third or subsequent offense, it shall be the duty of the court to revoke the license of the convicted party and of the boat or vessel used in such offense, and no further license shall be issued to such person or for said boat to engage in catching or taking of any seafoods from the waters of the State of Mississippi for a period of 1 year following such conviction. Further, upon conviction of such third or subsequent offense committed within a period of 3 years from the first offense, it shall also be the duty of the court to order the forfeiture of any equipment or nets used in such offense. Provided, however, that equipment as used in this section shall not mean boats or vessels. Any person convicted and sentenced under this section shall not be considered for suspension or other reduction of sentence. Except as provided under subsection 5 of Section 49-15-45, any fines collected under this section shall be paid to the Mississippi Commission on Wildlife, Fisheries and Parks to be paid into the Seafood Fund.

Annual License Fees. Not applicable since it is illegal to take Gulf sturgeon anywhere in the State of Mississippi.

Laws and Regulations. *Acipenser oxyrinchus* was listed as an endangered species by the Mississippi Game and Fish Commission and the Rare and Endangered Species Committee (1975) and is protected by law. The subspecies is also listed as endangered by the Mississippi Natural Heritage Program, 1977, and as a Special Animal Species by the Mississippi Parks Commission, Bureau of Outdoor Recreation, Jackson, MS.

LOUISIANA

Administrative Organization.

Louisiana Department of Wildlife and Fisheries (LDWF)
P.O. Box 98000
Baton Rouge, Louisiana 70898
Telephone: (504) 765-3617

The LDWF is one of 21 major administrative units of the Louisiana government. A seven-member board, the Louisiana Wildlife and Fisheries Commission (LWFC) is appointed by the Governor. Six of the members serve overlapping terms of six years, and one serves a term concurrent with the Governor. The commission is a policy-making and budgetary-control board with no administrative functions. The legislature has sole authority to establish management programs and policies; however, the legislature has delegated certain authority and responsibility to the LDWF. The Secretary of the LDWF is the executive head and chief administrative officer of the department and is responsible for the administration, control and operation of the functions, programs and affairs of the department. The secretary is appointed by the Governor with consent of the Senate.

Within the administrative system, an Assistant Secretary is in charge of the Office of Fisheries. In this office a Marine Fisheries Division and an Inland Fisheries Division may have management jurisdiction over the Gulf sturgeon. The Enforcement Division, in the Office of the Secretary, is responsible for enforcing all fishery statutes and regulations.

The LDWF's Natural Heritage Program is responsible for administering the laws, rules, and regulations regarding threatened and endangered species (R.S. 56:1830). In addition, under a full authorities Section 6 agreement with the FWS, the take of threatened and endangered species may be authorized by permits issued by the Department.

Louisiana has habitat protection and permitting programs and a federally approved CZM program.

Legislative Authorization. Title 56 Louisiana Revised Statutes contains rules and regulations that govern marine fisheries in the state.

Reciprocal Agreement and Limited Entry Provisions. Not applicable, since take of Gulf sturgeon is illegal in Louisiana.

Commercial Landings Data Reporting Requirements. Not applicable, since take of Gulf sturgeon is illegal in Louisiana.

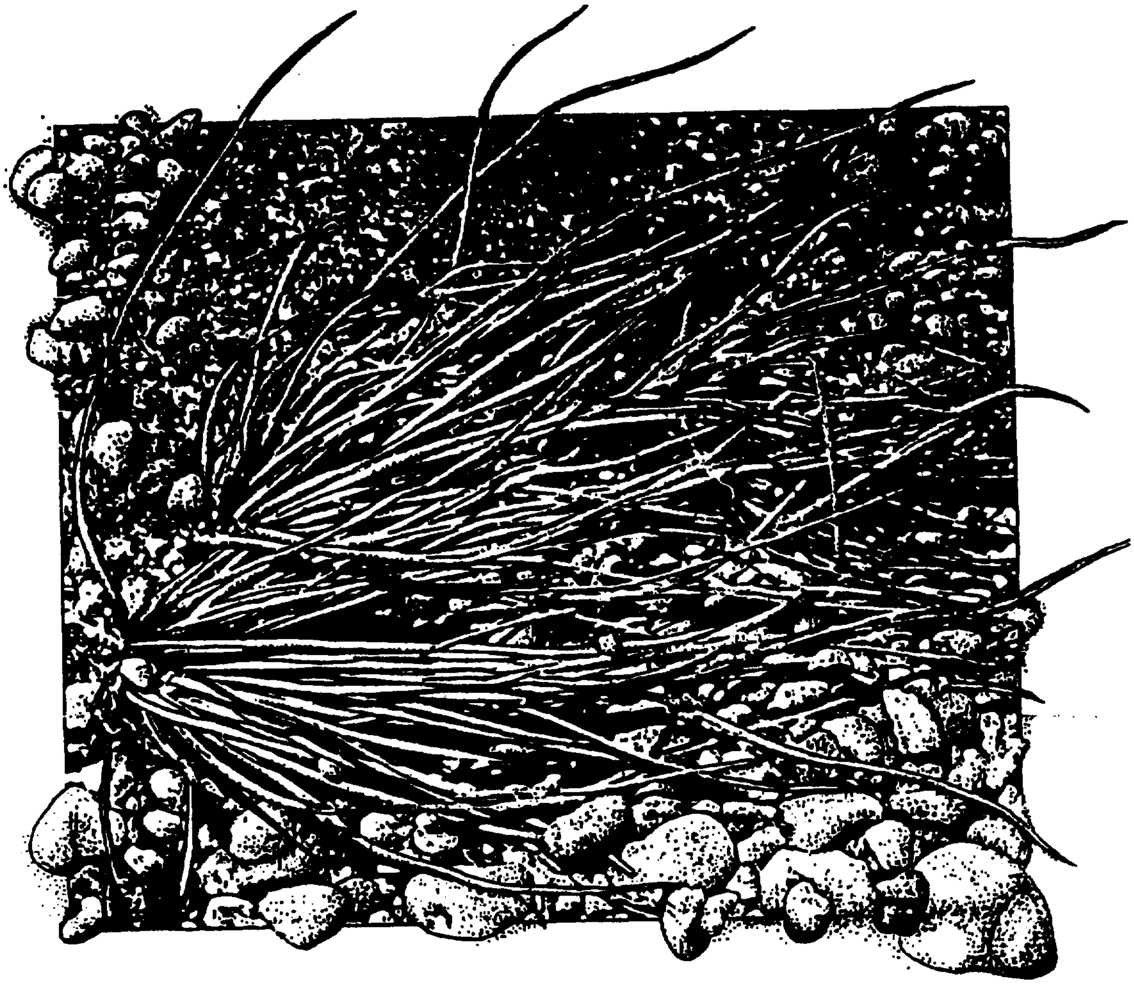
Penalties for Violations. The fine for each illegally caught fish is $2,500.00

Annual License Fees. Not applicable, since take of Gulf sturgeon is illegal in Louisiana.

Laws and Regulations. Louisiana law currently prohibits take of all sturgeon anywhere in the state. The Louisiana Division of Natural Heritage is responsible for listing of endangered and threatened species.

Appendix C-3: Louisiana Quillwort Recovery Plan

Recovery Plan For The Louisiana Quillwort (*Isoetes louisianensis*) Thieret



U.S. Fish and Wildlife Service
Southeast Region
Atlanta, Georgia

LOUISIANA QUILLWORT

Isoetes louisianensis Thieret

RECOVERY PLAN

Prepared by

Julia Larke
Louisiana Natural Heritage Program
Louisiana Department of Wildlife & Fisheries

for

U.S. Fish and Wildlife Service
Jackson, Mississippi

and

U.S. Fish and Wildlife Service
Southeast Regional Office
Atlanta, Georgia

Approved: Noreen K. Clough
Noreen K. Clough, Regional Director,
Southeast Region, U.S. Fish and Wildlife Service

Date: September 30, 1996

Recovery plans delineate reasonable actions which are believed to be required to recover and/or protect the species. Plans are prepared by the U.S. Fish and Wildlife Service, sometimes with the assistance of recovery teams, contractors, State agencies, and others. Objectives will only be attained and funds expended contingent upon appropriations, priorities, and other budgetary constraints. Recovery plans do not necessarily represent the views nor the official positions or approvals of any individuals or agencies, other than the U.S. Fish and Wildlife Service, involved in the plan formulation. They represent the official position of the U.S. Fish and Wildlife Service only after they have been signed by the Regional Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

By approving this document, the Regional Director certifies that the information used in its development represents the best scientific and commercial data available at the time it was written. Copies of all documents reviewed in development of the plan are available in the administrative record, located at the Jackson, Mississippi, Field Office.

Acknowledgment:

The cover illustration was originally done by Julia Larke of the Louisiana Natural Heritage Program. It was enhanced by Ms. Larke and Terri Jacobson of the U.S. Fish and Wildlife Service.

Literature citations should read as follows:

U.S. Fish and Wildlife Service. 1996. Recovery Plan for Louisiana quillwort (*Isoetes louisianensis* Thieret). Atlanta, Georgia. 26 pp.

Additional copies may be purchased from:

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814

Telephone: 301-492-6403 or
1-800-582-3421

Fees for recovery plans vary, depending upon the number of pages.

EXECUTIVE SUMMARY

Current Status: *Isoetes louisianensis* is listed as endangered without critical habitat. It is currently known to occur in St. Tammany and Washington Parishes in southeastern Louisiana and in Jackson and Perry Counties in southern Mississippi. In Louisiana, all known sites are on private land; in Mississippi, all known sites occur on National Forest land.

Habitat Requirements and Limiting Factors: Louisiana quillwort occurs in the East Gulf Coastal Plain physiographic province in Pleistocene Prairie Terraces and Pleistocene High Terraces in southeastern Louisiana and in Pleistocene High Terraces in southern Mississippi. It appears to be restricted to sandy soils and gravel bars in or near shallow blackwater streams and overflow channels in riparian woodland/bayhead forests of pine flatwoods and upland longleaf pine. *Isoetes louisianensis* is extremely vulnerable because of its small population size and habitat loss from actions which affect the hydrology or stability of the streams it inhabits.

Recovery Objective: Delisting.

Recovery Criteria: This species will be considered for delisting when 10 reproductively viable and geographically distinct populations from different drainage systems are protected from foreseeable threats. A reproductively viable population is one which is reproducing and stable or increasing in size as shown by monitoring for at least a 10-year period.

Actions Needed:

1. Protect known populations by protecting their habitat.
2. Conduct life history research.
3. Monitor population trends and developing threats.
4. Search for additional populations in southeastern Louisiana, southern Mississippi, and south Alabama.
5. Preserve genetic stock.
6. Inform the public about the conservation needs of the species.

Estimated Cost of Recovery: It is not possible to estimate costs beyond the first few years. Cost estimates of recovery tasks over the next 3 years total $74,000.

Date of Recovery: Since the species' recovery depends upon the outcome of several recovery tasks, it is not possible to determine a date at this time.

TABLE OF CONTENTS

I. INTRODUCTION

A. Background

Isoetes louisianensis Thieret, Louisiana quillwort, is a member of the Isoetaceae, a family of primitive seedless plants related to ferns. The family consists of a single genus, *Isoetes*, with approximately 150 species occurring nearly worldwide in aquatic and moist terrestrial habitats. Twenty-five species occur in North America (Brunton *et al.* 1994, Taylor *et al.* 1993) and one of the rarest is *I. louisianensis*. Within the East Gulf Coastal Plain physiographic province this species occurs in the Pleistocene Prairie Terraces and High Terraces in southeastern Louisiana and in the Pleistocene High Terraces in southern Mississippi. Louisiana quillwort is apparently restricted to sandy soils and gravel bars in or near shallow blackwater creeks and overflow channels in narrow riparian woodland/bayhead forest communities in pine flatwoods and upland longleaf pine.

In southeastern Louisiana, it is currently known from eight sites in St. Tammany and Washington Parishes; in southern Mississippi, it is known from a single site in Jackson County, and from three sites in Perry County. Louisiana quillwort is extremely vulnerable because of its small population size and restricted range. On October 28, 1992, the U.S. Fish and Wildlife Service (1992) officially listed *Isoetes louisianensis* Thieret (Louisiana quillwort) as an endangered species under the Endangered Species Act of 1973, as amended.

B. Taxonomy and Description

Isoetes louisianensis Thieret was discovered by Garrie Landry in April 1972 at Thigpen Creek in Washington Parish, Louisiana, and later described (Landry and Thieret 1973). Type specimens are held at the Gray Herbarium (GH) and the University of Michigan (MICH). *Isoetes louisianensis* is a small, semi-aquatic, facultative evergreen plant with spirally-arranged leaves (sporophylls) arising from a globose, two-lobed corm. The pliant, hollow leaves are transversely septate and measure 2 to 3 millimeters (mm) (0.12 inch) wide, and up to 40 centimeters (cm) (16.0 inches) long. Spore-containing structures (sporangia) are embedded in the pale, broadened bases of the leaves. Kral (1983) has suggested that aquatic quillwort leaves may vary in length depending upon water depth.

Key morphological features that differentiate *Isoetes* taxa are megaspore ornamentation, texture, and size, and length of the velum (a membranous flap of tissue covering the sporangium) (Hickey 1986, Taylor *et al.* 1993). Megaspores are white and reticulate-cristate in texture with relatively thick proximal ridges; they measure 500 to 625 micrometers (μm) (approximately 0.02 inch) in diameter. Surface texture of the girdle (a narrow band along the distal side of the equatorial ridge encircling the megaspore) is obscure and not distinguishable from the overall texture of the spore. Microspores are light brown in mass and densely spinulose; they measure 25 to 35 μm (approximately 0.001 inch) in diameter. The velum in *I. louisianensis* covers less than one-half of the adaxial wall of the sporangium and the sporangial wall is brown-streaked. Biosystematic studies by Neil Luebke and Carl Taylor at the Milwaukee Public Museum indicate that this species is a tetraploid (2n=44) (Taylor *et al.* 1993).

Sporogenesis appears to be weather dependent and occurs from late spring through fall as evidenced by collections and field observations of *Isoetes louisianensis* (Larke #3193, #3456 LSU, USL; Leonard, Mississippi Natural Heritage Program, pers. comm. 1996; Sorrie, Sand Pines, North Carolina, pers. comm. 1996). Apparently, if conditions are warm and wet enough, sporangia develop and spores mature. From observations, megasporophylls appear to be located on the outer edges of the spirally arranged leaves and it seems that megasporangia mature and disperse spores just prior to microsporangia. It is possible that leaf development follows a continual pattern of megasporophylls alternating with microsporophylls, and specimens might be found that show mature microsporangia on the outer leaves and mature megasporangia in the inner leaves. An earlier suggestion that an alternating cycle of sporogenesis occurs, with microspores maturing in the fall and megaspores in the late winter or early spring (Landry and Thieret 1973) may have come from observations of specimens that were collected after megasporophylls had matured and dropped off the plant.

Landry and Thieret (1973) described *Isoetes louisianensis* as closely resembling the diploid species *I. engelmannii* A. Braun var. *caroliniana* A. A. Eaton (= *I. caroliniana* (A.A. Eaton) Luebke). However, they noted that the brown-spotted sporangial walls of *I. louisianensis* easily separated the two species. Boom (1980, 1982) considered *Isoetes louisianensis* a hybrid of *Isoetes engelmannii* A. Braun x *I. melanopoda* Gay & Durieu.

Luebke and Taylor (1986) questioned the hybrid specific status for *Isoetes louisianensis* proposed by Boom and submitted that it was a legitimate species. *Isoetes* hybrids typically are sterile because spores are often malformed and variable in size, shape and texture; their studies revealed that *I. louisianensis* spores readily germinated in culture and were uniform in size and texture. Boom concurred with Luebke and Taylor's determination (U.S. Fish and Wildlife Service 1992).

Taylor *et al.* (1993) recognized *Isoetes louisianensis* as a full species in their treatment of the genus *Isoetes* for the *Flora of North America*. *Isoetes louisianensis* is an allotetraploid (2n=44) of probable hybrid origin and the reticulate texture of the megaspore suggests *I. engelmannii* as a possible parent. Both *I. engelmannii* and *I. melanopoda* occur northward in the Mississippi River watershed and opportunities for contact via waterfowl exist because of the proximity of the Mississippi River flyway (Boom 1980, 1982). Further DNA and enzyme electrophoretic studies are needed to determine parentage.

The recently described *Isoetes hyemalis* (Brunton *et al.* 1994) is the only other tetraploid taxon in southeastern United States; it occurs in shallow creeks and sloughs primarily in the Coastal Plain in Virginia, North Carolina, South Carolina, Georgia, and Alabama. It also shares many features with possible diploid progenitors *I. engelmannii* and *I. caroliniana*. *Isoetes hyemalis* is very similar to *I. louisianensis* but it has a clear velum (not brown-streaked), and its megaspores are less reticulate and have a distinctly spiny equatorial band.

C. Distribution

Louisiana quillwort is currently known from two parishes in southeastern Louisiana and two counties in southern Mississippi in the Gulf Coastal Plain physiographic province (Figure 1). A report of this species from Worth County, Georgia was in error (U.S. Fish and Wildlife Service 1992). In this recovery plan, a population is characterized as one that is reproductively viable and geographically distinct. Populations occurring in different drainage systems, where gene flow appears to be limited, are considered geographically distinct. Because it is difficult to identify gene flow patterns in aquatic species, it may be more

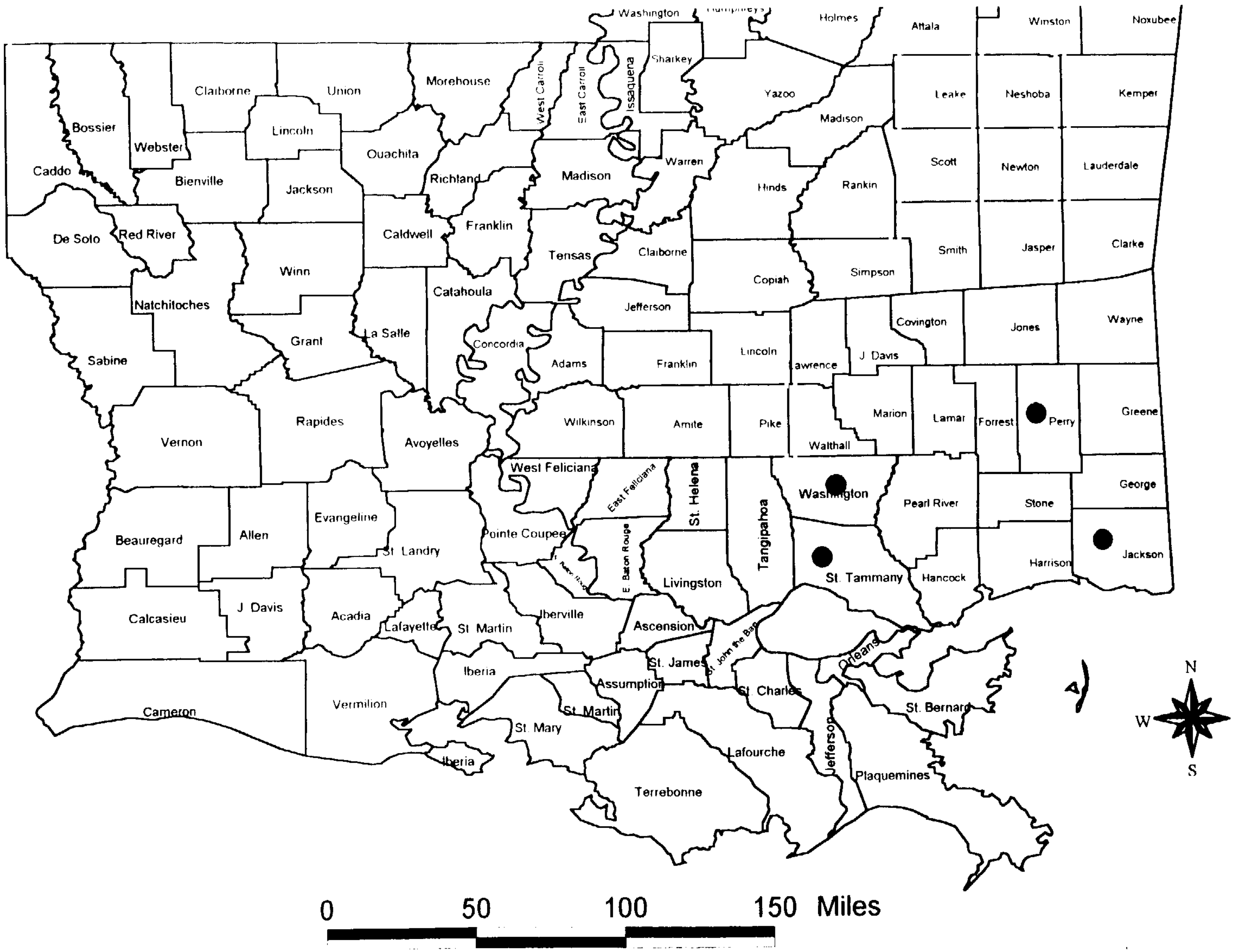


Figure 1. Current distribution of Louisiana quillwort

precise to use the term subpopulation when referring to populations in drainages of major watersheds. For Louisiana quillwort, population size in the spatial sense is linear, because plants follow the stream course, and spacing of individuals and subpopulations within the population tends to occur in patches or colonies. Ecological constraints, such as stream dynamics, moisture availability, and soil conditions limit population size and range for Louisiana quillwort.

Populations are located at the following sites in Louisiana:

Washington Parish:
The Bogue Chitto River watershed:
(1) Louisiana quillwort occurs in upper Mill Creek and the lower portions of Thigpen and Clearwater Creeks. Plants from the three sites constitute a single population. Over 2,600 plants are located along a 1.25 kilometer (km) (0.75 mile) section of Thigpen Creek; 335 plants occur in a 1.0 km (0.6 mile) section of Mill Creek; and, 20 plants occur along a 0.5 km (0.3 mile) section of Clearwater Creek. 2) Four plants occur at a site on Miller Creek.

St. Tammany Parish:
Tchefuncta River watershed:
The Bogue Falaya River drainage: (1) Over 1,500 plants are located along a 1.0 km (0.6 mile) section of a tributary to the Bogue Falaya. (2) Approximately 50 plants occur near the headwaters of a small drainage of LaTice Branch Creek.

The Little Bogue Falaya River drainage: Over 350 plants are located at the Little Bogue Falaya River southeast of Barkers Corner.

The Abita River drainage: (1) Approximately 400 plants occur along a 0.5 km (0.3 mile) section of Abita Creek, and 18 plants occur at a site on Coon Creek, a small tributary of Abita Creek. These two sites are considered a single population. (2) Two plants are located at Ten-Mile Creek.

Bayou Chinchuba drainage: Bayou Chinchuba drains directly into Lake Pontchartrain. This population of over 350 plants is atypical because it occurs in a seasonally-flooded small depression in wet-loblolly pine flatwoods instead of near a streamside. (Tad Zebryk *in litt.* 1995).

In 1996, Louisiana quillwort was discovered in Mississippi by Bruce Sorrie in Jackson County and Steve Leonard in Perry County. Populations occur at the following sites:

Jackson County:

DeSoto National Forest, Red Creek Wildlife Management Area, Tchoutacabouffa River watershed:
Approximately 50 plants occur in overflow channels near the streamhead of a branch of Bayou Billie.

Perry County:

DeSoto National Forest, Camp Shelby National Guard Training Site, Pascagoula River watershed:
(1) Approximately 2,500 plants are located in five colonies along a 1.6 km (ca 1.0 mile) stretch near the headwaters of Pearces Creek. (2) 1,500 plants occur in scour channels aggregated mainly along a 0.3 km (0.2 mile) section of a small tributary to Joes Creek. (3) 20 plants occur near an intermittent stream draining into Whiskey Creek.

D. Habitat

The following discussion focuses primarily on descriptions of quillwort habitat in Louisiana. Mississippi populations were recently discovered and are not fully described in this document. Observations on the habitat of Mississippi sites were contributed by Steve Leonard, Natural Heritage Inventory Botanist, Camp Shelby National Guard Training Site, DeSoto National Forest (*in litt.* 1996).

In southeast Louisiana, geomorphology, soils, hydrology, and vegetation combine to form an environment that supports one of the rarest quillworts in North America. The habitat has been well described by McInnis (1991a) and Hartfield (1991). Louisiana quillwort is apparently restricted to areas in or near shallow, blackwater streams in riparian woodland and bayhead forests of pine flatwoods and upland pine forests. These creeks originate in the dissected hills of the Pleistocene High Terraces and flow out into extensive flatwoods and bayhead forests of the Prairie Terrace formation. In these areas, *Isoetes louisianensis* grows singly, or in large patches of several hundred plants.

Plants grow in stable sand and gravel bars and moist overflow channels with silty sand substrate, and on low, sloping banks near and below water levels. They occur in a relatively firm substrate of fine sandy loam, and sometimes coarser sands and small to medium-sized gravel. One site at a seasonally flooded small depression is atypical because it is not a streamside habitat. This population may maintain itself because of an abandoned artesian well nearby, or because it is fed by subsurface seepage from the larger wetland surrounding the site. The surrounding flatwoods show evidence of flooding and immature *Isoetes* plants could easily have washed into the safe site of the moist depression (Zebryk *in litt.* 1995).

Sandy blackwater streams in southeast Louisiana are typically a clear, tannin-colored brown. They are shallow and range from only a few centimeters deep in riffle areas to 0.75 meters (m) (2.5 ft) deep, with occasional deeper pools (McInnis 1991a). Stream widths vary from 0.6 to 4.6 m (2 to 15 ft), narrowing in shallow areas, widening in deeper areas, and occasionally splitting or braiding temporarily between mossy hummocks, exposed tree roots, or cypress knees. Debris from flooding has been observed as high as 2.2 m(approximately 7 ft) and more commonly about 1.0 m (over 3 ft). Floodplain widths vary, from under 10 m to over 150 m(30 to over 500 ft).

Plants are regularly inundated following rains and may remain submerged for extended periods during flooding. Corms rooted in sandy soil are often overlain with coarser gravel, in some cases to nearly 4 cm (1.5 inches) in depth. Two *Isoetes* species (*I. georgiana* and *I. hyemalis*), that grow in similar habitat in southeastern United States, often are anchored in soils by a subterranean or surfical network of tree rootlets which allow the plants to withstand intense scouring by flood waters (Brunton *in litt.* 1995). Similar anchoring has been observed in *I. louisianensis* populations in Louisiana.

Quillwort populations in Louisiana appear to be facultatively evergreen. During summer dry periods, plants within the same population were observed to remain evergreen if growing in water, and to wither and die back if growing in areas such as overflow channels that became dry if located at a distance from the main channel. In Mississippi, all of the known Louisiana quillwort populations occur at sites that dry out during the summer (Leonard *in litt.* 1995). Brunton (*in litt.* 1995) notes that *I. georgiana* and *I. hyemalis* are found at sites that dry out completely by early summer and stay dry until early winter.

Soils from five of the six quillwort sites in St. Tammany Parish are mapped as Myatt fine sandy loam, frequently flooded (Natural Resources Conservation Service 1990). Myatt soils are found on broad flats or stream terraces in depressional areas or narrow drainageways; soil is level with a slope of less than 1 percent and is poorly drained with very slow water run-off. Brief flooding is said to occur mainly in the winter and spring, although flooding can occur anytime during the year. The site near Bayou Chinchuba is mapped as Abita silt loam, a soil type located in slightly raised positions on stream terraces. The adjacent stream is mapped as Myatt sandy loam. Although the soil survey for Washington Parish has not yet been published, the general soil map shows the quillwort sites occurring in the Myatt-Stough-Cahaba association (Natural Resources Conservation Service 1971).

Soils at the Perry County, Mississippi quillwort sites are mapped as Bibb silt loam and Trebloc silt loam in the Perry County Interim Soil Survey (Natural Resources Conservation Service, undated) (Leonard pers. comm. 1996). The soil type at the Jackson County site is not known at this time.

Vegetation along blackwater creeks is a riparian woodland/bayhead forest community with filtered light from a mostly closed canopy. The canopy is composed of *Nyssa biflora* (swamp blackgum), *Magnolia virginiana* (sweetbay magnolia), *Taxodium distichum* (bald cypress), *Acer rubrum* (red maple), *Quercus laurifolia* (laurel oak), and *Pinus taeda* (loblolly) and occasionally, *Pinus glabra* (spruce pine). Understory species include *Cyrilla racemiflora* (black titi), *Leucothoe axillaris* (fetterbush), *Itea virginica* (virginia willow), *Viburnum dentatum* (arrowwood), *Rhododendron viscosum* (summer azalea), *Vaccinium elliottii* (Elliott's blueberry), *Ligustrum sinense* (chinese privet), and various species of *Ilex* (holly). In areas where the floodplain widens, bayhead forests may be present with a similar species composition as the riparian zones (McInnis 1991a). Louisiana quillwort has been found growing in association with aquatics *Oronticum aquaticum* (golden club), *Potamogeton pusillus* (pondweed), and *Sparganium americanum* (bur-weed), and other species such as *Viola primulifolia* (violet), *Micranthemum umbrosum, Scirpus divaricatus* (bulrush), *Justicia lanceolata* (water-willow), *Hypoxis leptocarpa* (stargrass), *Woodwardia areolata* (netted chainfern), *Lycopus virginicus* (bugleweed), *Pallavicinia lyellii* (a liverwort), and *Mnium affine* (a moss).

E. Reproductive Biology

Species of *Isoetes* appear to have evolved either by ecological isolation and genetic divergence, or by interspecific hybridization and chromosome doubling as divergent species migrated into the same aquatic habitats (Taylor *et al.* 1993). Early researchers, such as, Pfeiffer (1922) and Reed (1965), and later Boom (1980, 1982), characterized the genus and recognized that a proliferation of interspecific hybrids existed. A polyploid series has been identified in aquatic *Isoetes*, implying that some species in the series may have evolved abruptly through hybridization and allopolyploidy (Taylor *et al.* 1985). Of the 25 described species of quillwort in North America, 10 are polyploid submerged or emergent aquatics (Brunton *et al.* 1994, Taylor *et al.* 1993). Evidence for such hybridization has been obtained from distribution patterns, spore morphology, chromosome numbers, *in vitro* hybridizations, and enzyme electrophoresis (Hickey *et al.* 1989, Taylor *et al.* 1985).

When Louisiana quillwort was first discovered, Thieret (1980) collected live plants with surrounding soil and cultivated them in a greenhouse at the University of Southwestern Louisiana. Plants were still thriving after 6 months. Thieret noted that "numerous young quillwort plants appeared in the soil of the pots. Many of these, while still only about 1 cm long and still attached to the megaspore, floated to the surface of the water." He postulated that this phenomenon could be evidence, in natural conditions, for downstream dispersal of young plants. Brunton (*in litt.* 1995) observed this condition in young plants of *Isoetes hyemalis* in Alabama and agrees with Thieret's premise.

Taylor and Luebke (1986) experimented with spore germination and growing sporelings of aquatic species of *Isoetes*. They speculate (pers. comm. 1996) that the spiny surface ornamentation of microspores (and to a lesser degree, megaspores) may lend itself to trapping, as spores become caught in the bases of the parent or nearby plants, or become embedded in soil nearby. In this manner, spores maintain close proximity to the colony despite sometimes swift water currents. Taylor and Luebke also suggest that an optimal grain size of the sandy loam substrate may favor capture of spores in the soil near the bases of sporophyte plants. After fertilization of the gametophyte, young sporophytes can emerge close to the parent sporophyte in a manner observed by Thieret (1980) and Taylor and Luebke (1986) and take root nearby or be dispersed downstream. This process may explain the often dense growth patterns in quillwort populations.

F. Reasons for Listing and Threats

Isoetes louisianensis is one of the rarest quillworts in the United States and is extremely vulnerable because of its small population size and restricted range. The current state of knowledge would suggest that suitable small-stream habitat is rare in Louisiana and Mississippi. However, the recent discovery of this species in Mississippi may indicate greater occurrence in the southern third of the state. It is not inconceivable that Louisiana quillwort will be found in southern Alabama as botanists search for stream habitat similar to that of Mississippi (Leonard *in litt.* 1996).

Habitat loss through land use practices that significantly transform riparian forest communities and alter stream quality and dynamics, poses the most serious threat to populations of Louisiana quillwort. This species is adapted to a dynamic stream environment and is negatively affected by adverse anthropogenic changes. Anthropogenic constraints change natural drainage patterns and stream dynamics, potentially damaging quillwort habitat and possibly inhibiting formation of new habitat. Dredging, ditching, channelization, road construction, and off-road vehicles (ORV) can alter natural processes and result in habitat loss. In addition, the effects of timber removal, mining, feral hogs, beaver dams, and plant collection are discussed in this section.

Timber removal increases surface runoff and contributes to stream erosion and sediment siltation. Removal of canopy alters light and temperature regimes on the forest floor; soils become drier and weedy vegetation tends to invade. Logging adjacent to creeks creates debris and detritus which can obstruct water flow and change stream dynamics. While streamside management zones (SMZs) are theoretically protective buffers to the streams themselves, observations of logging practices in Mississippi show that logging sometimes occurs to the stream edge, that slash is frequently left in the drainage, and that quillwort habitat is crossed by skidders and trucks during timber harvest. These generally rough logging trails and roads are then used by hunters and others until saplings regenerate and block vehicular access (Leonard *in litt.* 1996).

Sand and gravel mining poses a significant threat, as evidenced by portions of Clearwater Creek in Washington Parish, Louisiana, that have been completely cleared, channelized, and re-routed. Degradation of water quality from siltation, prolific algal growth, and sediment pollution from overflow of adjacent gravel pits was observed at the creek site (McInnis 1991a). Mining operations in or adjacent to creeks and rivers can have a detrimental effect upon aquatic resources. A recent study by Brown and Curole (1995) discussed impacts of gravel mining in Louisiana on mussel assemblages. In their study, it was noted that most damage occurred upstream from mining activity resulting in channel degradation, bank erosion, and the formation of broader, shallow braided streams.

Feral hogs pose a potential threat to quillwort habitat in DeSoto National Forest in Mississippi. Rooting has been observed at one of the Camp Shelby sites. Wildlife managers on the national forest are aware of this problem and they are considering appropriate measures for controlling the hogs (Leonard pers. comm. 1996).

Beaver dams occur in drainages supporting quillwort habitat in Louisiana and in Mississippi. Beaver activity could easily inundate a population by impounding a stream and downstream plants could also be affected by changes in water flow.

Plant collectors could present a danger to quillwort populations if they are over zealous in their collecting of a species with such a small population size and extent. University students, environmental managers, members of botanical clubs, and others interested in making a field trip to observe this species need to remain aware of the rarity of Louisiana quillwort and treat its environment in an ecologically sound manner.

McInnis (1991a) and Larke (1996) searched, without success, numerous small-stream, riparian woodlands that appeared to have similar physiognomy and vegetation to known quillwort sites. The following conditions were observed at sites in Louisiana <u>not</u> supporting quillwort: (1) silty substrate with little coarse sand or gravel; (2) instable substrate; (3) steep banks; (4) absence of sand and gravel bars; (5) differing stream dynamics with either too much energy preventing establishment of vegetation on gravel bars, or with too little energy resulting in swampy conditions; (6) excessive dryness during periods of low precipitation; and, (7) alteration due to activities such as channelization and ORV use.

Observations in Mississippi reveal that quillworts at drier sites are subject to desiccation and often cannot be seen during late June, July, and August. Therefore, it may not be possible to conclude that a particular stream does not have quillworts if one is searching during the hotter and drier summer months (Leonard *in litt.* 1996). It is also necessary to consider broader climate trends when surveying for quillwort (*e.g.*, searches for quillwort during wet years might prove more successful than searches in drought years). More field observations are needed to fully understand the optimum environmental conditions for Louisiana quillwort populations.

Because development pressure within the known range is severe, populations may be unknowingly extirpated. Although the known range of Louisiana quillwort has recently broadened from two parishes in southeastern Louisiana to include two counties in southern Mississippi, any negative environmental impacts to quillwort habitat are important because of the small global range of this species. Research (Gilpin and Soule 1986) has shown that the possibility of local extinction is greater for species in variable dynamic environments and that more individuals are needed to maintain a minimum viable population (McInnis 1991a).

G. Conservation Measures

In 1992, Cavenham Timber Company established a portion of Thigpen Creek supporting quillwort as a protected Nature Area. The area is well-marked by signs indicating no trespassing and no wheeled or track vehicles. Timbering in the area is prohibited. Weyerhauser Timber Company purchased Cavenham Timber land in southeast Louisiana in 1996, and they are maintaining the protected Nature Area.

The Natural Areas Registry Program, a joint endeavor between The Nature Conservancy (TNC) and the Louisiana Department of Wildlife and Fisheries (LDWF), proposed the Thigpen Creek Natural Area in the early 1990's. A registry is a non-legal binding agreement to promote habitat conservation in significant natural areas. The landowner agrees to follow TNC/LDWF management recommendations designed to promote conservation of the biological diversity at the site. On Thigpen Creek, one of the private landowners with quillwort on their property has registered their land. Five others have registered as part of a buffer zone adjacent to the proposed Natural Area. Additional landowners in the area may reconsider their original decision not to register now that the local timber company has led the way in choosing to protect their quillwort colonies. Preliminary contacts have been made to landowners of quillwort sites in St. Tammany Parish to elicit their help in protection of this species.

All of the known Louisiana quillwort populations in Mississippi occur on DeSoto National Forest land. Three of them occur on lands leased from the U.S. Forest Service by the Mississippi Military Department for Camp Shelby, U.S. Army Reserve and National Guard Training Site in Perry County. The fourth population occurs at the Red Creek Management Area in Jackson County. Federal agencies are required to ensure that actions they authorize, fund, or carry out do not jeopardize the continued survival of the species. Military operations in wetlands are limited, and tracked vehicle use is restricted to designated wetland crossings. All new construction plans for projects that might impact wetlands and thus quillwort habitat include field inspection and habitat assessment. Attention is also given to upland construction where runoff and sedimentation might adversely impact known colonies (Leonard *in litt.* 1996).

Surveys for new populations have been conducted in Louisiana by the Louisiana Natural Heritage Program. Other surveys are ongoing or planned for Mississippi and Alabama. Additional research and field studies currently being conducted with *Isoetes* species, and specifically biosystematic research with *Isoetes louisianensis* by Taylor and Luebke at the Milwaukee Public Museum, are rapidly increasing our understanding of the life history and ecology of these obscure plants. An ecological study of Louisiana quillwort habitat at Camp Shelby, Mississippi has recently been initiated by University of Southern Mississippi biologists (Leonard *in litt.* 1996). Results of these studies will allow biologists and land managers to make more informed decisions in conserving and protecting Louisiana quillwort populations and their habitat.

A sixth grade class in Sanford, Connecticut, undertook a class project of developing a plan to recover the Louisiana quillwort after learning of the species' status from the Fish and Wildlife Service's public notification process on draft recovery plans. The students wrote articles, made speeches and posters, and heightened the public's awareness of the Louisiana quillwort's plight. They also developed their own list of actions to be implemented to improve the status of the species, many of which corresponded with those in the Fish and Wildlife Service's recovery plan. Similar activities should be encouraged as educational experiences for students. These efforts help to inform the public on the recovery process and conservation needs of endangered species.

II. RECOVERY

A. Recovery Objective

The objective of this plan is the conservation of Louisiana quillwort habitat to ensure that populations are self-sustaining components of their ecosystem. Delisting is a primary goal of this plan. Louisiana quillwort will be considered for delisting when 10 viable and geographically distinct populations from distinctly separate drainages are protected. A viable population is one which is reproducing and stable or increasing in size as shown by monitoring for at least a 10-year period.

Recovery criteria may be revised based upon the availability of new information, including information gathered from identified recovery tasks.

B. Narrative Outline

1. Protect existing populations and their habitat from further impacts. Based upon survey work to date, populations have been located in 12 drainages, eight in Louisiana and four in Mississippi. Over half of the known sites occur in St. Tammany Parish, Louisiana in areas undergoing intensive development. In Mississippi, currently known sites occur on national forest land. Continued survival of this species depends upon protection of the hydrology, soils, and plant communities in drainages where Louisiana quillwort is known to occur.

   1.1 Ensure protection of populations on Federal land. The Endangered Species Act (ESA) provides for the protection of endangered plants on Federal lands through Section 7 and Section 9. Federal agencies must ensure that activities they implement, fund, or permit are not likely to jeopardize the continued existence of a listed species. Federal agencies are also instructed to implement programs for the conservation of listed species. Section 9 prohibits the malicious damage or destruction of endangered plants on Federal lands and prohibits their removal, without a permit. The Fish and Wildlife Service will work with the Forest Service to ensure the protections of populations on their lands.

1.2 Protect populations on private land. All populations in Louisiana occur on private land. Survival of the species in Louisiana depends upon achieving protection for known sites.

1.2.1 Pursue land acquisition. Land acquisition for Natural Area reserves by organizations such as The Nature Conservancy, the Louisiana Department of Wildlife and Fisheries, or local area land trusts provide a high level of protection. The newly proposed Little Bogue Falaya Natural Area is a relatively small tract along a stretch of the creek containing Louisiana quillwort. It is currently being considered by The Nature Conservancy as a possible preserve site. However, current trends in preserve acquisition are to acquire large tracts of land with many rare species, and small area preserves such as the Little Bogue Falaya, with a single rare species, do not have as high priority for purchase.

1.2.2 Utilize conservation agreements and easements where appropriate. In Washington Parish, the Weyerhauser Timber Company Nature Area at Thigpen Creek provides protection for a section of creek supporting Louisiana quillwort. Conservation agreements and easements such as those of the Natural Areas Registry Program at Thigpen Creek Natural Area in Washington Parish also provide species protection. Preliminary contacts have been made by letter to landowners at quillwort sites in St. Tammany Parish.

1.2.3 Utilize indirect protection through Louisiana Natural and Scenic Rivers Act where applicable. State agencies provide indirect protection through their permitting processes. The Louisiana Natural and Scenic Rivers Act established the Louisiana Department of Wildlife and Fisheries Scenic River System in the 1970's. Four rivers within the range of Louisiana quillwort are protected as part of the Scenic Rivers program: Pushepatapa Creek in Washington Parish; Bogue Chitto River in Washington and St. Tammany Parishes; the Bogue Falaya in St. Tammany Parish; and the Tchefuncta River and its tributaries in Washington, Tangipahoa, and St. Tammany Parishes. Tributaries of these scenic rivers are afforded protection if it is shown that activities on the tributary will negatively impact the river downstream. Indirect protection of quillwort habitat occurs because the following activities are prohibited on Scenic Rivers: channelization, channel re-alignment, clearing and snagging, impoundments of any type and commercial clear-cutting of timber within 50 to 100 m (165 to 330 ft.) of the low watermark. Activities that need permits are: bridge, pipeline, and powerline crossings; waste water discharges; and land development adjacent to the stream.

1.3 Enforce State laws protecting environmental quality. The Louisiana Department of Environmental Quality (DEQ) is responsible for permitting discharge into the State's streams and rivers. Sand and gravel mining operations near Louisiana quillwort habitat affect the hydrology, water quality, and substrate stability (Hartfield 1991). DEQ personnel can provide protection for the habitat by establishing rigorous permit requirements.

1.4 Enforce Federal law protecting Louisiana quillwort on private land. Habitat protection opportunities, through the ESA, are limited for listed plants on private lands. Federal agencies are required to ensure that any action they carry-out, fund, or authorize does not jeopardize the continued survival of a listed species. Compliance with Section 404 of the Clean Water Act and Section 7 of the Endangered Species Act, U.S. Army Corps of Engineers and Natural

Resources Conservation Service wetland determinations can provide indirect protection of endangered or threatened species. Federal permit requirements for receiving federal funds to develop private property, or develop wetland sites, offers some protection for quillwort habitat.

1.5 Establish management guidelines for the protection of Louisiana quillwort and its habitat. Water quality and natural hydrologic regimes of stream systems providing habitat for Louisiana quillwort must be safeguarded in order to maintain viable populations. The following timber company management guidelines for minimizing streamside habitat loss, as developed by McInnis (1991b), may serve as a basis for the development of management plans for this species:

Streamside zone protection - A streamside buffer of 50 m (165 ft) in which timber harvest is restricted is suggested. However Brunton (*in litt.* 1995) recommends a larger buffer of 2 to 3 tree lengths (approximately 100 m or 330 ft) to achieve protection from edge effects. Protection of a riparian zone will ensure that habitat conditions are not altered, such as changes in ambient light, increase in sediment load from run-off, or alteration of stream flow from debris deposition.

Timber management in areas other than streamside zones - To minimize erosion and maintain stream quality and watershed values, timber harvesting should involve selective cutting. Harvesting should be conducted during dry periods to prevent soil compaction and rutting, especially in wetland areas dominated by sweetbay, swamp blackgum, and bald cypress. Mechanical site preparation methods such as drum-chopping or disking should not be used. Timber removal should be conducted in a manner that favors maintenance of indigenous ground cover and minimizes soil disruption. Prescribed burning is considered compatible with management of an area for quillwort, especially in surrounding uplands. Herbicide application should be prohibited.

Sand and gravel mining - Surface mining for sand and gravel should be prohibited near known quillwort habitat and should be carefully monitored in watersheds. Mining in the area of Clearwater Creek has significantly degraded stream quality through sediment deposition. Dams around gravel pits erode and frequently break through during periods of heavy rainfall. Such an event would critically degrade the microhabitat of Louisiana quillwort and could pose a significant threat to a population.

Beaver dams - Beaver activity has been noted near sites near Thigpen Creek in Louisiana and near Pearces Creek in Mississippi. It should be closely monitored in both Louisiana (and Mississippi) to prevent permanent inundation of quillwort habitat.

Additional quidelines need to be designed to protect habitat from off-road vehicle use, flood control measures, road construction, and feral hogs.

2. Conduct biosystematic research on the species. Fertile live specimens of *Isoetes louisianensis* have been cultivated for biosystematic research by Taylor and Luebke. Specimens were collected from widely separated sites: 1) the northernmost site in the Bogue Chitto River drainage in Washington Parish; 2) from mid-range in the Abita River and Little Bogue Falaya River drainages in central St. Tammany Parish; and, 3) from the southernmost site near Bayou Chinchuba in south St. Tammany Parish. Taylor and Luebke plan to report results upon completion of their studies.

3. Monitor populations to learn more about the habitat, life history, and to determine positive and negative trends. All known sites should be checked at least yearly over a period of not less that 10 years. Population numbers and vitality should be recorded, as well as observations on specific habitat characteristics. Negative environmental impacts such as bank erosion, sand sedimentation, trash dumping, or increased competition from removal of canopy trees should also be noted. Monitoring of the population's status and habitat will aid in determining optimal habitat conditions.

4. <u>Search for additional populations</u>. Further systematic survey is needed. Many potential sites on private property in Louisiana have not been surveyed. It is highly probable that additional populations exist in the region near the known occurrences of this species. Surveys in Louisiana should also focus on Prairie Terraces west of the Mississippi in southwest Louisiana flatwoods in Allen, Beauregard, Calcasieu, and Jefferson Davis Parishes.

   Potential quillwort habitat exists in the Pleistocene Prairie Terraces that extend from near Picayune, Mississippi in a narrow band along the Gulf Coast to Alabama. Although Rosso (1987) looked for *Isoetes louisianensis* without success in Forrest, Lamar, Lauderdale, Marion, Pearl River, Stone and Walthall counties, the recent discoveries of Louisiana quillwort in the Pleistocene High Terraces in Perry County and Jackson County have broadened the potential search range. Further surveys in Mississippi and Alabama are recommended.

5. <u>Preserve genetic material</u>. The collection, storage, and maintenance of genetically representative material from the wild is necessary to guard against destruction of populations. This material could also be used for education, research, and reestablishment, if needed. The Center for Plant Conservation can provide guidance in implementing this task.

6. <u>Inform the public on conservation needs of Louisiana quillwort</u>. Public education increases awareness of the rarity of this species and the importance of maintaining its habitat. As more is learned about the habitat and life history of Louisiana quillwort, Federal and State permitting agencies will be better able to protect quillwort habitat. Informing Corps of Engineers and Natural Resources Conservation Service wetland biologists, as well as those with State agencies and with private consulting firms, is needed to improve species recognition and understanding of quillwort habitat requirements. Any streamside *Isoetes* in southeastern Louisiana or southern Mississippi should be assumed rare. Management guidelines

developed under Task 1.5 will provide valuable assistance to landowners and others in the protection of this species' habitat.

Programs such as the Forest Stewardship Program, a national program coordinated in Louisiana by the Louisiana Department of Agriculture and Forestry, Office of Forestry, in cooperation with a number of State and Federal agencies, including the Louisiana Department of Wildlife and Fisheries Forestry Section, provide forest management plans to private landowners throughout the State. School programs, nature center programs, and public television can provide ways for the public to become aware of the rarity of Louisiana quillwort and importance of safeguarding its aquatic habitat. Such efforts will benefit other endangered species and the protection of natural environments.

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III. IMPLEMENTATION SCHEDULE

The following Implementation Schedule outlines recovery actions and their estimated costs for the first 3 years of the recovery program. It is a guide for meeting the objective discussed in Part II of this plan. This Schedule indicates task priorities, task numbers, task descriptions, duration of tasks, the responsible agencies, and lastly, estimated costs.

Priorities in column 1 of the following Implementation Schedule are assigned as follows:

1 - An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

2 - An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant negative impact short of extinction.

3 - All other actions necessary to meet the recovery objective.

<u>Keys to acronyms used in Implementation Schedule</u>:

ALNHP - Alabama Natural Heritage Program
COE - U.S. Army Corps of Engineers
CPC - Center for Plant Conservation
DEQ - Department of Environmental Quality
HC - Habitat Conservation, U.S. Fish and Wildlife Service
LANHP - Louisiana Natural Heritage Program, Louisiana Department of Wildlife and Fisheries
LDAF - Louisiana Department of Agriculture and Forestry
LDWF - Louisiana Department of Wildlife & Fisheries
MSNHP - Mississippi Natural Heritage Program, Mississippi Department of Wildlife, Fisheries, & Parks
NRCS - U.S. Department of Agriculture, Natural Resources Conservation Service
TE - Endangered Species Division, U.S. Fish and Wildlife Service
TNC - The Nature Conservancy
USFS - U.S. Forest Service
USFWS - U.S. Fish and Wildlife Service

IMPLEMENTATION SCHEDULE

PRIORITY NUMBER	TASK NUMBER	TASK DESCRIPTION	TASK DURATION	RESPONSIBLE PARTY			COST ESTIMATES ($K)			COMMENTS/NOTES
				USFWS						
				Region	Division	Other	FY 1	FY 2	FY 3	
1	1.1	Protect populations on Federal lands.	Ongoing	4	TE	USFS				
1	1.2-1.2.3	Protect populations on private lands.	Ongoing	4	TE	TNC/LDWF LANHP	3.0	3.0	3.0	Estimates do not include cost of land acquisition.
1	1.3	Enforce State laws protecting environmental quality.	Ongoing	4	TE	DEQ, LDWF, LANHP	---	---	---	
1	1.4	Enforce Federal law protecting Louisiana quillwort on private land.	Ongoing	4	TE, HC	NRCS, COE	---	---	---	
1	1.5	Develop management guidelines.	1 year	4	TE	LANHP, USFS, TNC/LDWF	3.5	---	---	
2	2	Conduct biosystematic research on the species.	2 years	4	TE	LANHP & Others	10.0	8.0	---	
2	3	Monitor populations to learn more about the life history; monitor trends.	Ongoing	4	TE	LANHP, USFS	5.0	5.0	5.0	
2	4	Search for additional populations.	2 years	4	TE	ALNHP, LANHP, MSNHP, COE, USFS, NRCS	6.0	6.0	---	
3	5	Preserve genetic stock.	Ongoing	4	TE	CPC, Others	3.0	3.0	3.0	
3	6	Public information efforts.	Ongoing	4	TE	LANHP, USFS, LDWF, TNC, LDAF	2.5	2.5	2.5	

IV. APPENDIX

List of Reviewers

The following agencies, organizations, and individuals were mailed copies of this recovery plan. This does not imply that they provided comments or endorsed the contents of this plan.

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Appendix C-4: Red-cockaded Woodpecker Recovery Plan

Recovery Plan for the

Red-cockaded Woodpecker (*Picoides borealis*)

Second Revision

Original Approved: August 24, 1979
First Revision Approved: April 11, 1985

U.S. Fish and Wildlife Service
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1-27-03

DISCLAIMER

This Recovery Plan Revision outlines the actions that, to the best of current understanding, are necessary to recover red-cockaded woodpeckers. It does not represent the view or official position of any individuals or agencies involved in the development of the plan, other than the U.S. Fish and Wildlife Service. It represents official policy of the U.S. Fish and Wildlife Service only after the regional director has signed it as approved. This revision is subject to further modification as dictated by new findings, changes in species status, and completion of recovery tasks. Implementation of this plan is the responsibility of federal and state management agencies in the areas where the species occurs. Implementation is done through incorporation of management guidelines identified within this Recovery Plan Revision into agency decision documents. Decision documents, as defined by the National Environmental Policy Act (NEPA), are subject to the NEPA process for public review and alternatives selection.

LITERATURE CITATION SHOULD READ AS FOLLOWS:

U.S. Fish and Wildlife Service. 2003. Recovery plan for the red-cockaded woodpecker (*Picoides borealis*): second revision. U.S. Fish and Wildlife Service, Atlanta, GA. 296 pp.

ADDITIONAL COPIES MAY BE PURCHASED FROM:

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Fees for documents vary depending on postage and number of pages.

STANDARD ABBREVIATIONS

The following standard abbreviations for units of measurement are found throughout this document:

cm = centimeters	in = inches	m^2 = square meters
m = meters	ft = feet	ft^2 = square feet
km = kilometers	mi = miles	dbh = diameter at breast height
ha = hectares	ac = acres	
g = grams	oz = ounces	

ACKNOWLEDGMENTS

The process of revising the 1985 red-cockaded woodpecker recovery plan began in August 1995, when potential recovery team members were identified. In January 1996, 15 potential members were asked to participate on the team; all accepted. The first team meeting was held in March 1996; two additional meetings, each one week long, were held in April and December 1997. Between March 1996 and March 2000, team members individually spent hundreds of hours working on the revision, including participation in team meetings, writing, and reviewing. The U.S. Fish and Wildlife Service is very appreciative of the time and hard work put forth by team members during this process. Combined, the team has approximately 257 years of red-cockaded woodpecker experience in the private, state, and federal sectors. Their professional experiences with red-cockaded woodpeckers have included research, population and habitat management, and regulatory and policy responsibilities. They have unselfishly contributed their knowledge, time, and expertise to the many challenges of the recovery plan revision process. The U.S. Fish and Wildlife Service thanks each of them for their contributions and is grateful to have worked with such a team.

By April 1999, much of the Introduction had been drafted. However, several major tasks remained to be accomplished. These tasks included writing Recovery, Listing, Executive Summary, and other sections; compiling and editing the contributions of 15 other authors; and creating tables, Literature Cited, and Index. In April 1999, the U.S. Fish and Wildlife Service hired Ms. Susan Daniels as a wildlife biologist and recovery team member to take the lead on completing these tasks. The recovery team and U.S. Fish and Wildlife Service are proud to extend special thanks to “one of our own” for her continuous hard work during the past four years on this challenging project. Sue has done an outstanding job of assembling and completing this revision.

Ultimately, recovery of the red-cockaded woodpecker is and will be dependent upon the on-the-ground hard work of biologists, foresters, technicians, researchers, and land managers working on the private, state, and federal properties where the birds survive. During the past seven years, many of these individuals have been asked to supply information including population and habitat data, maps, and management costs. The U.S. Fish and Wildlife Service and the recovery team are particularly grateful to these many individuals for their timely and reliable responses to our requests. They have supplied a tremendous amount of information for this document.

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EXECUTIVE SUMMARY

CURRENT STATUS

The red-cockaded woodpecker (*Picoides borealis*) is a federally listed endangered species endemic to open, mature and old growth pine ecosystems in the southeastern United States. Currently, there are an estimated 14,068 red-cockaded woodpeckers living in 5,627 known active clusters across eleven states. This is less than 3 percent of estimated abundance at the time of European settlement. Red-cockaded woodpeckers were given federal protection with the passage of the Endangered Species Act in 1973. Despite this protection, all monitored populations (with one exception) declined in size throughout the 1970's and into the 1980's. In the 1990's, in response to intensive management based on a new understanding of population dynamics and new management tools, most populations were stabilized and many showed increases. Other populations remain in decline, and most have small population sizes. Our major challenge now is to bring about the widespread increases in population sizes necessary for recovery.

BASIC ECOLOGY AND POPULATION DYNAMICS

Red-cockaded woodpeckers are a cooperatively breeding species, living in family groups that typically consist of a breeding pair with or without one or two male helpers. Females may become helpers, but do so at a much lower rate than males. The ecological basis of cooperative breeding in this species is unusually high variation in habitat quality, due to the presence or absence of a critical resource. This critical resource is the cavities that red-cockaded woodpeckers excavate in live pines, a task that commonly takes several years to complete.

Red-cockaded woodpeckers exploit the ability of live pines to produce large amounts of resin, by causing the cavity tree to exude resin through wounds, known as resin wells, that the birds keep open. This resin creates an effective barrier against climbing snakes. Longleaf pine is a preferred tree species for cavity excavation because it produces more resin, and for a longer period of time, than other southern pines.

Group living has profound influence over population dynamics. In non-cooperatively breeding birds, breeders that die are replaced primarily by the young of the previous year. Thus, variation in reproduction and mortality can have strong, immediate impacts on the size of the breeding population. However, in red-cockaded woodpeckers and other cooperative breeders, a large pool of helpers is available to replace breeders. As a result, the size of the breeding population is not strongly affected by how many young are produced each year, or even on how many breeders may die. Because of this, we use the number of potential breeding groups rather than number of individuals as our measure of population size. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young.

Because of the cooperative breeding system, red-cockaded woodpecker populations are unusually resistant to environmental and demographic variation, but highly sensitive to the spatial arrangement of habitat. The buffering effect of helpers against annual variation operates only when helpers can readily occupy breeding vacancies as they arise. Helpers do not disperse very far and typically occupy vacancies on their natal territory or a neighboring one. If groups are isolated in space, dispersal of helpers to neighboring territories is disrupted and the buffering effect of the helper class is lost. When this happens, populations become much less likely to persist through time. Also, the cooperative breeding system does not allow rapid natural growth of populations. Colonization of unoccupied habitat is an exceedingly slow process under natural conditions, because cavities take long periods of time to excavate and birds do not occupy habitat without cavities. As forests age and old pines become abundant, rates of natural cavity excavation and colonization may increase.

Understanding these three components of the population dynamics of red-cockaded woodpeckers provides us the foundation for recovery efforts: (1) population size and trend are determined by the number of potential breeding groups rather than annual variation in reproduction and survival; (2) the buffering capacity of the helper class must be maintained, by maintaining close aggregations of territories; and (3) colonization of unoccupied habitat will be very slow without management assistance.

HABITAT REQUIREMENTS AND LIMITING FACTORS

Red-cockaded woodpeckers require open pine woodlands and savannahs with large old pines for nesting and roosting habitat (clusters). Large old pines are required as cavity trees because the cavities are excavated completely within inactive heartwood, so that the cavity interior remains free from resin that can entrap the birds. Also, old pines are preferred as cavity trees, because of the higher incidence of the heartwood decay that greatly facilitates cavity excavation. Cavity trees must be in open stands with little or no hardwood midstory and few or no overstory hardwoods. Hardwood encroachment resulting from fire suppression is a well-known cause of cluster abandonment. Red-cockaded woodpeckers also require abundant foraging habitat. Suitable foraging habitat consists of mature pines with an open canopy, low densities of small pines, little or no hardwood or pine midstory, few or no overstory hardwoods, and abundant native bunchgrass and forb groundcovers.

Limiting factors are those that directly affect the number of potential breeding groups, because this is the primary determinant of population size and trend. Several factors currently impact the persistence of breeding groups. Foremost among these are the factors that limit suitable nesting habitat, namely fire suppression and lack of cavity trees. Fire suppression has resulted in loss of potential breeding groups throughout the range of red-cockaded woodpeckers, because the birds cannot tolerate the hardwood encroachment that results from lack of fire. This limitation is addressed through the use of prescribed burning. Lack of cavity trees, and potential cavity trees, limits the number of breeding groups in most populations. This limitation is addressed in the short-term through cavity management tools such as artificial cavities and restrictor plates, and over the long-term by growing large old trees in abundance.

Another factor directly limiting the number of potential breeding groups is habitat fragmentation and consequent isolation of groups, which results in disrupted dispersal of helpers and failure to replace breeders. This limitation is best addressed through the appropriate placement of clusters of artificial cavities, and implementation of silvicultural practices that minimize fragmentation.

There are several other threats to the existence and recovery of the species, not limiting most populations currently, but which will become more important as the current limitations are addressed. Chief among these are (1) degradation of foraging habitat through fire suppression and loss of mature trees, and (2) loss of valuable genetic resources because of small size and isolation of populations. As currently limiting factors such as lack of cavities are relieved, the continued growth and natural stability of red-cockaded woodpecker populations will depend on provision of abundant, good quality foraging habitat and careful conservation of genetic resources.

POPULATION AND SPECIES VIABILITY

Four types of threats to species and population viability have been identified: genetic stochasticity (consisting of both inbreeding and genetic drift), demographic stochasticity, environmental stochasticity, and catastrophes. We now have some knowledge of population sizes of red-cockaded woodpeckers necessary to withstand these extinction threats, primarily from research performed with a spatially explicit, individually based simulation model of population dynamics developed specifically for this species.

Red-cockaded woodpeckers exhibit inbreeding depression and inbreeding avoidance behaviors. Inbreeding is expected to affect population viability in populations of less than 40 potential breeding groups, and may be a significant factor affecting viability in isolated populations of 40 to 100 potential breeding groups as well. Immigration rates of 2 or more migrants per year can effectively reduce inbreeding in populations of any size, including very small ones.

Effects of demographic stochasticity on population viability vary with the spatial arrangement of groups. Populations as small as 25 potential breeding groups can be surprisingly resistant to random demographic events, if those groups are highly aggregated in space. Populations as large as 100 potential breeding groups can be impacted by demographic stochasticity, if groups are not aggregated and dispersal of helpers is disrupted. Demographic stochasticity is not expected to affect populations larger than 100 potential breeding groups. Similarly, effects of environmental stochasticity vary with the spatial arrangement of groups. Based on preliminary results of the model and estimates of environmental stochasticity derived from the North Carolina

Sandhills, 250 potential breeding groups will likely withstand effects of environmental stochasticity regardless of their spatial arrangement.

Loss of genetic variation through the process of genetic drift is an inevitable consequence of finite population size. New genetic variation arises through the process of mutation. In large populations, mutation can offset loss through drift and genetic variation is maintained. Just how large a population must be to maintain variation is a difficult question. Currently, researchers recognize that in general, only populations with actual sizes in the thousands, rather than hundreds, can maintain long-term viability and evolutionary potential in the absence of immigration. However, if populations are connected by immigration rates on the order of 1 to 10 migrants per generation (0.5 to 2.5 migrants per year), the genetic variation maintained by these populations is equal to that of one population as large as the sum of the connected populations. Thus, sufficient connectivity among populations can maintain genetic variation and long-term viability for the species.

RECOVERY GOAL

The ultimate recovery goal is species viability. This goal is represented by delisting. Once delisting criteria are met, the size, number, and distribution of populations will be sufficient to counteract threats of demographic, environmental, genetic, and catastrophic stochastic events, thereby maintaining long-term viability for the species as defined by current understanding of these processes. Regions and habitat types currently occupied by the species will be represented to the best of our ability, given habitat limitations.

RECOVERY CRITERIA

Recovery criteria have been formulated using eleven recovery units delineated according to ecoregions. Populations required for recovery are distributed among recovery units to ensure the representation of broad geographic and genetic variation in the species. Viable populations within each recovery unit, to the extent allowed by habitat limitations, are essential to the recovery of the species as a whole.

Population sizes identified in recovery criteria are measured in number of potential breeding groups. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young. A traditional measure of population size has been number of active clusters. Potential breeding groups is used in recovery criteria in addition to active clusters, because number of active clusters can include varying proportions of solitary males and captured clusters. (A captured cluster is one that does not support its own group, but is kept active by a member or members of a neighboring group.) Increases in proportions of captured clusters and solitary males are early indicators of population decline. Estimates of all three parameters—number of active clusters, proportion of solitary males, and proportion of captured clusters—are required to derive estimates of potential breeding groups.

To facilitate use of potential breeding groups as a measure of population size, we have provided a range of numbers of active clusters considered the likely equivalents of the required number of potential breeding groups. Estimated number of active clusters is likely to be at least 1.1 times the number of potential breeding groups, but it is unlikely to be more than 1.4 times this number. Thus, an estimated 400 to 500 active clusters will be necessary to contain 350 potential breeding groups, depending on the proportions of solitary males and captured clusters and also on the estimated error of the sampling scheme. It is expected that all recovery populations will have sampling in place that is adequate to judge potential breeding groups. If this is not the case, only the highest number of active clusters in the range given can be substituted to meet the required population size.

Delisting

Delisting shall occur when each of the following criteria is met. Rationale for each criterion is given immediately following this list. See Tables 1, 2, and 3 for population designation. All properties identified as part or all of a recovery population (Tables 1, 2, and 3) should be managed for maximum size that the habitat designated for red-cockaded woodpeckers will allow. (Maximum size is generally based on 200 ac [81 ha] per group).

Criterion 1. There are 10 populations of red-cockaded woodpeckers that each contain at least 350 potential breeding groups (400 to 500 active clusters), and 1 population that contains at least 1000 potential breeding groups (1100 to 1400 active clusters), from among 13 designated primary core populations, and each of these 11 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size. The 13 designated primary core populations, and the recovery units in which they are located, are listed in Table 1.

Criterion 2. There are 9 populations of red-cockaded woodpeckers that each contain at least 250 potential breeding groups (275 to 350 active clusters), from among 10 designated secondary core populations, and each of these 9 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size. The 10 designated secondary core populations, and the recovery units in which they are located, are listed in Table 2.

Criterion 3. There are at least 250 potential breeding groups (275 to 350 active clusters) distributed among designated essential support populations in the South/Central Florida Recovery Unit, and six of these populations (including at least two of the following: Avon Park, Big Cypress, and Ocala) exhibit a minimum population size of 40 potential breeding groups that is independent of continuing artificial cavity installation.

Designated essential support populations in the South/Central Florida Recovery Unit are listed in Table 3.

Criterion 4. The following populations are stable or increasing and each contain at least 100 potential breeding groups (110 to 140 active clusters): (1) Northeast North Carolina/Southeast Virginia Essential Support Population of the Mid-Atlantic Coastal Plain Recovery Unit, (2) Talladega/Shoal Creek Essential Support Population of the Cumberlands/Ridge and Valley Recovery Unit, and (3) North Carolina Sandhills West Essential Support Population of the Sandhills Recovery Unit; and these populations are not dependent on continuing artificial cavity installation to remain at or above this population size. These populations are also listed in Table 3.

Criterion 5. For each of the populations meeting the above size criteria, responsible management agencies shall provide (1) a habitat management plan that is adequate to sustain the population and emphasizes frequent prescribed burning, and (2) a plan for continued population monitoring.

Rationale for Delisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift. One primary core population has the potential to harbor 1000 potential breeding groups within the near future; this criterion is included because such a large population may well be resistant to loss of genetic variation through drift. Eleven of 13 primary core populations are required for delisting because it is recognized that at any given time, one or two may be suffering hurricane impacts. Thirteen primary core populations are designated because of available habitat and because this number, together with 10 secondary core populations (below), may serve to facilitate natural dispersal among populations and maximize retention of genetic variability. Primary and secondary core populations provide for the conservation of the species within each major physiographic unit in which it currently exists, with the exception of South/Central Florida. This recovery unit is represented by several, smaller, essential support populations (below). Populations that depend on continuing artificial cavity installation to maintain stable or increasing trends are barred from meeting delisting criteria because this management technique is considered appropriate for short-term management only.

Criterion 2. A population size of 250 potential breeding groups is the minimum size considered robust to environmental stochasticity, and is well above the size necessary to withstand inbreeding and demographic stochasticity. Nine of 10 designated secondary core populations are required for delisting to allow for hurricane impacts.

Criterion 3. This unique habitat type is represented to the extent that available habitat allows. Unique genetic resources are conserved as much as reasonably possible.

Because of small size, some of these populations will remain vulnerable to extinction threats and may eventually be lost. The likelihood of extirpation of small populations is minimized by enhancing the spatial arrangement of territories so that they are highly aggregated.

Criterion 4. These unique or important habitats, and genetic resources contained within this population, will be represented at the time of delisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. Continued habitat management and population monitoring are necessary to ensure that the species does not again fall to threatened or endangered status.

Downlisting

Downlisting shall occur when each of the following criteria is met. Rationale for each criterion is presented immediately following this list.

Criterion 1. The Central Florida Panhandle Primary Core Population in the East Gulf Coastal Plain Recovery Unit is stable or increasing and contains at least 350 potential breeding groups (400 to 500 active clusters).

Criterion 2. There is at least one stable or increasing population containing at least 250 potential breeding groups (275 to 350 active clusters) in each of the following recovery units: Sandhills, Mid-Atlantic Coastal Plain, South Atlantic Coastal Plain, West Gulf Coastal Plain, Upper West Gulf Coastal Plain, and Upper East Gulf Coastal Plain.

Criterion 3. There is at least one stable or increasing population containing at least 100 potential breeding groups (110 to 140 active clusters) in each of the following recovery units: Mid-Atlantic Coastal Plain, Sandhills, South Atlantic Coastal Plain, and East Gulf Coastal Plain.

Criterion 4. There is at least one stable or increasing population containing at least 70 potential breeding groups (75 to 100 active clusters) in each of four recovery units, Cumberlands/Ridge and Valley, Ouachita Mountains, Piedmont, and Sandhills. In addition, the Northeast North Carolina/Southeast Virginia Essential Support Population is stable or increasing and contains at least 70 potential breeding groups (75 to 100 active clusters).

Criterion 5. There are at least four populations each containing at least 40 potential breeding groups (45 to 60 active clusters) on state and/or federal lands in the South/Central Florida Recovery Unit.

Criterion 6. There are habitat management plans in place in each of the above populations identifying management actions sufficient to increase the populations to recovery levels, with special emphasis on frequent prescribed burning during the growing season.

Rationale for Downlisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift.

Criterion 2. This population size, 250 potential breeding groups, is sufficient to withstand extinction threats from environmental uncertainty, demographic uncertainty, and inbreeding depression. These 6 populations, in combination with the single population identified in criterion (1), will represent each major recovery unit.

Criterion 3. A second population in these coastal recovery units will decrease the species' vulnerability to hurricanes. The West Gulf Coastal Plain is excluded because there are no candidate populations there. The lower size, 100 potential breeding groups, is considered sufficient to withstand threats from demographic uncertainty and inbreeding depression, and is much more quickly attained than 250 potential breeding groups thought necessary to withstand environmental stochasticity.

Criterion 4. These special habitats will be represented at the time of downlisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. This unique region will be represented at the time of downlisting. Forty potential breeding groups is at the lower end of estimates of sizes necessary to withstand inbreeding depression and are considered robust to demographic stochasticity if territories are highly aggregated in space.

Criterion 6. These habitat management plans are necessary to ensure progress toward delisting.

ACTIONS NEEDED

The primary actions needed to accomplish the ultimate (delisting) and interim (downlisting) recovery goals are (1) application of frequent fire to both clusters and foraging habitat, (2) protection and development of large, mature pines throughout the landscape, (3) protection of existing cavities and judicious provisioning of artificial cavities, (4) provision of sufficient recruitment clusters in locations chosen to enhance the spatial arrangement of groups, and (5) restoration of sufficient habitat quality and quantity to support the large populations necessary for recovery.

DATE OF RECOVERY

We estimate that, with full implementation of this recovery plan, red-cockaded woodpeckers will be downlisted by the year 2050 and delisted by 2075.

TABLE 1. Designated primary core populations (13) by recovery unit. Location (state) and individual properties comprising recovery populations are also listed. At delisting, the Central Florida Panhandle will contain 1000 or more potential breeding groups, and at least 11 of the remaining 12 primary core populations will contain 350 or more potential breeding groups. See 7 for more information, including definitions of recovery roles and recovery units. See map insert also.

Recovery Unit **Population**	**Property Full Name**	**State**
East Gulf Coastal Plain		
(1) Central Florida Panhandle	Apalachicola Ranger District, Apalachicola National Forest	FL
	Ochlockonee River State Park	FL
	St. Marks National Wildlife Refuge	FL
	Tate's Hell State Forest	FL
	Wakulla Ranger District, Apalachicola National Forest	FL
(2) Chickasawhay	Chickasawhay Ranger District, DeSoto National Forest	MS
(3) Eglin	Eglin Air Force Base	FL
Mid-Atlantic Coastal Plain		
(4) Coastal North Carolina	Croatan National Forest	NC
	Holly Shelter Game Lands	NC
	Marine Corps Base Camp Lejeune	NC
(5) Francis Marion	Francis Marion National Forest	SC
Sandhills		
(6) Fort Benning	Fort Benning	GA
(7) North Carolina Sandhills East	Calloway Tract	NC
	Carver's Creek Tract	NC
	Fort Bragg	NC
	McCain Tract	NC
	Weymouth Woods State Nature Preserve	NC
South Atlantic Coastal Plain		
(8) Fort Stewart	Fort Stewart	GA
(9) Osceola/Okefenokee	Osceola National Forest	FL
	Okefenokee National Wildlife Refuge	GA
Upper East Gulf Coastal Plain		
(10) Bienville	Bienville National Forest	MS
Upper West Gulf Coastal Plain		
(11) Sam Houston	Sam Houston National Forest	TX
West Gulf Coastal Plain		
(12) Angelina/Sabine	Angelina National Forest	TX
	Sabine National Forest	TX
(13) Vernon/Fort Polk	Fort Polk	LA
	Vernon Unit, Calcasieu Ranger District, Kisatchie National Forest	LA

TABLE 2. Designated secondary core populations (10) by recovery unit. Location (state) and individual properties comprising recovery populations are also listed. At delisting, at least 9 of these populations will contain 250 or more potential breeding groups. See 7 for more information, including definitions of recovery roles and recovery units. See map insert also.

Recovery Unit **Population**	**Property Full Name**	**State**
East Gulf Coastal Plain		
(1) Conecuh/Blackwater	Blackwater River State Forest	FL
	Conecuh National Forest	FL
(2) DeSoto	DeSoto Ranger District, DeSoto National Forest	MS
(3) Homochitto	Homochitto National Forest	MS
Ouachita Mountains		
(4) Ouachita	Ouachita National Forest	AR
Piedmont		
(5) Oconee/Piedmont	Oconee National Forest	GA
	Piedmont National Wildlife Refuge	GA
Sandhills		
(6) South Carolina Sandhills	Carolina Sandhills National Wildlife Refuge	SC
	Sand Hills State Forest	SC
South Atlantic Coastal Plain		
(7) Savannah River	Savannah River Site	SC
Upper East Gulf Coastal Plain		
(8) Oakmulgee	Oakmulgee Ranger District, Talladega National Forest	AL
West Gulf Coastal Plain		
(9) Catahoula	Catahoula Ranger District, Kisatchie National Forest	LA
	Winn Ranger District (portion), Kisatchie National Forest	LA
(10) Davy Crockett	Davy Crockett National Forest	TX

TABLE 3. Designated essential support populations (16) by recovery unit. Location (state) and individual properties comprising recovery populations are also listed. At delisting, North Carolina Sandhills West, Northeast North Carolina/Southeast Virginia, and Talladega/Shoal Creek will each contain 100 or more potential breeding groups, and 6 populations (including at least 2 of the following: Avon Park, Big Cypress, and Ocala) in South/Central Florida will each contain 40 or more potential breeding groups. See 7 for more information, including definitions of recovery roles and recovery units. See map insert also.

Recovery Unit **Population**	**Property Full Name**	**State**
Cumberlands/Ridge and Valley		
(1) Talladega/Shoal Creek	Shoal Creek Ranger District, Talladega National Forest	AL
	Talladega Ranger District, Talladega National Forest	AL
Mid-Atlantic Coastal Plain		
(2) Northeast North Carolina/ Southeast Virginia	Alligator River National Wildlife Refuge	NC
	Dare County Bombing Range	NC
	Palmetto-Peartree Preserve	NC
	Pocosin Lakes National Wildlife Refuge	NC
	Piney Grove Preserve	VA
Sandhills		
(3) North Carolina Sandhills West	Camp Mackall	NC
	Sandhills Game Lands	NC
South/Central Florida		
(4) Avon Park	Avon Park Air Force Range	FL
	Kicco Wildlife Management Area	FL
(5) Babcock/Webb	Babcock/Webb Wildlife Management Area	FL
(6) Big Cypress	Big Cypress National Preserve	FL
(7) Camp Blanding	Camp Blanding Training Site	FL
(8) Corbett/Dupuis	J. W. Corbett/Dupuis Wildlife Management Area	FL
(9) Goethe	Goethe State Forest	FL
(10) Hal Scott Preserve	Hal Scott Preserve	FL
(11) Ocala	Ocala National Forest	FL
(12) Picayune Strand	Picayune Strand State Forest	FL
(13) St. Sebastian River	St. Sebastian River State Buffer Preserve	FL
(14) Three Lakes	Three Lakes Wildlife Management Area	FL
(15) Withlacoochee – Citrus Tract	Withlacoochee State Forest - Citrus Tract	FL
(16) Withlacoochee – Croom Tract	Withlacoochee State Forest - Croom Tract	FL

PART I. INTRODUCTION

1. LISTING

A. REASONS FOR LISTING

The red-cockaded woodpecker was listed as endangered in 1970 (35 Federal Register 16047) and received federal protection with the passage of the Endangered Species Act in 1973. Once a common bird distributed continuously across the southeastern United States, by the time of listing the species had declined to fewer than 10,000 individuals in widely scattered, isolated, and declining populations (Jackson 1971, Ligon *et al.* 1986).

This precipitous decline was caused by an almost complete loss of habitat. Fire-maintained old growth pine savannahs and woodlands that once dominated the southeast, on which the woodpeckers depend, no longer exist except in a few small patches. Longleaf pine (*Pinus palustris*) ecosystems, of primary importance to red-cockaded woodpeckers, are now among the most endangered systems on earth (Simberloff 1993, Ware *et al.* 1993). Shortleaf (*P. echinata*), loblolly (*P. taeda*), and slash pine (*P. elliottii*) ecosystems, important to red-cockaded woodpeckers outside the range of longleaf, also have suffered severe declines (Smith and Martin 1995).

Loss of the original pine ecosystems was primarily due to intense logging for lumber and agriculture. Logging was especially intense at the turn of the century (Frost 1993, Martin and Boyce 1993, Conner *et al.* 2001). Two additional factors resulting in the loss of original pine systems in the 1800's and earlier were exploitation for pine resins and grazing by free-ranging hogs (*Sus scrofa*; Wahlenburg 1946, Frost 1993). Later, in the 1900's, fire suppression and detrimental silvicultural practices had major impacts on primary ecosystem remnants, second-growth forests, and consequently on the status of red-cockaded woodpeckers (Frost 1993, Ware *et al.* 1993, Ligon *et al.* 1986, 1991, Landers *et al.* 1995, Conner *et al.* 2001). Longleaf pine suffered a widespread failure to reproduce following initial cutting, at first because of hogs and later because of fire suppression (Wahlenburg 1946, Ware *et al.* 1993). These factors are discussed in more detail below.

Loss of the Original Ecosystems

Southern pine savannahs and open woodlands once dominated the southeastern United States, and may have totaled over 80 million ha (200 million ac) at the time of European colonization (Conner *et al.* 2001). Longleaf pine communities characterized the Atlantic and Gulf coastal regions, and covered an estimated 24 to 37 million ha (60 to 92 million ac; Wahlenburg 1946, Frost 1993, Ware *et al.* 1993, Landers *et al.* 1995). Roughly one quarter of the longleaf communities also supported other pines such as loblolly, shortleaf, slash, and pond pine (*P. serotina*) in various proportions depending on soil conditions, especially in transitional zones between the coastal plains and other physiographic regions (Frost 1993, Landers *et al.* 1995).

Today, longleaf forests have declined to less than 1.2 million ha (3 million ac; Landers *et al.* 1995), of which roughly 3 percent remains in relatively natural condition (Frost 1993). Little old growth remains, and virtually no longleaf forest has escaped changes in the natural fire regime (Simberloff 1993, Walker 1999). Shortleaf pine was prevalent outside the range of longleaf, especially on dry slopes and ridges in the Interior Highlands and Oklahoma, and has declined considerably (Landers 1991, Smith and Martin 1995). In the precolonial forests, loblolly pine was present as a minor component of riparian hardwood ecosystems or in association with shortleaf pine in some upland interior forests (White 1984, Landers 1991, Christensen 2000).

Southern pine forests today are very different from precolonial communities not only in extent, but also in species composition, age, and structure (Ware *et al.* 1993, Noel *et al.* 1998). Original pine forests were old, open, and contained a structure of two layers: canopy and diverse herbaceous groundcover. These forests were dominated by longleaf pine in the coastal plain, longleaf and shortleaf pines in the Piedmont and interior highlands, and slash pine (*P. elliottii* var. *densa*) in south Florida. Forests dominated by loblolly pine were restricted to a portion of southern Arkansas and perhaps eastern Virginia and extreme northeastern North Carolina (White 1984, Christensen 2000). In contrast, much of today's forest is young, dense, and dominated by loblolly pine, with a substantial hardwood component and little or no herbaceous groundcover (Ware *et al.* 1993, Noel *et al.* 1998).

Original longleaf communities in the Atlantic and Gulf coastal plains were first heavily impacted by exploitation for naval stores and then virtually eliminated by widespread logging and the subsequent reproductive failure of longleaf pine (Frost 1993, Ware *et al.* 1993). Naval stores industries harvested pine resin for the production of tar, pitch, and turpentine—commodities in high demand during colonial times. Pine woodlands were logged for lumber and conversion to agricultural fields. Impacts to easily accessible areas began with the arrival of Europeans, but technological developments of the 1800's, such as the copper still, steam power, and especially railroads, dramatically increased the rate and area of loss (Frost 1993). In the late 1800's logging operations moved to the previously inaccessible interior forests of longleaf, shortleaf, and loblolly pines. For over a decade these operations removed a reported 3 to 4 billion board feet per year (Frost 1993); an estimated 13 billion board feet of longleaf was extracted in 1907 alone (Wahlenburg 1946, Landers *et al.* 1995). This especially intense period of logging from 1870 to 1930 resulted in the loss of nearly all of the remaining old growth forest in the southeast (Frost 1993, Martin and Boyce 1993, Conner *et al.* 2001).

A common logging practice before the late 1800's was to leave a fair number of residual trees, including small trees, some of those infected with red heart fungus (*Phellinus pini*), and some that had been boxed for resin production (Wahlenburg 1946, Conner *et al.* 2001). Cavity trees of red-cockaded woodpeckers probably were left in much higher proportion than their numbers, due to the likelihood of red heart infection and the abundant resin coating. These residual pines enabled the red-cockaded woodpeckers to survive the original devastation (Phillips and Hall 2000). Loss of residual trees in the twentieth century has been a major factor in the decline of woodpecker populations (Costa and Escano 1989, Conner *et al.* 2001; see 2D).

Fire Suppression

Precolonial fire frequencies in the southeast have been estimated at 1 to 3 years for the Atlantic and lower Gulf coastal plains (Stout and Marion 1993, Ware *et al.* 1993, Frost 1998), 4 to 6 years for the Piedmont and upper Gulf coastal plain, and 7 to 25 years for the southern Appalachians and interior highlands (Masters *et al.* 1995, Frost 1998). Fire frequency increases with size of fire compartments, and natural firebreaks in the southeastern coastal plains were rare (Ware *et al.* 1993, Frost 1998). Historically, fires were ignited by Native Americans and by lightning. Lightning was the primary ignition source shaping the evolution of these fire-maintained ecosystems, but Native Americans may have played a substantial role in maintaining them (Delcourt *et al.* 1993, Frost 1993). Such maintenance vanished, of course, as Native Americans were severely impacted by the diseases and aggression of incoming Europeans. Natural fire frequency also declined as fires were reduced in area because of roads, plowed fields, and other human-made firebreaks (Frost 1993, Ware *et al.* 1993).

Europeans brought their perceptions of fire with them as they colonized North America. In Europe, fire was an integral part of traditional swidden agriculture (i.e., shifting cultivation) and was celebrated by peasants as a source of renewal (Pyne 1998). In contrast, urban intellectuals and authorities viewed fire as a destructive force. This view was rooted in a social context: controlling the use of fire could facilitate control of the populace by discouraging the nomadic system (Pyne 1998). Such socially constructed perceptions of fire impacted natural fire regimes in all of Europe's colonies (Pyne 1998).

In North America, after European settlement and prior to the mid 1800's, farmers burned the woodlands regularly to improve forage for free-ranging livestock. Burning the open woods decreased with the fencing of livestock in the mid to late 1800's (Frost 1993), although many people continued to use fire in agricultural fields well into the 1900's (Martin and Boyce 1993). In the twentieth century, the rise of mechanical and chemical agriculture has replaced fire-based agricultural methods.

Active fire suppression began to be institutionalized in the southeastern United States between 1910 and 1930 (Frost 1993, Ware *et al.* 1993). Several factors influenced its rise. First was the existing bias against fire brought to this continent by European intellectuals (Pyne 1998). Then, in the late 1800's, fire suppression grew in response to the extreme intensity of fires burning the logged-over slash across the entire eastern United States. Fires in pine resin orchards were similarly intense and had been suppressed for some time to protect resin production (Frost 1993). Many ecologists denounced fire as detrimental to southern pines rather than an integral or useful component of the natural system. Suppression of fire increased with the rise of pine plantations, a land use that began in the 1930's and 40's and continues to increase today (Martin and Boyce 1993, Stout and Marion 1993, Ware *et al.* 1993).

Fire suppression has severe and numerous impacts on southern pine ecosystems, including changes in tree species composition and forest structure. Longleaf pine cannot reproduce without access to the mineral soil, and will be replaced under fire suppression by other species of pines and hardwoods. The structure of the forest changes from two layers, a canopy and a diverse groundcover, to a multi-layered midstory and canopy with little or no groundcover. With increasing hardwood midstory, arthropod communities change in species abundance, species composition, and distribution on the substrate (Collins 1998, Provencher *et al.* 2001a). Red-cockaded woodpeckers are directly and adversely affected by each of these changes (see 2D and 2E).

Reproduction of longleaf pine has been severely restricted since the precolonial era, first because of the impacts of free-ranging hogs and more recently because of the absence of fire (Wahlenburg 1946, Frost 1993, Ware *et al.* 1993). A short period of reproduction took place after hogs were fenced and before fires were suppressed. Most second-growth longleaf in existence today is 70 to 100 years in age and reproduced naturally during this short period of opportunity (Kelly and Bechtold 1990, Frost 1993, Landers *et al.* 1995). Reproduction of longleaf in the twentieth century has been, and still is, constrained by hardwood midstory developed as a result of fire suppression (Landers *et al.* 1995, Frost 1993, Peet and Allard 1993).

Detrimental Silvicultural Practices

Several silvicultural practices have been detrimental to red-cockaded woodpeckers, including short rotations, clearcutting, and conversion to sub-optimal pine species. Cutting of second-growth longleaf pines began during World War II and continues today. Removal of second-growth longleaf has exceeded growth by over 40 percent, and much of the remaining longleaf is aging without replacement (Landers *et al.* 1995).

The years following World War II also saw the rise of plantation forestry. Plantations of dense slash or loblolly pines covered over 4.9 million ha (12 million ac) by the mid 1960's and over 6.1 million ha (15 million ac) at present (Ware *et al.* 1993). Plantations typically have been under rotations of 35 to 70 years for sawtimber production and 20 to 40 years for pulp production (Conner *et al.* 2001), and industry has continued to shift from logs and poles to pulp (Landers *et al.* 1995). With technological developments such as chainsaws, the practice of leaving 'cull' pines that were infected with red heart fungus or boxed for resin production declined. These two practices—short rotations and the removal of all trees—had substantial negative impacts on the woodpecker populations that remained after the initial logging (Conner *et al.* 2001).

B. CURRENT THREATS

Despite protection under the Endangered Species Act in 1973, populations of red-cockaded woodpeckers continued to decline throughout the 1970's and into the 1980's in all parts of the species' range (Baker 1983, Ligon *et al.* 1986, 1991, Ortego and Lay 1988, Conner and Rudolph 1989, Costa and Escano 1989, James 1991, 1995, Haig *et al.* 1993, Kelly *et al.* 1994). Only one population was reported to be increasing during this time (Hooper *et al.* 1991a). In the 1990's, most populations were stabilized and many have shown increases (R. Costa, pers. comm.). Stabilizing the declines was the result of a new understanding of population dynamics (see 2B) and the use of powerful management tools such as artificial cavities, translocation, and prescribed burning (see 3B and 3F). Our challenge now is to bring about the widespread increases in population sizes necessary to recover the species.

Primary threats to species viability for red-cockaded woodpeckers all have the same basic cause: lack of suitable habitat. Red-cockaded woodpeckers require open mature pine woodlands and savannahs maintained by frequent fire, and there is very little of this habitat remaining (Lennartz *et al.* 1983, Frost 1993, Simberloff 1993, Ware *et al.* 1993). On public and private lands, both the quantity and quality of red-cockaded woodpecker habitat are impacted by past and current fire suppression and detrimental silvicultural practices (Ligon *et al.* 1986, 1991, Baker 1995, Cely and Ferral 1995, Masters *et al.* 1995, Conner *et al.* 2001). Serious threats stemming from this lack of suitable habitat include (1) insufficient numbers of cavities and continuing net loss of cavity trees (Costa and Escano 1989, James 1995, Hardesty *et al.* 1995); (2) habitat fragmentation and its effects on genetic variation, dispersal, and demography (Conner and Rudolph 1991b); (3) lack of foraging habitat of adequate quality (Walters *et al.* 2000, 2002a, James *et al.* 2001); and (4) fundamental risks of extinction inherent to critically small populations from random demographic, environmental, genetic, and catastrophic events (Shaffer 1981, 1987).

Fire suppression and exclusion is still a profound threat to red-cockaded woodpecker populations (see 2D, 2G). Hardwood encroachment due to fire suppression has been a leading cause of loss of woodpecker groups on both public and private lands and continues to be a major threat throughout the species' range (Van Balen and Doerr 1978, Hovis and Labisky 1985, Conner and Rudolph 1989, 1991a, Costa and Escano 1989, Loeb *et al.* 1992, Baker 1995, Cely and Ferral 1995, Escano 1995, Masters *et al.* 1995). Moreover, most assessments of the impacts of fire suppression on woodpecker groups have been restricted to effects of hardwood midstory on nesting and roosting habitat. Recent research indicates that exclusion of fire from foraging habitat has negative impacts as well (James *et al.* 1997, 2001, Hardesty *et al.* 1997, Doster and James 1998, Walters *et al.* 2000, 2002a). Even if nesting and roosting habitat is frequently burned, lack of fire in the foraging habitat can reduce group size and productivity (James *et al.* 1997, 2001, Hardesty *et al.* 1997, Walters *et al.* 2000, 2002a). Thus, negative effects of fire suppression are more pervasive than previously thought.

Widespread and frequent application of early-mid growing season fire throughout lands managed for red-cockaded woodpeckers is essential to the recovery of the species (Conner and Rudolph 1989, 1991a, Baker 1995, James 1995). Regrettably, there are several major difficulties affecting the increased use of fire across the southeast. These difficulties include lack of funding for both public land management agencies and private landowners; prohibitive smoke regulations; increasing density of human populations and associated development; proliferation of firebreaks such as roads, fields, and power lines; and perhaps most importantly, the prejudice against fire held by many private citizens and some public land managers. As this prejudice, built by decades of intensive anti-fire publicity, shifts toward acceptance of the natural role of fire and its benefits for resource management and catastrophic fire prevention, smoke regulations and funding constraints may change. Extreme caution is needed, however, in moving from restoration to maintenance burns. Should restoration burns of fuel-heavy forests cause loss of human life or property, public perception will be slow to change.

Logging is a potential threat to woodpecker populations on private lands (Cely and Ferral 1995), as harvests of mature pines continues at a high rate. One recent study estimated the current rate of pine cutting on private lands in parts of South Carolina and Georgia at 4.0 percent per year, a rate much higher than those estimated by similar methods for temperate or tropical rainforest (Pinder *et al.* 1999). Trees being cut were in older, natural stands established during the 1930's and 1940's. Other researchers have predicted that as these second-growth forests mature, there may well be another episode of substantial forest harvest (Ware *et al.* 1993, Landers *et al.* 1995). Moreover, the total area of both private and public lands that support longleaf pine is still sharply declining, from an estimated 1.53 million ha (3.77 million ac) in 1985 (Kelly and Bechtold 1990) to 1.19 million ha (2.95 million ac) in 1995 (Outcalt and Sheffield 1996). Privately owned lands have sustained the greatest losses. Private lands continue to support significant amounts of longleaf, although much of it occurs in parcels of less than 20.2 ha (50 ac; Outcalt and Sheffield 1996). One of the most common ways longleaf pine cover is lost is by replacement of other pine species after logging (Outcalt and Sheffield 1996). Widespread conversion of longleaf to plantations of other pine species began in the 1940's and this process still continues today. Plantations of off-site pine species (species that were not the original cover type) now cover over 6.1 million ha (15 million ac) in the southeast (Stout and Marion 1993, Ware *et al.* 1993).

Silvicultural practices on public lands have improved in recent years. Agency responses to legislated protection of red-cockaded woodpeckers include longer rotation times (USFS 1995), increases in the area under protection (USFS 1995), and elimination of intentional conversion of native pines to off-site species. Enlightened management plans emphasize prescribed burning, pine thinning to open dense second-growth stands, and retention of scattered relict old growth pines (USFS 1995). For many public lands, timber removal is now an important management tool rather than an overriding objective (USFS 1995). Overall, current timber production and conversion to off-site pines on public lands are less of a threat than earlier this century, although effects of past practices are still nearly overwhelming.

As described above (this section and 1A), fire suppression and past timber harvests have resulted in an almost complete loss of habitat for red-cockaded woodpeckers. Species recovery is only possible through habitat restoration (see 2D, 2E, 3F, 3G; James 1995, Smith and Martin 1995). However, restoration of habitat may itself jeopardize red-cockaded woodpeckers, if approached without suitable caution. Clearcutting of off-site pine species to restore longleaf and shortleaf pines can potentially disrupt woodpecker populations (Ferral 1998, F. C. James, pers. comm.). Restoration of native pines is best achieved through conversion of habitat patches rather than large clearcuts, especially if woodpeckers are using off-site pines for foraging or dispersal (Ferral 1998, see 3G).

One of the primary threats to red-cockaded woodpeckers, stemming from past habitat loss, is a severe bottleneck in the number of pines available as cavity trees (Costa and Escano 1989, Rudolph *et al.* 1990b, Conner *et al.* 1991a, Walters *et al.* 1992a). Red-cockaded woodpeckers require older pines for cavity excavation for two reasons: (1) only older pines have sufficient heartwood to house a cavity at preferred cavity heights (Jackson and Jackson 1986, Clark 1993, Conner *et al.* 1994) and (2) older pines are more likely to be infected with red heart fungus (Wahlenburg 1946, Conner *et al.* 1994), which substantially reduces the time required for cavity excavation (Conner and Rudolph 1995a, see 2D). Red-cockaded woodpeckers survived the 20^{th} century (although at drastically reduced numbers) because timber harvest practices of the 19^{th} and early 20^{th} century left some relict pines standing. Harvest methods used during the mid 20^{th} century did not follow this practice, and many relict pines were cut during this period. Still, most cavity trees in existence today are survivors of the original removal of the primary forest (Jackson *et al.* 1979, Rudolph and Conner 1991). These pines are older than the surrounding forest and suffer high rates of mortality due to increased effects of wind, lightning, southern pine beetles (*Dendroctonus frontalis*) and other pests, and natural senescence (Jackson *et al.* 1978, Conner *et al.* 1991a, Conner and Rudolph 1995b, Rudolph and Conner 1995, Watson *et al.* 1995). Because the surrounding forest is much younger in age, few potential cavity trees are available as replacements. As second-growth forests are allowed to age, more potential cavity trees will become available. In the meantime, a net loss of cavity trees threatens current populations (Costa and Escano 1989). Crisis intervention through intensive cavity management (artificial cavities and restrictors; see 3B) is helping to offset cavity loss but the threat will remain until mature and old growth trees are restored.

A second major impact of habitat loss on the viability of red-cockaded woodpeckers is the resultant fragmented distribution. Fragmentation and isolation have occurred both among groups within a population and among populations, with serious consequences for red-cockaded woodpeckers. Red-cockaded woodpeckers are particularly sensitive to effects of isolation because of the limited dispersal characteristic of cooperative breeders (Walters *et al.* 1988a, Daniels and Walters 2000a; see 2B). Fragmentation among populations increases the vulnerability of those populations to adverse genetic, demographic, and environmental events (Walters *et al.* 1988a, Conner and Rudolph 1991b, Hooper and Lennartz 1995; see below and 2C), because the dispersal that can help offset such threats is easily disrupted. Fragmentation and isolation of groups within a population can substantially increase that population's risk of extinction (Crowder *et al.* 1998, Letcher *et al.* 1998, Walters *et al.* 2002b). Populations of red-cockaded woodpeckers are surprisingly persistent if the spatial arrangement of groups within the population is tightly clumped. If groups are isolated and dispersal behavior disrupted, risk of population extinction increases (Crowder *et al.* 1998, Letcher *et al.* 1998, Walters *et al*. 2002b, see 2C).

Managers have some limited tools to combat effects of fragmentation (e.g., strategic location of recruitment clusters, retention of forest cover, and translocation). More importantly, as populations recover, isolation effects will not be as intensely acute as they are at present, because larger populations have greater resistance to impacts from environmental and demographic threats, greater retention of genetic variation, and thus greater probability of persistence. However, effects of fragmentation are likely to remain serious threats to population viability throughout the period of recovery.

A third threat to red-cockaded woodpeckers from past habitat loss is lack of suitable foraging habitat. As described above, recent research indicates that optimal foraging habitat is maintained by fire and contains an old growth or mature pine component (Conner *et al.* 1991b, Hardesty *et al.* 1997, James *et al.* 1997, 2001, Walters *et al.* 2000, 2002a). Restoration of foraging habitat will likely increase red-cockaded woodpecker densities (Walters *et al.* 2000, 2002a, James *et al.* 2001; see 2E), which in turn will positively influence demography and dispersal. However, the threat to woodpecker populations from low-quality or insufficient foraging habitat is not as immediate as threats from habitat fragmentation and lack of suitable nesting habitat. Fragmentation and lack of nesting habitat are presently limiting populations and are responsible for recent declines (Walters 1991). Foraging habitat, on the other hand, affects population densities; it may be a secondary factor currently limiting populations and will likely become a primary limiting factor once abundant nesting habitat is provided (Walters *et al.* 2000, 2002a). Foraging habitat is therefore an important concern for long-term viability.

One last identified threat to species viability that stems from habitat loss is the set of risks inherent to critically small populations. These are similar to fragmentation effects, but rather than occurring through isolation, these threats are related to population size. Small populations may be extirpated because of random environmental, demographic, genetic, and catastrophic events (Shaffer 1981, 1987; see 2C). Random environmental events affect an entire population; for example, an exceptionally severe winter that causes high adult mortality. Random demographic events act on individuals within populations; for example, a death due to predation, or a brood consisting of all males. Random genetic events are losses or gains in frequency of any given gene, simply due to chance inheritance. Lastly, catastrophic events, which can affect large as well as small populations, are similar to environmental events but larger in scale. Any of these processes alone or in concert can cause the extirpation of a small population. Such processes will continue to remain threats until population sizes are sufficient to withstand them (Shaffer 1981, 1987, Crowder *et al.* 1998, Letcher *et al.* 1998, Walters et al. 2002b; see 2C). Catastrophes will continue to threaten even the largest populations in perpetuity, although the species as a whole will not be in danger once enough large populations are established (e.g., Hooper and McAdie 1995).

Other factors unrelated to habitat loss may threaten red-cockaded woodpeckers, but their importance has not yet been determined. Foremost among unevaluated threats are the risks from pesticides and other environmental contaminants. Suburban groups of woodpeckers may be at especially high risk of adverse effects from toxins. Similarly, impacts of exotic species have not yet been assessed. Exotic species such as melaleuca (*Melaleuca quinquenervia*) and red imported fire ants (*Solenopsis invicta*) may be negatively affecting woodpeckers in some parts of their range.

Unlike many endangered and threatened species, red-cockaded woodpeckers are well studied (see Jackson 1995). Biologists are developing a good understanding of what constitutes optimal habitat for this species. Further information from experimental research is certainly needed to understand the best ways to restore ecosystems and habitat for red-cockaded woodpeckers, but a detailed picture of excellent red-cockaded woodpecker habitat is now emerging. In addition, managers are now equipped with effective tools to stabilize existing populations until sufficient quantity and quality of habitat for self-sustaining populations can be provided (Walters 1991). However, such habitat restoration and interim crisis management requires ample funding and a strong political will (Conner *et al.* 2001). Any weakness in determination or political will, with accompanying changes in law and policy, would constitute an extremely serious threat to the species.

2. GENERAL BIOLOGY AND ECOLOGY

A. TAXONOMY AND SPECIES DESCRIPTION

Red-cockaded woodpeckers are currently recognized as *Picoides borealis.* The species is endemic to the southeastern United States but other members of the genus are found throughout the Americas. Red-cockaded woodpeckers were first described for science as *Picus borealis*, “le pic boreal”, by the French businessman and amateur naturalist Vieillot (1807). In 1810, unaware of Vieillot’s description, Alexander Wilson described the species as *Picus querulus* because of its distinctive vocalizations (Wilson 1810).

Wilson gave the species the English common name we use today, red-cockaded woodpecker, in reference to the several red feathers of males, located between the black crown and cheek patch, that are briefly displayed when the male is excited. In Wilson’s time, “cockade” was a common term for a ribbon or other ornament worn on a hat as a badge. The cockade is a poor field mark because it is rarely seen in the field, but does identify the sexes of adult birds in the hand.

Red-cockaded woodpeckers are relatively small. Adults measure 20 to 23 cm (8 to 9 in) and weigh roughly 40 to 55 g (1.5 to 1.75 oz; Jackson 1994, Conner *et al.* 2001). They are larger than downy woodpeckers (*Picoides pubescens*), similar in size to yellow-bellied sapsuckers (*Sphyrapicus varius*), and smaller than other southeastern woodpeckers. Size of red-cockaded woodpeckers varies geographically, with larger birds to the north (Mengel and Jackson 1977). Because of this, Wetmore (1941) considered the birds of peninsular Florida to be a subspecies (*P. b. hylonomus*) which was later recognized by the American Ornithologists' Union (1957). Mengel and Jackson (1977), however, examined a larger series of specimens and considered the variation in the species to be smoothly clinal with no justification for distinguishing the birds in south Florida from those elsewhere.

Red-cockaded woodpeckers are black and white with a ladder back and large white cheek patches. These cheek patches distinguish red-cockaded woodpeckers from all others in their range. Red-cockaded woodpeckers are black above with black and white barring on their backs and wings. Their breasts and bellies are white to grayish white with distinctive black spots along the sides of breast changing to bars on the flanks. Central tail feathers are black and outer tail feathers are white with black barring. Adults have black crowns, a narrow white line above the black eye, a heavy black stripe separating the white cheek from a white throat, and white to grayish or buffy nasal tufts. Bills are black, and legs are gray to black.

Sexes of adult red-cockaded woodpeckers are extremely similar in plumage and generally indistinguishable in the field. In contrast, sexes of juveniles can be distinguished in the field until the first fall molt, because juvenile females have black crowns whereas juvenile males have red crown patches. Sexes of nestlings in the hand often can be distinguished by eight days of age: capital feather tracks, observed through the transparent skin before feather emergence, appear grayish black in females and reddish in males (Jackson 1982).

Juveniles may be distinguished from adults in the field by duller plumage, white flecks often present just above the bill on the forehead, and by diffuse black shading in the white cheek patch. In the hand, red-cockaded woodpeckers can be aged by the relative length and shape of the vestigial tenth primary until this primary is molted in the fall. This primary of juveniles is longer and more rounded than that of adults (Jackson 1979a). Second-year red-cockaded woodpeckers often can be identified because juveniles do not molt their secondaries during their first fall molt, whereas older birds do. As a result, the secondaries of juveniles during the second calendar year appear more worn and brown in contrast to newer black primaries (Jackson 1994).

B. Sociobiology and Cooperative Breeding

The Breeding System

Red-cockaded woodpeckers live in groups that share, and jointly defend, all-purpose territories throughout the year. Group living is a characteristic of their cooperative breeding system. Red-cockaded woodpeckers are one of only a handful of bird species found in the United States that exhibit this unusual system. In cooperative breeding systems, some mature adults forego reproduction and instead assist in raising the offspring of others (Emlen 1991). The cooperative breeding system of red-cockaded woodpeckers is well studied, and several recent reviews are available (Walters 1990, 1991, Jackson 1994). In this species, most helpers are males that remain and assist the breeders, who typically are their parents or other close kin, on their natal territory (Ligon 1970, Lennartz and Harlow 1979, Lennartz *et al.* 1987, Walters *et al.* 1988a). A few females become helpers on their natal territories, and a few individuals of each sex disperse to become helpers of unrelated breeders in other groups (Lennartz *et al.* 1987, Walters *et al.* 1988a, DeLotelle and Epting 1992). Helpers are strictly non-breeders (Haig *et al.* 1994b), but participate in incubation, feeding and brooding of nestlings and feeding of fledglings, as well as territory defense, nest defense, and cavity excavation. Groups may contain as many as four helpers, but most groups consist of only a breeding pair with no helpers, or a breeding pair plus one helper. Groups containing more than two helpers are uncommon.

Red-cockaded woodpecker groups are highly cohesive. Each individual has its own roost cavity, but typically group members congregate immediately after emerging from their cavities at dawn, and then move together through their large territories until they return to their cavities at dusk. Much like a primate troop, they visit only a portion of their territory or home range each day, and travel different routes on different days.

Group formation is best understood in terms of alternative life-history tactics practiced by young birds (Walters 1991). Young birds may either disperse in their first year to search for a breeding vacancy, or they may remain on the natal territory and become a helper. The proportion of each sex adopting each strategy varies among populations (Lennartz *et al.* 1987, Walters *et al.* 1988a, DeLotelle and Epting 1992), but dispersal is always the dominant strategy for females whereas both strategies are common among males. A dispersing individual, if it survives, may become a breeder at age one, but many fail to locate a breeding vacancy and exist as a floater at age one, or in a few cases as a helper in a new group (Walters *et al.* 1988a, 1992a). Some dispersing males locate a territory but no mate, and hence are solitary males at age one. Solitary males and floaters, like helpers (see below), may become breeders at subsequent ages.

It is those individuals who choose to remain at home as helpers rather than disperse that are primarily responsible for group formation. Individuals may remain helpers for up to eight years, but most become breeders within a few years (Walters *et al.* 1988a, 1992a). Helpers may become breeders by inheriting breeding status on their natal territory or by dispersing to a nearby territory to fill a breeding vacancy. When helpers move, it is usually to an adjacent territory, and they rarely disperse across more than two territories.

In contrast, individuals of both sexes dispersing in their first year sometimes move long distances, more than 100 km in a few cases (Walters *et al.* 1988b, Conner *et al.* 1997c, Ferral *et al.* 1997). Still, typical dispersal distances of even first-year birds are much lower than in other avian species. The median dispersal distance of females is only two territories from the natal site, and about 90 percent settle 1 to 4 territories from the natal site (Daniels 1997, Daniels and Walters 2000a). Males are even more sedentary, since many of them adopt the helping strategy. About 70 percent of males become breeders on the natal territory or an immediately adjacent one (Daniels 1997).

Once a male acquires a breeding position, by whatever pathway, he almost invariably holds it until his death (Walters *et al.* 1988a). Females, however, regularly practice breeding dispersal: roughly 10 percent of breeding females switch groups between breeding seasons each year (Walters *et al.* 1988a, Daniels and Walters 2000b). Females invariably depart when their sons inherit breeding status on their territory, but usually remain when a helper unrelated to them inherits breeding status. Females also are likely to leave if their mate dies and there are no helpers to assume the breeding vacancy, rather than pair with an immigrant replacement male, although not all do so. This may be a means to avoid young males as mates (Daniels and Walters 2000b, below). Also, young females (age one or two) that experience reproductive failure are likely to move (Daniels and Walters 2000b). Like first-year birds, dispersing adult females occasionally move very long distances (Walters *et al.* 1988b), but typically move to a neighboring group (Walters *et al.* 1988a, Daniels 1997).

Reproduction

Red-cockaded woodpeckers are highly monogamous. The group produces a single brood, and the breeding male and female within the territory are almost invariably the genetic parents of all offspring (Haig *et al.* 1993, 1994b). There is no evidence that helpers ever sire offspring, and the frequency of extra-pair fertilization involving individuals outside the group is among the lowest yet recorded in birds (Haig *et al.* 1994b).

Typical values of reproductive parameters, and the range of variation among years and populations, are available from several published studies (Lennartz *et al.* 1987, Walters *et al.* 1988a, Walters 1990, DeLotelle and Epting 1992, LaBranche and Walters 1994, DeLotelle *et al.* 1995, James *et al.* 1997) and project final reports (North Carolina Sandhills and coastal North Carolina, Walters and Meekins 1997, Walters *et al.* 1997, 1998; Eglin Air Force Base and Apalachicola National Forest, Florida, Hardesty *et al.* 1997). Unless otherwise indicated, values reported below represent a summary of data from these sources.

Not all groups attempt nesting in a given year. On average about 10 percent of the groups do not nest, but this ranges from as low as 3 percent to as high as 21 percent. Groups with young breeders, especially one-year-old males, are especially likely to forego nesting (Walters 1990). If the group does nest, the eggs are usually laid in the most recently completed cavity available, which typically is the breeding male's roost cavity (Conner *et al.* 1998a). If the nest fails, the group may renest. On average about 30 percent of nest failures are followed by a second attempt, but annual variation in the rate of renesting is high. There are records of a group making a third nesting attempt following two failed nests, and of a group attempting a second brood after a successful first nest (LaBranche *et al.* 1994, Schillaci and Smith 1994, reviewed by Phillips *et al.* 1998), but both are exceedingly rare (Phillips *et al.* 1998). Equally rare are instances of two nests of a single pair in existence at the same time (Rossell and Britcher 1994, R. Conner *et al.*, unpublished, J. Walters, unpublished). It seems that almost any odd variation of the typical reproductive process can occur in rare instances. Other examples include two females residing together within a group and laying clutches synchronously in a common nest, or laying in separate nests. Successful instances of the former, but not the latter, have been observed. Such instances are of theoretical interest because they constitute plural breeding, which is characteristic of more complex types of cooperative breeding systems (Emlen 1991).

Normally, however, one brood is produced as a result of one or perhaps two nesting attempts involving only two parents. Most groups that attempt nesting fledge young, as nest failure rates are low for a species in the temperate zone, although fairly typical for a primary cavity nester (Martin and Liu 1992, Martin 1995). Nest failure rates average about 20 percent, and this is fairly consistent among years and among populations. Nest predation, nest desertion, and loss of nest cavities to cavity kleptoparasites appear to be the primary causes of nest failure. Failure rate is higher during the egg stage than during the nestling stage, which suggests that nest desertion, rather than nest predation or loss of cavities to kleptoparasites, is the major cause of failure (Ricklefs 1969). The relative frequencies of these three causes of nest loss have never been measured directly, however.

Nest predation rates may be lower than in other cavity nesters because of the protection provided by the resin barrier around the cavity, which clearly interferes with climbing by snakes (Rudolph *et al.* 1990b). The frequency of nest predation may vary regionally, although there is no direct evidence of this. One possibility is that it is higher in areas where most cavities are in species other than longleaf, and thus where the resin barrier is diminished (Conner *et al.* 1998a), for example in Arkansas (Neal 1992).

In contrast to nest predation, nest desertion may be more common than in other cavity nesters because of the complex social system and resulting intense competition for breeding vacancies (see below) characteristic of this species. Lennartz *et al.* (1987) suggested that nest failure is often associated with repeated territorial intrusions by conspecifics, and other forms of social disruption. Immigrants often associate with groups as affiliated floaters or unrelated helpers (Walters *et al.* 1988a). Such individuals are a particularly likely source of social disruption that might cause groups to forego nesting, or fail if they do attempt to nest (DeLotelle and Epting 1992).

The primary cavity kleptoparasites linked to nest failure are red-bellied woodpeckers (*Melanerpes carolinus*), red-headed woodpeckers (*M. erythrocephalus*), eastern bluebirds (*Sialia sialis*), and southern flying squirrels (*Glaucomys volans*). These species are known to usurp nest cavities from red-cockaded woodpeckers and to destroy nests in cavities they usurp. Occasionally, red-headed woodpeckers, red-bellied woodpeckers, and flying squirrels may consume eggs and small nestlings (Jackson 1994).

Although red-cockaded woodpecker groups produce broods fairly reliably, these broods are relatively small. This is because clutch size is modest and, more importantly, because partial brood loss is greater than in other species of primary cavity nesters in the United States (LaBranche and Walters 1994). Most clutches contain 2 to 4 eggs, although the full range is 1 to 5 eggs. Even larger clutches are occasionally reported, but these probably (and in some cases certainly) result from two females laying in the same nest (see above). There is variation among populations in clutch size, with population averages ranging from 2.9 to 3.5 eggs, but there does not appear to be a regular geographic pattern in this variation.

Incubation begins before the clutch is complete, and eggs hatch asynchronously (Ligon 1970). As often occurs in species with asynchronous hatching, partial brood loss occurs soon after hatching. Some reduction in brood size is due to failure of eggs to hatch, but much of it is due to mortality of nestlings within the first few days after hatching. The relative frequencies of these forms of loss are not known precisely, and neither are the mechanisms producing the mortality. Eggs may fail to hatch because they are infertile, but it is likely that some do not hatch because the birds cease incubating them after the first eggs hatch. It is also likely that the last young to hatch often starve. A recent study, the first to use video cameras mounted in modified artificial cavities, found that youngest nestlings were most likely to die (Sanders 2000). This study also found no evidence of sibling aggression, so it appears improbable that siblicide is a regular component of partial brood loss.

Partial brood loss, measured by dividing the number of fledglings by the number of eggs in successful nests, averages about 40 percent. It is, however, highly variable among years and among populations. This is one parameter that appears to exhibit systematic geographic variation. Partial brood loss tends to be higher in coastal populations compared to inland ones, and in southern populations compared to northern ones. Population averages vary from around 30 percent in a northern, inland population (North Carolina Sandhills) to about 50 percent in a southern, coastal population (Eglin Air Force Base in Florida), and 59 percent in central Florida.

The average number of young fledged from successful nests is about two in northern populations. Broods of 1 to 4 are common, and rarely five young are fledged from a single nest. Because some groups do not nest and others fail in their attempts, the average number of young produced per group is about one-half fledgling less, ranging from 1.4 to 1.7 among populations, and from 1.0 to 1.9 among years within populations. Thus one can expect about 1.5 young to be produced per group in northern populations. Productivity in Florida populations typically is somewhat less, due largely to greater partial brood loss. In Florida most groups fledge only one or two young, occasionally three. Annual values range from 0.9 to 1.6, and the typical value for a Florida population is about 1.2 fledglings per group per year.

For the first several days after fledging, the young birds are somewhat reluctant to fly, and spend considerable time perched high up in the pines, clinging to the trunk. Parents and helpers sometimes forage some distance away from the young at this time, but return frequently to feed them. During this initial period, the fledglings often do not return to the cluster with the adults in the evening, but instead roost in the open wherever the adults leave them at the end of the day. The next morning, the adults return and locate the fledglings, and resume feeding them.

By the end of the first week out of the nest, however, the young are much more active, and move with the adults as the group travels through the territory. Frequently fledglings will follow adults closely, and beg loudly for food as the adult forages. They may even displace the adult from a particularly productive foraging location. Fledglings often are highly aggressive toward one another, and clear dominance hierarchies are evident among siblings. Males, which are recognizable from their red crown patches, usually are dominant to females. Most of the aggression consists of a dominant fledgling displacing a subordinate from an adult that is carrying food or foraging. The fledglings gradually begin to obtain food for themselves, but continue to beg for food and squabble with each other for some time. It is not unusual to see young being fed two months after fledging, and young are occasionally seen begging as late as the subsequent winter (Ligon 1970).

The sex ratio among fledglings has been reported as biased toward males in a South Carolina population (Gowaty and Lennartz 1985), biased toward females in a Florida population (Epting and DeLotelle, unpublished) and unbiased (i.e., 1:1) in three North Carolina populations (Walters 1990, unpublished, LaBranche 1992) and another Florida population (Hardesty *et al.* 1997). Examination of data on fledgling sex ratios from other populations across the region reveals similar variability (R. DeLotelle, unpublished). It has been proposed that in some cooperatively breeding birds sex ratios are biased toward the helping sex as an adaptive evolutionary strategy (Gowaty and Lennartz 1985, Emlen *et al.* 1986, Lessells and Avery 1987, Ligon and Ligon 1990). This hypothesis has been referred to as the repayment model (Emlen *et al.* 1986). However, in a close examination of the repayment model, Koenig and Walters (1999) found it unable to account for sex ratios in red-cockaded woodpeckers and that the model itself may not be correct. Also, the model does not explain the observed variation in sex ratios among populations of red-cockaded woodpeckers. Generally the cause of this variation is poorly understood, and in particular the relationship between other demographic factors and fledgling sex ratios remains unknown. Sex ratio likely will continue to be of theoretical interest, but it has little bearing on management.

As discussed previously, many fledglings remain with the group through their first year and beyond, and become helpers. But even young that disperse in their first year may remain with the group for many months. Some young disperse in late summer, only weeks after fledging. However, most of those who have not yet departed by the onset of cooler weather in autumn remain with their natal group through the winter, and disperse in late February, March or even April. Although both natal and breeding dispersal can occur at any time, the two primary periods during which movement occurs are just before and just after the breeding season.

Helpers contribute substantially to both incubating eggs and feeding young, and their presence increases productivity. Groups with helpers produce more young than groups without helpers, but this is due in part to an association between the presence of helpers and high territory quality, as well as actual contributions of helpers to reproduction. The best estimate of the helper effect, controlling for effects of territory quality, is that productivity is increased by 0.39 fledglings per group per year by the presence of a helper, and by an additional 0.36 fledglings by the presence of a second helper (Heppell *et al.* 1994). For unknown reasons, the usual positive effect of helpers on productivity seems to be lacking in two of the Florida populations (DeLotelle and Epting 1992, Hardesty *et al.* 1997, but see James *et al.* 1997).

The mechanism by which helpers increase productivity is not entirely clear. One might assume that since helpers contribute substantially to feeding, groups with helpers should be able to raise larger broods. Indeed, in some cooperative breeders feeding by helpers results in higher provisioning rates, and reduced partial brood loss. In others, however, feeding by helpers instead results in reduced feeding effort by the breeders, and positive impacts of helpers are due to reduced nest failure rather than reduced partial brood loss (Emlen 1991). The latter scenario may characterize red-cockaded woodpeckers, but the evidence is equivocal. Lennartz *et al.* (1987) reported that higher productivity by groups with helpers on the Francis Marion National Forest was due to reduced partial brood loss. The extent of partial brood loss also is related to the age of the breeders (see below), however, and breeder age can be confounded with presence of helpers in small data sets. Using a much larger sample, and controlling for the age of the female breeder, Reed and Walters (1996) found that in the North Carolina Sandhills higher productivity of groups with helpers was not due to reduced partial brood loss. Instead, groups with helpers were more likely to attempt nesting, and less likely to fail. Khan (1999) found, for this same population, that feeding by helpers resulted in less feeding by parents rather than more food being delivered to nestlings.

Reproductive success is strongly affected by age in both sexes. Young birds are less successful than old birds, and this is manifested in all components of reproduction. That is, young birds are less likely to attempt nesting, more likely to fail, and suffer more partial brood loss. Productivity of one-year-old birds of both sexes is especially poor, but reduced productivity is evident through age three, and the effect is somewhat stronger in males. Ages 4 to 8 are the peak reproductive years, as productivity is reduced somewhat at ages 9 and beyond in both sexes. This may represent senescence (see below).

Mortality

Data on mortality rates come from the same sources as data on reproduction (see above). Good estimates are available from completely marked populations or subpopulations, and patterns are clear and consistent. For a bird of its size residing in temperate regions, the red-cockaded woodpecker exhibits exceptionally high survival rates. Survival rates of adult male helpers and breeders generally are about 5 percent higher than that of breeding females. There is distinct geographic variation in survival similar to that observed for partial brood loss. Survival rates are about 75 percent for males and 70 percent for females in the northern, inland population in the North Carolina Sandhills, about 80 percent and 75 percent respectively in coastal populations in North Carolina, and 86 percent and 80 percent respectively in central Florida. Such an association between increased survival and reduced fecundity is common in animal life histories. Annual variation in adult survival within populations is sufficiently small that it can largely be attributed to random chance rather than changes in environmental conditions (Walters *et al.* 1988a). This level of variation can have large effects in small populations, however, and it appears that there are occasional poor years in which survival is substantially reduced. Also, some populations are vulnerable to periodic catastrophic mortality due to hurricanes (see 2C).

With survival rates as high as these, it comes as no surprise that some individuals live to old ages. A captive female lived to 17 years (J. Jackson, pers. comm.), and a male in the North Carolina Sandhills lived to 16 years of age in the wild (J. Carter III, pers. comm.). The number of very old birds is less than one might expect, however, because red-cockaded woodpeckers apparently experience senescence. In the North Carolina Sandhills survival rates fall to around 50 percent beginning at age 9 in females and age 11 in males. Survival of one-year-old males is also reduced, but only if they are breeders: helper males of age one have typical high survival rates. Survival is fairly constant at ages 1 to 10 in males, and 1 to 8 in females.

Survival during the first year is more prone to underestimation than survival at subsequent ages, due to the greater possibility of dispersal out of the sampling area. Nevertheless, it is quite clear that survival rates are much lower during the first year than thereafter. In three North Carolina populations, survival of males during the first year ranges from 46 percent to 57 percent, and of females from 36 percent to 45 percent. Within a population, survival of males is 10 to 15 percent higher than survival of females. It is not clear whether geographic variation in survival during the first year exists, although there is some evidence that survival is higher in Florida (DeLotelle and Epting 1992). Survival during the first year is affected by the proportion of individuals dispersing rather than remaining as helpers (dispersing lowers survival), and by the number of available breeding vacancies (survival improves as the number of vacancies increases), as well as by the physical environment. This makes it more difficult to detect geographic variation.

Differences between age-sex classes suggest that dispersal is associated with reduced survival. By regressing survival against the proportion of birds dispersing among various categories of females, Daniels and Walters (2000b) estimated the mortality cost of movement for breeding females in the North Carolina Sandhills at 33 percent. That is, dispersal between breeding seasons adds another 33 percent to the probability of mortality above what is expected for sedentary birds. Specifically, the expected survival rate for females that do not move is 74 percent, whereas that for females that do move is 41 percent. This is a surprisingly high cost, given the short distances that most individuals move. This result may reflect the intensity of competition for breeding vacancies, the benefits of belonging to a group, or perhaps the benefits of ready access to a suitable roost cavity.

Overall the mortality pattern is fairly typical of cooperatively breeding avian species. It is characterized by relatively low survival during the first year, especially of dispersers; relatively high survival of breeders and helpers; and senescence at the end of the life span. Compared to non-cooperative species, survival of both juveniles and adults is high, and the life span is long.

Population Dynamics

The population dynamics of the red-cockaded woodpecker are intimately related to the species' unusual social system (Walters 1990, 1991). In demographic terms, population dynamics are strongly affected by the presence of a large class of non-breeding adults, helpers. Helpers provide a pool of replacement breeders in addition to young of the year, and thereby act as a buffer between mortality and productivity in regulating population size. That is, the number of breeding groups in one year is not strongly affected by either productivity or mortality in the previous year. Instead, the size of the helper class is affected by these variables, while the number of potential breeding groups remains remarkably constant. If mortality exceeds productivity, the number of helpers will decrease, because the number of replacement breeders drawn from the helper class will exceed the number of fledglings recruited into it. If productivity exceeds mortality, the opposite will occur, and the number of helpers will increase. Therefore average group size is an important indicator of population health, as it indicates the potential to maintain the size of the breeding population in the face of fluctuations in mortality and productivity. Of course the strength of the buffering effect of helpers depends on the size of the helper class. In small populations the number of helpers may be so few that poor survival or reproduction can have a direct, negative effect on the size of the breeding population (Lennartz and Heckel 1987, DeLotelle *et al.* 1995).

In evolutionary terms, adoption of the helping strategy is closely linked to patterns of territory occupancy (Walters 1990, 1991). Remaining on the natal territory as a helper can be viewed as a strategy, involving delayed reproduction and dispersal, and altered dispersal behavior, to acquire a breeding position. Helpers stay at home and wait for a breeding vacancy to arise in their vicinity, either on the natal territory or a neighboring one (Walters *et al.* 1992b). This strategy is thought to be an effective one when competition for breeding vacancies is intense (Zack and Rabenold 1989). Further, the intense competition for breeding vacancies that characterizes cooperative breeders is thought to result from unusually large variation in territory quality (Stacey and Ligon 1991, Emlen 1991, Koenig *et al.* 1992).

In red-cockaded woodpeckers, variation in territory quality is related to the presence of cavities. Because cavities take so long to construct, an individual does better to acquire a breeding position on an existing territory containing suitable cavities than to occupy vacant habitat and construct new cavities (Walters 1991, Walters *et al.* 1992a, Conner and Rudolph 1995a). Thus habitat lacking suitable cavities is poor quality, and habitat with existing, suitable cavities is high quality. The birds ignore poor quality habitat, even though they could excavate cavities and then reproduce successfully there, and compete intensely for openings in high quality habitat. When artificial cavities are added to unoccupied but otherwise suitable habitat, it immediately becomes high quality habitat, and is quickly occupied (Copeyon *et al.* 1991, Walters *et al.* 1992a).

The implication of this view of population dynamics is that the breeding population size (usually measured as the number of potential breeding groups) is determined by the number of high quality territories, which depends on the number and distribution of suitable cavities. This is consistent with the behavior of populations during the species' decline (Walters 1991), as well as with recent increases in some populations under new management. The dominant feature in population declines has been gradual abandonment of territories rather than poor survival or reproduction. In many cases it is clear that territory abandonment was related to loss of cavities to tree death or cavity enlargement, or to encroachment by hardwood midstory (Jackson 1978b, Van Balen and Doerr 1978, Conner and Rudolph 1989, Costa and Escano 1989). With so many threats to cavities, it was easy to lose territories, and thus populations declined, despite the continued presence of helpers and good productivity on those territories that remained suitable. Often territories are occupied by an unpaired male for a period prior to abandonment, so that response to loss of cavities and other adverse events is delayed (Jackson 1994). This may be because once territories deteriorate, young birds no longer remain as helpers and females no longer consider them acceptable, but the breeding male refuses to leave. The territory is no longer acceptable to dispersing males, however, so once the original breeding male dies, which may be many years later, the territory is finally abandoned.

New groups on new territories arise by two processes, pioneering and budding (Hooper 1983). Pioneering is the occupation of vacant habitat by construction of a new cavity tree cluster, which according to the view of population dynamics just presented, is expected to be rare. Budding is the splitting of a territory, and the cavity tree cluster within it, into two. Budding is common in many other cooperative breeders, and might be expected to be more common than pioneering in red-cockaded woodpeckers, since the new territory contains cavities from the outset.

The available data indicate that budding indeed is more common than pioneering, and that pioneering is quite rare. In the North Carolina Sandhills, the observed rate of pioneering over 16 years is one event per 1572 existing groups per year, and in Croatan National Forest in coastal North Carolina, over 7 years it is one event per 332 existing groups per year (J. Walters, unpublished). These translate into population growth rates of 0.06 percent and 0.3 percent per year. However, at nearby Marine Corps Base Camp Lejeune, the rate of pioneering over 10 years has been one event per 46 existing groups per year, a population growth rate of 1.5 percent per year (J. Walters, unpublished). During these same periods, rates of population growth through budding have been 0.6 percent, 2.1 percent, and 0.6 percent for the North Carolina Sandhills, Croatan National Forest, and Marine Corps Base Camp Lejeune respectively. Combining budding and pioneering, growth rates are 0.7 percent, 2.4 percent, and 2.2 percent per year respectively. During the years when the North Carolina Sandhills population was declining (1980 to 1984) the growth rate through these processes was 0.1 percent per year, whereas over the subsequent years, when the population was stable, it was 0.9 percent. A population growth rate of 10 percent per year through these processes was reported for the Francis Marion National Forest (Hooper *et al.* 1991a). In this case pioneering and budding events were inferred rather than directly observed, unlike in North Carolina, and it is possible that the rate of population growth was overestimated. Still, this study suggests that the rate of population growth through budding and pioneering potentially can be substantially greater than what has been observed in North Carolina.

Why the rates of budding and pioneering vary so much is a mystery. It appears from the North Carolina data that rates may be higher in small populations (Croatan, Lejeune) than in large ones (Sandhills), but this is inconsistent with the data from the Francis Marion. Another interpretation is that the rates are higher where turnover of breeders is less, and thus opportunities to replace deceased breeders are fewer. A third hypothesis is that budding and pioneering are stimulated by burning specifically, or habitat improvement generally. This is consistent with the North Carolina data in that rates have been higher in recent years in the Sandhills and Lejeune, following reintroduction of growing season fire, and lower in the last several years on Croatan, since burning during the growing season there has been reduced. A fourth hypothesis is that conditions for population growth may be more favorable in flatwoods habitat than in sandhills habitat.

Rates of budding and pioneering may vary for unknown reasons, but it is clear that they are almost always quite low. These rates were too low to counter losses of territories during the 1970's and 1980's when populations were declining, and they limit the potential for recovery currently, even if losses of territories can be prevented. Thus it is easy to understand why, until the advent of artificial cavity construction, populations generally have been stable or declining rather than increasing.

Understanding that population size is determined by the number of territories with suitable cavities makes designing management to increase populations straightforward (Copeyon *et al.* 1991, Walters 1991). To prevent loss of occupied territories, existing cavity trees should be protected, so that a sufficient number of suitable ones are maintained at all times. This can involve eliminating encroaching hardwoods, protecting cavities with restrictors, or replacing lost cavities with artificial ones. To increase the number of suitable territories, cavities can be added in unoccupied habitat, such as abandoned territories with existing cavities and completely vacant areas. In theory it might be possible to rehabilitate abandoned territories by placing restrictors on existing cavities or eliminating hardwoods. In practice, however, only recently abandoned territories seem to be reoccupied without the addition of new cavities (Doerr *et al.* 1989). This may be because cavities deteriorate if unused for long periods. Therefore, for both abandoned territories and vacant habitat, usually the only effective means to create a suitable territory is to construct new artificial cavities in open pine habitat.

Where a management strategy based on maintaining and creating suitable territories has been followed, it has been effective in increasing populations. There have been successes at Eglin Air Force Base (Hardesty *et al.* 1997, J. Walters *et al.*, unpublished), Osceola National Forest (USFWS, unpublished), Marine Corps Base Camp Lejeune (Walters *et al.* 1995), Fort Stewart (T. Beaty, unpublished), Fort Benning (M. Barron, unpublished), Noxubee National Wildlife Refuge (J. Tisdale, unpublished), and Piedmont National Wildlife Refuge (R. Shell, unpublished). Rates of population increase are similar across sites, suggesting that a rate of increase of 10 percent per year is perhaps the best that can be achieved (without resorting to translocation). It may be that the pool of new breeders (i.e., helpers, floaters, and first-year birds) generally is not large enough to permit higher rates of increase.

The current understanding of population dynamics suggests not only that management designed to increase the number of suitable territories will be effective, but also that management designed instead to increase productivity and survival will be ineffective in most circumstances. Thus measures designed to thwart nest predators, prevent cavity kleptoparasitism (except to prevent cavity enlargement), or eliminate predators of fledglings and adults often will be ineffective in promoting population growth. Such measures may be necessary, however, in intensively managed, extremely small populations where every individual is critically important. The population at the Savannah River Site provides the best example of successful, intensive management of a small population (Haig *et al.* 1993, Franzreb 1997).

Like so many other characteristic traits of this species, the origin of its complex social system and unusual population dynamics can be traced back to its most unique feature, excavation of cavities for roosting and nesting in live pine trees. The understanding of these relationships that has been achieved is cause for optimism about the future of the species. Unlike for so many other species, it appears that our understanding of the species' biology is sufficient to construct a management strategy likely to produce recovery, and recent results support this supposition. Ability to implement this strategy is now the key to recovery.

C. POPULATION AND SPECIES VIABILITY

A viable species is one that can reasonably be expected to avoid extinction over a long period of time. Similarly, a viable population is one that is self-sustaining over a long period. For any endangered species, achieving species viability is the ultimate conservation goal, and the ultimate objective of a recovery plan such as this one. How species viability relates to population viability is dependent on population structure. Species viability may be achieved by maintaining a number of independent viable populations and/or by maintaining a network of interacting populations, none of which are viable on their own. We conclude that, for red-cockaded woodpeckers, the appropriate strategy is to maintain a number of independent demographically viable populations and a number of interacting populations within and between recovery units to promote genetic viability. Here we discuss information about population structure that led us to these conclusions, and then how population viability is best achieved.

Population Structure

Given the historic distribution of its habitat and comments by early naturalists about its abundance, it is highly likely that red-cockaded woodpeckers originally were distributed fairly continuously over broad areas. Since the birds are so sedentary (see 2B), one presumes that originally there may have been considerable genetic substructure within populations, but that distinct, genetic population boundaries were lacking. That is, genetic similarity probably changed gradually with distance, rather than suddenly at population boundaries. In fact, it may have been difficult to even delineate distinct populations.

Such is not the case currently. Now the species is distributed largely as distinct populations, with large gaps of unoccupied land between them. Most of these populations are quite small, and only a few are of more than modest size (see map insert and Tables 5, 6, 7, and 9). Typical dispersal distances of both sexes are sufficiently short to maintain genetic substructure within populations even under current conditions. Daniels and Walters (2000a) found that an individual's close relatives are highly concentrated within three territories of the natal site. Thus one can expect genetic similarity to change with distance within populations, as opposed to the uniform structure that occurs when mating is random within populations.

Although this species is highly sedentary compared to other birds, some individuals move long distances (Walters *et al.* 1988a). There is sufficient documentation (Walters *et al.* 1988b, Conner *et al.* 1997c, Ferral *et al.* 1997, R. Costa, pers. comm.) to conclude that long-distance movements between populations are rare but regular events, and that the birds can move through seemingly inhospitable habitat. It appears that movement from small populations into large ones is much more common than the reverse. Because of this, and the rarity of such movements, they are of little consequence demographically; that is, their contribution to sustaining populations is trivial. However, they may be frequent enough to be important genetically, and may function to maintain genetic variability within populations. Producing immigrants that contribute to this function may be one of the primary purposes that small support populations serve.

The most reasonable conclusion, based on current information, is that demographically, populations of red-cockaded woodpeckers function as closed populations. That is, their persistence depends totally on within-population demography, and not at all on exchange between populations. Thus red-cockaded woodpeckers do not exhibit any of the various types of metapopulation structure (Stith *et al.* 1996). Local extinction followed by natural recolonization from another population is extremely unlikely for this species. (The event closest to natural recolonization was the appearance of a male from the Savannah River Site within a recruitment cluster on Fort Gordon, two years after the Fort Gordon population was extirpated. This dispersal event would not likely have resulted in the formation of a breeding pair without the use of translocation.)

Further, immigration rates are too low for one population to rescue another from extinction as occurs in another cooperatively breeding woodpecker, the acorn woodpecker (*M. formicivorous*; Stacey and Taper 1992). Neither are immigration rates high enough to enable source-sink relationships between populations. However, in areas of low density (e.g., northeastern North Carolina), widely scattered groups considerable distances apart may function as a single population. Dispersal distances are longer when population density is lower (Daniels 1997), apparently because the distance moved is a function primarily of the number of groups encountered rather than of habitat, mortality or speed of movement. Thus migration between two sizeable populations only 24.2 km (15 mi) apart may be rare (e.g., only one movement between the Camp Lejeune and Croatan National Forest populations in North Carolina over 11 years), whereas two groups 24.2 km (15 mi) apart in an area of low density (e.g., only one other group between them) may exchange individuals regularly.

Red-cockaded woodpecker populations should not be viewed as closed genetically, however. Nearly all probably experience some immigration, much of it from smaller support populations. Rates of immigration and genetic relationships between populations are not well enough known to determine precisely the rate of gene flow, nor its effect on genetic variability within populations. All that can be said is that the existence of gene flow needs to be considered when evaluating the genetic viability of populations (see below).

There are, however, both allozyme (Stangel *et al.* 1992, Stangel and Dixon 1995) and random amplified polymorphic DNA (RAPD) data (Haig *et al.* 1994a, 1996) available that reveal general genetic relationships between populations. These data indicate that most (93 percent, Haig *et al.* 1994a) genetic variation occurs among individuals within populations. Genetic differences between populations increase somewhat with geographic distance, but there is little geographic structure to genetic variability. Genetic differences between populations are greater than is typical of birds, but equivalent to those in other endangered birds. However, populations do not exhibit unique alleles. Some small populations exhibit reduced heterozygosity, but not all do, and generally there is no consistent relationship between population size and genetic variability (Stangel and Dixon 1995). All of this information is consistent with recent isolation of populations in a formerly continuously distributed species, with low levels of gene flow between populations. Populations probably are diverging genetically and losing variability currently, but isolation evidently is too recent for them to differ much yet.

Threats to Population Viability

Information on population structure indicates that the best approach to viability is to manage for independent populations that are individually viable, with appropriate recognition of low levels of gene flow between populations. To assess population viability, generally four threats are considered: (1) demographic stochasticity, (2) environmental stochasticity, (3) catastrophes and (4) genetic drift and inbreeding (Shaffer 1981, 1987). All four threats must be adequately addressed to ensure viability. Here we examine each threat, treating demographic stochasticity and environmental stochasticity together as demographic considerations, and catastrophes and genetic concerns as separate issues. In the previous recovery plan (USFWS 1985) only catastrophes and genetic factors were considered.

Demographic Considerations

Demographic stochasticity refers to effects of random events on the reproduction and survival of individuals, whereas environmental stochasticity refers to effects of unpredictable events that alter vital rates. For example, if every individual has a 50 percent probability of annual survival, in a population of 20 individuals 10 will not die each year. Instead some years by chance nine will die, in others eleven and so forth. This is demographic stochasticity, which is analogous to sampling error. It may be that in years with severe winters the probability of survival is only 30 percent, whereas in years with mild winters it is 70 percent. This is an example of environmental stochasticity.

Demographic stochasticity is inevitable, but is usually considered to be a threat only to small populations, i.e., less than 50 individuals (Meffe and Carroll 1997). Environmental stochasticity varies widely in strength, depending on the species and the nature of its interactions with its environment. Viability in the face of these threats usually is assessed by incorporating them in simulations of population dynamics, and determining the probability of extinction over long time periods in populations of various sizes. The chief obstacle to a comprehensive viability analysis previously has been lack of a suitable population model. Standard, simple population models do not incorporate the social complexity of the species, notably the buffering effect of the large, nonbreeding helper class (see 2B). These complexities can be handled by stage-based matrix models (Caswell 1989, McDonald and Caswell 1992). Application of these models to red-cockaded woodpeckers has produced important insights about population behavior and management (Heppell *et al.* 1994, Maguire *et al.* 1995). But even these models do not incorporate critically important spatial dynamics resulting from helpers filling breeding vacancies only on or very near their natal territory. A model that assumes that nonbreeders fill breeding vacancies randomly within the population cannot be expected to portray population dynamics accurately enough to perform viability analysis.

The advent of spatially-explicit, individual-based simulation models in ecology provides a tool capable of handling the complex population dynamics of red-cockaded woodpeckers (DeAngelis and Gross 1992, Judson 1994, Dunning *et al.* 1995). These models are not without their faults, a notable one being the large number of parameters that must be accurately estimated if model results are to be trusted (Conroy *et al.* 1995). A spatially-explicit, individual-based model of the population dynamics of red-cockaded woodpeckers has been developed by Letcher *et al.* (1998), using data from the North Carolina Sandhills.

Letcher *et al.* (1998) used their model to assess effects of demographic stochasticity on populations of various sizes and spatial distributions. Their most notable result was the strong effect of spatial structure on viability. If territories were highly clumped, populations of as few as 25 groups were remarkably persistent, whereas if territories were scattered, populations as large as 169 groups declined. New group formation through budding and pioneering (see 2B), which was not then incorporated into the model, would presumably be sufficient to counter the small declines experienced by the largest populations. Still, the model predicts that demographic stochasticity will be a threat to populations as large as 100 groups if spatial structure is poor, but will not be a threat to populations as small as 25 groups if spatial structure is favorable. Recent analyses indicate that even smaller populations, as small as 10 groups, can be remarkably persistent if the territories are maximally clumped (Crowder *et al.* 1998, Walters et al. 2002b). These model results are consistent with empirical evidence. Across the range it seems that small aggregates of groups persist surprisingly well, whereas small, low-density populations always seem to decline. Even in somewhat larger populations, loss of isolated groups is a problem (Conner and Rudolph 1991b).

We conclude that demographic stochasticity is, as usual, a threat only to small populations. However, the threshold of vulnerability varies considerably with spatial structure. Vulnerable populations may be twice the typical size, or half the typical size, depending on the configuration of the population. It certainly is possible to avoid this threat for populations as small as 25 groups, and it may be possible to avoid it for populations of only 10 groups. Managers therefore should strive to aggregate their populations, and to avoid isolation of groups, where isolation is defined as being beyond the dispersal range of helpers. Based on data from the North Carolina Sandhills (Walters *et al.* 1988a, Daniels 1997), 3.2 km (2 mi) appears to be a reasonable standard to use for the maximum dispersal range of helpers (less than 10 percent of helpers [17 of 240] dispersed more than 3.2 km [2 mi]; Daniels 1997). This maximum dispersal distance refers to habitat that contains no barriers to dispersal. The ideal spatial configuration is one in which every group is within dispersal range of helpers from several other groups.

Evaluating environmental stochasticity is more difficult. Letcher *et al.*'s (1998) model is suitable for this purpose, but accuracy of results will depend not only on the validity of the model, but also on estimates of the magnitude of stochasticity. Typically stochasticity is incorporated as annual variation, and therefore the appropriate variance of each demographic parameter must be determined. It is quite clear from available data that annual variation in productivity is considerable, but annual variation in mortality appears to be fairly small (Walters *et al.* 1988a).

Preliminary analyses of population viability incorporating environmental as well as demographic stochasticity have recently been completed using the model developed by Letcher *et al.* (1998). In these analyses, the magnitude of environmental stochasticity was estimated from observed annual variation in the North Carolina Sandhills population, and annual variation in productivity, adult survival, and fledgling survival was incorporated (Crowder *et al.* 1998, Walters et al. 2002b). Budding was incorporated into the simulations as well. These results suggest that populations of 100 or fewer groups are vulnerable to extinction, even when territories are maximally clumped. Populations of 250 or more groups are not vulnerable to environmental stochasticity, according to these simulations, even if territories are not highly clumped. Viability of populations between 100 and 250 groups depends on spatial configuration as well as population size, although this has not yet been analyzed in detail.

Clearly, more analyses are necessary before a more precise viability criterion can be defined, but results at hand permit some important conclusions. First, as expected, populations must be considerably larger to avoid the threat of environmental stochasticity than they need be to avoid the threat of demographic stochasticity. Second, the population sizes necessary to achieve viability against these two demographic threats are much smaller than is typical. This is an intuitive result, since the presence of helpers can be expected to dampen oscillations in the breeding population caused by variation in productivity and breeder survival. Years of poor productivity, or low breeder survival, will lead to a reduction in the size of the helper class rather than a reduced number of potential breeding groups. Third, the level of assistance, in the form of translocated birds, required to avoid extinction of small populations may be low enough to be feasible. Fourth, spatial configuration becomes increasingly important to viability as populations become smaller.

It is encouraging that population sizes required to avoid demographic threats to viability fall within a range that is achievable. Producing populations of two thousand groups, were that required, would be inconceivable. Managing to produce populations of 250 or more potential breeding groups with a favorable spatial structure, on the other hand, is a realistic goal. Indeed a few populations already match this description.

Genetic Considerations

There are two genetic threats to population viability. The first, inbreeding depression, threatens only small populations, whereas the second, genetic drift, can threaten even large populations (reviewed in Lande 1995). Inbreeding depression reduces the survival and productivity of individuals, and results from the segregation of partially recessive, deleterious alleles. The resulting negative effect on population dynamics increases vulnerability to extinction. The amount of inbreeding depression depends on the rate of inbreeding and the opportunity for selection to purge recessive lethal and semi-lethal mutations (Lande 1995). Genetic drift results in the loss of genetic variation, which may reduce a species' ability to adapt and persist in a changing environment, and thereby its viability over long time periods. The rate of loss is inversely related to population size and mutation rate, and viability is achieved when the population size is large enough that loss to drift is in equilibrium with gain from mutation.

The red-cockaded woodpecker is one of the few species for which inbreeding depression has been demonstrated in wild populations, as opposed to assumed from theoretical considerations. In the North Carolina Sandhills, productivity of both closely related (i.e., coefficient of relationship greater than 0.125) pairs and their inbred progeny is substantially lower than that of unrelated pairs and their progeny (Daniels and Walters 2000a). This is due to both reduced hatching rates of eggs and reduced survival of fledglings to age one year. These are precisely the sort of traits one expects to be affected by segregation of partially recessive, deleterious alleles, and in fact reduced hatching rate is the classical manifestation of inbreeding depression in domestic birds (Daniels and Walters 2000a).

Although inbreeding depression is clearly a threat to red-cockaded woodpecker populations, its effects may not yet be evident due to the recent nature of reductions in population size. The available genetic data indicate that most small populations do not yet exhibit high levels of homozygosity (see above). Furthermore, Stangel and Dixon (1995) found no evidence that small populations were experiencing increased morphological variability. They examined fluctuating asymmetries of paired characters, which are often used as an indicator of developmental stability (Leary and Allendorf 1989). Developmental instabilities are thought to be one of the manifestations of inbreeding depression.

Although it appears that there has not yet been sufficient time for the various manifestations of inbreeding depression to become prevalent, they can be expected to increase in the near future in populations that remain small and isolated. Franklin (1980) suggested that populations with an effective size of 50 individuals or less would be vulnerable to inbreeding effects. Since the red-cockaded woodpecker can be characterized as a species in which large populations have been reduced suddenly to small size, it is reasonable to apply this standard to this species. That is, it is unlikely that previous selection has already purged recessive alleles from red-cockaded woodpecker populations. Instead, this species probably is quite vulnerable to this threat.

Effective size refers to an idealized population in which individuals mate randomly and all contribute equally to reproduction. In this hypothetical ideal population, all individuals pass on an equal number of their genes to subsequent generations. Effective size is a theoretical standard used to estimate the retention and loss of genetic variation in a real population. The effective population size itself is never measured directly; it is calculated using formulas based on genetic theory and demographic data collected from real populations.

The actual population size is almost always higher than the effective size, because several characteristics of animals and populations act to make the genetic contribution of individuals to subsequent generations unequal. For example, some pairs or individuals may consistently produce more offspring than others, and some individuals live longer than others. It is mainly this variation in reproductive success that makes effective size less than actual size.

Thus, it is possible to calculate the effective size of a population if its demography is known. Such calculations indicate that for red-cockaded woodpeckers, the actual population size needed to achieve an effective size of 50 individuals is 31 to 39 potential breeding groups, depending on the details of the demography of particular populations (Reed *et al.* 1988b, 1993, D. Heckel and M. Lennartz, unpublished). According to Franklin's (1980) suggestion that an effective size of 50 is necessary to withstand threats from inbreeding depression, stable or increasing populations of 40 or more potential breeding groups are not threatened by inbreeding depression.

Daniels *et al.* (2000) came to a fairly similar conclusion by using the spatially explicit model developed by Letcher *et al.* (1998). They estimated inbreeding levels over time in red-cockaded woodpecker populations of various sizes and rates of immigration. In their simulations, mean inbreeding increased rapidly in very small, declining populations with no immigration, but remained tolerably low in closed, stable populations of 100 occupied territories. Moderately high levels of immigration were required to stabilize small declining populations and maintain reasonable inbreeding levels (kinship coefficients less than 0.10). That is, inbreeding depression is not expected to affect populations that are receiving 2 or more migrants per year. In the absence of immigration, Daniels *et al.* (2000) found that a stable population of 50 to 100 or more breeding groups was necessary to avoid inbreeding depression. Thus, based on the work by Daniels *et al.* (2000) as well as Franklin's (1980) initial suggestion, we conclude that stable or increasing populations of at least 40, and possibly as many as 100 potential breeding groups—or an immigration rate of 2 or more migrants per year—are required to protect against inbreeding depression.

The population size necessary to avoid loss of genetic variation due to genetic drift, however, is much larger. Franklin (1980) first proposed that an effective size of 500 individuals would allow maintenance of long-term viability, because loss of genetic variation from drift would be offset by the creation of new variation through natural mutation. Recently, however, this number has been a topic of some debate (Lande 1995, Franklin and Frankham 1998, Lynch and Lande 1998, Allendorf and Ryman, in press). Lande (1995) indicated that only populations with an effective size of over 5000 individuals can be expected to maintain viability in the absence of immigration, because not all mutations are beneficial. Others argue that an effective population size of 500 to

1000 individuals is sufficient (Franklin and Frankham 1998). At issue is the potential effects of harmful mutations: Franklin and Frankham (1998) consider these effects negligible, but others have suggested that slightly deleterious mutations are capable of causing population extinction even at effective sizes of several hundreds (Lande 1994, Lynch *et al.* 1995, Lynch and Lande 1998). The debate will likely continue, but a reasonable conclusion is that only populations with actual sizes in the thousands, rather than hundreds, can maintain long-term viability and evolutionary potential in the absence of immigration (Allendorf and Ryman, in press).

Thus, without immigration, populations of red-cockaded woodpeckers that have reached recovery goals may still be susceptible to loss of genetic variability through genetic drift. One practical way to reduce this threat is to promote immigration, both natural (from support and other core populations) and artificial (from translocation). Sufficient connectivity among populations, in the order of 1 to 10 migrants per generation in each direction (0.25 to 2.5 migrants per year), can maintain genetic variation and long-term viability for the species (Mills and Allendorf 1996). Populations connected by this level of immigration maintain genetic variation equal to that of one population as large as the sum of the connected populations (F. Allendorf, pers. comm.). As populations increase, natural dispersal among them will likely increase, but determining actual rates of natural immigration is a critical research need.

A second practical way to reduce the effects of genetic drift is to recover the species as quickly as possible. Loss of genetic variation increases with decreasing population size, but such loss also increases dramatically if populations remain small over time (Hartl 1988). Current efforts to increase populations, and the lack of such efforts, have substantial effects on the total genetic variation that will be retained by the species in the future.

Finally, one population, Central Florida Panhandle, may be large enough at delisting to retain its genetic variability despite genetic drift. This population will harbor 1000 potential breeding groups at delisting. For red-cockaded woodpeckers, 1000 potential breeding groups is considered equivalent to an effective population size of 1280 to 1560 individuals (Reed *et al.* 1988b, 1993). Several researchers consider a population of this effective size capable of maintaining genetic variability (Franklin and Frankham 1998, Allendorf and Ryman, in press).

Catastrophes

Catastrophes are rare, irregularly occurring events that produce extreme changes in demography and population dynamics. There are two types of catastrophes that threaten red-cockaded woodpecker populations: catastrophic winds (hurricanes, downbursts, and tornadoes) and outbreaks of southern pine beetles. The beetles kill cavity trees, but not birds—at least not directly. It is possible that loss of foraging habitat and cavity trees to beetles could alter survival and productivity of woodpeckers, but this has not been demonstrated. Outbreaks of sufficient size to constitute a catastrophe at the population level will probably be restricted to small populations dependent on tree species other than longleaf pine. Longleaf is sufficiently resistant to beetles to preclude outbreaks large enough to constitute a catastrophe. In other habitat types, the only real threat to population viability is loss of cavity trees, and this can be countered by construction of artificial replacement cavities. Appropriate forest management can minimize the likelihood of catastrophic outbreaks.

Hurricanes, however, are the greatest catastrophic threat to population viability. The devastation wrought by Hurricane Hugo on the population inhabiting the Francis Marion National Forest demonstrated all too clearly that such storms can produce catastrophic changes in mortality (Hooper *et al.* 1990). Further, by eliminating all cavity trees on many territories Hugo resulted in a catastrophic increase in the rate of territory abandonment, beyond that attributable to mortality alone. Because of the distribution of red-cockaded woodpeckers, most populations face a significant risk from hurricanes, although there is little risk to some inland populations (Hooper and McAdie 1995). That hurricanes will regularly strike woodpecker populations is inevitable, and therefore any strategy to ensure species and population viability must address this form of catastrophe specifically.

The first element in addressing the hurricane threat is to reduce risk to the species as a whole by maintaining a number of populations that are broadly spaced geographically, and including as many inland populations as possible among them (Hooper and McAdie 1995). The second element is to reduce risk of extinction of individual populations through rehabilitation following the catastrophes that occur. The Hugo experience demonstrates that it is possible, albeit at considerable expense, to reduce impacts at the population level and facilitate recovery to approach pre-storm levels through proper management immediately following the storm (Watson *et al.* 1995). The critical activity is to construct artificial cavities quickly, and distribute them so that as few territories as possible are completely lacking in cavity trees. This will maximize the number of territories that remain occupied, which is the most critical component of population dynamics. It is anticipated that one or two recovery populations, as well as a number of support populations, will be in the process of recovering from storms at any given time (Hooper and McAdie 1995). Some support populations may be lost to hurricanes, despite proper rehabilitation efforts, but recovery populations should not be.

The third and final element in addressing the hurricane threat is to manage individual populations at risk to reduce their vulnerability to wind damage. Hooper and McAdie (1995) offer a number of suggestions, such as reducing access of wind into stands and creating conditions for growth that favor development of greater wind resistance. More research in this area is needed before a detailed policy can be developed, but managers of populations at risk should consider the factors discussed by Hooper and McAdie (1995) in developing their forest management plans.

A Strategy for Species Viability

The strategy to recover the red-cockaded woodpecker consists of recovering a number of individual populations, designated recovery populations, to levels at which they are individually viable against environmental stochasticity. Populations large enough to be resilient to environmental stochasticity will also be able to withstand threats from demographic stochasticity and inbreeding. Currently, our best estimate of the population size necessary to withstand effects of environmental stochasticity is 250 potential breeding groups. However, this is a minimum estimate based on model simulations, and it may contain some error. To be conservative, a number of larger populations (350 potential breeding groups) will exist at the time of recovery. These two population sizes, 250 and 350 potential breeding groups, are probably insufficient to avoid loss of genetic variation through genetic drift, at least in the absence of immigration. (Some researchers consider 350 breeding groups the minimum size necessary to produce enough novel variation to offset loss from drift).

There are several strategies to reduce the loss of genetic variation as much as possible. First, recovery populations should be increased as far beyond the above population sizes as the habitat base will allow. Second, populations should be recovered as rapidly as possible, because loss of genetic variation increases with the length of time that populations remain small. Third, recovery populations represent the full range of habitat types now occupied by red-cockaded woodpeckers, and this range will aid the conservation of local genetic resources. Finally, dispersal between populations should be facilitated to the fullest extent possible. We have increased the total number of designated recovery populations identified in the 1985 recovery plan (USFWS 1985) in part to enhance the likelihood of natural dispersal among these populations once the species is recovered. We stress the importance of support populations as sources of immigrants to replace lost variability, and that support populations should be maintained until and after recovery. We recognize that translocation may need to be employed to maintain genetic variation within populations and species-wide, if natural dispersal is found to be insufficient.

Support populations should include at least 40 to 100 potential breeding groups, depending on spatial configuration, in order to eliminate demographic stochasticity and inbreeding depression as threats to their existence. If they can be maintained at even higher levels, their likelihood of extirpation due to environmental stochasticity will be reduced. Support populations that cannot meet the 40 to 100 size criterion can still serve the purpose of providing genetic variability to other populations, but extirpation of some of these is anticipated. We recommend that they be maintained at the largest size the habitat base will support.

The value of support populations depends on their genetic and spatial relationship to recovery populations. Value cannot be assessed precisely until more information about actual immigration, or how probability of immigration depends on distance and intervening habitat type, is available. The number of support populations required for each recovery population cannot be determined until information on levels of gene flow necessary to compensate for lost genetic variability is available. In the meantime, all support populations, including those of less than 40 potential breeding groups, should be considered necessary to species viability.

The designated recovery populations were selected to eliminate the risk of extinction to the species as a whole due to hurricanes. Measures designed to reduce vulnerability to wind damage and to rehabilitate populations following storms should be sufficient to prevent extirpation of those individual recovery populations at risk. However, some support populations may be lost to hurricanes, with risk being a function of population size, location, and expected frequency of storms.

Populations must be managed to achieve favorable spatial configuration, as well as large size. Specifically, groups should be clustered to the extent possible, so that each group has multiple other groups within 3.2 km (2 mi). Special attention should be paid to the edges of the population, to keep isolation of individual groups there to a minimum.

Habitat restoration within populations is a critical aspect of species recovery. Populations are limited by available cavities and by the quality of foraging habitat. Limitation by available cavities has been documented by experimental research (Walters *et al.* 1992). Limitation by quality of foraging habitat is evidenced by smaller territories in areas where the habitat is better (see 2E). Without restoration of nesting and foraging habitat, species viability is not achievable.

In summary, the strategy to achieve species viability is to maintain a number of recovery populations within each recovery unit that, with immigration, are individually viable to genetic and demographic threats. Development and maintenance of viable recovery populations is dependent on restoration and maintenance of appropriate habitat. The threat to species viability from hurricanes is substantially reduced by maintaining a sufficient number of recovery populations, including inland ones, so that anticipated, periodic catastrophic reductions in some recovery populations do not threaten the species as a whole.

D. Cavities, Cavity Trees, and Clusters

Red-cockaded woodpeckers are unique among North American woodpeckers in that they nest and roost in cavities they excavate in living pines (Steirly 1957, Short 1982, Ligon *et al.* 1986). This unusual behavior is thought to have evolved in response to the scarcity of snags and hardwoods in the fire-maintained pine ecosystems of the southeast (Ligon 1970, Jackson *et al.* 1986). Excavation of cavities in live pines has given rise to additional unusual and complex behaviors, ranging from cooperative breeding (Walters *et al.* 1992a; see 2B) to daily excavation of resin wells to create resin barriers against predatory rat snakes (*Elaphe obsoleta*, Ligon 1970, Dennis 1971b, Jackson 1974, 1978a, Rudolph *et al.* 1990b). Use of live pines is also the primary reason why the species requires mature pines, the loss of which has resulted in endangerment. Cavities are an essential resource for red-cockaded woodpeckers throughout the year, because they are used for both nesting and roosting. Thus, a thorough understanding of cavity tree ecology is fundamental to red-cockaded woodpecker biology, management, and recovery. This section describes current knowledge in support of the guidelines for management of cavity trees and clusters presented in 8F.

Cavity Excavation and Selection of Cavity Trees

Excavation of cavities in live pines is an amazingly difficult task. Birds must first select an old pine (Jackson and Jackson 1986, Conner and O'Halloran 1987, DeLotelle and Epting 1988, Rudolph and Conner 1991), then excavate through 10 to 15 cm (4 to 6 in) of live sapwood, avoid dangerous pine resin that seeps from the cavity during excavation, and construct a cavity completely contained within the heartwood (Jackson 1977, Hooper *et al.* 1980, Conner and Locke 1982, Conner and O'Halloran 1987, Hooper 1988, Hooper *et al.* 1991b). Cavity excavation typically takes many years (Jackson *et al.* 1979, Rudolph and Conner 1991, Conner and Rudolph 1995a, Harding 1997).

The difficulty of cavity excavation is considered a major factor in the evolution of cooperative breeding in red cockaded woodpeckers (Walters 1990, Walters *et al.* 1988a, 1992a, 1992b; see 2B). Birds cannot easily exploit previously unoccupied habitat and build cavities, and so competition for territories with existing cavities is unusually intense. Young males delay reproduction and remain on their natal territory as helpers to increase their likelihood of obtaining a breeding site with existing cavities (Walters 1990, Walters *et al.* 1988a, 1992b). Natural formation of groups in previously unoccupied habitat (pioneering, Hooper 1983) is rare; its estimated annual rate is less than 3 percent of total groups in a population under current conditions (Walters 1990; see 2B).

Red-cockaded woodpeckers use a variety of pine species as cavity trees including longleaf, loblolly, shortleaf, slash, pond, pitch (*P. rigida*), and Virginia pines (*P. virginiana*; Steirly 1957, Lowery 1960, Mengel 1965, Sutton 1967, Hopkins and Lynn 1971, Jackson 1971, Murphy 1982). Longleaf, loblolly, and shortleaf pines are the most common species used for cavity trees and longleaf is considered preferred (Lowery 1960, Hopkins and Lynn 1971, Jackson 1971, Baker 1981, Bowman *et al.* 1997). All cavities are excavated in live pines, but occasionally woodpeckers roost and even nest in cavities in trees that have recently died (Hooper 1982, Patterson and Robertson 1983, R. Costa, pers. comm.).

Red-cockaded woodpeckers are able to exploit the resin of the live pine to protect against predation of nests and adults by arboreal snakes (Ligon 1970, Dennis 1971b, Jackson 1974, 1978a, Rudolph *et al.* 1990b). The birds create and maintain resin wells, or wounds in the cambium, to coat the trunk with resin which then effectively interferes with the snakes' ability to climb the tree (Rudolph *et al.* 1990b).

Longleaf pine may be preferred for use as cavity trees because it produces more resin and can sustain resin flow for more years than other southern pines (Wahlenburg 1946, Hodges *et al.* 1977, 1979, Bowman and Huh 1995, Ross *et al.* 1995). The production of more resin affords the birds greater protection against snakes, and also provides the tree with greater protection against insects such as southern pine beetles (Hodges *et al.* 1979). Annual survival of longleaf cavity trees was twice that for loblolly and shortleaf cavity trees in east Texas, in part because of longleaf pine's greater resistance to southern pine beetles (Conner and Rudolph 1995a). Because of higher survival and the ability to sustain resin flow over time, longleaf pines may remain in use as cavity trees for several decades—much longer than shortleaf or loblolly pines (Conner and Rudolph 1995a, Harding 1997).

Cavity excavation time appears to be longer in longleaf pines than in either loblolly or shortleaf pines. In Texas, excavation time averaged 6.3 years in longleaf pines, two to three times greater than the average times for loblolly and shortleaf pines (Conner and Rudolph 1995a). In North Carolina, excavation times for cavities in longleaf averaged from 10 to 13 years, and from 6 to 9 years for loblolly (Harding 1997). Cavity excavation is an intermittent process, with month-long or longer breaks to allow resin flow to subside through resinosis (saturation of sapwood with hardened resin; Conner and Rudolph 1995a). Thus, longleaf may require longer excavation times because of its greater resin flow (Conner and Rudolph 1995a). Variation in estimated excavation times may result from geographic variation in resin flow (Harding 1997), itself a function of site and tree factors (Hodges *et al.* 1979, Ross *et al.* 1995), or from variation in research methods.

Selection of and Requirement for Old Trees

Red-cockaded woodpeckers select and require old pines for cavity excavation (Jackson and Jackson 1986, Conner and O'Halloran 1987, DeLotelle and Epting 1988, Rudolph and Conner 1991). Age of cavity trees depends on the ages of pines available, but there is a minimum age, generally 60 to 80 years depending on tree and site factors, below which use as a cavity tree is highly unlikely or simply not possible (DeLotelle and Epting 1988, Hooper 1988, Rudolph and Conner 1991). Currently, cavity trees average roughly 80 to 150 years in age and can be much older (Rudolph and Conner 1991, Hedrick 1992). Cavity trees are generally the oldest trees available in today's forests (Jackson *et al.* 1979, Engstrom and Evans 1990, Rudolph and Conner 1991), and the optimal age for cavity trees may be well above the average age of cavity trees under current forest conditions. For example, red-cockaded woodpeckers in national forests of Texas continue to select the oldest trees available for initiation of cavities as the forests have aged 20 years during the course of study (Rudolph and Conner 1991).

One reason red-cockaded woodpeckers require old trees for cavity excavation is that they need sufficient heartwood diameter at preferred cavity heights to construct the cavity completely within the heartwood. Cavities must be completely within the heartwood to prevent pine resin in the sapwood from entering the chamber (Jackson and Jackson 1986, Clark 1993), and the estimated minimum amount of heartwood required is 14.0 to 15.2 cm (5.5 to 6 in; Conner *et al.* 1994). Preferred cavity heights generally range from 6.1 to 15.2 m (20 to 50 ft; Baker 1971b, Hopkins and Lynn 1971, Hooper *et al.*

1980, Conner and O'Halloran 1987), a possible adaptation to minimize likelihood of ignition by frequent fire (Conner and O'Halloran 1987, Clark 1992, Conner *et al.* 1994). The age of the tree determines heartwood diameter at cavity height, as older pines have more heartwood at greater heights. In eastern Texas, longleaf pines between 70 and 90 years old had adequate heartwood at appropriate heights to contain a cavity (Conner *et al.* 1994). Fifty year-old longleaf pines examined by Clark (1992) had insufficient heartwood for cavity excavation.

A second reason that woodpeckers select old trees for cavity excavation is that old pines have a higher frequency of infection by red heart fungus, and the associated decay of the heartwood becomes more advanced as the tree ages (Wahlenburg 1946). Woodpeckers can and do excavate cavities into undecayed heartwood (Beckett 1971, Conner and Locke 1982, Hooper 1988, Hooper *et al.* 1991b), but the presence of red heart fungus can substantially reduce the time required for cavity excavation (Conner and Rudolph 1995a). In Texas, for example, average excavation times for cavities in pines with and without decayed heartwood were 3.7 and 5 years, respectively (Conner and Rudolph 1995a).

Heartwood decay by red heart fungus was not frequently found in longleaf cavity trees in Texas until they were over 120 years old (Conner *et al.* 1994). Red heart is a very slow growing fungus (Affeltranger 1971, Conner and Locke 1982, 1983), and at least 12 to 20 years may be required between initial inoculation and the decay of sufficient heartwood to house a cavity (Conner and Locke 1983). Also, red heart fungus enters the heartwood of the tree through heartwood in large branches, and so trees must be old enough to have large branches before bole heartwood can be infected (Affeltranger 1971, Conner and Locke 1982). However, regional differences may exist in the ages and rates at which pines become infected with heartwood decaying fungi. A study in Texas reported a 46 percent infection rate for 50 longleaf cavity trees that averaged 126 years in age (Conner *et al.* 1994), whereas this rate was more than doubled for similarly aged longleaf cavity trees in South Carolina (97 percent infection rate for trees averaging 130 years in age; Hooper 1988).

Red-cockaded woodpeckers actively select pines with heartwood decayed by red heart fungus (Steirly 1957, Jackson 1977, Conner and Locke 1982, Hooper 1988, Hooper *et al.* 1991b, Rudolph *et al.* 1995). In fact, red-cockaded woodpeckers are able to detect and locate cavities in the specific area of the bole that is infected (Rudolph *et al.* 1995). Preference for decayed heartwood results in the selection of cavity trees that are older than necessary for them to have enough heartwood to contain a cavity (Hooper 1988, Hooper *et al.* 1991b, Rudolph *et al.* 1995). For example, cavity trees in Texas averaged 24.8 cm (9.75 in) in heartwood diameter, considerably larger than the 15.2 cm (6 in) estimated minimum (Rudolph *et al.* 1995). In fact, preference for red heart infection rather than age itself may drive the general preference for old trees (Hooper 1988).

Red-cockaded woodpeckers have been shown to select pines that have thinner sapwood and greater heartwood diameters than pines generally available nearby (Conner *et al.* 1994). This is also related to age: such trees are older, growing more slowly, and usually have a higher rate of red heart infection than pines not used for cavity excavation. Diameter growth of trees typically accelerates annually as younger trees mature, attains a maximum, and slows as trees approach maturity (Kramer and Kozlowski 1979). Heartwood diameter increases significantly with tree size and age in both loblolly and longleaf pines (Clark 1992, 1993).

Old growth pines are relatively rare throughout the south. Old growth remnants (both single trees and stands) within today's forests are critically important habitat and will continue to be so over the next 20 to 30 years, until second and third-growth forests mature and potential cavity trees become more widely available. Woodpeckers require potential cavity trees in abundance throughout the landscape, because of currently high mortality of natural cavity trees and high rates of damage to existing cavities by pileated woodpeckers (*Dryocopus pileatus*; Conner *et al.* 1991a, Conner and Rudolph 1995b, Saenz *et al.* 1998; see 2F).

Selection of Trees with High Resin Production

Red-cockaded woodpeckers are known to select, as cavity trees, pines that have higher resin flow than surrounding pines (Bowman and Huh 1995, Conner *et al.* 1998a). Moreover, breeding males select the cavity tree with the highest resin flow for use as the nest tree (Conner *et al.* 1998a). Thus, woodpeckers benefit from pines with high resin production potential, likely indicated by high crown volume and crown weight (Conner and O'Halloran 1987). Ross *et al.* (1997) showed that longleaf pine cavity trees in stands with low densities and on forest edges produced significantly more resin than similar cavity trees within interior forest stands with higher stem densities. Several studies have observed the tendency of red-cockaded woodpeckers to place their cavities near forest edges and in areas of low tree densities (Conner and O'Halloran 1987, Conner *et al.* 1991b, Ross *et al.* 1997), presumably because of higher resin flow in these locations.

The Cavity Tree Cluster

Each red-cockaded woodpecker in a group roosts in a cavity year-round, and it is usually the breeding male's cavity that holds the group's nest in the spring. The aggregation of active (in use) and inactive (previously used) cavity trees within an area defended by a single group is called the cluster (Walters *et al.* 1988a). This aggregation of cavity trees is dynamic, changing in shape as new cavity trees are added through excavation and existing cavity trees are lost to death or a neighboring group. To protect cavity trees, a buffer zone of continuous forest, 61 m (200 ft) in width, is generally established around the minimum convex polygon containing a group's active and inactive cavity trees. For this recovery plan, the term cluster is defined as the minimum convex polygon containing all of a group's cavity trees *and* the 61 m (200 ft) buffer surrounding that polygon. The minimum cluster area size is 4.05 ha (10 ac), as some clusters may only contain one cavity tree. To facilitate record keeping and protection, individual cavity trees within a cluster are commonly marked with metal numbered tags, painted for easy detection, and mapped.

Disturbance within the Cluster

Human-caused disturbances in cluster areas during the nesting season may disrupt red-cockaded woodpecker nesting activities, decrease feeding and brooding rates, and cause nest abandonment. Such activities may include but are not limited to all-terrain and other off-road vehicles, motorized logging equipment, and other vehicles that make excessive noise and disturbance to which the woodpecker groups have not previously become accustomed. Use of vehicles and other activities throughout the year may cause indirect impacts to red-cockaded woodpeckers through excessive soil compaction, damage to cavity tree roots, and disturbance of the groundcover. Soil compaction and root damage elevate cavity tree mortality (Nebeker and Hodges 1985, Hicks *et al.* 1987, Conner *et al.* 1991a); changes in the groundcover may affect prey abundance (Collins 1998), nutrient value of prey (James *et al.* 1997), and fire frequency and intensity through changes in fuel.

Geographic Variation in Habitat

There is geographic variation in nesting and roosting habitat of red-cockaded woodpeckers. The largest populations tend to occur in the primarily longleaf pine forests and woodlands of the Coastal Plains and Carolina Sandhills (Carter 1971, Hooper *et al.* 1982, James 1995, Engstrom *et al.* 1996). Woodpeckers are also found in shortleaf/loblolly forests of the Piedmont, Cumberlands, and Ouachita Mountain regions (Mengel 1965, Sutton 1967, Steirly 1973). Pine habitat occupied by red-cockaded woodpeckers covers a wide moisture gradient ranging from hydric slash pine (*P. elliottii* var. *densa)* flatwoods in Florida (Beever and Dryden 1992, Bowman and Huh 1995) to dry ridge and mountain tops in Oklahoma (Masters *et al.* 1989, Kelly *et al.* 1993), Alabama, and Mississippi. Density of pine overstory in areas occupied by red-cockaded woodpeckers varies from fairly dense in Texas (Conner and O'Halloran 1987, Conner and Rudolph 1989), to sparse in the Orlando, Florida vicinity (DeLotelle *et al.* 1987), to extremely low in the Big Cypress National Preserve (Patterson and Robertson 1981).

Structure of Vegetation within Clusters

Alteration of the natural fire regime during the past century has caused fundamental changes in the vegetation structure of upland habitats throughout the south. These changes include a gradual encroachment of hardwoods, increasing dominance of off-site pine species such as slash and loblolly, and more densely wooded forests in general (Jackson *et al.* 1986, Ware *et al.* 1993). Loblolly pine was present historically, but forests dominated by loblolly were very rare; its presence and dominance has increased dramatically as a result of fire suppression (White 1984). Each of these changes is detrimental to red-cockaded woodpeckers, and hardwood encroachment especially is a major cause of the species' decline and endangered status (see 1A).

The association of red-cockaded woodpeckers with open, park-like pine woodlands has long been known (Thompson and Baker 1971, Van Balen and Doerr 1978, Locke *et al.* 1983, USFWS 1985). Encroachment of hardwood midstory causes abandonment of cavity trees and clusters (Beckett 1971, Hopkins and Lynn 1971, Van Balen and Doerr 1978, Locke *et al.* 1983, Hovis and Labisky 1985, Conner and Rudolph 1989, Loeb *et al.* 1992). Cluster abandonment has been documented when hardwood and pine midstory basal area exceeds 5.7 m^2/ha (25 ft^2/ac; Conner and Rudolph 1989, Loeb *et al.* 1992). Negative effects of midstory growth above 3.7 m (12 ft) have also been shown (Hooper *et al.* 1980).

Thus, effective midstory control is an absolute prerequisite to management, conservation, and recovery of red-cockaded woodpeckers throughout their range. Such control is not an easy task. After seven decades of fire suppression, many clusters have developed an extensive hardwood component with an impressive underground root stock, particularly in the more mesic sites where loblolly and shortleaf pines are the dominant tree species (Conner and Rudolph 1989). Repeated prescribed burning during the late dormant or early growing season is an effective means to remove hardwoods and restore native groundcovers, and has the least detrimental impacts on soil structure and desired groundcovers (Provencher *et al.* 2001a, 2001b, see 3G). However, excessive quantities of hardwoods (or very large trees) may require removal by hand, mechanical means (Conner *et al.* 1995), one-time herbicide application (Conner 1989), or a combination of these methods prior to restoration burning. Chemical and/or mechanical techniques may be useful if rapid midstory reduction is required, for example if a cluster has been recently abandoned or supports only a solitary male because of excessive hardwoods. If chemical and/or mechanical techniques are used, it is important that regular prescribed burning follows these treatments. Maintenance of open habitat structure is best achieved through use of early to mid growing-season fire fueled by native grasses; late growing season fire can be detrimental to overstory pines (Sparks *et al.* 1998, 1999).

Reduction of hardwood midstory and thinning of overstory pines in clusters outside of the nesting season does not negatively affect red-cockaded woodpeckers (Conner and Rudolph 1991a), but mechanical removal of midstory should not be done when red-cockaded woodpeckers are nesting (Jackson 1990). If clusters have been abandoned due to unsuitable habitat conditions, they should be conserved and restored to suitable midstory conditions to increase the probability of reoccupation by woodpeckers (Doerr *et al.* 1989).

Red-cockaded woodpeckers can tolerate some hardwood overstory trees (basal area less than 2.3 m^2/ha; 10 ft^2/ac) within clusters (Hooper *et al.* 1980, Hovis and Labisky 1985, Conner and O'Halloran 1987). Small numbers of overstory hardwoods or large midstory hardwoods at low densities are consistent with historic landscapes in some habitats, and do not have the same negative effects on red-cockaded woodpeckers as the dense hardwood midstories resulting from fire suppression. Oak inclusions and upland hardwood species, such as post oak (*Quercus stellata*) and bluejack oak (*Q. incana*), occur naturally in association with the pine ecosystems of the south. Such species are integral components of the southern pine ecosystem and should not be cut in the name of red-cockaded woodpecker management.

Stream drainages, with associated shrub and midstory layers and hardwoods, are also integral parts of the southern pine ecosystems. However, woodpeckers may not be able to tolerate the complex vegetative structure of stream drainages near cavity trees. Therefore, management of cavity tree habitat for red-cockaded woodpeckers should be primarily focused in upland portions of the forest landscape. Stands developed and managed to recruit new woodpecker groups or replace cluster habitat should be located away from stream drainages whenever possible.

Density of pines in clusters varies according to habitat type, geography, and silvicultural history. The sparsest woods occupied by red-cockaded woodpeckers are the hydric slash pine woodlands of south Florida (Beever and Dryden 1992). Slightly more dense are the clusters in longleaf woodlands of south and central Florida; average basal area of clusters in these Florida longleaf woodlands currently ranges from 1.8 to 5.7 m^2/ha (8 to 25 ft^2/ac; DeLotelle *et al.* 1983, Shapiro 1983, Hovis and Labisky 1985, Bowman *et al.* 1997). For clusters in longleaf pine woodlands north of Florida, estimated average basal area ranges from 9.2 to 13.8 m^2/ha (40 to 60 ft^2/ac) of basal area (Crosby 1971, Hopkins and Lynn 1971, Thompson and Baker 1971). Clusters in natural loblolly and/or shortleaf pine forests average slightly higher densities (Thompson and Baker 1971, Hooper *et al.* 1980, Conner and O'Halloran 1987, Conner and Rudolph 1989).

Woodpecker cluster stands are typically less dense than surrounding stands (Crosby 1971, Thompson and Baker 1971, Grimes 1977, Locke *et al.* 1983, Shapiro 1983, Wood 1983, Hovis and Labisky 1985, Conner and O'Halloran 1987, Conner *et al.* 1991b, Loeb *et al.* 1992, Bowman *et al.* 1997) and they may be the least dense stands available. For example, Conner *et al.* (1991b) reported a preference for seed-tree and shelterwood cuts for cavity excavation in longleaf pine woodlands. For clusters, basal areas as low as 9.2 m^2/ha (40 ft^2/ac) in longleaf stands and from 9.2 to 13.8 m^2/ha (40 to 60 ft^2/ac) in shortleaf/loblolly stands are suitable (Conner *et al.* 1991b). However, seed-tree and shelterwood cuts with excessive pine or hardwood midstory are not acceptable as nesting habitat.

There are several reasons why red-cockaded woodpeckers might select stands with relatively low pine density as cluster sites. Pines in low-density stands grow larger in diameter, have greater crowns and root systems, and higher resin flow. Such pines are more resistant to wind damage and attacks by bark beetles, may be used as cavity trees at younger ages, and provide woodpeckers with greater protection against predation. In addition, sparse woods may have a greater proportion of area in grass and forb groundcovers than more dense forests, and these groundcovers in turn affect arthropod abundance (Collins 1998) and the ability of the stand to carry fire. Another reason for the preference for sparsely wooded stands, apart from the above benefits, may be that the low density of pine itself is a reflection of frequent fire.

Cavity Tree Mortality and Protection

Southern Pine Beetles

Infestation by southern pine beetles is the major cause of cavity tree mortality in loblolly and shortleaf pines (Conner *et al.* 1991a). Cavity trees are lost to southern pine beetles during epidemics, such as the death of 350 cavity trees including more than 50 entire clusters during the early 1980's in the Sam Houston National Forest (Conner *et al.* 1991a, 1997a). Cavity trees are also lost to southern pine beetles at endemic population levels, at a lower but steady rate (Conner *et al.* 1997a). Loss of cavity trees resulting from both epidemic and endemic southern pine beetles can substantially impact woodpeckers, particularly small populations in the loblolly and shortleaf pines of Texas, Arkansas, Louisiana, Mississippi, and elsewhere (Conner and Rudolph 1995b, Rudolph and Conner 1995).

Factors that increase risk to cavity trees and other important, mature pines in the cluster to southern pine beetle infestation include physical disturbance of soils and roots during thinning and midstory reduction, high density of pines within the cluster, and excessive hardwood midstory outside the cluster (Thatcher *et al.* 1980, Nebeker and Hodges 1985, Hicks *et al.* 1987, Conner *et al.* 1997a).

Fortunately, pines with artificial cavities, used to mitigate losses of cavity trees to southern pine beetles, are not infested at a rate significantly different from pines with naturally excavated cavities (Conner *et al.* 1998b). Risk of beetle infestation can be reduced by favoring pines with high resin producing ability, by pine thinning, and by minimizing disturbance during periods of high beetle activity (Mitchell *et al.* 1991). Loblolly and shortleaf pine stands should be maintained at basal areas less than 18.4 m^2/ha (80 ft^2/ac) or an average spacing of at least 7.6 m (25 ft) between pines in mature stands, to retard the spread of beetle infestations (Thatcher *et al.* 1980, Hicks *et al.* 1987, Nebeker and Hodges 1985, Mitchell *et al.* 1991). For southern pines, defense against bark beetle attack is positively related to the trees' ability to produce oleoresins (Lorio 1986). Because of differences in resin production, longleaf pines are much less susceptible to beetle attack than loblolly and shortleaf pines, and shortleaf pines are less susceptible than loblolly.

Other Causes of Mortality

Wind is the second greatest cause of cavity tree mortality in non-hurricane situations (Conner *et al.* 1991a). Cavity trees can be uprooted or snapped by high velocity winds. Patterns of harvest near clusters should be carefully planned to avoid funneling wind toward cavity trees (Conner *et al.* 1991a, Conner and Rudolph 1995c). A forest buffer of uncut trees greater than 61 m (200 ft) wide around cavity trees is adequate protection to minimize wind damage, wind snap, and wind throw during isolated severe summer thunderstorms (Conner and Rudolph 1995c).

Hurricane winds are a major threat to coastal woodpecker populations (Engstrom and Evans 1990, Hooper *et al.* 1990, Hooper and McAdie 1995, Lipscomb and Williams 1995). For example, when Hurricane Hugo struck the Francis Marion National Forests in South Carolina during September 1989, it destroyed 87 percent of the cavity trees, 67 percent of the woodpeckers, and 70 percent of the foraging habitat (Hooper *et al.* 1990, Hooper and McAdie 1995). Drilled and inserted artificial cavities (Copeyon 1990, Allen 1991, Taylor and Hooper 1991), having just been developed, enabled the rapid recovery of the Francis Marion population (Watson *et al.* 1995). Conservation of inland populations and many separate coastal populations will minimize the risk of extinction from hurricanes (USFWS 1985, Hooper and McAdie 1995). Hooper and McAdie (1995) also suggest that pines needed for future nesting habitat be grown in open conditions to promote the development of large crowns, extensive root systems, and strong boles. Another strategy to minimize impacts from hurricane winds is to avoid the creation of openings greater than 10.1 ha (25 ac) in or near forests managed for red-cockaded woodpeckers in hurricane-prone areas.

The third major cause of cavity tree mortality is fire. Managers must take appropriate measures to protect cavity trees from prescribed burns and wildfires so that loss is minimized. Foremost among these protective measures is regular burning within the cluster and around cavity trees, to keep fuel at acceptable levels. Other techniques are described in 8K.

Implications for Management

Cavities, cavity trees, and cavity tree clusters currently limit red-cockaded woodpecker populations, and thus their careful management is foremost in woodpecker conservation and recovery. Red-cockaded woodpeckers require large old trees as nesting and roosting sites, in habitat that is free of pine and hardwood midstory. Each cavity tree is an important resource that must be protected, and until potential cavity trees become more widely available, additional cavities and clusters must be judiciously provided through the use of artificial cavity technology. Hardwood encroachment causes abandonment of cavity tree clusters, with direct effects on population status. Encroaching hardwoods must therefore be controlled, preferably by frequent, early to mid growing season fire. These management actions—protection of existing cavity trees, provisioning of artificial cavities and clusters as appropriate, and hardwood control—form the basis of red-cockaded woodpecker management (see 8B, 8E, 8F, and 8K for more information). Loss of cavity trees and hardwood encroachment were primary factors in the decline of the species throughout its range (see 1A). Removal of these limiting factors is therefore fundamental to recovery.

E. FORAGING ECOLOGY

Our understanding of the foraging ecology of red-cockaded woodpeckers is increasing, although much work remains to be done. Natural geographic variation in forest ecology and woodpecker demography as well as the highly altered structure of today's forests make documenting habitat preferences and requirements a complex and challenging task. Despite these difficulties, a body of research has been developed describing foraging ecology and habitat relationships of red-cockaded woodpeckers. Here, we summarize research into diet, habitat selection, and habitat effects on fitness. In 8I, we present guidelines for providing foraging habitat that is suitable in quality and quantity based on current knowledge. Further research will help us to better understand foraging habitat requirements and may result in revisions of present guidelines.

Diet and Prey Abundance

Diet of Adults and Nestlings

Over 75 percent of the diet of red-cockaded woodpeckers consists of arthropods, especially ants and roaches, but also beetles, spiders, centipedes, true bugs, crickets, and moths (Beal *et al.* 1941, Baker 1971a, Harlow and Lennartz 1977, Hanula and Franzreb 1995, Hess and James 1998, Hanula and Engstrom 2000, Hanula *et al.* 2000b). Ants are particularly common in the diet of adults, comprising over half the stomach contents of adults and sub-adults in the Gulf coast region (Beal *et al.* 1941) and the Apalachicola National Forest in Florida (Hess and James 1998). Other arthropods comprised an estimated 34 percent and 17 percent, respectively, of the adult diet in these two studies (Beal *et al.* 1941, Hess and James 1998). *Crematogaster ashmeadii* was the most prominent of the ant species in the diet of red-cockaded woodpeckers in the Apalachicola, comprising 74 percent of the ant biomass taken (Hess and James 1998). Species composition of arthropod prey taken by adults elsewhere in the range has not yet been evaluated.

Fruits and seeds make up the small remaining portion of the adult diet. Red-cockaded woodpeckers have been known to eat the fruits or seeds of pines (*Pinus spp.*), poison ivy (*Rhus radicans*), magnolia (*Magnolia spp*.), myrtle (*Myrica spp*.), wild cherry (*Prunus serotina*), wild grape (*Vitus spp*.), blueberry (*Vaccinum spp*.), and blackgum (*Nyssa sylvatica*). Fruits and seeds comprised 14 percent by volume of the stomach contents of adults collected throughout the year in the Gulf Coastal Plain (Beal *et al.* 1941). Similarly, fruits and seeds made up 16 percent of the yearly diet of adults in Florida (Hess and James 1998). Plant material was rarely seen in the diets of woodpeckers in the Francis Marion National Forest of South Carolina (Hooper and Lennartz 1981).

The diet of nestlings also consists principally of arthropods, and fruits may be given on occasion (Baker 1971a, Harlow and Lennartz 1977, Hanula and Engstrom 2000, Hanula *et al.* 2000b). Large arthropod prey are commonly fed to nestlings in addition to or instead of ants (Hanula and Franzreb 1995, Hess and James 1998, Hanula and Engstrom 2000, Hanula *et al.* 2000b), and there is some evidence that breeding groups increase their reproductive success by feeding large prey (Schaefer 1996). In the Apalachicola National Forest, the diet of nestlings (as estimated by stomach contents) consisted mainly of roughly equal proportions of ants, beetles, spiders, and centipedes (Hess and James 1998). In several populations in Georgia and South Carolina, wood roaches were the most common item fed to nestlings, comprising from 26 to 62 percent of the nestling diet (as estimated from photographs of feeding visits; Hanula and Franzreb 1995, Hanula and Engstrom 2000, Hanula *et al.* 2000b).

Prey Selection, Location, and Abundance

Red-cockaded woodpeckers generally capture arthropods on and under the outer bark of live pines and in dead branches of live pines. Pines that have recently died are also a notable source of prey (Ligon 1968, Hooper and Lennartz 1981, Schaefer 1996, Bowman *et al.* 1997). Red-cockaded woodpeckers rarely excavate through the bark of live pines to capture prey, but do excavate into dead branches (Ligon 1968, Ramey 1980, Hooper and Lennartz 1981, Porter and Labisky 1986, Schaefer 1996).

Differences in foraging behavior between the sexes in red-cockaded woodpeckers are well documented (Ligon 1970, Hooper and Lennartz 1981, Engstrom and Sanders 1997, Hardesty *et al.* 1997). Males commonly forage in the crown of the tree, and are often on dead branches. Females commonly forage on the trunk, especially the lower trunk, and rarely forage on dead branches. This difference may serve to expose males and females, separately, to the areas of the tree with highest concentrations of arthropods (Hooper 1996, Hanula and Franzreb 1998). Recently, C. Rudolph (pers. comm.) suggested that foraging behaviors differ by social status as well as sex. Breeding males may spend more time in the inner crown of the tree, whereas helper males may forage more on the crown's outer branches (C. Rudolph, pers. comm.).

Several studies have assessed abundance and location of potential prey of red-cockaded woodpeckers (Hooper 1996, Hanula and Franzreb 1998, Hess and James 1998, Hanula *et al.* 2000a). Relative abundance of arthropods changes depending on the part of the tree sampled. On the boles of the tree, the most abundant arthropods were true bugs, spiders, and roaches (Hooper 1996). On live branches, roaches, spiders, beetles and ants were most common (Hooper 1996). Ants appear to be by far the most common arthropod on dead branches (Hooper 1996, Hanula and Franzreb 1998). A large proportion of the arthropods on pine trees have gotten there by crawling up from the ground, which points to the condition of the ground cover as an important factor influencing abundance of prey for red-cockaded woodpeckers (Hanula and Franzreb 1998).

Thus, several studies have documented a variety of arthropod species in the diet of red-cockaded woodpeckers, and others have described patterns of arthropod abundance and distribution. Whether birds are selecting prey species in greater proportion than their availability remains unknown. Assessing prey selection is extremely difficult, in large part because of extraordinary variability in the distributions of arthropods but also because each method of studying diet has its bias. In addition, diets of both adults and nestlings are highly variable: ants, for example, comprised from 0 to 94 percent of the stomach contents of nestlings and from 4 to 95 percent of the stomach contents of adults in Florida (Hess and James 1998). Nor is it clear whether plant material is a preferred or sub-optimal food. Plants may be selected to fill a nutritional need or exploited when prey is scarce.

Factors Affecting Prey Abundance

Arthropod abundance and biomass increases with the age and size of pines (Hooper 1996, Hanula *et al.* 2000a). Whether this relationship continues to increase with age, or levels off and declines at some threshold age, is an issue of some controversy at the present time (R. Conner, pers. comm.). Hanula *et al.* (2000a) found that arthropod abundance per tree increased linearly with stand age, and that biomass per tree increased until approximately age 60 after which it began to decline. This study showed a similar, positive relationship between arthropods and tree diameter, and negative relationships between density of pines and arthropod abundance and biomass per tree. It is not yet clear which factors—size, age, and/or density—are more important in determining arthropod abundance and distribution. Further research is required before the relationships among tree age, size, and density and prey abundance are fully understood.

Fire frequency also affects arthropod abundance and diversity. Large-scale, well-replicated research into longleaf pine ecosystem restoration in Florida documented increases in densities of herb-layer arthropods as a result of prescribed burning, and proposed their use as indicators of restoration success (Provencher *et al.* 2001a). In Texas, the abundance of arthropods on the boles of shortleaf and loblolly pines was higher in stands with grass and forb groundcover than in stands with substantial hardwood midstory (Collins 1998). Hanula *et al.* (2000a) documented positive relationships between tree age and the abundance of both herbaceous groundcovers and insects, although there were no direct relationships between measures of herb and insect abundance. Other studies have emphasized that the effects of fire on arthropods vary by species; that is, fire can have negative, neutral, or positive effects on various insects (New and Hanula 1998, J. Hanula, pers. comm.).

Most importantly, several recent studies have shown a positive relationship between fire frequency (as shown by groundcover) and fitness of red-cockaded woodpeckers (James *et al.* 1997, 2001, Hardesty *et al.* 1997). James *et al.* (2001) specifically documented an increase in fledging rate following the reintroduction of growing season fire, relative to control plots burned during the dormant season.

Frequent fire increases fitness of red-cockaded woodpeckers through more than one mechanism: first, by reducing hardwoods, and secondly, by increasing abundance and perhaps nutrient value of prey (James *et al.* 1997, Provencher *et al.* 1998, but see Hanula *et al.* 2000). The increase in insect abundance is at least partially independent of the reduction in hardwoods. James *et al.* (1997) revealed this independence by showing an effect of fire on fitness in a study area that had few hardwoods. Provencher *et al.* (1998) documented two to seven-fold increases in insect densities following growing season fire of hardwood-encroached longleaf stands. They then showed that reductions in hardwoods by herbicides and mechanical felling did not result in similar increases in insect densities until the stands were burned during the growing season (Provencher *et al.* 2001a). Thus, frequent growing season fire may be critically important in providing red-cockaded woodpeckers with abundant prey.

Selection of Foraging Habitat

Throughout their range, red-cockaded woodpeckers use open pine habitats for foraging. Considerable geographic variation in habitat types exists, illustrating the species' ability to adapt to a wide range of ecological conditions within the constraints of mature or old growth, open southern pine ecosystems. Red-cockaded woodpeckers use such natural habitat types as longleaf pine savannahs, flatwoods, sandhills, and clayhills; slash pine savannahs and flatwoods; pond and/or slash pine pocosins; shortleaf pine savannahs and forests, and shortleaf/loblolly pine savannahs and forests (Nesbitt *et al.* 1978, Ramey 1980, DeLotelle *et al.* 1983, Hooper and Harlow 1986, Porter and Labisky 1986, Bradshaw 1995, Epting *et al.* 1995, Bowman *et al.* 1997). Red-cockaded woodpeckers also use loblolly pine forests for foraging, although historically pure stands of loblolly were rare (White 1984). Longleaf pine ecosystems provide the optimal habitat for red-cockaded woodpeckers and were historically the most extensive habitat type (Conner *et al.* 2001).

Red-cockaded woodpeckers show a strong preference for living pines as foraging substrate (Hooper and Lennartz 1981, Porter and Labisky 1986, Jones 1994, Bowman *et al.* 1997). Pines used for foraging include longleaf, slash, loblolly, shortleaf, Virginia, and pond. Sand pine may be used rarely (Hardesty *et al.* 1997), and cypress is used on occasion, averaging an estimated 10 percent of foraging time in south-central Florida (Nesbitt *et al.* 1978, DeLotelle *et al.* 1983). Hardwoods are also used on occasion. Use of hardwoods typically accounts for 0 to 5 percent of foraging time (Hooper and Lennartz 1981, Repasky 1984, Porter and Labisky 1986, Bradshaw 1995, Hardesty *et al.* 1997). Reports of somewhat higher use include 7 percent of foraging time in Louisiana (Jones 1994) and 12 percent in Kentucky (Zenitsky 1999). Thus, hardwoods comprise a trivial or minor component of foraging substrate for red-cockaded woodpeckers throughout their range.

Dying and recently dead pines are an important foraging resource for red-cockaded woodpeckers (Ligon 1968, Hooper and Lennartz 1981, Schaefer 1996, Bowman *et al.* 1997). Pines infested with or recently killed and vacated by southern pine beetles may be an especially important, though unpredictable, food source in shortleaf and loblolly habitats (Schaefer 1996). Red-cockaded woodpeckers feed on southern pine beetles themselves, especially pupae in the bark. The birds also feed on adults and larvae of secondary attackers to beetle-infested trees, such as long-horned beetles

(*Cerambycidae*) and metallic wood-boring beetles (*Buprestidae*). However, southern pine beetle epidemics can cause dramatic losses of critical nesting habitat. If beetle populations are large and pines near cavity trees (or cavity trees themselves) are infested, some pines are generally removed in the attempt to control growing beetle infestations and prevent loss of nesting and foraging habitat.

Selection of Tree Species

Whether red-cockaded woodpeckers prefer to forage on a particular species of pine has not been clearly demonstrated, and it may be that no such preference exists. Previous research has yielded conflicting results, all of which could be confounded by other factors such as tree age and size, density of surrounding trees, and presence of hardwood midstory. Longleaf pine stands were selected over slash pine stands in northern Florida (Porter and Labisky 1986), but elsewhere in Florida slash pines were selected over longleaf (Nesbitt *et al.* 1978). Bowman *et al.* (1997) suggested that slash pine in south central Florida may provide important foraging in addition to longleaf. In the North Carolina Sandhills, woodpeckers did not select trees based on tree species, but over 90 percent of available pines were longleaf (Walters *et al.* 2000, 2002a). Woodpeckers in coastal North Carolina did not select among longleaf, loblolly, and pond pines, even though the proportion of loblolly and pond pines together averaged over 20 percent of available pines (Zwicker and Walters 1999). Finally, it may be that in habitats that were traditionally longleaf, dominance of longleaf was sufficient to retard the evolution of selection among pine species by red-cockaded woodpeckers. Future research in habitat containing mixed pine species both historically and currently would help document the presence or absence of this behavior.

Selection of Older and Larger Trees

All studies examining selection of individual trees by foraging red-cockaded woodpeckers have found that the birds select large, old trees over small, young trees (Hooper and Lennartz 1981, Porter and Labisky 1986, DeLotelle *et al.* 1987, Bradshaw 1995, Jones and Hunt 1996, Engstrom and Sanders 1997, Hardesty *et al.* 1997, Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Reports vary as to the specific sizes at which trees are avoided and preferred. Also, some researchers suggest that all trees over a specific size (generally, 25.4 cm [10 in] dbh) are equal in foraging value (Hooper and Harlow 1986), whereas others suggest that foraging value of trees increases continually with increasing size and age of trees (Engstrom and Sanders 1997, Hardesty *et al.* 1997, Doster and James 1998, Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Such disagreements are likely due to differences in study methods and to differences in available habitat, because what the birds select or avoid must always be a subset of what is available. Available habitat changes because of natural geographic variation but also because of variation in the extent of forest alteration (e.g., fire suppression and tree cutting). Despite the disagreements, it is clear that tree age and size strongly influence selection of pines for foraging. Results of previous studies are summarized below.

Reported sizes below which trees are avoided (that is, used less than their availability) varies from 12.7 cm (5 in) dbh in coastal South Carolina (Hooper and Lennartz 1981) to 20.3 and 25.4 cm (8 and 10 in) dbh in northwest Florida (Porter and Labisky 1986, Hardesty *et al.* 1997) and Louisiana (Jones and Hunt 1996), and 25.4 cm (10 in) dbh in the North Carolina Coastal Plain and Sandhills (Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Reported sizes above which trees are selected (used more than their availability) include 20.3 and 25.4 cm (8 and 10 in) dbh in northwestern Florida (Porter and Labisky 1986, Hardesty *et al.* 1997), 25.4 cm (10 in) dbh in coastal South and North Carolina (Hooper and Lennartz 1981, Zwicker and Walters 1999), 30.5 cm (12 in) dbh in southwestern Georgia (Engstrom and Sanders 1997), the North Carolina Sandhills (Walters *et al.* 2000, 2002a), coastal Virginia (Bradshaw 1995), and Arkansas (Doster and James 1998), and 40 cm (15.7 in) in Louisiana (Jones and Hunt 1996). Again, these differences are due in part to differences in available habitat, because what the birds select or avoid depends on what is there.

Fewer studies have assessed specific ages at which individual pines are avoided or selected, although several more have assessed effects of average stand age (see below). Age and size of trees are highly correlated, at least until age 80 or greater (Platt *et al.* 1988b, Walters *et al.* 2000), and at present it is not known whether tree age, size, or both age and size is most important to foraging woodpeckers. In the Coastal Plain and Sandhills of North Carolina, trees under 60 years in age were avoided whereas those over 60 years (Coastal Plain) and 70 years (Sandhills) were selected (Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). In northwestern Florida, trees less than 50 years in age were avoided, trees 50 to 150 years in age were used in proportion to their availability, and trees 150 years in age and older were preferred (Hardesty *et al.* 1997).

A preference by woodpeckers for the oldest and largest trees available has been shown in several studies (Hardesty *et al.* 1997, Engstrom and Sanders 1997, Zwicker and Walters 1999, Walters *et al.* 2000, 2002a). Bradshaw (1995) also reported a preference for the largest trees, although he combined all trees over 30.5 cm (12 in) dbh into one category. Such preference for the oldest and largest trees available suggests that tree selection by red-cockaded woodpeckers may be operating in either of two ways: (1) woodpeckers always select the oldest and largest trees in any habitat, or (2) an optimal size and age exists above which selection becomes equal, but this optimum remains unseen because currently these trees are not generally available in meaningful amounts (Zwicker and Walters 1999). In contrast, other studies report that selection tapers off above middle-aged, medium-sized trees—suggesting that middle-aged trees are of equal importance to the oldest and largest trees (Hooper and Lennartz 1981, Hooper and Harlow 1986). Again, such disagreements are likely due to differences in study methods and available habitat. As public forests regain an old growth component and research methods are standardized, biologists will likely reach a consensus on what ages and sizes of trees are preferred by foraging red-cockaded woodpeckers.

Patch Selection

Habitat selection at a scale larger than individual trees, but smaller than stands, is referred to here as patch selection. Patch selection by red-cockaded woodpeckers has been explored in three studies. Bowman *et al.* (1997) found that woodpeckers foraged in patches containing fewer but larger trees than patches chosen randomly. Walters *et al.* (2000, 2002a) found that woodpeckers used patches containing larger trees and lower hardwood midstory than unused patches. Doster and James (1998) found that red-cockaded woodpeckers prefer to forage in patches containing larger pines, a lower overstory pine density, and less hardwood midstory than randomly chosen patches nearby.

Stand Selection

Use of stands by red-cockaded woodpeckers is influenced by the size of the stand, stand age, density of pines, density of large pines, fire history (hardwood midstory), season, and proximity to cavity trees and territorial boundaries (Hooper and Harlow 1986, Porter and Labisky 1986, DeLotelle *et al.* 1987, Epting *et al.* 1995, Bradshaw 1995, Walters *et al.* 2000, 2002a). Two studies documented a positive relationship between stand use and stand age after controlling for effects of cavity trees and territorial boundaries (DeLotelle *et al.* 1987, Epting *et al.* 1995). Porter and Labisky (1986) reported that preferred stands were much older than avoided stands (mean stand age = 72 and 18 years, respectively). Similarly, Jones (1994) reported that stands of trees less than 50 years old were avoided, and stand use increased continually with increasing stand age (Jones 1994, Jones and Hunt 1996). Hooper and Harlow (1986) also reported a positive effect of stand age on use but considered it to be weak.

Stand use and density of all pines may be positively related if densities are generally low (DeLotelle *et al.* 1987) and unrelated or negatively related if densities are high (Hooper and Harlow 1986, Bradshaw 1995). Effects of pine density on stand use also changes depending on the size of trees in question: increasing density of large trees is beneficial (Hooper and Harlow 1986, Bradshaw 1995, Walters *et al.* 2000, 2002a), whereas high densities of small pines are detrimental (Porter and Labisky 1986, Walters *et al.* 2000, 2002a). For example, stand use increased with increasing density of pines greater than or equal to 30.5 cm (12 in) dbh in Virginia (Bradshaw 1995), 35.6 cm (14 in) dbh in central North Carolina (Walters *et al.* 2000, 2002a), and 22.9, 35.6, and 48.3 cm (9, 14, and 19 in) dbh in coastal South Carolina (Hooper and Harlow 1986, although they considered these effects to be weak and, for the largest size class, due mainly to the presence of cavity trees.) Stand use decreased with increasing densities of pines less than 25.4 cm (10 in) dbh in central North Carolina (Walters *et al.* 2000, 2002a); similarly, dense stands of young trees (average 559 stems/ac and 18 yrs in age) were avoided in northwest Florida (Porter and Labisky 1986).

Hardwoods appear to have a negative influence on stand use. Stand use decreased with increasing density of hardwoods in several studies (Hooper and Harlow 1986, Epting *et al.* 1995, Bradshaw 1995, Jones and Hunt 1996), and stand use was negatively influenced by the average height of midstory hardwoods in North Carolina (Walters *et al.* 2000, 2002a). Jones and Hunt (1996) found that stands in which greater than 10 percent of canopy trees were hardwoods were avoided.

Finally, during the non-breeding season red-cockaded woodpeckers may travel long distances to access open stands of large pines, whereas during the breeding season birds may use stands containing smaller pines or a greater hardwood component if they are near nest cavities (Bradshaw 1995, Jones and Hunt 1996).

Home Range and Habitat Quality

Size of home ranges of red-cockaded woodpeckers have been described over much of the species' range and in several habitat types (Hooper *et al.* 1982, Wood 1983, Nesbitt *et al.* 1983, Repasky 1984, Porter and Labisky 1986, DeLotelle *et al.* 1987, Epting *et al.* 1995, Bradshaw 1995, Engstrom and Sanders 1997, Bowman *et al.* 1997, Hardesty *et al.* 1997, Doster and James 1998, Walters *et al.* 2000, 2002a). In studies with sample sizes of over 10 groups, average year-round home range size was estimated to be 83.0 ha (205 ac) in south-central North Carolina (Walters *et al.* 2000, 2002a), 87.0 ha (215 ac) in coastal South Carolina (Hooper *et al.* 1982), roughly 80.1 ha (198 ac) in coastal Georgia (Epting *et al.* 1995), 129.0 ha (319 ac) in central Florida (DeLotelle *et al.* 1995), and 108.9 ha (269 ac) in northwestern Florida (Hardesty *et al.* 1997). In addition, notable studies among those estimating home range based on fewer than 10 groups include one study in the northern edge of the species' current range (Bradshaw 1995), one in the southern edge of the species current and historic range (Nesbitt *et al.* 1983), and one in extremely rare old growth longleaf forest in southwest Georgia (Engstrom and Sanders 1997). Bradshaw (1995) reported that average year-round home range size for 6 groups in coastal Virginia was 120.2 ha (297 ac); Nesbitt *et al.* (1983) estimated that summer range for 5 groups in south Florida was 144.5 ha (357 ac); and Engstrom and Sanders (1997) reported that home range size for 7 groups in old growth forest in southwest Georgia was 46.9 ha (116 ac), the smallest average size yet reported (based on all-day follows). Also, Doster and James (1998) reported an average home range of only 24.7 ha (61 ac) for 5 groups of woodpeckers in shortleaf pine habitat of Arkansas, but this estimate was not based on all-day follows because rough terrain inhibited data collection.

Thus, home ranges in Florida tend to be larger than those farther north (DeLotelle *et al.* 1987, Hardesty *et al.* 1997), and those in fire-maintained old growth forest are substantially smaller than those in second-growth (Engstrom and Sanders 1997). Larger samples would be helpful in confirming these effects, but are not available for specific cases (e.g., Virginia Coastal Plain, old growth forest). Together these results suggest that the natural size and density of pines as well as degree of forest alteration (such as history of harvests and fire suppression) impact home range size. The size of a home range or territory may also increase if it is not constrained by the presence of neighboring groups (DeLotelle *et al.* 1987).

Several studies have related variation in home range (or territory) size within a population to habitat characteristics of the home range (Hooper *et al.* 1982, Bowman *et al.* 1997, Hardesty *et al.* 1997, Walters *et al.* 2000, 2002a). Hooper *et al.* (1982) reported that for 24 groups in coastal South Carolina, territory size generally increased with increasing pine density and basal area. In contrast, Hardesty *et al.* (1997) reported that for 25 groups in northwest Florida, home range size decreased with increasing pine density and basal area. Walters *et al.* (2000, 2002a) found home range size of 30 groups in south-central North Carolina was independent of pine density and basal area, but increased with increasing invasion by hardwoods. Thus, home range size depends on the quality of available foraging habitat: less habitat is needed if the quality of that habitat is high. Increasing pine density may be beneficial if pine density is low, or detrimental if density is high. This inverse relationship between quality and quantity of foraging habitat provides important evidence that foraging habitat can limit red-cockaded woodpecker populations, and underscores the critical need to restore quality of foraging habitat (F. C. James, pers. comm.).

In summary, studies of home range size suggest that red-cockaded woodpeckers require from 40.5 to 161.9 ha (100 to 400 ac) per group, depending upon the quality of foraging habitat, and that high quality foraging habitat has an open structure with an intermediate pine density and sparse or absent hardwood midstory. These characteristics of high-quality foraging habitat are consistent with those suggested by analyses of patch and stand selection (above) and group fitness (below). Moreover, this evidence points to the limitation of woodpecker populations by the quality of their foraging habitat, and illustrates the need for broad-scale habitat restoration.

Group Fitness and Habitat Quality

Understanding the relationships between group fitness (e.g., reproductive success, group size, adult survival) and quantity and quality of foraging habitat is key to formulating appropriate foraging guidelines for red-cockaded woodpeckers. However, current habitats are quite altered from original conditions, and this altered state diminishes our ability to see effects of habitat on group fitness and to determine an optimal amount of foraging habitat. Also, at least two other factors are important to group fitness: presence of helpers (Lennartz *et al.* 1987, Walters 1990, Neal *et al.* 1993a, Beyer *et al.* 1996) and increasing age and experience of breeders (Lennartz *et al.* 1987, Walters 1990, DeLotelle and Epting 1992) are known to increase reproduction. Finally, habitat effects are hard to identify because sample sizes are low, in number of groups studied and/or number of years with which group fitness is estimated. Substantial variation in reproduction can be attributed to stochastic environmental events (e.g., Neal *et al.* 1993a), which can mask other effects in small samples. Despite constraints of available habitat, confounding effects of other factors, and low power due to small samples, important progress has been made in determining effects of habitat quality on fitness.

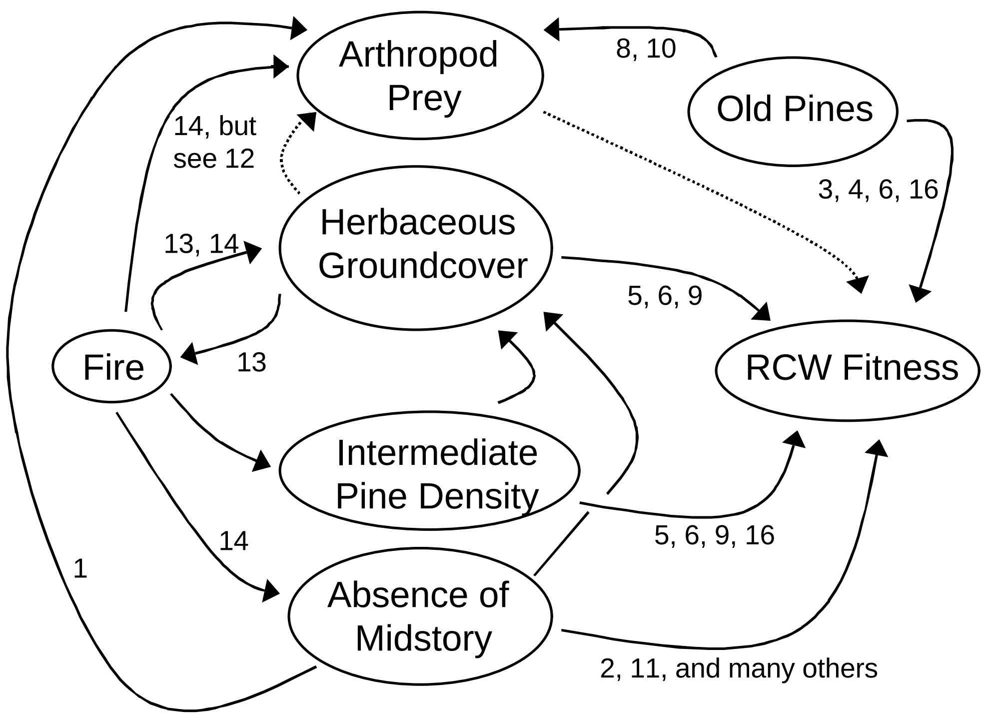
Several aspects of foraging habitat may affect group fitness. First, territory or home range size has been shown to affect group size and/or reproduction in some populations (DeLotelle and Epting 1992, Hardesty *et al.* 1997, USFWS 1985) but not in others (James *et al.* 1997, Walters *et al.* 2000, 2002a). For two studies reporting an influence of home range/territory size on fledgling production, much of the effect appears to have come from whole brood loss or failure to nest (DeLotelle and Epting 1992, Hardesty *et al.* 1997). This suggests that there is a threshold home range size below which reproduction becomes difficult, and it is possible that studies not showing this effect did not sample below the threshold. Home range size for successfully and unsuccessfully nesting groups in northwest Florida averaged 126.3 and 72.4 ha (312 and 179 ac) respectively (Hardesty *et al.* 1997); a threshold home range size for this population under current habitat conditions would fall between these two estimates.

Effects of home range size on fitness vary, of course, with the quality of foraging resources. This point is best illustrated by the large, healthy groups on home ranges averaging only 46.9 ha (116 ac) in the fire-maintained, old growth longleaf forest of the Wade Tract, GA (including considerable overlap among home ranges, Engstrom and Sanders 1997). These groups have the smallest average home range and the highest average group size and reproduction yet reported (average group size 3.0 to 3.6; average fledglings from successful nests 2.3 to 2.5; Engstrom and Sanders 1997). In addition, effects of foraging habitat on group fitness may interact with the general health of the population. For example, Conner and Rudolph (1991b) reported that loss of foraging habitat affected group size in small isolated populations but not in larger populations.

Recent research has revealed that fire history of the foraging habitat affects group fitness in several different ways (Figure 1). Group size and/or reproduction is negatively affected by dense stands of pines (Hardesty *et al.* 1997, James *et al.* 1997, 2001, Walters *et al.* 2000, 2002a), positively related to percent of ground covered by wiregrass (*Aristida spp.*) or forbs (Hardesty *et al.* 1997, James *et al.* 1997), and negatively related to increasing hardwood midstory (Walters *et al.* 2000, 2002a). At Eglin Air Force Base in Florida, reproduction was negatively affected by pine density above 16.1 m^2 of basal area per ha (70 ft^2/ac). Similarly, group size in the North Carolina Sandhills was negatively affected by density of pines less than 35 cm dbh (14 in; Walters *et al.* 2000, 2002a). Frequent fire increases the quality of foraging habitat in several ways: it provides an open structure by reducing density of overstory and midstory pines and hardwoods, it encourages grass and forb groundcovers, and it may also increase nutrient cycling through the ecosystem and the nutrient content of prey (James *et al.* 1997; Figure 1).

Finally, group fitness increases with increasing numbers of old trees in the foraging habitat (Figure 1). In Louisiana, density of groups, group fitness, and the number of old growth trees (90 to 120 years in age) were all strongly positively related (Conner *et al.* 1999). In Texas, group size increased with increasing area of pines greater or equal to 60 years in age both within 400 meters of the cluster (Conner and Rudolph 1991b) and at a larger, regional scale (520 to 5200 ha, Rudolph and Conner 1994). Similarly, in central North Carolina group size increased with increasing density of flat-tops (very old pines) in home ranges (Walters *et al.* 2000, 2002a). Effects of habitat quality on group size are of utmost importance, because of stabilizing effects of helpers on population dynamics, the increase in reproduction in larger groups, and decrease in groups consisting of solitary males.

FIGURE 1. Relationships among fire, habitat components, arthropods, and fitness of red-cockaded woodpeckers (RCW) as illustrated by a summary of research. Solid lines indicate a positive effect (direct or indirect) that has been documented in at least one study; dotted lines indicate potential effects not yet documented. Numbers refer to the citations listed below.



1. Collins 1998
2. Conner and Rudolph 1989
3. Conner and Rudolph 1991b
4. Conner *et al.* 1999
5. James *et al.* 1997
6. James *et al.* 2001
7. Hanula and Franzreb 1998
8. Hanula *et al.* 2000
9. Hardesty *et al.* 1997
10. Hooper 1996
11. Loeb *et al.* 1992
12. New and Hanula 1998
13. Platt *et al.* 1988
14. Provencher *et al.* 1998, 1999, 2001
15. Rudolph and Conner 1994
16. Walters *et al.* 2000, 2002a

Other studies have not found a relationship between group fitness and the amount and quality of foraging habitat as measured by traditional variables such as the number and basal area of pines greater than 25 cm (10 in) dbh (Hooper and Lennartz 1995, Beyer *et al.* 1996, Ferral 1998, Wigley *et al.* 1999).

At the present time, we recognize that fitness of woodpecker groups increases if they have substantial amounts of foraging areas that are burned regularly and have little or no hardwood midstory, an abundant grass and forb groundcover, low densities of small and medium-sized pines and higher densities of large old pines. Again, these results are consistent with those from studies of tree selection, patch selection, stand selection, and home range/habitat quality relationships (see above).

Geographic Variation in Foraging Habitat

There is substantial geographic variation in habitat occupied by red-cockaded woodpeckers. Historically, longleaf pine ecosystems were the most common habitat type and still support most of the largest remaining populations (Carter 1971, Hooper *et al.* 1982, James 1995, Engstrom *et al.* 1996). Within these longleaf pine habitats there is variation in structure and species composition according to soil type and moisture. Red-cockaded woodpeckers also exist in other habitat types including shortleaf pine communities of Arkansas and Oklahoma (Wood 1983, Masters *et al.* 1989, Kelly *et al.* 1993, Hines and Kalisz 1995, Zenitsky 1999), transitional zones of the Piedmont (Steirly 1957), pond pine communities of eastern North Carolina (J. Carter III, pers. comm.), native hydric slash pine system of south Florida (Beever and Dryden 1992), and loblolly forests in many areas (e.g., Hooper and Harlow 1986). Despite natural geographic variation in habitats, the basic ecology of red-cockaded woodpeckers remains unchanged throughout their range: red-cockaded woodpeckers select old pines in open stands for nesting and foraging, and the open structure that characterizes nesting and foraging habitat is best maintained by frequent, growing season fire.

Longleaf Pine Communities

Species composition and structure of longleaf pine communities vary according to interacting moisture, soil, and fire factors. Frequently burned sites with deep sandy soils support what are variously known as sandhill, high pine, or xeric sand communities. These xeric sand communities are found throughout the southeast, on alluvial sands, recently exposed terraces, and relict dunes of the entire Coastal Plain as well as along the fall line that marks the transition between Coastal Plain and Piedmont in the Carolinas and Georgia. Two distinct longleaf ecosystems occur on these deep sandy soils: xeric and subxeric longleaf pine woodlands (Peet and Allard 1993, Christensen 2000). Xeric longleaf pine woodlands are characterized by widely scattered longleaf pines, a sparse midstory of turkey (*Quercus laevis*) and bluejack oaks, and sparse groundcovers dominated by wiregrasses (*Aristida stricta* north of the Congaree/Cooper rivers in South Carolina and *A. beyrichiana* to the south, Peet 1993). Within this xeric woodland type, five series have been identified (Peet and Allard 1993): fall line, Atlantic, and southern (Gulf) xeric longleaf woodlands, and Atlantic and Gulf maritime longleaf woodlands. Subxeric longleaf pine woodlands contain the above species as well as many more that are adapted to somewhat moister conditions (Christensen 2000). This ecosystem type dominated much of the Coastal Plain uplands prior to European settlement (Ware *et al.* 1993, Christensen 2000). Peet and Allard (1993) identified three series within the subxeric ecosystem type: fall line, Atlantic, and Gulf subxeric longleaf pine woodlands.

Mesic longleaf pine communities include flatwoods and savannahs, which differ from each other mainly in structure. Savannahs are characterized by an open canopy and grass groundcover, whereas flatwoods have a somewhat denser canopy and a midstory of shrubs and subcanopy trees (Christensen 2000). The primary cause of variation between flatwoods and savannahs is interacting effects of fire and soil moisture (Peet and Allard 1993). There is no generally accepted classification of these mesic longleaf pine communities (Christensen 2000). Southern flatwoods include saw palmetto (*Serenoa repens*), gallberry-fetterbush (*Ilex glabra-Lyonia lucida*), and fern phases. If burned more frequently, these flatwoods may become more like savannahs (Christensen 2000). Longleaf pine savannahs in the Atlantic and Gulf regions contain many endemic species (Peet and Allard 1993, Walker 1993, Christensen 2000), and species diversity for these community types is among the highest in North America (Walker and Peet 1983).

All of these longleaf community types can support red-cockaded woodpeckers if sufficient old growth and mature pines are available for cavity trees. However, researchers have suggested that in some locations, such as sites of low productivity, extremely dry or wet locations, red-cockaded woodpeckers may need more foraging habitat than those in mesic habitats (Hardesty *et al.* 1997, DeLotelle *et al.* 1987, 1995). These researchers have observed very large home ranges in some locations, possibly because arthropods are limited by sparse groundcovers or low pine density. Expansion of home range size in these habitat types may be a response to low site productivity or a result of past alteration of the forest through overharvest or fire suppression. Low site productivity can also affect how an ecosystem recovers following alteration (Provencher *et al.* 1997, 1998, 2001). Whether the effect is natural or human-induced, some populations of red-cockaded woodpeckers in wet or very dry sites are using more foraging habitat. Further research is required before we fully understand how differences in longleaf pine community types influence the foraging ecology of red-cockaded woodpeckers.

Shortleaf Pine Communities

Shortleaf pine communities supporting red-cockaded woodpeckers are found in the Ouachita Mountains of Arkansas and Oklahoma (McCurtain County Wilderness Area and Ouachita National Forest) and in eastern Texas (parts of Sam Houston National Forest, Davy Crockett National Forest, and the W. G. Jones and I. D. Fairchild State Forests). The western edge of the Cumberland Plateau in Kentucky (Daniel Boone National Forest) supported red-cockaded woodpeckers in shortleaf pine habitats until severely impacted by southern pine beetles in the summer of 2000. Shortleaf pine communities are fire maintained, with a two-layered structure of pine overstory and diverse bunchgrass groundcover much like those of longleaf communities. Loblolly and other pines may be present as secondary components. Unlike most longleaf pine woodlands, many shortleaf pine communities supporting red-cockaded woodpeckers are in regions of complex topography (Masters *et al.* 1989, 1995, Kalisz and Boettcher 1991, Hines and Kalisz 1995, Zenitsky 1999). These rugged areas have steep and narrow ridges, and communities dominated by shortleaf pine are confined to slopes of southern and western exposure and to the ridgetops (Masters *et al.* 1989, Foti and Glenn 1991, Kalisz and Boettcher 1991). Mesic sites such as drainages and north-facing slopes are typically dominated by white oak (*Quercus alba*) and some maples (*Acer* spp.; Masters *et al.* 1989, Foti and Glenn 1991).

Historic shortleaf pine/bunchgrass communities have sustained massive intrusion by hardwoods as a result of fire suppression and exclusion, and this intrusion has caused precipitous declines of red-cockaded woodpeckers in these regions (Masters *et al.* 1989, 1995). Return intervals of fire prior to European settlement have been estimated as 3 to 6 years for shortleaf pine ecosystems in rugged terrain (Masters *et al.* 1995). Reintroduction of fire, using a prescribed burning program patterned after the precolonial fire regime, is vital to the survival and recovery of red-cockaded woodpeckers in these regions (Masters *et al.* 1989, 1995).

Several studies indicate that foraging behavior of red-cockaded woodpeckers in shortleaf habitat is similar to that of woodpeckers on the coastal plain. Woodpeckers foraging on shortleaf pines select large old trees in patches that have less hardwood midstory than the surrounding forest (Murphy 1982, Doster and James 1998, Zenitsky 1999). One study of the once critically endangered and now extirpated population in Kentucky reported a preference for hardwoods as foraging substrate, for 2 of 5 groups during the 1991 nesting season only (Hines and Kalisz 1995). However, further research in this population showed no such effect (Zenitsky 1999). Again, the severe decline of red-cockaded woodpeckers in Kentucky (prior to 1997) and other shortleaf habitats was directly related to hardwood encroachment (Masters *et al.* 1989, 1995), and their foraging behavior did not appear to differ from red-cockaded woodpeckers elsewhere in the range (Murphy 1982, Doster and James 1998, Zenitsky 1999).

Red-cockaded woodpeckers can tolerate some overstory hardwoods in foraging habitat, and even in clusters if more than 15.2 m (50 ft) from cavity trees. Inclusions of xeric hardwood species such as post, blackjack (*Quercus marilandica*), and other oaks (*Quercus* spp.), especially in shortleaf forests, are natural components of the ecosystem and do not need to be totally removed for woodpecker management. However, such hardwoods must remain a minor component overall. In the shortleaf forests of Oklahoma, precolonial density of hardwoods was an estimated 4.6 to 5.7 m^2 basal area per ha (20 to 25 ft^2/ac; Masters *et al.* 1995). Such densities should be considered maximum for red-cockaded woodpecker management. Estimated pine basal area of precolonial Oklahoma is similar to that of longleaf forests, at 8.0 m^2/ha (35 ft^2/ac; Masters *et al.* 1995).

Loblolly Pine Habitats

Because of fire sensitivity, loblolly pine historically was much less widespread than today (White 1984, Landers 1991, Christensen 2000). Prior to fire suppression, loblolly pine was a minor component of riparian and other mesic forests in the coastal plain and a secondary component of mixed pine and pine hardwood forests in interior uplands. Forests dominated by loblolly were rare and restricted to a portion of southern Arkansas and perhaps eastern Virginia/northeastern North Carolina (White 1984, Christensen 2000). Currently, because of fire suppression during the past century and silvicultural practices favoring the species (White 1984), loblolly pine is the dominant pine throughout the southeast, in areas that were historically covered by longleaf pine, shortleaf pine, and shortleaf/loblolly pine forests (White 1984). These off-site loblolly pine forests have provided and continue to provide important resources for red-cockaded woodpeckers. However, ample opportunities exist for the careful restoration of site-appropriate pines in areas currently dominated by off-site loblolly. Foraging ecology of red-cockaded woodpeckers in off-site loblolly is consistent with that of red-cockaded woodpeckers in predominantly longleaf forests: red-cockaded woodpeckers foraging on loblolly select older pines in open stands (e.g., Hooper and Harlow 1986, Zwicker and Walters 1999). The rare forests dominated by natural, historically occurring loblolly pine warrant special consideration and conservation. Foraging ecology of red-cockaded woodpeckers within this habitat type has not been addressed.

Pond Pine Communities

The remaining pond pine communities that support red-cockaded woodpeckers are found primarily in northeastern North Carolina (J. H. Carter III, pers. comm.). Pond pines were likely sparsely distributed in the upland shrub bogs known as pocosins, but fire suppression has led to increased pine density and hardwood encroachment. Foraging requirements of red-cockaded woodpeckers in this habitat type have not been studied at all. Management of woodpeckers in pond pines is complicated by the catastrophic nature of the natural fire regime, dangerous accumulation of fuels during years of fire suppression, southern pine beetle outbreaks, and high rates of cavity enlargement by pileated woodpeckers (J. H. Carter III, pers. comm.). Reintroduction of fire is required for continued survival and recovery of woodpeckers in these habitats, but further research is necessary to determine best methods of prescribed burning and foraging habitat requirements.

South Florida Slash Pine Communities

Native slash pine communities support red-cockaded woodpeckers in south Florida (Beever and Dryden 1992). This subspecies of slash pine (*Pinus elliottii* var. *densa*) is the only native pine in this region and is similar to longleaf in both appearance and fire resistance. Native slash pine has a grass stage and large taproot as does longleaf pine (Landers 1991). Much of the native slash used by red-cockaded woodpeckers is in hydric communities (Beever and Dryden 1992). It may be that slash pine replaces longleaf pine in this region because it can better tolerate very wet conditions.

For red-cockaded woodpeckers, native slash pine habitats differ from those farther north in that the pines are generally smaller and may be more sparsely distributed (Patterson and Robertson 1981, Beever and Dryden 1992, Landers and Boyer 1999). The largest size that south Florida slash pines achieve, even in old growth woodlands, is typically 20 to 30 cm (8 to 12 in). Cavity trees in this habitat type are much smaller than normally found in other habitats (Beever and Dryden 1992, Bowman and Huh 1995). However, the presence of fire and old trees in both nesting and foraging areas are critically important here as elsewhere.

Woodpeckers in native slash pine have not been well studied. Preliminary research has indicated that home ranges of birds in native slash pine are larger than those in other habitats (Patterson and Robertson 1981, Beever and Dryden 1992), but the relationship between habitat requirements and habitat quality has not been investigated in this forest type. Thus, it is not known whether larger home ranges in south Florida result from degraded habitat, natural differences in habitat quality, population density, or even lack of cavity trees. Although further research is necessary to determine the cause of large home ranges in south Florida, results from studies elsewhere suggest that as habitat quality increases, the size of these home ranges will decrease. It is likely that, as pine density, age, and herbaceous groundcovers of south Florida slash pine woodlands increase, resident woodpeckers will still require more foraging habitat than woodpeckers in most other regions but less than they appear to be using at the present time.

Slash pine (*Pinus elliottii* var. *elliottii*) was historically a minor component of coastal pine forests. It is a mesic pine that was generally found in damp swales, narrow drainages, and along pond margins within longleaf pine forests (Landers 1991, Christensen 2000). Slash pine is now much more widespread than historically, as a result of fire suppression and aggressive planting programs. Off-site slash pine forests support small numbers of red-cockaded woodpeckers in some areas. Restoration of these sites to site-appropriate pines would be beneficial; however, caution must be used to avoid unnecessary impacts to red-cockaded woodpeckers (Ferral 1998, see 3G).

Previous Management Guidelines

Previous guidelines for management of foraging habitat (USFWS 1985, Henry 1989) emphasized the number of pines greater than 25.4 cm (10 in) dbh that should be provided each group of woodpeckers, in stands meeting some broad criteria (e.g., overstory hardwoods 50 percent or less of canopy tree basal area, pines 30 years in age or greater). These guidelines were important and useful in several ways: the guidelines provided much-needed protection against overharvest of pines; they stressed that red-cockaded woodpeckers require a large quantity of land and they furnished this large quantity of land fairly successfully; and they represented the best estimate of foraging requirements available from research at that time. However, these guidelines were also flawed in some ways: the actual number of pines recommended was based on one population and a small sample (n=18); the guidelines may have encouraged high densities of small and medium sized pines now known to be detrimental; and most importantly, researchers have been unable to detect any relationship between the total number or total basal area of pines greater or equal to 25.4 cm (10 in) dbh within a group's foraging area and measures of fitness such as group size or reproduction (e.g., Hooper and Lennartz 1995, Beyer *et al.* 1996, Wigley *et al.* 1999). This continued failure to find any relationship between fitness and total number of small and medium sized pines strongly suggests that these variables are not the best way to measure quality or quantity of foraging habitat.

This last point – the lack of relationship between number of pines greater than 25.4 cm (10 in) dbh and group size and/or reproduction—is shown clearly in an analysis recently performed by R. Hooper (unpublished), combining data from nine data sets for a total of 198 groups with mean group size greater or equal to 2 adults. In only two of the data sets did mean number of pine stems greater or equal to 25.4 cm (10 in) dbh approach the standard of 6350 pines set by the 1985 Recovery Plan (USFWS 1985), and one of those data sets determined the original standard. With one exception (Hooper and Lennartz (1995) lacked habitat data for individual groups), these data were pooled for regression analyses of number of pine stems greater or equal to 25.4 cm (10 in) dbh against mean fledglings produced and mean group size. These regressions were significant or nearly significant, but they explained a trivial amount of the variation in independent variables (mean fledglings: df = 1, 196; $R^2 = .02$; $P < 0.05$; mean group size: df = 1, 179; $R^2 = .04$; $P < 0.01$). Thus, number of young fledged and group size were at best weakly related to the number of pine trees $\geq$ 25.4 cm (10 in) dbh available to the various groups, and unspecified factors accounted for 98 percent of the variation in number of young fledged and 96 percent of the variation in the group size. Thus, number of pines greater or equal to 25.4 cm (10 in) dbh is not a particularly good measure of foraging habitat requirements.

Implications for New Management

Supplying good quality foraging habitat is a critical aspect of red-cockaded woodpecker recovery, especially over the long term, as immediate threats from cavity and cluster limitation are reduced. Our understanding of what constitutes good quality foraging habitat comes from a synthesis of research into selection of foraging habitat and effects of habitat characteristics on group fitness.

Both habitat selection and group fitness are influenced by the structure of the foraging habitat. Important structural characteristics include (1) healthy groundcovers of bunchgrasses and forbs, (2) minimal hardwood midstory, (3) minimal pine midstory, (4) minimal or absent hardwood overstory, (5) a low to intermediate density of small and medium sized pines, and (6) a substantial presence of mature and old pines (e.g., Figure 2). Thus, the quality of foraging habitat is defined by habitat structure. Although geographic variation in habitat types exist, these structural characteristics of good quality habitat remain true for all geographic regions and habitat types. Previous guidelines

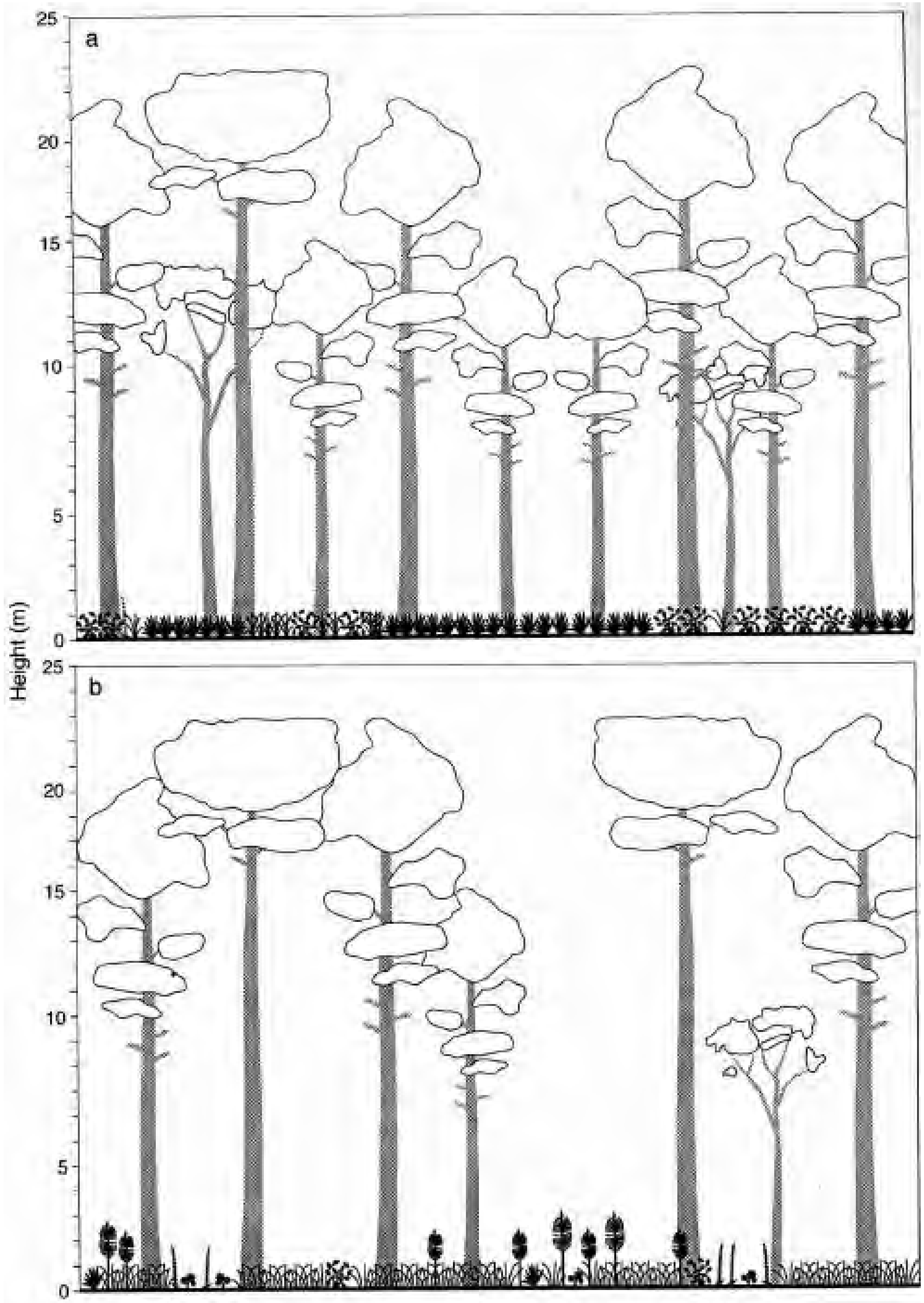


FIGURE 2. Diagrams of (a) adequate and (b) good foraging habitat, as illustrated by James *et al.* (2001). Copyright Ecological Applications; used with permission.

stressed quantity of foraging habitat, as defined by number of medium and large trees. Here we expand this emphasis to include habitat quality, as defined by habitat structure, and use area metrics to address quantity. Red-cockaded woodpeckers require foraging habitat that is suitable in both quantity and quality.

Quantifying habitat structure (and thus habitat quality) is more complex than simply requiring a given amount of habitat or number of trees, because habitat structure is measured by multiple variables. Guidelines for foraging habitat (see 8I) are based on the quantification of structural characteristics to the best of current abilities. Frequent fire can facilitate the restoration and maintenance of all but one of these structural characteristics (mature and old pines), and may provide further benefits by increasing the availability of nutrients. In addition, appropriate silvicultural methods will protect, throughout the landscape, the mature and old trees on which red-cockaded woodpeckers thrive.

F. Community Ecology: Cavity Kleptoparasitism, Cavity Enlargement, and Predation

Red-cockaded woodpeckers are a keystone species of fire-maintained southern pine ecosystems because the cavities they create influence the presence or abundance of a suite of cavity-dwelling species in an otherwise cavity-poor environment (Rudolph *et al.* 1990a, Conner and Rudolph 1995a). Excavation of cavities into live pines by red-cockaded woodpeckers requires a relatively long period of time (Jackson *et al.* 1979, Conner and Rudolph 1995a, Harding 1997). Thus, these cavities are in high demand (Dennis 1971a, Harlow and Lennartz 1983, Rudolph *et al.* 1990b, Loeb 1993, Conner et al. 1997b). Approximately 27 species of vertebrates are known to use cavities excavated by red-cockaded woodpeckers (Table 4; Baker 1971b, Beckett 1971, Dennis 1971a, Hopkins and Lynn 1971, Jackson 1978a, Belwood 1981, Harlow and Lennartz 1983, Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995, Conner et al. 1997b, Loeb and Hooper 1997, Phillips and Gault 1997). Many of these vertebrates use either enlarged (below) or abandoned cavities, but red-bellied woodpeckers, red-headed woodpeckers, eastern bluebirds, several other bird species, and southern flying squirrels use normal, unenlarged cavities that red-cockaded woodpeckers could also use. Southern flying squirrels are generally the most commonly observed species in red-cockaded woodpecker cavities other than red-cockaded woodpeckers (Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995, Laves and Loeb 1999, Mitchell *et al.* 1999), although these observations were made during daylight hours. Eastern bluebirds were more common than flying squirrels in coastal South Carolina (Loeb and Hooper 1997).

Cavity Kleptoparasitism

If a cavity created and used by red-cockaded woodpeckers is usurped by another species, the interaction between that species and red-cockaded woodpeckers is termed cavity kleptoparasitism (Kappes 1997). Until recently, authors have referred to this

TABLE 4. Species using normal and enlarged cavities excavated by red-cockaded woodpeckers[1].

Taxon	Species	Scientific Name
Birds	Wood duck	*Aix sponsa*
	Tufted titmouse	*Baeolophus bicolor*
	Northern flicker	*Colaptes auratus*
	Pileated woodpecker	*Dryocopus pileatus*
	American kestrel	*Falco sparverius*
	Red-bellied woodpecker	*Melanerpes carolinus*
	Red-headed woodpecker	*Melanerpes erythrocephalus*
	Great crested flycatcher	*Myiarchus crinitus*
	Eastern screech owl	*Otis asio*
	Red-cockaded woodpecker	*Picoides borealis*
	Carolina chickadee	*Poecile carolinensis*
	Eastern bluebird	*Sialia sialis*
	White-breasted nuthatch	*Sitta carolinensis*
	Brown-headed nuthatch	*Sitta pusilla*
	European starling	*Sturnus vulgaris*
Mammals	Wagner's mastiff bat	*Eumops glaucinus floridanus*
	Southern flying squirrel	*Glaucomys volans*
	Evening bat	*Nycticeius humeralis*
	Raccoon	*Procyon lotor*
	Eastern gray squirrel	*Sciurus carolinensis*
	Eastern fox squirrel	*Sciurus niger*
Reptiles/Amphibians	Corn snake	*Elaphe guttata*
	Rat snake	*Elaphe obsoleta*
	Broadhead skink	*Eumeces laticeps*
	Five-lined skink	*Eumeces spp.*
	Gray treefrog	*Hyla spp.*
	Lizard spp.	Lacertilia
Invertebrates	Honeybee	*Apis mellifera*
	Spider spp.	Arachnida
	Wasp spp.	Hymenoptera
	Ant spp.	Hymenoptera
	Moth spp.	Lepidoptera
	Mud daubers	Sphecidae

[1]Sources: Baker 1971b, Beckett 1971, Dennis 1971a, Hopkins and Lynn 1971, Jackson 1978a, Belwood 1981, Harlow and Lennartz 1983, Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995, Conner et al. 1997b, Loeb and Hooper 1997, Phillips and Gault 1997.

interaction as cavity competition (e.g., Ligon 1970, Jackson 1978a, Carter *et al.* 1983, Rudolph *et al.* 1990a, Loeb 1993, Kappes and Harris 1995), but the term cavity kleptoparasitism is more correct (Kappes 1997). As Kappes (1997) explains, competition describes an interaction in which both species exhibit a negative effect from the presence of the other. Because cavity usurpers are acquiring a limited resource created by another species, the interaction provides benefits for the usurping species and negative effects on red-cockaded woodpeckers. Kleptoparasitism is the appropriate term for such a positive-negative relationship.

Cavity kleptoparasitism may negatively affect individual woodpeckers or woodpecker groups on occasion (see below). Occasional loss of nests or cavities is unlikely to have population-level impacts in red-cockaded woodpecker populations that are healthy and of medium to large size. However, critically small populations or isolated groups may not be able to tolerate high rates of kleptoparasitism. Also, effects of kleptoparasites may vary with habitat quality. Further research is needed into relationships among kleptoparasites, habitat quality, and red-cockaded woodpecker abundance.

Red-bellied Woodpeckers

Red-bellied woodpeckers are a common cavity kleptoparasite of red-cockaded woodpeckers (Neal *et al.* 1992, Kappes 1997). Usurpation of cavities by red-bellied woodpeckers may result in open roosting for red-cockaded woodpeckers. For example, Kappes (1997) observed 15 adults open roosting during a winter in Florida; 14 of these 15 had suffered loss of cavities to red-bellied woodpeckers. However, how much open roosting may affect survival or territory occupancy is not yet known. Rates of kleptoparasitism by red-bellied on red-cockaded woodpeckers may vary inversely with habitat quality (F. James, pers. comm.). Similarly, red-cockaded woodpeckers in optimal habitat are likely to suffer less impact from each usurpation event. Thus, increasing the overall quality of the habitat for red-cockaded woodpeckers may be an effective means of controlling effects of cavity usurpation by red-bellied woodpeckers. Retention of snags and provision of nest boxes may reduce effects of red-bellied woodpeckers as well (Loeb and Hooper 1997, below).

Southern Flying Squirrels

Reported rates of occupancy of red-cockaded woodpecker cavities by southern flying squirrels range from 9 to 34 percent (Dennis 1971a, Rudolph *et al.* 1990a, Loeb 1993, Laves and Loeb 1999, Mitchell *et al.* 1999). Southern flying squirrels prefer active cavities with non-enlarged entrance tunnels over those with entrance tunnels enlarged (Rudolph *et al.* 1990a, Loeb 1993), and cavity inserts over natural cavities (Lotter 1997). From among active cavities, southern flying squirrels prefer cavities with enlarged chambers over those with regular chambers (Rossell and Gorsira 1996).

Southern flying squirrels could potentially affect red-cockaded woodpeckers through usurpation of cavities or through predation. There is disagreement among researchers over whether cavity usurpation has any negative effects. Some suggest that cavity usurpation lowers nest attempts (Loeb and Hooper 1997), but others have found no evidence that the presence or abundance of southern flying squirrels increases open roosting or decreases nest attempts (Rudolph *et al.* 1990a, Conner *et al.* 1996, Laves 1996, Mitchell *et al.* 1999). Whether or not flying squirrels are significant predators of red-cockaded woodpecker nests is discussed below.

It has been suggested in the past that southern flying squirrels increase with increasing hardwood midstory (Conner and Rudolph 1989, Loeb *et al.* 1992). Yet, Conner *et al.* (1996) observed regular use of red-cockaded woodpecker cavities by southern flying squirrels in loblolly-shortleaf pine habitat with and without hardwood midstory and in open longleaf pine habitat that was nearly devoid of hardwood vegetation. Southern flying squirrels are abundant and ubiquitous, and at the present time the influence of plant species composition and vegetative structure on flying squirrel distributions is not understood.

Reducing Impacts from Cavity Kleptoparasites

The availability of snags may reduce potential impacts of cavity kleptoparasites on red-cockaded woodpeckers. Rates of cavity kleptoparasitism appear to be inversely related to the density of snags within clusters (Harlow and Lennartz 1983, Kappes and Harris 1995). Placement of nest boxes within cavity tree clusters may have a similar effect of lowering use of red-cockaded woodpecker cavities by other species (DeFazio *et al.* 1987, Loeb and Hooper 1997). Improving overall habitat quality and increasing woodpecker density may also reduce effects of kleptoparasites.

Cavity Enlargement

Enlarged cavities are those whose entrance tunnels have been widened by one of several species of woodpeckers (Conner *et al.* 1991a, Neal *et al.* 1992). Cavity enlargement is generally done by pileated woodpeckers, but red-bellied and red-headed woodpeckers and northern flickers also enlarge cavities created by red-cockaded woodpeckers (J. H. Carter III, pers. comm.). Pileated woodpeckers greatly expand entrance tunnels and can also enlarge the cavity chamber if sufficient heartwood is present (Conner *et al.* 1991a). Over a period of thirteen years in the Angelina National Forest in eastern Texas, pileated woodpeckers enlarged 41 percent (114 of 276) of unprotected natural red-cockaded woodpecker cavities (Saenz *et al.* 1998).

Cavity enlargement by pileated woodpeckers can have strong negative impacts on individual red-cockaded woodpeckers and, more importantly, on the entire population. Red-cockaded woodpeckers will abandon their clusters if damage to cavities by pileated woodpeckers is great. However, the enlarged cavities created by pileated woodpeckers provide important habitat for many other relatively large secondary cavity users, such as American kestrels (*Falco sparverius*), eastern screech owls (*Otus asio*), and fox squirrels (*S. niger;* Conner *et al.* 1997b, Saenz *et al.* 1998). In fact, just as red-cockaded woodpeckers are the primary source of cavities for other similar-sized cavity users, pileated woodpeckers are key to the availability of cavities for large cavity-nesting species (Saenz *et al.* 1998). Therefore, the challenge to management is to reduce the effects of cavity enlargement on red-cockaded woodpeckers without overly impacting large cavity-nesting species of concern.

Why pileated woodpeckers enlarge cavities is unknown. Enlarged cavities are rarely used by pileated woodpeckers for roosting or nesting (Conner et al. 1997b). Saenz *et al.* (1998) suggest that pileated woodpeckers are attracted to trees bearing signs of woodpecker excavation, but that heavy resin flow often prevents complete nest excavation. Damage by pileated woodpeckers decreases with increasing availability of snags in the general area (Saenz *et al.* 1998), just as rates of cavity kleptoparasitism may decrease with increasing snags. Thus, managers should retain snags throughout lands managed for red-cockaded woodpeckers and consider their protection during prescribed burns.

Cavity damage by pileated woodpeckers may also be related to human disturbance. Initial attempts at midstory control within the cluster may attract pileated woodpeckers if midstory outside the cluster is excessive (J. H. Carter III, pers. comm., R. Costa, pers. comm.). Again, restoration of high quality habitat for both foraging and nesting may reduce impacts from pileated woodpeckers.

Cavity Restrictors

Metal plates that restrict the entrance diameter of red-cockaded woodpecker cavities (Carter *et al.* 1989) can be used to rehabilitate some currently unsuitable cavities or to prevent the enlargement of currently suitable cavities (see 3B). Although these plates may prevent further damage by larger species of woodpeckers, they will not deter the use of cavities by southern flying squirrels or other small species of birds. When cavity availability is limited (less than four suitable cavities per group or less than one suitable cavity per group member) and enlargement by pileated woodpeckers is common, use of cavity restrictors is absolutely essential to protect existing cavities from enlargement and rehabilitate cavities with minor to moderate entrance enlargement. Use of restrictors to prohibit use of cavities by red-bellied woodpeckers is not recommended (see 3B).

Restrictors require careful monitoring on an annual basis, to ensure that negative effects on red-cockaded woodpeckers are minimized (see 3B). For this reason, their use must be judicious rather than haphazard or wholesale. In addition, enlarged cavities that have been abandoned for several years should not be restricted or should have any existing restrictors removed, so that they may be available to secondary cavity nesters.

Similarly, if cavities are not limited, then restrictors are not necessary and some enlarged cavities can be tolerated.

Predation

Rat Snakes

Red-cockaded woodpeckers excavate resin wells around cavity entrances to create a coat of fresh resin, typically extending several meters below and above the entrance and occasionally to the ground. They also scale loose bark from the bole of the cavity tree and nearby pines. During the 1970's, several biologists realized that these behaviors serve to protect the nests against predation by rat snakes (Ligon 1970, Dennis 1971b, Jackson 1974, 1978a), and in the late 1980's Rudolph *et al.* (1990a) documented experimentally the effectiveness of the resin barrier against climbing rat snakes.

Rat snakes are excellent tree climbers (Jackson 1976) and frequently prey on cavity-nesting birds (Fitch 1963, Jackson 1970). They attempt to climb cavity trees and cavity trees with nests more often than expected by chance alone, evidence that rat snakes are able to detect which trees contain cavities and also which cavity trees contain nests (Neal *et al.* 1993b). Sometimes, rat snakes are able to breach the resin barrier and prey on cavity contents such as eggs, nestlings, or even adults (Jackson 1978a, Neal *et al.* 1993b, 1998).

However, reports of individual predation events by rat snakes on red-cockaded woodpeckers are relatively scarce, and there is no evidence that such predation affects woodpeckers at the population level. For example, there was no difference in average reproduction between nests in cavity trees fitted with snake exclusion devices and untreated cavity trees over three years in the longleaf pines of northwest Florida (L. Phillips, unpublished). It is likely that the resin barrier is a highly effective means of deterring rat snakes, especially in longleaf pine.

Southern Flying Squirrels

Although flying squirrels are known to eat eggs of red-cockaded woodpeckers on occasion (Harlow and Doyle 1990), there is little consistent evidence that flying squirrels significantly depress reproduction of red-cockaded woodpeckers. Two experimental studies have been conducted comparing reproductive success of red-cockaded woodpeckers in clusters with and without squirrel removal (Laves and Loeb 1999, Mitchell *et al.* 1999). Laves and Loeb (1999) reported lowered reproduction in clusters without squirrel removal, resulting from increased whole brood loss in one year and increased partial brood loss in the following year. Mitchell *et al.* (1999) reported no difference in overall reproduction between clusters with and without squirrel removal, but noted increased partial brood loss in clusters that had squirrels removed. In addition, Conner *et al.* (1996) did not detect any relationship between abundance of southern flying squirrels and reproductive success of red-cockaded woodpeckers in eastern Texas. No study has yet shown an effect of flying squirrels on red-cockaded woodpeckers at the population level (Mitchell *et al.* 1999). Thus, it appears that impacts of flying squirrels on red-cockaded woodpeckers are not strong, at least in the populations in which they have been assessed.

Indirect Interactions

Red-cockaded woodpeckers, their cavity kleptoparasites, and nest predators such as rat snakes likely have direct and indirect interactions among them (J. Kappes, pers. comm.). Predation by snakes on kleptoparasites may reduce potential impacts of kleptoparasites on red-cockaded woodpeckers. Snake predation could potentially cause red-bellied woodpeckers or other cavity nesters to shift nest sites to snags, which are less easily climbed than live pine trees. Further research is required before we begin to understand such complex species interactions.

Implications for Management

In general, predator control is not an effective method of achieving stabilization or increases in bird populations, because predators rarely regulate population size in birds (Côté and Sutherland 1997). For red-cockaded woodpeckers, predators were not among the original causes of decline, and their removal will not result in population increases. Only habitat restoration, including prescribed burning, protection of mature and old growth trees, and cavity provisioning, can stabilize and increase populations by removing the original causes of decline.

Critically small populations, however, may not be able to withstand the loss of an occasional nest to predation by southern flying squirrels or rat snakes. For these populations, predator management techniques (see 3C) may be considered, but should not take the place of more fundamental management. Such methods are not appropriate in larger populations, because they may cause unintentional harm and can focus attention and resources away from habitat management and restoration. Further research into both direct and indirect species interactions is desirable before managers use predator exclusion techniques. Such exclusion may have unanticipated consequences, including negative effects on red-cockaded woodpeckers (J. Kappes, pers. comm.). Effects of such actions are simply not sufficiently understood to warrant their widespread use. Those who choose to use predator management techniques in small populations are encouraged to apply an experimental approach with adequate controls.

In contrast, cavity enlargement by pileated woodpeckers can have population-level effects in even fairly large populations by causing cluster abandonment. Restrictors (see 3B) are an essential management tool to be used judiciously in appropriate circumstances, with proper maintenance. Whether cavity kleptoparasitism by red-bellied woodpeckers negatively affects red-cockaded woodpecker populations requires further study. Effects of cavity kleptoparasitism by flying squirrels are under debate but are not considered strong or consistent enough to warrant flying squirrel removal or exclusion except perhaps in critically small populations (less than 30 potential breeding groups). Provision of nest boxes is a non-invasive technique that may help reduce effects of cavity kleptoparasitism (Loeb and Hooper 1997). Some evidence suggests that any effect of red-bellied woodpeckers (F. C. James, pers. comm.) and southern flying squirrels (Loeb and Hooper 1997) may increase with habitat degradation. In general, maintaining good quality nesting and foraging habitat (see 8F, 8I), providing sufficient numbers of suitable, unenlarged or restricted cavities (8E), and retaining snags in the landscape are the best management tools to reduce possible effects of occasional predation and cavity kleptoparasitism and to control the far more serious impacts from cavity enlargement.

G. The Role of Fire in Southern Pine Ecosystems

Fire is an integral component of the southern pine/bunchgrass ecosystems of the southeastern United States, and fire suppression is a principal factor in the decline of these ecosystems and characteristic species such as red-cockaded woodpeckers (see 1A). In this section, we review the history of fire in the region and the fire dependence of the species comprising southern pine ecosystems. In 3F, we discuss prescribed fire and red-cockaded woodpecker management, including description of ignition techniques, benefits to other species, and concerns about negative impacts. Guidelines for using prescribed fire in the management of red-cockaded woodpeckers are presented in 8K.

History of Fire in the Southeast

Fire is a natural ecosystem component that gained and lost importance in North America as the glaciers retreated and advanced. Pyrophytic vegetation in what is now the southeastern United States evolved in response to fires ignited by lightning long before the last glacial retreat roughly 10,000 years ago (Komarek 1968, 1974, Ware *et al.* 1993). Aboriginal people immigrated into the region during the last glacial period, and so the development and spread of fire-dependent ecosystems as the last glaciers retreated were influenced by both climate and the presence of Native Americans (Delcourt *et al.* 1993, Frost 1993, Ware *et al.* 1993). Modern plant assemblages have remained relatively stable for the past 6,000 years (Webb 1988, Frost 1998), despite some oscillations in fire frequency caused by minor changes in climate (Frost 1998). Thus, the ecosystems in place at the time of European exploration of North America had been in place for thousands of years (Frost 1998), and those in the southeastern region were shaped primarily by fire.

Prior to European colonization, there were few natural firebreaks in the southeast, and so fires burned for extended periods and over large regions. Return intervals for these natural fires were as frequent as 1 to 3 years in much of the Atlantic and Gulf Coastal Plains, and as frequent as 4 to 6 years in Upper Gulf Coastal Plains and the

Piedmont (Wahlenburg 1946, Frost 1998). Some areas, such as slopes with northern aspect and wetlands, may have burned at frequencies of 7 to 25 years (Frost 1998).

Fire intensity is intimately related to fire frequency, and together they are a primary determinant of ecosystem structure and species composition. Over much of the southeast, frequent fires were low in intensity, as evidenced by the species adaptations and structure of longleaf and shortleaf communities (below). In some regions, fires were less frequent and of stand-replacing intensity. Such areas support pines that are adapted to stand-replacing fires, such as sand, Table Mountain (*P. pungens*), pitch, and pond pines (Landers 1991). Only the latter two species are used by red-cockaded woodpeckers. Occasionally, some patches of longleaf and shortleaf communities may have undergone stand-replacing fires as a result of unusually long fire intervals. Thus, precolonial longleaf and shortleaf ecosystems were likely mosaics of mostly multi-aged woodlands with occasional even-aged stands (Landers 1991). Community species composition and tree density varied as functions of the fire regime, moisture gradient, and soil fertility.

The relative role of Native Americans in augmenting the lightning fire regime likely varied regionally, depending upon the frequency of lightning fire (Frost 1998). Native Americans may have shifted the seasonality of fire from the lightning season to include fires in fall and winter as well (Higgins 1986, Frost 1998). In general, however, it is not necessary to distinguish the exact contributions of anthropogenic and lightning fire to understand the role of fire in shaping and maintaining the ecosystems of the southeast. Native Americans were an integral component of these developing ecosystems for the 10,000 years of the Holocene.

Like the Native Americans, early European settlers also used fire as a tool, practicing slash and burn agriculture throughout the southeast during the 18th and 19th centuries. Farmers and ranchers continued to use fire to improve grazing quality for free ranging livestock into the first half of the 20th century, setting fires primarily in the early spring (Otto 1986, Frost 1993). As timber surpassed cattle in economic importance, however, fire was increasingly seen as the enemy of the woodland manager. Fire detection and suppression systems were instituted, and large fires became increasingly rare.

Much of the 20th century was a time of active, aggressive fire suppression. Increasing human-made firebreaks such as roads, fields, and power lines also reduced the extent of natural fires and fire frequency. Prescribed fire was recognized by some as an important tool to reduce the risk of catastrophic wildfire (Sachett 1975) and was occasionally used to improve game habitat (Stoddard 1935), but these fires were set in the winter months. Dormant season fires were not as effective as natural, intense, growing season fire in maintaining the open pine woodlands and savannahs that red-cockaded woodpeckers require. By the 1960's, fire suppression and exclusion threatened the existence of the species.

Fire Dependence and Adaptation

Many species of the southern pine-bunchgrass ecosystems show adaptations to frequent, low intensity fires, including red-cockaded woodpeckers. A fundamental adaptation of red-cockaded woodpeckers to fire is the excavation of roost and nest cavities in live pines, a behavior that may have evolved in response to the lack of snags and hardwoods in fire-maintained pine systems (Ligon 1970, Jackson *et al.* 1986). This ability to excavate cavities in live pines is not only important to red-cockaded woodpeckers but also to the many other species that use these cavities in the otherwise cavity poor environment (Brennan *et al.* 1995, Conner *et al.* 1997a; see 2F). Excavation of cavities in live pines has in turn led to the complex and unusual cooperative breeding system of red-cockaded woodpeckers (Walters 1990, Walters *et al.* 1992a; see 2B). A second adaptation of red-cockaded woodpeckers to fire is the abandonment of cavity clusters in the presence of substantial hardwood midstory. This may be a mechanism for avoiding the dangerous fires that will inevitably occur when the midstory is ignited. The severe impact and continuing threat of fire suppression to red-cockaded woodpeckers are discussed in 1A and 1B.

Plants of the southern pine ecosystems are well adapted to and require frequent burning. Many groundcover plants require growing season fires for flowering and fruit and seed production (Platt *et al.* 1988a, Streng *et al.* 1993, Walker 1993). Platt *et al.* (1988a) showed that herbaceous plants undergoing growing season fire not only increased flower production but also increased synchronicity of flowering, facilitating pollination and reducing risk of hybridization. Populations of these herbaceous plants, therefore, are regulated by fire. Ferguson (1998) recounted a typical example of a population of Florida skullcaps (*Scutelleria floridana*) reduced to three individuals which then swelled to over 100 individual plants following a growing season fire. Walker (1993) lists nearly 400 rare, mostly herbaceous plants of longleaf pine communities, of which over 90 percent are adapted to growing season fire. Diversity of herbaceous plants in longleaf systems place these among the most highly diverse ecosystems in North America (Walker and Peet 1983, Peet and Allard 1993). This diversity is maintained by frequent fire and severely threatened by fire suppression (Christensen 1981, Ware *et al.* 1993, Peet and Allard 1993, Glitzenstein *et al.* 1998b, Walker 1998). Over 120 species of plants associated with red-cockaded woodpecker habitats are currently on the regional list of proposed, endangered, threatened, and sensitive species (USFS 1995).

Pine trees in general are noted for being fire-adapted, but longleaf and south Florida slash pines in particular are extremely well adapted to fires of high frequency and low intensity (Landers 1991). Adaptations providing these two species with resistance to fire damage include the grass stage of seedlings, a large taproot, special bark characteristics, absence of branches below the crown, and the typical clumped arrangement of needles at the growing tips of branches (Wahlenburg 1946, Landers 1991). Longleaf and south Florida slash pine seedlings maximize taproot growth and minimize early height growth; the reverse is true of loblolly pine (Landers 1991). In addition, fire enhances seed germination and seedling establishment. Reproduction of longleaf and development of longleaf seedlings is especially enhanced by growing-season fire, as evidenced by long-term research into the reproduction of longleaf pine in the Escambia Experimental Forest, Alabama (W. D. Boyer, pers. comm.). Finally, both fire-adapted species facilitate the ignition and spread of fire by producing highly resinous, long needles and shedding them frequently (Platt *et al.* 1988b, 1991, Noss 1989, Landers 1991). This facilitation of fire maintains environmental conditions that are beneficial to these species but detrimental to competitors. Through its profound influence on the fire regime, longleaf pine is a key species in the longleaf pine communities (Platt *et al.* 1988b, 1991, Noss 1989, Landers 1991). Fire suppression and the resulting invasion of hardwoods have altered almost all longleaf pine ecosystems (Frost 1993).

Engstrom (1993) reported 36 species of mammals and 86 species of birds (35 permanent residents, 22 winter residents, and 29 breeders) characteristic of southeastern longleaf pine ecosystems. Many of these animals, and many more plant species, are threatened by fire suppression. USFS (1995) reported that 56 animal species associated with red-cockaded woodpecker habitats are currently on the regional list of proposed, endangered, threatened, and sensitive species. In addition, entire associations of species have been affected, such as the threatened gopher tortoise (*Gopherus polyphemus*) and the 13 listed and candidate species of animals that depend on gopher tortoise burrows (USFS 1995). Fire benefits shortleaf pine communities as well, although these have not received as much research attention as longleaf systems. Masters *et al.* (1998) reported that species richness and diversity of small mammals increased in relation to midstory reduction and prescribed fire, and no species was adversely affected by fire.

Guyer and Bailey (1993) reported 34 amphibian and 38 reptilian species that are closely associated with longleaf pine forests. Thirty-five percent of the amphibians and reptiles inhabiting longleaf pine forests, and 56 percent of the longleaf pine specialist species, were listed by at least one conservation agency as being of special concern. Fire suppression was identified as a primary cause of the decline of these species.

There is growing evidence that frequent fire may increase arthropod diversity and abundance (Folkerts *et al.* 1993, Collins 1998, Provencher *et al.* 1997, 2001). Groundcovers maintained by frequent fire may support more arthropods than areas with a hardwood midstory (Provencher *et al.* 1997, 2001, Collins 1998), although populations of some species, especially those in the leaf litter, may initially decline after burning. Provencher *et al.* (1997, 2001) suggest that invertebrate densities may increase following fire because resprouting plant tissue contains higher levels of nitrogen relative to carbon than older tissue (Christensen 1993), thus providing more palatable forage. It has been hypothesized that nutrient content of arthropods increases also, following the release by fire of nitrogen and other nutrients into the soil (James *et al.* 1997).

Implications for Management

Fire is an essential element of southern pine ecosystems, critical to the maintenance of habitat for red-cockaded woodpeckers and many other species. Frequent fire has helped to shape and maintain some of the most highly diverse ecosystems outside the tropics. However, natural fire can no longer maintain suitable habitat for red-cockaded woodpeckers and associated species, because the fragmentation of landscapes has reduced fire spread, duration, and therefore fire frequency. Thus, prescribed fire is a fundamental solution to the conservation of red-cockaded woodpeckers and their ecosystems. To maximize benefits, the frequency, intensity, and season of prescribed fire should mimic the historic natural fire regime as closely as possible (see 3F).

3. MANAGEMENT TECHNIQUES

A. POPULATION MONITORING

Population monitoring is a critical component of the conservation and recovery of red-cockaded woodpeckers. Effective monitoring begins with explicit identification of monitoring objectives, the appropriate metrics to be used in meeting objectives, and familiarity with necessary sampling and monitoring techniques. It is then up to managers and researchers to apply these standards in good faith. Finally, monitoring results must be compared to stated objectives. It is the responsibility of the Red-cockaded Woodpecker Coordinator to evaluate monitoring results within the framework of recovery objectives (1 – 6, below), using information reported annually by managers and researchers (Annual Reports, below). Fortunately, red-cockaded woodpeckers are more easily monitored than most species because of their conspicuous active cavity trees and the exceptional stability of territory locations.

Here we identify six objectives for population monitoring: (1) to determine population status and trend; (2) to qualify for and evaluate translocation; (3) to evaluate management techniques other than translocation, using an experimental approach (adaptive management); (4) to measure impacts of activities not related to species management; (5) to document success or failure of mitigation; and (6) to conduct research. Appropriate metrics, monitoring techniques, and other information for each of these objectives are given below. Guidelines for population monitoring are given in 8C. Guidelines for monitoring cavity availability are given in 8E, and banding protocol is presented in Appendix 2. Many activities conducted for monitoring purposes require federal permits (see Appendix 1) and may require state permits as well.

Population Size and Trend

Determination of population size and trend is a primary objective of monitoring red-cockaded woodpecker populations. Such determination is the foundation of assessing progress toward recovery goals. Critical thresholds of population sizes are described in Recovery Criteria (6). Recommended rate of population increase and critical values of population declines are identified and defined in 8A.

The two metrics most important to monitoring population size and trend are number of potential breeding groups and number of active clusters. We define and describe these two metrics below, along with associated variables. Together these two metrics give a reasonable assessment of population health. Monitoring group size and/or reproductive success is not necessary to determine population size and trend. We provide protocol for the monitoring of group size and reproductive success in Appendix 2, should managers and researchers choose to evaluate these parameters as well. Monitoring group size and reproductive success is strongly recommended for critically small populations (less than 30 potential breeding groups) on public lands, and required for those populations receiving translocated birds for population augmentation (below).

Number of Active Clusters

An active cluster is a cluster in which one or more of the cavity trees exhibit fresh resin as a result of red-cockaded woodpecker activity or in which one or more red-cockaded woodpeckers are observed. Number of active clusters is a traditional measure of population size, and is generally known exactly rather than estimated. However, because this metric gives no information as to the status of the group occupying each cluster (e.g., potential breeding group, solitary male, or captured cluster), it is best accompanied by estimates of number of potential breeding groups (below).

Counting the number of active clusters consists of two management actions: (1) evaluating the activity status of known clusters (cluster activity checks) and (2) surveying for new clusters. Here we give brief protocols for each.

Cluster Activity Checks.--Activity status of each known cluster is assessed during the breeding season or just prior to it (March – July), by one or more experienced red-cockaded woodpecker biologists. It is conducted during those months because populations are lowest then and because consistency in data collection is vital to accurately assessing and comparing population trends.

All potentially active clusters are checked for evidence of red-cockaded woodpecker activity. Potentially active clusters are all clusters active within the last 5 years and all inactive clusters, including recruitment clusters, that have undergone restoration of appropriate habitat structure and/or cavity installation within that time. Evidence of activity includes fresh resin on one or more cavity trees as a result of red-cockaded woodpecker activity or the presence of one or more birds. Within each cluster, all cavities that have been active within the last 5 years are evaluated until an active cavity is located or birds are observed. If all cavities are inactive in a cluster that is normally active, a thorough search for new cavity trees is conducted in suitable habitat within 0.4 km (0.25 mi) of the cluster center.

The accuracy of this metric, number of active clusters, can be compromised if cavity trees are inappropriately assigned into clusters. Cluster designation requires at least some intense monitoring initially (see Reed *et al.* 1988a).

Number of active clusters is to be counted in all red-cockaded woodpecker populations, but the recommended frequency of cluster activity checks varies with population size. These recommendations are given in management guidelines for population monitoring (8C). To save time and effort, other monitoring activities can be conducted at the time cluster activity checks are conducted. Chief among these are evaluating the availability of suitable cavities (8E) and estimating the number of potential breeding groups (below).

Surveys for New Cavity Trees and Clusters.--Comprehensive surveys for new cavity trees and clusters within occupied and potentially occupied habitat can be conducted at approximately 10-year intervals, by trained personnel following specific protocol. During these surveys, all clusters that have been inactive for more than five years are checked for activity also. In most habitat types, surveys are best conducted by foot, using transects spaced to allow overlapping visual coverage of all potential cavity trees (pines at least 60 years in age, in pine and pine-hardwood stands regardless of tree density). Proper spacing of transects varies with overstory density, midstory density and height, and terrain. Aerial surveys, by helicopter or small fixed wing aircraft, are useful in certain habitats such as pocosin or bays where access by foot is difficult. Such surveys, performed by experienced observers, can locate most clusters containing multiple cavity trees but rarely detect all cavity trees in a cluster or all clusters. In other words, aerial surveys document the presence of cavity trees but not their absence. Ground surveys are used to verify the results of aerial surveys and to locate all cavity trees in detected clusters.

Initial surveys for active cavity trees and clusters are a fundamental step in beginning management of red-cockaded woodpecker populations. However, repeated surveys for new clusters in previously unoccupied habitat are not recommended at this time. In recent years, this management action has yielded little return for substantial investment (R. Costa, pers. comm.), presumably because most forests are currently quite young and because pioneering by red-cockaded woodpeckers is rare (see 2B).

Number of Potential Breeding Groups

An active cluster may contain a potential breeding group, a solitary male, or be captured by a neighboring group. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young. A solitary male is an adult male occupying a cluster without a mate. A captured cluster is one that does not support its own group, but is kept active by a member or members of a neighboring group. Increasing proportions of active clusters without potential breeding groups are early indicators of population decline. For this reason, number of potential breeding groups is a critically important metric. In small populations that are sampled completely, number of potential breeding groups is known exactly. In larger populations that are not sampled completely, number of potential breeding groups is estimated. Here we give directions on monitoring techniques to determine or estimate number of potential breeding groups, followed by a discussion of sampling methods.

Number of potential breeding groups is assessed during the breeding season by conducting (1) nest checks in active clusters until nesting is documented and (2) morning follows in active clusters in which no nesting is observed. Nest checks are periodic visits to active clusters during the breeding season, and consist of (1) lightly scraping on active cavity trees in an effort to flush incubating birds, (2) listening for nestlings begging for food, (3) inspecting potential nest cavities using a video probe or climbing equipment, and/or (4) watching for adults carrying food to a cavity. Nest checks are conducted every 7 to 11 days until a nest is detected. If nesting is documented, the cluster supports a potential breeding group and no further nest checks are required (unless reproductive success is being monitored, see below and Appendix 2). It is important that frequency of nest visits and the date of their initiation are consistent across years to allow accurate determination of population trend.

Morning follows are required for each active cluster in which no nest has been documented by the middle of the breeding season. Morning follows are roughly equivalent to "group checks" described by the U.S. Forest Service (USFS 1995). The target group is observed for a half an hour to an hour, immediately after the birds exit their cavities in the morning, to determine group status. Group status is classified as (1) potential breeding group, indicated by two or more birds that remain together and peacefully interact; (2) solitary male, indicated by a bird that remains solitary for the duration of the follow; or (3) captured cluster, indicated by no birds or a bird that roosted in the target cluster but joined a neighboring group. Care must be taken to accurately classify the group. Red-cockaded woodpeckers roosting extra-territorially in clusters occupied by one or more residents, captured clusters, and territorial conflicts can confuse the observer and result in erroneous status classifications. If doubt as to group status exists, the follow time is extended or the follow is repeated on another day. Two observers may be necessary if two clusters are located very close together or if cavity trees within a cluster are spread over a large area. If an extended follow or several follows fail to adequately yield the status of a group, managers may choose to color-band one or more adults to determine group status without doubt. Morning follows are preferable to evening roost checks because evening checks can miss group members that are roosting in unknown cavity trees or in neighboring clusters.

Currently, nest checks in combination with morning follows are considered sufficient to estimate number of potential breeding groups, and more intensive monitoring such as color-banding of adults and nestlings is considered unnecessary for this purpose. Of course, this approach must be implemented conscientiously if sound data are to be collected. If, in the future, it appears that nest checks and morning follows are not being implemented well, use of color-bands to estimate number of potential breeding groups may be recommended.

Sampling.--Recommended sample sizes for estimating number of potential breeding groups vary according to population size. These recommendations are given under Population Monitoring Guidelines (8C). Sample sizes may be adjusted in the future as more information concerning annual variation and sampling error is obtained. Currently, most estimates of solitary males and captured clusters are derived from populations that are color-banded, not monitored using the combination of nest checks and morning follows described above.

The best method of sampling to estimate number of potential breeding groups is to select a random sample annually, without replacement, from the set of all potentially active clusters (defined above). Stratified random sampling is to be used whenever it is suspected that some groups are consistently experiencing different conditions than others. Examples of consistently different conditions include differences in natural habitat type, past or present habitat management or silvicultural treatments, or human activities such as military training. Stratified random sampling is achieved by dividing the area to be sampled into homogeneous habitat types, habitat management history, or human activity levels. These strata are then sampled in proportion to the number of clusters that they contain, with the total combined sample equal to recommended sample size. Information concerning individual strata is limited if within-strata sample sizes are small, but accuracy of population-level parameters can be greatly increased in heterogeneous populations by using this method. Input from a wildlife statistician is strongly recommended.

Annual random sampling without replacement, stratified where appropriate, is our recommended sampling method to estimate number of potential breeding groups for populations that are not undergoing any banding. For populations in which some adults and nestlings are being banded, changing the sample annually is inefficient. For these populations, we recommend that a random sample without replacement be selected once every 5 years, and that this sample remain fixed for that 5-year period. Stratified random sampling at 5-year intervals should be used wherever appropriate. Again, consulting with a wildlife statistician is recommended.

Translocation

Translocation is described in 3D and guidelines for its use are given in section 8H and Appendix 3. There are several objectives for monitoring as part of a translocation program. First, a sample of groups is monitored to identify specific birds available for translocation. Second, eligibility status of the donor population must be evaluated and specific impacts of translocation must be assessed. Third, populations receiving translocated birds from donor populations are intensively monitored to qualify for the translocation program, to evaluate translocation success, and, potentially, to assess population-level benefits of this management technique. Similarly, in populations that are undergoing translocation of birds within the population, recipient clusters or target areas are monitored to evaluate translocation success and potentially to assess population-level benefits. We discuss each of these objectives in turn below.

Translocation of red-cockaded woodpeckers requires state and federal endangered species and bird banding permits (see Appendix 1). Specific protocols, available from the Red-cockaded Woodpecker Recovery Coordinator, are followed, and all translocation attempts are reported to the Recovery Coordinator through the Annual Report process.

Identification of Available Birds

Birds potentially available for translocation are identified by color-banding entire groups and determining group composition. This is required whether the bird is to be translocated within the population or to another population. Protocol for the banding of adults and nestlings are presented in Appendix 2. Group composition is determined by color-band observation throughout the breeding season and again by morning follows (described above) conducted just prior to the removal of birds to assess status of individuals and to determine whether the group in question meets the criteria for bird availability (see 8H). It is estimated that three to five groups will have to be banded to identify one bird available for translocation. All translocated birds are to be color-banded.

Assessing Impacts to the Donor Population

Ideally, impacts on the donor population of removing birds for translocation are assessed through the experimental approach of adaptive management (discussed in more detail below). Using this approach, donor populations are divided into one or more treatment blocks that undergo removal of birds, and one or more control areas from which no birds are removed. These assignments should be as free as possible of potentially confounding effects, such as systematic differences in habitat type or quality. Treatment and control areas are then randomly sampled at a sample size large enough to support statistical comparison. As a minimum, monitoring of samples consists of cluster activity checks and nest checks/morning follows, to derive number of active clusters and number of potential breeding groups. Preferably, all groups within the treatment and control areas are color-banded so that effects on group size and/or reproductive success (Appendix 2) can be estimated. Statistical comparisons can then be made of the proportion of clusters remaining active from one year to the next, the proportion of clusters retaining potential breeding groups from one year to the next, average group size, and/or reproductive success between treatment and control areas. Statistically significant differences in these variables will be important documentation of translocation impacts.

Currently, such experimental assessment of translocation impacts is strongly recommended but not required for participation in the translocation program. The minimum level of monitoring for donor populations is the same as that described for determining population size and trend above: monitoring number of active clusters and potential breeding groups through cluster activity checks, nest checks, and morning follows for a randomly selected sample of the size recommended in 8C, Table 11. Additionally, knowledge of group composition is required of the groups donating birds to determine bird availability (see above). If a negative change in population status is documented by this level of monitoring, such that the population no longer meets the criteria necessary to be a donor population as listed in 8H, the donor population may not contribute birds for translocation until the criteria are once again met. Without the experimental approach described above, it will not be known whether the change in population status is specifically due to removal of birds. However, regardless of the cause of the change, once a population no longer meets eligibility criteria no more birds can be removed until these criteria are once again met.

Monitoring Success of Translocations

Monitoring success of translocations is a critical aspect of the translocation program (3D, 8H). A translocation event is considered successful if the translocated bird obtains a breeding position in the target area, and the target area is defined according to the explicitly stated objective of each translocation. For more information on defining translocation success, see 3D and 8H. Once a translocated bird is released, no observations are required until the following breeding season. Observations of translocated birds should be minimized to reduce disturbance as much as possible.

Populations must be completely color-banded to qualify for population augmentation (receiving birds from donor populations). This requirement helps to ensure that recipient populations are managed at an intensity level appropriate to the great value inherent in the individual red-cockaded woodpeckers being translocated. This requirement also ensures that translocation success is accurately evaluated. Monitoring group size and reproductive success through complete color-banding (Appendix 2) yields knowledge of group composition necessary to accurately track status and location of translocated individuals.

For within-population translocations, monitoring requirements are less intensive. Groups within target areas should be banded to track success of the translocation. Donor groups have to be color-banded to identify available birds. Regular monitoring for size and trend is conducted as described above.

In addition to documenting the success or failure of an individual translocation event, monitoring can be used to better understand the benefits of translocation to recovering populations. Here the question is, how and how much does translocation contribute to population increases? Again, assessment of treatment effects is best achieved through the experimental approach of adaptive management. Such an approach consists of dividing the population into treatment areas receiving birds and control areas to which no birds are translocated. Treatment and control areas are best monitored by color-banding, which gives excellent estimates of group size, reproductive success, and change in proportions of active clusters and potential breeding groups. Statistically significant differences in these important metrics would provide important evidence of population-level benefits of translocation.

Such an approach may be difficult to use in populations undergoing population augmentation because only critically small populations (less than 30 potential breeding groups) are eligible to receive birds from donors. Thus, sample sizes of treatment and control areas would be low. Also, translocated birds may potentially appear anywhere within the population, and therefore treatment and controls may be difficult to delineate. Still, an experimental approach applied in any population undergoing translocation could potentially supply extremely valuable information on this management technique, whether the birds are sourced within or outside the population.

Evaluating other Management Actions

Population monitoring can be used to evaluate effects of other management actions as described for assessing population-level benefits of translocation, above. Such an approach is the foundation of adaptive management, in which management itself is conducted as an experiment and is responsive to new information gathered in this way. Delineated sections of populations receive treatment, and metrics such as group size and reproductive success (Appendix 2) or changes in proportions of active clusters and potential breeding groups (Population Size and Trend, above) are evaluated for statistically significant differences between treatments and controls. Some management activities that should be assessed in this way include restoration of site-appropriate pine species and pine thinning. Certain management activities, such as frequent prescribed burning, midstory reduction, and maintenance of suitable cavities, are to be applied in all clusters and therefore are not to be subjected to experiments.

Evaluating Impacts of Activities other than Species Management

Documentation of specific impacts of non-management activities on red-cockaded woodpeckers requires intensive monitoring. Examples of activities that may impact red-cockaded woodpeckers are development (e.g., roads, golf courses, housing areas), military training (e.g., impact areas, mechanized training, bivouacs, etc.), and timber management practices (e.g., thinnings, harvests). Monitoring is often required to document effects of the implementation of Reasonable and Prudent Alternatives and Reasonable and Prudent Measures pursuant to Section 7 of the Endangered Species Act.

Intensive monitoring of potential impacts consists of collecting data on cluster activity, group status, group size and composition, and reproductive success. Often, this intensive monitoring is restricted to affected clusters and sometimes neighboring clusters. This is usually done in assessing incidental take (see 4A) as related to a given activity, but such studies are often inadequate to provide definitive evidence of the cause of losses, especially since some losses may not manifest until years after the initial impact.

Impacts to woodpecker groups are best measured by an experimental approach in which treated clusters are paired with control clusters. We recommend these experiments be designed by biologists experienced with the study population, using input from a wildlife statistician. Simple monitoring of affected groups, as described above, can only document their continued existence. Experiments, however, may reveal impacts to group size or reproduction and can identify causes of effects as well.

Mitigation Monitoring

Monitoring may be required for implementation of Habitat Conservation Plans pursuant to Section 10 of the Endangered Species Act and for actions taken to offset violations of Section 9 of the Act. These cases generally require the use and documentation of specified monitoring actions. For further information concerning mitigation, see 4A.

Monitoring for mitigation includes (1) monitoring of clusters to be impacted and the neighboring clusters, and (2) monitoring of the population containing the mitigation site. The level of monitoring for impacted and neighboring clusters is determined on a case-by-case basis. Monitoring of the population containing the mitigation site is typically intensive, consisting of complete color-banding and assessment of cluster activity, potential breeding groups, group size, and reproductive success. Documentation of newly created groups requires comprehensive knowledge of the current distribution of woodpecker clusters and groups within the subject population.

This comprehensive knowledge of the population to contain the mitigation site is needed prior to the installation of artificial cavities. If artificial cavities are placed too close to another group (0.4 km [0.25 mi] or less), the provisioned site is likely to be captured by the adjacent group and no new group will be formed. If artificial cavities are placed too far from other groups (more than 1.6 to 3.2 km [1 to 2 mi]), the likelihood of woodpeckers finding the new site is reduced unless translocation is used.

Comprehensive knowledge of the mitigation site is also necessary for accurate determination of new group formation. Formation of a new group cannot be assumed from simply observing red-cockaded woodpeckers in the provisioned site unless the birds observed are known not to be part of a previously existing group. Birds from adjacent groups can be expected to routinely forage around and within the new site and may cross-roost in the new cluster. Mitigation is successful only when monitoring clearly demonstrates that a new group (of equivalent status to the group impacted, solitary male or potential breeding group) has been formed and that it represents a net gain of one group in the area occupied by the provisioned site and all immediately adjacent territories (within 3.2 km [2 mi]). The newly established group has to remain in the cluster for at least six months, including the breeding season, or there is evidence of nesting (i.e., one or more eggs are laid). Such determination is only possible through intensive monitoring including color-banding (Appendix 2).

Research Monitoring

Research monitoring is used to investigate all aspects of the biology of red-cockaded woodpeckers, including, but not limited to, demography, social behavior, and habitat use. Color-banding of red-cockaded woodpeckers is often conducted. Research monitoring that involves handling, banding, or disturbance of red-cockaded woodpeckers requires the appropriate state and federal endangered species and bird banding permits. Typically, but depending on the circumstances, a Section 7 consultation and/or Section 10 Scientific Research Permit may be required.

Annual Reporting of Monitoring Results

Managers are required to submit an Annual Red-cockaded Woodpecker Population Data Report (hereafter referred to as Annual Report) to the Red-cockaded Woodpecker Recovery Coordinator containing results of their annual monitoring efforts. Such reporting is a critical aspect of woodpecker management and recovery.

B. CAVITY MANAGEMENT: ARTIFICIAL CAVITIES AND RESTRICTOR PLATES

Loss of cavities and cavity trees was a primary cause of the decline of red-cockaded woodpeckers, and is a substantial threat currently (see 1A, 1B). Today's forests simply do not contain sufficient numbers of mature and old growth trees for populations to remain stable or increase in the absence of human intervention. Red-cockaded woodpeckers will abandon clusters if sufficient suitable cavities are not available. Cluster abandonment can lead directly to population extirpation (Costa and Escano 1989), because populations of red-cockaded woodpeckers are regulated by the number of potential breeding groups rather than by annual variation in reproduction and survival (Walters 1991; see 2B), and because natural formation of new clusters is very slow at least under current conditions of relatively young forests and small populations (see 2B). Therefore, cavity management through the use of artificial cavities and restrictor plates is absolutely critical to the conservation of most populations.

Cavity ecology, including reassons why the birds need mature and old growth trees, is discussed in 2D. Community ecology, including the use and enlargement of red-cockaded woodpecker cavities by other species, is discussed in 2F. In this section, we describe the various methods of artificial cavity installation and their respective advantages and disadvantages, and also show how restrictor plates are used. Guidelines for the use of artificial cavities and restrictor plates are presented in 8E.

Artificial Cavities

Artificial cavities for red-cockaded woodpeckers were developed in the late 1980's and early 1990's (Copeyon 1990, Copeyon *et al.* 1991, Allen 1991, Taylor and

Hooper 1991), and have since revolutionized management of red-cockaded woodpeckers. Prior to their development, biologists were unable to address the severe limitation in cavities impacting most populations, and therefore had little ability to slow, much less reverse, the decline of the species. With the advent of artificial cavity technology, cavities and entire clusters can be provided. In combination with aggressive habitat management, cavity management can stabilize and increase populations.

The power of the new technology to conserve and protect red-cockaded woodpeckers was illustrated soon after development, when Hurricane Hugo destroyed nearly 90 percent of the cavity trees on the Francis Marion National Forest in 1989. Rapid and extensive use of drilled cavities and cavity inserts following the devastation saved a large proportion of the population and allowed for population growth in subsequent years (Watson *et al.* 1995). During the 1990's, many other populations were stabilized, and some increased, through cavity provisioning in combination with prescribed burning. In addition, other recently developed conservation and management tools such as translocation, mitigation, and Habitat Conservation Plans are based to a large degree on the use of artificial cavities.

However, artificial cavities have not always been used effectively. Widespread and haphazard installation of artificial cavities can have negative impacts on red-cockaded woodpeckers and their potential cavity trees, and misdirects valuable management efforts and funds. Before artificial cavities are installed, managers should have a clear understanding of population dynamics in this species, especially the role of cavities and the effects of spatial structure on population growth or decline (see 2B, 2C). In addition, managers need to be well versed in the benefits and drawbacks of the various installation methods, so that they know what to expect of cavities already installed in their populations and can choose the appropriate method for additional cavities. Finally, proper maintenance of artificial cavities is essential (e.g., Montague et al. 1995).

There are basically four methods of constructing artificial cavities: Copeyon-drilled cavities and starts, cavity inserts, and modified drilled cavities. Copeyon-drilled cavities and starts were developed at North Carolina State University (Copeyon 1990). Cavity inserts were developed at the Southeastern Forest Experiment Station of the U.S. Forest Service, Clemson University (Allen 1991). Taylor and Hooper (1991) created the modified version of Copeyon's drilled cavity.

Basically, drilled cavities are constructed by drilling two tunnels: first, an entrance tunnel that the birds will use, and second, an access tunnel that is then used by the drill operator to ream out the cavity chamber. The access tunnel is plugged and sealed after the chamber is constructed. The two drilled methods, Copeyon and modified drilled, differ in the dimensions of the access tunnel and consequently in their durability. Drilled starts are drilled entrance tunnels with a widened interior. Cavity inserts are pre-fabricated nest boxes inserted into an opening in the tree created with a chainsaw. More detailed descriptions of these techniques are given below, followed by a comparison of their relative merits and applications.

Construction of Copeyon-drilled Cavities and Starts

The Copeyon-drilled method of cavity construction is illustrated in Figures 2 and 3. Candidate trees for Copeyon-drilled cavities must have at least 15.2 cm (6 in) of heartwood and no more than 8.9 cm (3.5 in) of sapwood, and less sapwood is preferred.

To construct the cavity, a gasoline-powered drill equipped with a wood-boring bit 5.1 cm (2 in) in diameter is used to excavate an entrance tunnel through the sapwood and into the heartwood, at a slightly upward angle. The same bit is used to begin a second tunnel 5.1 to 10.2 cm (2 to 4 in) above the entrance tunnel. This access tunnel is then continued at a downward angle of roughly 60 degrees, using a 4.2 cm (1.65 in) bit, until the back of the entrance tunnel is intersected and 7.5 to 10 cm (3 to 4 in) below the entrance tunnel have been opened to form a rudimentary chamber. The rudimentary chamber is then hollowed out, using the 4.2 cm (1.65 in) bit, to complete the cavity. The extent to which a cavity approaches the shape and dimensions of a naturally excavated cavity depends on the width of sapwood, the diameter of the heartwood core, and the skill of the drill operator. Care must be taken to avoid drilling into the sapwood at the front of the cavity chamber, by drilling at too steep an angle, or at the rear of the cavity, by drilling too deep.

The access tunnel is sealed with wood plugs and non-toxic wood putty. A thin, flexible wood veneer called “wiggle board” may be used to line the entrance tunnel instead of wood putty. A comprehensive maintenance schedule is required in the weeks immediately following construction, to inspect for resin leakage.

Upon completion of the cavity, resin wells are drilled with a 1.3 cm (0.5 in) twist bit or cut with a knife or chisel, and the area several feet above and below the cavity is scraped with a bark knife or hoe blade to give the tree the reddish appearance of an active red-cockaded woodpecker cavity tree. Non-toxic white or almond paint is sprayed below resin wells, above and below the cavity entrance, and completely around the tree bole in the vicinity of the cavity to simulate natural pine resin.

Drilled starts are constructed using the above method to create an entrance tunnel (Figure 3). The access tunnel and cavity chamber are not constructed. Instead, a 4.2 cm (1.65 in) bit is used to enlarge the rear of the entrance tunnel (within the heartwood) to give the red-cockaded woodpecker room to excavate the cavity chamber. Such an advanced start may be large enough for a red-cockaded woodpecker to roost within, and red-cockaded woodpeckers can complete a drilled start in several months to a year (J. Carter III, pers. comm., Harding 1997). Drilled starts can be placed in trees with too much sapwood and/or too little heartwood to accept a drilled cavity.

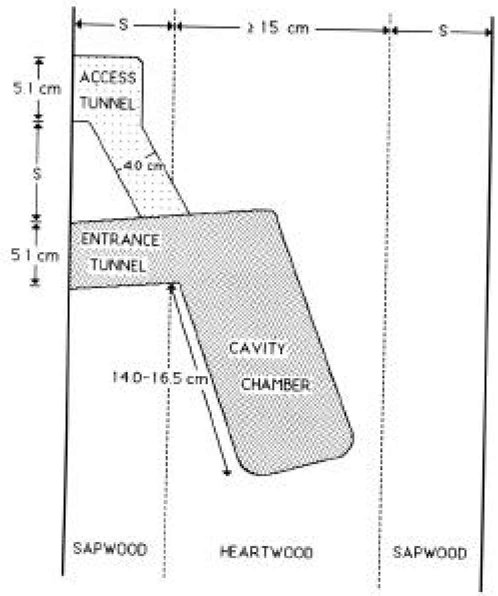


FIGURE 3. Diagram of Copeyon-drilled cavity (Copeyon 1990).
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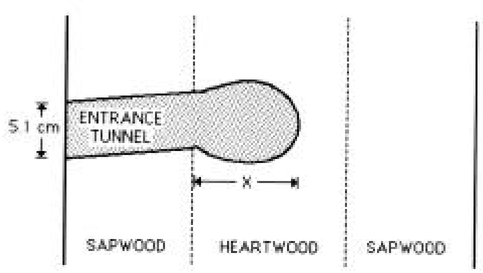

FIGURE 4. Diagram of Copeyon-drilled start (Copeyon 1990).
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Construction of Modified Drilled Cavities

Taylor and Hooper's (1991) modification of Copeyon's drilled cavity technique differs from the original technique in that larger bits are used to begin the access tunnel (8.9 cm [3.5 in] bit) and to construct the vertical access tunnel and cavity chamber (7.6 cm [3 in] bit). Using this technique, most of the access tunnel and cavity chamber can be excavated at once. Resin wells are created and the trunk is painted to resemble a natural cavity tree just as described above.

Construction of Cavity Inserts

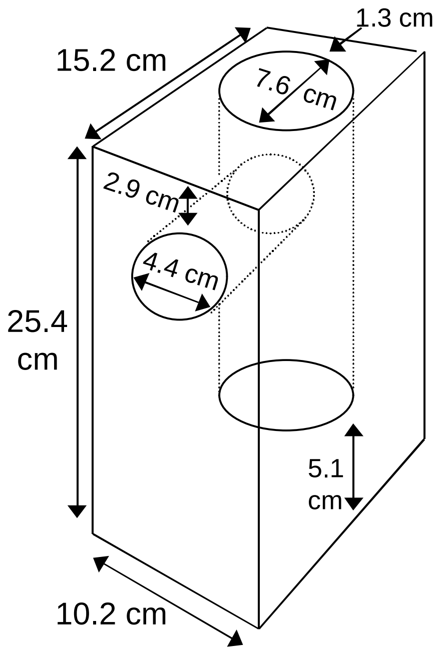
The cavity insert (Allen 1991) is a completely different approach to cavity construction. In this method, a chainsaw is used to cut a rectangular opening in a pine tree, and a wooden block with a pre-drilled cavity is inserted into the opening (Figure 4). The cavity insert is secured in the tree with wooden wedges and non-toxic wood putty. A full frontal restrictor plate is used to prevent damage by pileated woodpeckers. Because inserts may be placed in trees that are mostly sapwood, the insert must be heavily coated with a non-toxic waterproof sealant to prevent resin leakage through small, sometimes imperceptible, cracks into the cavity chamber. Cavity inserts are held primarily within the sapwood of the tree, and so can be placed in pines that have little heartwood. Trees of at least 38.1 cm (15 in) in diameter at cavity height are required. (If trees of this size are not available, use the drilled cavity or drilled start technique). Resin wells are created, and the trunk is scraped and painted to simulate a natural cavity tree.

Southern yellow pine (*Pinus* spp.) is the preferred wood to use in constructing inserts. In the past, western red cedar (*Thuja plicata*) was used, but we now suggest using southern yellow pine as it is a harder wood than western red cedar.

Comparison of Construction Methods

Preliminary work evaluating the four methods of cavity provisioning was conducted in the Francis Marion National Forest (Hooper *et al*., unpublished), an appropriate location for such an investigation because of the large-scale provisioning of all cavity types following Hurricane Hugo. Although the population increased rapidly following the devastation of Hugo (Watson *et al.* 1995), a declining trend has been present since 1996 (USFWS, unpublished). Aging of the artificial cavities is considered a potential contributing factor to recent declines, in addition to problems implementing the prescribed burning program.

FIGURE 5. Diagram of a cavity insert (adapted from Allen 1991). Full restrictor plate and non-toxic coating, both required on all inserts, are not illustrated here.



Hooper *et al.'s* (unpublished) data suggests that Copeyon-drilled cavities and starts remain in use for a remarkably long period. After an average of 8.5 years, more than two-thirds of Copeyon-drilled cavities remained in use, and one quarter of the remaining available Copeyon-drilled cavities were in use as nest cavities. Half of all the original drilled starts were in use as cavities 8.5 years later, and one quarter of the remaining available cavities that were originally drilled starts were in use as nest cavities. Cavity inserts did not exhibit the same durability. Just less than half of cavity inserts remained in use after 8.5 years, and none were used as nest cavities. However, cavity inserts were installed in clusters of consistently lower quality than those in which drilled cavities were placed (D. Allen, pers. comm.). Because clusters receiving inserts had suffered heavier hurricane damage and had virtually no old pines remaining after the storm, comparisons of durability between inserts and drilled cavities are biased by differential habitat quality. Modified drilled cavities showed the lowest durability of all cavity types, without the same systematic bias in habitat quality. Less than one third of modified drilled cavities were used an average of 7.3 years later, and none as nest cavities.

Differences in cavity survival did not appear to result from differential mortality of trees holding the various cavity types (Hooper *et al.*, unpublished). Less than 2 percent of pines with artificial cavities died from structural failure of the tree bole resulting from cavity installation, and this did not differ between trees containing inserts and those with drilled cavities. Cavity trees with inserts did not appear to suffer more damage from wind or physiological stress than other cavity trees, a conclusion also reached by Lowder (1995). Instead, lowered survival of inserts was due to higher rates of flooding and cavity enlargement. Inserts were not fitted with full restrictor plates (below), which would have reduced enlargement rates considerably. Almost half of all inserts had the interior altered by the birds to the point where the insert was breached and the tree itself was visible. Such expansion did not appear to affect the activity status of the inserts.

Lowered survival of modified drilled cavities was due to high rates of damage to the entrance tunnel and access plug. The larger access plug was far more likely to rot, and the septum between the access plug and entrance tunnel was more likely to be altered by decay or by other woodpeckers, than were those of Copeyon-drilled cavities. Enlargement of completed drilled starts was negligible.

Recommended Construction Methods

In light of the current value of cavity trees and potential cavity trees, we have formulated careful guidelines for the construction of artificial cavities (see 8E). Copeyon-drilled cavities are recommended for cavity provisioning if pines with sufficient heartwood are available. Managers may choose to drill starts instead of cavities if the cavities are not likely to be needed for a year or more. (Drilled starts over one year in age were found to be as useful to the birds as Copeyon-drilled cavities; Hooper *et al.*, unpublished.) Use of inserts is recommended when cavities are needed rapidly and there are no pines old enough to support a Copeyon-drilled cavity. Use of the modified drilled method of cavity construction is to be avoided.

Use of either method of artificial cavity installation, cavity inserts or drilled cavities, requires conscientious and careful application with special attention to potential problems specific to each method. Inserts require a full restrictor plate and heavy coating with a non-toxic waterproof sealant. All inserts must be inspected carefully for cracks prior to and following installation; any damaged inserts should be discarded. Flooding of inserts can be minimized by using restrictors, by constructing entrance tunnels at a slightly upward angle, and by drilling a drainage hole, 0.95 cm (0.375 in) in diameter from the lower front of the box to the bottom of the cavity chamber. Finally, red-cockaded woodpeckers have a tendency to breach the cavity chamber of inserts. This behavior has the potential to result in resin-related deaths, although it is likely that such breaching occurs slowly enough to allow resinosis (saturation of sapwood with hardened resin; see Conner and Rudolph 1995a), and that resin leaks into the cavity chamber are rare.

When Copeyon-drilled cavities and starts are used, it is imperative that they be screened for at least one month following installation and checked for resin leaks as described below. All artificial cavities and starts must be inspected and maintained as described below and in section 8E.

Cavity Screening, Resin Leakage, and Maintenance Checks

All drilled starts and drilled cavities must be screened with heavy wire mesh (0.64 by 0.64 cm [0.25 by 0.25 in]) to prevent access by red-cockaded woodpeckers for at least four weeks after installation to ensure that no resin is leaking into the cavity chamber. If leaks are detected, cavities must remain screened and additional checks conducted. Persistent resin leakage into entrance tunnels can be treated using repeated scraping, applications of wood putty, replacement of wooden veneer, or redrilling with a 5.1 cm (2 in) diameter bit. If the leak is severe, cavities should be blocked with a wooden plug at least 7.6 cm (3 in) long and replaced elsewhere. Artificial cavities and starts should be constructed during the non-growing season (except in emergencies) to reduce the likelihood of resin leakage.

All artificial cavities, including inserts, and drilled starts should be checked for latent resin leakage during the first growing season after installation. If this check is negative no further maintenance checks are required for drilled starts and cavities unless the entrance tunnel begins to heal over from lack of red-cockaded woodpecker use. If an entrance tunnel is redrilled or scraped, screen it again as described above. Inactive artificial starts and cavities require periodically redressing of resin wells and rescraping of bark to enhance the likelihood of discovery and occupation by red-cockaded woodpeckers.

Cavity Height, Orientation, and Location

In general, artificial cavities should be placed as high as the recipient trees will allow, within the range of natural cavity heights in the surrounding habitat. Height of drilled cavities may be limited by the amount of heartwood present, and height of inserts may be limited by tree diameter; both will vary according to local conditions. For example, sites with low site index such as sandhills will support only low cavities. Cavities should be oriented so that the entrance faces west, because natural cavities show a tendency to be oriented in this direction (Locke and Conner 1983).

Cavities should be constructed within 66 m (200 ft) of existing cavity trees to maintain the integrity of the cluster. Inserts should not be placed in pines less than 45 years old, because the growth of the tree could damage the insert and possibly result in a dangerous situation. Additionally, inserts are not to be placed in relicts, flat-tops, and very old pines; these extremely valuable trees should be left for natural excavation or, if absolutely necessary, used to support drilled cavities.

Number and Definition of Suitable Cavities

Carrie *et al.* (1998) found that group size of red-cockaded woodpeckers in Louisiana increased with the number of cavities provisioned, and recommended a minimum of three to four suitable cavities per cluster. Results of the study more clearly supported the use of four suitable cavities rather than three as a minimum. A minimum of four suitable cavities per cluster has also been the traditional policy of the U.S. Fish and Wildlife Service. We therefore recommend that each cluster contain at least four suitable cavities. This recommendation does not apply to populations that have met the population goals identified in delisting criteria or in site-specific management plans.

A suitable cavity has a single entrance, an entrance tunnel that is not enlarged, a cavity chamber that is not enlarged, a solid base, and is dry and free of debris. In addition, the cavity plate must not contain large amounts of dead wood (Carrie *et al.* 1998). Relict, enlarged, or any suspect cavities must not be considered suitable for use by red-cockaded woodpeckers.

Restrictor Plates

The cavity restrictor was developed at North Carolina State University in the mid-1980's (Carter *et al.* 1989), to prevent and repair the enlargement of red-cockaded woodpecker cavity entrances. Cavity restrictors are square or rectangular metal plates with an inverted U-shaped or circular opening, 3.8 to 4.4 cm (1.5 to 1.75 in) wide, in the center of the plate. Typically, they are made of approximately 22-gauge stainless steel, aluminum, or sheet metal; expanded metal and quarter-inch hardware cloth are also suitable. Restrictors range in size from 7.6 by 7.6 cm (3 by 3 in) to much larger. Smaller restrictors are used for starts and cavity entrances that show little damage, while the largest sizes are used for enlarged cavities and to cover the front of cavity inserts. Cavity inserts are now fitted with full restrictor plates prior to installation.

The inverted U-shape opening was the original design (Carter *et al.* 1989). The opening extends from the entrance hole to the bottom of the restrictor plate, allowing the birds' feet to contact the tree surface when entering and exiting the cavity. If restrictor plates with circular openings are used, the metal directly below the opening of the entrance tunnel must be removed to allow the birds a secure foothold. Care must be taken to ensure that this metal is not so rough or jagged as to cause injury to the birds' toes or feet. Smooth, slick metal below the entrance is a deterrent to red-cockaded woodpecker use and may completely prevent use of some cavities.

For natural and drilled cavities, restrictors are attached to the tree with nails or screws at all four corners placed in pre-bored holes. Wood screws (1.3 cm [0.5 in] long) are preferred over nails because they allow easy repositioning of the restrictor with minimal damage. Screws or nails longer than 2.54 cm (1 in) should not be used because the cavity chamber may be breached, creating a hazard for cavity occupants. Restrictors are often painted brown with a non-toxic paint in order to blend with the tree.

The primary use of restrictors is to repair or prevent enlargement of cavity entrances (see also 2F), usually done by pileated woodpeckers but occasionally by red-bellied and red-headed woodpeckers, northern flickers (*Colaptes auratus*), and gray squirrels (*Sciurus carolinensis*. Pileated woodpeckers can seriously damage cavities in just minutes, and can completely destroy cavities in less than an hour, but the reasons for this behavior remain unknown. Further, pileated woodpeckers may damage some cavities in a cluster, while leaving others unharmed. Some cavities, or entire clusters, can exist undamaged for years in areas frequented by pileated woodpeckers, then suffer a sudden onset of damage. In extreme circumstances, pileated woodpeckers can damage or destroy most or all cavities in a cluster, leading to cluster abandonment. Commonly, a cluster suffers chronic damage over several years, leading to cluster instability and eventual abandonment. Because of the critical importance of suitable cavities to red-cockaded woodpeckers, use of restrictors to prevent and repair damage is an essential element of management for many populations. The number of cavities restricted in a cluster will vary according to circumstances, and may range from none to all cavities present. Knowing when to use restrictors to prevent damage, and when their use is not necessary, is a skill gained from experience and good judgment.

Whereas pileated woodpeckers can destroy red-cockaded woodpecker cavities by doubling the diameter of the entrance tunnel and exposing the cavity chamber, red-bellied woodpeckers, red-headed woodpeckers, and flickers normally enlarge cavity entrance tunnels and cavity chambers only enough to allow access. Over several years, these species can modify a cavity so that red-cockaded woodpeckers will rarely, if ever, use it. Although some rate of loss of red-cockaded woodpecker cavities due to modification by other species is natural, red-cockaded woodpeckers cannot always tolerate such losses in today's forests. In small, declining, or isolated populations, any loss of suitable cavities may not be tolerable. It will usually be necessary to use restrictors to repair enlargement by these species in such populations.

In the past, restrictors were sometimes used to exclude some avian cavity kleptoparasites, such as red-bellied woodpeckers, red-headed woodpeckers, and European starlings (*Sturnus vulgaris*), from cavities with either enlarged or unenlarged entrance tunnels. Variation in diameter of natural entrance tunnels allows access of some individuals or species to some cavities. For instance, both male and female red-bellied woodpeckers can enter some natural, unenlarged entrance tunnels, while only the slightly smaller females can access others. Eastern bluebirds and southern flying squirrels can access all cavities. However, use of restrictors on unenlarged cavities to exclude cavity kleptoparasites is not recommended, because of danger to red-cockaded woodpeckers. The difference between excluding a starling and excluding or entrapping a red-cockaded woodpecker is a matter of millimeters. Several deaths of adult red-cockaded woodpeckers resulting from entrapment in restricted cavities have been documented in the North Carolina Sandhills (J. Carter III, pers. comm.). In many cases, the affected red-cockaded woodpecker had successfully entered the cavity, but could not exit. Given that population-level impacts of cavity kleptoparasitism have not been demonstrated (Kappes 1993, Conner *et al.* 1996, Mitchell *et al.* 1999; see 2F), there is little justification for use of restrictors to exclude kleptoparasites.

Restrictors must be inspected annually, because restrictors that have loosened or come out of place are a serious hazard to red-cockaded woodpeckers and have resulted in multiple deaths throughout their range (R. Costa, pers. comm.). Injury and death can result from feet, wings, or legs of birds being caught under the edges or corners of restrictors. In populations where annual monitoring can not be accomplished, restrictors will not be used. Restrictors may have subtle costs as well: examination of a limited number of adult red-cockaded woodpeckers using restricted cavities showed visual evidence of excessive bill wear (J. H. Carter III, pers. comm.). Raulston *et al.* (1996) concluded that restrictors did not affect woodpecker survival or bill wear, but this was a small, short study and further research is warranted. With proper inspection and maintenance, restrictors may help keep a cavity in use for many years (Wood *et al.* 2000).

In summary, restrictors are an important management tool, but they must be used in the appropriate situations only, installed by experienced personnel, and monitored annually. Widespread use of restrictors without specific need for them is not recommended, because they are potentially dangerous. Cavity restrictors are best used to prevent or repair enlargement of cavities by pileated woodpeckers. In small populations, their use against cavity damage by other species may also be necessary. Restrictors should not be used to prevent starlings and other woodpeckers from using the cavity, because red-cockaded woodpeckers can be entrapped as well.

C. Predator and Cavity Kleptoparasite Control

Red-cockaded woodpecker populations that are healthy and of medium to large size require no predator control and few measures to combat cavity kleptoparasites. Predators and cavity kleptoparasites were not among the original causes of the decline of red-cockaded woodpeckers, and their removal or control will not result in population or species recovery. Critically small populations, however, may not be able to tolerate even occasional loss of nests or cavities. Managers of critically small populations (less than 30 potential breeding groups) may choose to use predator management techniques, but only in concert with aggressive management of foraging and nesting habitat.

But, managers should be aware that predator exclusion devices may have unexpected consequences, since indirect interactions among predators, kleptoparasites, and red-cockaded woodpeckers are not understood. For this reason, use of snake exclusion techniques is generally discouraged. Snake exclusion devices should only be considered for trees containing newly installed artificial cavities or on active trees with a minimal resin barrier that are likely to be used as nest sites. If predator management is conducted, use of an experimental approach with adequate controls is strongly encouraged.

Methods of predator and kleptoparasite control are described in this section, and guidelines for their use are presented in 8G. A general discussion of predation, cavity kleptoparasitism, and cavity enlargement is given in 2F, and use of restrictors to control cavity enlargement is described in 3B and 8E. Most control measures used in red-cockaded woodpecker populations have been designed for one of two taxa: flying squirrels and rat snakes. Methods vary from lethal measures to non-invasive techniques such as bark shaving (Saenz *et al.* 1999), provision of nest boxes (Loeb and Hooper 1997), and retention of snags (Kappes and Harris 1995). In general, the least invasive techniques are preferred.

Exclusion of Rat Snakes

Three artificial methods of excluding rat snakes from cavity trees have been explored: snake nets, snake excluder devices (SNEDs), and the bark-shaving technique. Snake nets were developed by Neal *et al.* (1993b, 1998), and consist of a folded nylon monofilament net stapled to cavity trees at roughly 1.5 m (5 ft) above the ground. Rat snakes attempting to climb cavity trees get entrapped in the nets and soon die from heat stress. Red-cockaded woodpeckers can also get caught in these nets. Samano *et al.* (1998) reported the death of four red-cockaded woodpeckers and the entrapment of a fifth (rescued by biologists) in snake nets in a single year. Because of the documented danger to red-cockaded woodpeckers and the lethal effects on snakes, use of snake nets is prohibited.

Snake excluder devices (SNEDs) were developed by Withgott *et al.* (1995), and consist of a strip of lightweight aluminum flashing attached to the trunk of the cavity tree at ground level or up to 1.5 m (5 ft) above the ground. Withgott *et al.* (1995) used a 60 cm (23.6 in) wide band of aluminum flashing that they wrapped around and stapled to the bole of cavity trees. Prior to stapling the flashing in place, the bark on the bole of the cavity tree was scraped to smooth the surface and permit a tighter fit. The bark was also scraped relatively smooth about 30 cm (1 ft) above and below each SNED after installation. SNEDs proved to be highly effective in preventing climbing by rat snakes, and did not appear to affect use of the tree by red-cockaded woodpeckers (Withgott *et al.* 1995). Neal *et al.* (1998) reported numerous over-climbs of SNEDs on red-cockaded woodpecker cavity trees in Arkansas and Mississippi that were fitted with narrow metal flashing (less than 0.9 m [3 ft]), whereas only one over-climb occurred on 92 cavity trees fitted with metal flashing greater than 0.9 m (3 ft) wide. Thus, SNEDs greater than 0.9 m (3 ft) wide appear to be an effective, non-lethal method to reduce rat snake predation on red-cockaded woodpecker nest cavities. SNEDs require adequate annual maintenance, to check for dangerous tears in the aluminum and to remove any resin accumulation.

Bark-shaving was recently developed by Saenz *et al.* (1999) as an effective means of deterring climbing by rat snakes. A very sharp draw knife is used to shave the bark around the circumference of the tree in a 1 m (3.3 ft) band, at breast height, to eliminate furrows and rough surfaces without cutting into the cambium (Saenz *et al.* 1999). Breast height was chosen for ease of execution. This technique proved to be nearly 100 percent effective in experimental trials, and the one over-climb event occurred 3 ½ months after shaving on a tree that had developed a rough surface again (Saenz *et al.* 1999). Reshaving prevented the snake from climbing this tree again. Thus, bark-shaving can be used at the start of the nesting season or upon installation of artificial cavities, to give roughly three months of additional protection. Care must be taken not to damage the cavity tree by cutting into xylem tissue. Also, resistance to fire may be decreased by bark-shaving (Saenz *et al.* 1999), and any cavity tree thus treated should be well protected against fire.

The resin barrier created by red-cockaded woodpeckers is an extremely effective means of excluding rat snakes from cavity trees, especially in highly resinous longleaf pines (Ligon 1970, Dennis 1971b, Jackson 1974, 1978a, Rudolph *et al.* 1990a). In longleaf pine habitats, no additional measures are needed to control rat snakes regardless of population size. For critically small populations (less than 30 potential breeding groups) in pine types other than longleaf, managers may choose to install snake excluder devices or use the bark-shaving technique on trees likely to be used as nest trees. Managers may also choose to use bark-shaving to provide short-term protection against snakes when installing artificial cavities. Bark-shaving may be especially useful just before the nesting season, to protect active artificial cavity trees that do not yet have a resin barrier.

In summary, use of snake exclusion techniques should be restricted to pines containing newly installed artificial cavities, or pines with minimal resin but likely to be used as nest sites, in critically small populations. Use of snake exclusion techniques in other situations is discouraged.

Exclusion of Southern Flying Squirrels

Southern flying squirrel excluder devices (SQEDs) were developed by Montague *et al.* (1995), and consist of sheets of aluminum flashing that are wrapped around the cavity tree above and below the cavity entrance. Small portions of the flashing extend perpendicular to the bole of the pine tree. If kept clean of hardened pine resin, the SQEDs serve as an effective barrier and deny squirrel access to red-cockaded woodpecker cavities when they climb up and down the bole of cavity trees (Montague *et al.* 1995, Loeb 1996). However, a "skilled" flying squirrel can fly directly to a cavity entrance if adjacent pines are sufficiently close to permit a glide path. SQEDs require inspection and maintenance at least yearly, to ensure no dangerous tears develop and to keep them free from resin. Again, use of SQEDs is not necessary in populations of 30 or more potential breeding groups.

Montague *et al.* (1995) recommended that cavities reclaimed from southern flying squirrels be vacuumed to remove chewed pine needles and squirrel feces that are typically present in cavities with squirrels. Cavity cleaning may increase the probability that red-cockaded woodpeckers will reoccupy the cavity.

Lethal vs. Non-lethal Methods of Control

Rat snakes, southern flying squirrels, and other predators and kleptoparasites are all important components of southern pine ecosystems. Measures to control these species should not be applied in all areas managed for red-cockaded woodpeckers. Large and medium-sized populations located in areas of quality habitat should have sufficient reproduction and population size to easily offset any losses caused by predation and kleptoparasitism.

However, in critically small populations (less than 30 potential breeding groups) where appropriate habitat is in the process of being restored, or where populations are being reintroduced, predator and kleptoparasite management may be applied. Retention of snags and creation of nest boxes are important management options (Harlow and Lennartz 1983, DeFazio *et al.* 1987, Kappes and Harris 1995, Loeb and Hooper 1997). Use of lethal devices and euthanasia to control predators and kleptoparasites is discouraged.

D. TRANSLOCATION

Translocation is the artificial movement of wild organisms between or within populations to achieve management objectives. It is an important tool for the management and recovery of red-cockaded woodpeckers, if used in the appropriate situations and in the appropriate manner. In this section, we describe the reasons for using translocation and give a brief review of its use and success in red-cockaded woodpecker management. Guidelines for its use are presented in 8H.

Translocation of red-cockaded woodpeckers has four specific applications for which it is best suited: (1) augmentation of a population in immediate danger of extirpation, (2) development of a better spatial arrangement of groups, to reduce isolation of groups or subpopulations, (3) reintroduction of birds to suitable habitat within their historic range, and (4) management of genetic resources. We refer to the first application as population augmentation. This consists of moving birds from a healthy donor population to a critically small recipient population (less than 30 potential breeding groups). We refer to the second application as strategic recruitment, which is achieved by moving birds from within or between populations to recruitment clusters strategically located to link groups and subpopulations. All translocations, including those intended to augment a population, should serve to develop better spatial arrangements of groups.

Population augmentation is a means of buffering at-risk recipient populations against effects of demographic and environmental stochasticity (see 2C), which can result in extirpation of critically small populations regardless of other management efforts. This management action also serves to counteract the inbreeding depression that can reduce the persistence of very small, isolated populations (Haig *et al.* 1993, Daniels *et al.* 2000). Augmentation is not necessary for larger populations because they are not so highly vulnerable to stochastic events (other than catastrophes).

Strategic recruitment is a means to develop the beneficial spatial arrangements that can dramatically increase persistence and health of red-cockaded woodpecker populations (Conner and Rudolph 1991b, Crowder *et al.* 1998, Letcher *et al.* 1998, Walters et al. 2002b). Linking isolated groups and subpopulations with newly established breeding groups in strategically located recruitment clusters may be a slow process, because each new cluster must be within helper dispersal distance of active clusters. However, over time strategic recruitment can optimize spatial arrangements of groups within populations.

Reintroduction is the establishment of new populations in restored habitat within the species historic range. Reintroduction is currently being used experimentally to establish a new population in northern Florida (Hagan and Costa 2001), but at this time it is not a management technique available for widespread use. Establishment of new populations is not a criterion for delisting the species. Still, reintroduction can have a critical role in restoration of historic communities and conservation of local species diversity.

For the purposes of population augmentation or strategic recruitment, a potential mate can be moved to a cluster inhabited by a solitary individual (mate provisioning), or potential pairs can be moved simultaneously to unoccupied clusters. Reintroduction of birds is best accomplished by simultaneously translocating multiple potential pairs to suitable habitat (Carrie *et al.* 1999, Hagan and Costa 2001). Another current application of translocation is its use for mitigation (see 4A). Future use of the technique may include the translocation of individuals among recovered populations and essential support populations to counteract species-wide genetic drift (see 2C).

Benefits and Drawbacks to Translocation

Translocation has its benefits and drawbacks. It can be an important method to counteract loss of genetic variation but may also serve to disrupt valuable local genetic resources (Haig *et al.* 1994a, Hedrick 1995). It is an especially useful tool in the management of red-cockaded woodpeckers, because population dynamics in this species are regulated by the number of potential breeding groups in a population, not the annual number of young produced (Walters 1991; see 2B). Therefore, some juvenile birds may be moved without affecting the overall population size or trend. However, impacts to the donor areas and populations must be carefully evaluated and controlled (Griffith *et al.* 1989, Haig *et al.* 1993). Most importantly, translocation must not be used as a substitute for habitat management and restoration, two more difficult but much more fundamental management tasks (e.g., Pitelka 1981, Meffe 1992). Causes of population decline should always be identified and removed before translocation is attempted (Short *et al.* 1992, Meffe 1992, Caughley 1994).

Translocation can potentially disrupt local adaptations and genetic coadaptation. Local adaptations to environmental conditions confer highest fitness to individuals remaining in a specific area, whereas genetic coadaptation gives highest fitness to those individuals retaining coadapted gene complexes. Coadapted gene complexes are sets of genes that evolved together and impart greater fitness than the sum of each individual gene’s contribution. A coadapted gene’s effect depends on the presence of one or more other genes (Templeton *et al.* 1986). In red-cockaded woodpeckers, there is no direct evidence of local adaptations or coadaptation, but researchers have documented some genetic structure across the species’ range (Stangel *et al.* 1992, Haig *et al.* 1994a, 1996, Stangel and Dixon 1995). Restricting translocations to short geographic distances only is important to the conservation of local genetic resources (Haig *et al.* 1994a).

Translocation can also spread parasites. Fortunately, the prevalence of blood parasites in red-cockaded woodpeckers is low, and cavities are relatively free of blood-feeding insects (Pung *et al.* 2000).

Thus, in general, translocation of red-cockaded woodpeckers is a short-term tool to be used in specific crisis situations with utmost caution and only after habitat suitable in quality and quantity exists (Griffith *et al.* 1989, Kleiman 1989) and habitat management plans emphasizing frequent fire are fully implemented. In addition, translocation may have a long-term application among recovered populations to counteract species-wide genetic drift, if natural dispersal is deemed insufficient for adequate gene flow. Translocations for this purpose require careful planning to offset effects of genetic drift without affecting local genetic resources (see Hedrick 1995).

History of Translocation of Red-cockaded Woodpeckers

Prior to the development of artificial cavities (Copeyon 1990, Allen 1991) and translocation (DeFazio *et al.* 1987), many managers and biologists were pessimistic about the long-term persistence of red-cockaded woodpeckers (Ligon *et al.* 1986, Escano 1995). In particular, there was little hope of conserving and restoring the many small, declining populations. Recently, however, most populations have been stabilized and/or increased (Hooper *et al.* 1990, Richardson and Stockie 1995, Watson *et al.* 1995, Walters and Meekins 1997, Walters *et al.* 1997, USFWS unpublished). For some small populations, increases in population size were achieved through aggressive habitat management and cavity provisioning without resorting to translocation (Richardson and Stockie 1995, Watson *et al.* 1995, Walters and Meekins 1997, Walters *et al.* 1997, USFWS unpublished). However, the stabilization and increase of other critically small populations has required the use of translocation in concert with intensive habitat and cavity management (DeFazio *et al.* 1987, Allen *et al.* 1993, USFWS unpublished).

Initially, translocations were performed as emergency efforts to rescue individual birds from military construction impacts (e.g., Odom *et al.* 1982) or loss of habitat to timber harvests (e.g., Reinman 1984). These early efforts met with very little success, and several authors criticized the use of translocation especially as mitigation for destruction of occupied clusters (Cely 1983, Jackson *et al.* 1983). Odom (1983) concluded, “red-cockaded woodpecker relocation is not recommended as a management tool at this time”, but also noted its potential and called for further research. Following these initial attempts in the early 1980's, experiments were performed in the late 1980's and early 1990's to test translocation methods and its usefulness as a recovery tool (Allen *et al.* 1993, Costa and Kennedy 1994).

Perhaps the best known of these experiments in translocation was the extremely intensive effort to conserve and restore the critically endangered red-cockaded woodpecker population in the Savannah River Site in South Carolina (Allen *et al.* 1993, Gaines *et al.* 1995, Franzreb 1999). By late 1985, this population was reduced to one breeding pair and two solitary males (DeFazio *et al.* 1987) and aggressive management was begun, including habitat management, cavity installation, and translocation (Gaines *et al.* 1995). From 1986 to 1995, 54 red-cockaded woodpeckers were translocated, including 21 translocated from four donor populations outside the study area and 33 from within the population (Franzreb 1999). By 2000, the Savannah River Site population consisted of 31 potential breeding groups (P. Johnston, pers. comm.). Clearly, translocation was an important part of the dramatic change in this population’s status.

Following the success of the Savannah River Site translocation attempts (Allen *et al.* 1993), the Southern Region of the U.S. Forest Service decided to implement red-cockaded woodpecker translocations as a management tool in 1989 (Escano 1988). Because the Apalachicola National Forest in Florida contained the largest and only recovered red-cockaded woodpecker population, it was chosen as the primary donor population. From 1989 to 1992, 18 red-cockaded woodpeckers were translocated from the Apalachicola NF to seven other national forest units (Hess and Costa 1995).

Recently, translocation has been used with great success in the reintroduction of one population and to augment several extremely small populations. Reintroduction of red-cockaded woodpeckers into Avalon Plantation in Florida, beginning in 1998, has resulted in a population of 7 potential breeding groups in 2001 (Hagan and Costa 2001). The population at the Joseph W. Jones Ecological Research Center was increased, using translocation, from a solitary male in 1998 to 5 breeding pairs in 2001, and Southlands Experimental Forest increased from three males in 1997 to 8 potential breeding groups in 2001. Other recent examples of the successful use of translocation to augment critically small populations include increases in the Chickasawhay National Forest and Fort Jackson. Currently, translocation remains an important crisis management tool to be used with caution in appropriate circumstances.

Translocation Success

Efforts to measure the success of translocation as a management technique have been hampered by inconsistent data collection and differing definitions of success (Costa and Kennedy 1994). Definitions of success have varied, ranging from the individual being present soon after release to the fledging of offspring the following breeding season (Costa and Kennedy 1994). To further confuse the issue, definitions of success must change depending upon the objective of the translocation: for augmentation of a critically small population, reproduction of a translocated bird anywhere in the population is considered successful; however, if the objective is strategic recruitment of a new group by translocating birds from within the population to a specific area, then reproduction of those individuals in an area other than the target area is not considered a success.

Currently, the average estimated success rate for translocation is roughly 50 to 60 percent, for various meaningful definitions of success including presence in the recipient cluster in the following breeding season (Hess and Costa 1995), evidence of breeding in the following season or of pair-bonding just prior to the breeding season (Costa and Kennedy 1994), and remaining at or near the release site for 30 days (Franzreb 1999). Similarly, Franzreb (1999) reported that roughly half of adults and subadults (25 of 49) translocated to and within the Savannah River Site reproduced somewhere within that population. Higher success has been reported for simultaneous movement of multiple pairs (50 to over 70 percent present in the following breeding season; Carrie *et al.* 1999, Hagan and Costa 2001, USFWS unpublished), an encouraging development in translocation methods for red-cockaded woodpeckers and one which has been emphasized for other species as well (Griffith *et al.* 1989). Reproduction specifically at the recipient cluster is currently estimated to have occurred in 27 percent of translocations conducted between 1989 and 1995 (48 of 178, Edwards and Costa, in review).

Success of translocations has increased as methods have improved. Information is slowly accumulating on the effects of age, sex, and other factors such as distance, habitat condition, and the number of birds released on the likelihood of successful translocation. This research has been invaluable in formulating both a regional translocation strategy and specific guidelines for the movement of birds. Researchers agree that moving females to territories with solitary males, and moving potential pairs simultaneously, are the most successful types of movements (Rudolph *et al.* 1992, Allen *et al.* 1993, Costa and Kennedy 1994, Hess and Costa 1995, Hagan and Costa 2001, Edwards and Costa, in review). Birds are less likely to return to their original cluster if moved more than roughly 19.3 km (12 mi; Allen *et al.* 1993, Franzreb 1999). Other factors, such as insufficient number or poor condition of recipient cavities, problems in transport, and problems at the time of release, reduce success of translocations (Hess and Costa 1995). Finally, Rudolph *et al.* (1992) suggested that simultaneous movement of multiple pairs (5-10) might increase success. Again, this method has yielded encouraging results. Carrie *et al.* (1999) reported a success rate, defined as birds present in the following breeding season, of over 70 percent (12 of 17) after releasing multiple potential pairs in the Sabine National Forest. Other translocations of multiple pairs have shown success rates from 50 to over 70 percent as well (USFWS unpublished); for example, of 13 individuals translocated to the Joseph W. Jones Ecological Research Center in Georgia between 1999 and 2001, 10 remained in the beginning of the 2001 breeding season (J. Stober, pers. comm.).

In summary, it is apparent that translocation has an important but very specific role in the conservation and recovery of red-cockaded woodpeckers. It is not to be used as a substitute for more fundamental management actions that provide good quality foraging and nesting habitat. In the presence of good quality foraging and nesting habitat, translocation can be an effective short-term tool to counteract effects of demographic and environmental stochasticity and a useful measure over the long-term to reduce loss of genetic variation in isolated populations. Translocation is best performed by moving multiple pairs of juvenile red-cockaded woodpeckers, simultaneously, to recruitment clusters that are strategically located to improve the spatial structure of the population.

E. SILVICULTURE

Silviculture is the theory and practice of controlling the establishment, composition, structure, and growth of forests to achieve management objectives (Smith 1986). It was developed primarily for the purpose of timber production, but can be used for other purposes including biological conservation (Smith 1986, Thompson *et al.* 1995). Silviculture is an important tool for the management of red-cockaded woodpeckers with or without the additional goal of timber production. Today's forests differ substantially in structure and species composition from the precolonial forests that supported red-cockaded woodpeckers in abundance (Conner and Rudolph 1989, Foti and Glenn 1991, Ware *et al.* 1993, Masters *et al.* 1995, Noel *et al.* 1998). Second growth forests can be dense, can contain many small young trees and few large old trees, and often have a complex vertical structure. Proper silviculture can restore and maintain the open, two-layered habitat required by red-cockaded woodpeckers. In this section, we discuss the compatibility and usefulness of silvicultural methods to management and recovery of red-cockaded woodpeckers. We give guidelines for the use of silviculture in 8J.

Conservation and recovery of red-cockaded woodpeckers are compatible with timber production within certain constraints (Rudolph and Conner 1996, Engstrom *et al.* 1996, James *et al.* 1997, 2001, Hedrick *et al.* 1998). Suitable forest structure and function must be retained to support red-cockaded woodpecker populations. Suitable forest structure includes a substantial amount of large pines, low densities of small and medium sized pines, sparse or absent hardwood midstory, and abundant diverse herbaceous groundcovers (Hardesty *et al.* 1997, James *et al.* 1997, 2001, Hedrick *et al.* 1998, Walters *et al.* 2000, 2002a). Foremost among important functions of southern pine forests is the ability to carry frequent growing season fires (Platt *et al.* 1988b, Engstrom *et al.* 1996).

Silvicultural methods can be divided into three systems: even-aged, two-aged, and uneven-aged management. Two-aged is sometimes included within even-aged management. Each system has several possible methods of regeneration, the simultaneous harvest and establishment of tree reproduction (Thompson *et al.* 1995). Even-aged management includes clearcutting, standard seed tree, and standard shelterwood methods. Two-aged management includes modified seed tree and irregular shelterwood methods, and uneven-aged management includes single tree selection and group selection methods. Several researchers have assessed the compatibility of these methods with restoration and maintenance of habitat for red-cockaded woodpeckers (USFWS 1985, Lennartz 1988, Walker and Escano 1992, Walker 1995, USFS 1995, Rudolph and Conner 1996, Engstrom *et al.* 1996, Hedrick *et al.* 1998). The suitability of each method varies with forest type, silvicultural history, ownership, and management objectives. Silvicultural systems also differ in how production of habitat is sustained over time. It is critical to sustain habitat in perpetuity for recovery of red-cockaded woodpeckers.

Silvicultural Systems

Even-aged Management

Even-aged management is the culture of trees of one age class in a given stand (Helms 1998). The forest is regulated at the landscape level, with equal areas in each age class. Regeneration methods of even-aged management differ in the amount of residual trees remaining after harvest. Clearcutting is the removal of all commercially valuable trees on site. In standard seed tree and shelterwood methods, residual trees are left standing as seed sources after the initial harvest and are removed following the establishment of reproduction. Regardless of regeneration method, intermediate thinnings are made to improve growth and health of trees by reducing tree density (Smith 1986, Walker 1995). Modified seed tree and irregular shelterwood are not included as even-aged management in this document (see Two-aged Management below).

Clearcutting, standard seed tree, and standard shelterwood methods are not generally compatible with management to recover red-cockaded woodpeckers, except when used to restore native, site-appropriate pines. The U.S. Forest Service now discourages use of clearcutting (USFS 1995). Even-aged silviculture results in fragmented habitat, and red-cockaded woodpeckers are especially sensitive to negative impacts of habitat fragmentation because of their cooperative breeding system (see 2B). Even-aged silviculture renders stands unsuitable as nesting or foraging habitat for decades. Even with long rotations, even-aged silviculture results in stand-level removal of the large old trees most important to red-cockaded woodpeckers. Even-aged silviculture can be useful in the removal of off-site pine species to restore native pines (see 3G). If within occupied habitat, such restoration is best limited to small areas (Ferral 1998).

Two-aged Management

Two-aged management is a modification of even-aged management in which two age classes exist in a given stand (Smith 1986, Rudolph and Conner 1996). Two-aged stands are created by modified seed tree and irregular shelterwood methods, which are similar to corresponding standard methods except that residual trees are never harvested. In two-aged management, 15 to 25 pines/ha (6 to 10 pines/ac) or more are left as residual trees. The forest is regulated in the same way as in even-aged management. Intermediate thinnings are important to reduce stand density and open the forest structure.

Modified seed tree and irregular shelterwood methods are compatible with management of red-cockaded woodpeckers (Conner *et al.* 1991b, Rudolph and Conner 1996, Hedrick *et al.* 1998). Two-aged silviculture promotes the growth of old and even very old trees in every stand, and older trees are important to both nesting and foraging (see 2D, 2E). Prescribed burning can be conducted throughout much of the forest without fear of damaging young pines, because pine reproduction is concentrated in limited areas. This is a strong advantage in forests of loblolly and/or shortleaf pines which are sensitive to fire when young (Farrar 1996, Hedrick *et al.* 1998). Finally, two-aged silviculture can open up the forest and establish lower pine densities preferred by red-cockaded woodpeckers (Conner *et al.* 1991b). Irregular shelterwood and modified seed tree methods are the cornerstone of restoration of the shortleaf pine/bluestem grass (*Andropogon* and *Schizachyrium* spp.) ecosystem on the Ouachita National Forest in Arkansas (USFS 1996).

Modified seed tree and irregular shelterwood methods have some drawbacks in their application for red-cockaded woodpecker management. The older residual pines are subject to increased windthrow, especially the more shallow rooted pine species (Smith 1986), and increased lightning strikes. In longleaf stands, however, mortality of residual pines is not likely to be greater than that of similarly aged pines in other stands (Boyer 1979). A second drawback to modified seedtree/shelterwood silviculture is that reduction in canopy cover may reduce needle litter, an important fuel (Engstrom *et al.* 1996). Also, an excessive pine midstory can develop, with detrimental effects on cluster occupancy (see 2D) and suitability of the stand for foraging (see 2E). Dense pine regeneration, even under residual pines, renders the stand unsuitable for foraging and such stands are not considered foraging habitat until the pine regeneration can be thinned considerably (see 8I and 8J for specific description of the pine size class distributions that are considered foraging habitat). Frequent prescribed burning can be an important tool to control density of pine regeneration.

Finally, modified seed tree and irregular shelterwood methods may not retain sufficient densities of large trees for newly regenerated stands to qualify as foraging habitat (see 8J). When using these methods in the presence of red-cockaded woodpeckers, long rotations or a greater number of residual pines are necessary to provide suitable foraging habitat.

Uneven-aged Management

Uneven-aged management results in stands with at least three age classes (Smith 1986, Helms 1998). Reproduction occurs throughout the forest in gaps created by the harvest of single trees or groups of trees (regeneration by single tree and group selection, respectively). If group selection is used, patches of trees removed are generally below 0.8 ha (2 ac) in size. The forest is regulated at the stand level, usually by either timber volume or stand structure. The forest can be regulated using one of several methods, including regulating by timber volume using the volume/guiding diameter limit (V-GDL) method (Reynolds 1959, Baker *et al.* 1996, Farrar 1996, Guldin and Baker 1998) or by stand structure using the BDq method (Marquis 1978, Baker *et al.* 1996, Farrar 1996, Guldin and Baker 1998). Another method of uneven-aged silvicultural management is the Stoddard-Neel approach (Mitchell *et al.* 2000).

The V-GDL method uses periodic inventories to measure tree growth, which is then established as the allowable harvest. The guiding diameter limit is the size above which the volume of trees meets the allowable cut. All trees above the guiding diameter limit are not necessarily cut; for every tree above the limit retained, an equal volume of trees below the limit are harvested (Farrar 1996, Guldin and Baker 1998). According to Guldin and Baker (1998), the classic marking rule for this method is to “cut the worst trees and leave the best”. In general, the V-GDL method of regulation is somewhat subjective and therefore can be difficult to apply (Farrar 1996, Guldin and Baker 1998).

The BDq method uses three parameters to describe the target after-cut stand structure: residual basal area (B), maximum diameter retained (D), and the ratio of number of stems in a given size class to those in the next larger class (q). The priority of these parameters is in the order given, so that trees above the maximum diameter are retained if residual basal area cannot be met without them (Baker *et al.* 1996, Farrar 1996, Guldin and Baker 1998). If the structure of the residual stand closely corresponds to q, the stand has a negative exponential (inverse-J) size distribution and is said to be well-balanced (Guldin and Baker 1998). Both q and D can be adjusted to increase the presence of large old trees to meet management objectives (Farrar 1996). The BDq method is preferred over the V-GDL method for most uses because it provides an objective means of monitoring the smaller size classes (Farrar 1996, Guldin and Baker 1998).

The Stoddard-Neel approach is a subjective method that has not been specifically quantified, but has the following characteristics (Mitchell *et al.* 2000). Perpetuation of the forest ecosystem as a whole is the overriding goal of management. Each tree is individually assessed according to its contributions to the ecosystem and the surrounding landscape. Harvest is considered only after it can be conducted without compromising conservation goals, and after that point, only harvesting a portion of the annual incremental growth is allowed. Specific harvest limits are set and reviewed every 10 years. Criteria for individual tree retention include pines with old growth characteristics, older canopy dominants, and longleaf pines in mixed pine stands. Criteria for individual tree selection include some defective trees, those with low crown vigor, and the promotion of an open, multi-aged canopy structure. Openings vary in size ranging from 0.1 ha to 0.2 ha (0.25 ac to 0.5 ac). Salvage logging of dead trees is allowed only if applied toward the allowable cut, and some dead and downed trees are maintained throughout the forest.

Uneven-aged management is compatible with restoration and maintenance of red-cockaded woodpecker habitat (Engstrom *et al.* 1996, James *et al.* 2001). Uneven-aged management can provide large old trees throughout the landscape. Densities of small and medium sized pines can be controlled to avoid detrimental effects on red-cockaded woodpeckers. Frequent prescribed burns can be used to control hardwoods and maintain herbaceous groundcovers in longleaf forest types. For loblolly and shortleaf forests, it is harder to use prescribed fire in uneven-aged stands because of fire sensitivity of young pines and the presence of young pines throughout the landscape (Rudolph and Conner 1996, Hedrick *et al.* 1998). However, prescribed burning at intervals of variable length may be used successfully in these forest types (Cain 1993, Farrar 1996, 1998, Cain *et al.* 1998). Annual and biennial fires interspersed with periods of up to 5 years without fire may effectively control midstory and encourage herbaceous groundcovers while allowing for reproduction of loblolly and shortleaf pines (Cain 1993, Cain *et al.* 1998). The Red Hills region of south Georgia and north Florida supports a large population of red-cockaded woodpeckers in longleaf systems effectively managed with a combination of single tree and group selection methods (Engstrom and Baker 1995, Engstrom *et al.* 1996). Finally, uneven-aged management has been used successfully to remove off-site pine species and restore native site-appropriate pines (e.g. McWhorter 1996).

There are several drawbacks in the application of uneven-aged silviculture to the management of red-cockaded woodpeckers. The number of harvests, and consequently habitat disturbance, can be greater than that of two-aged management (Rudolph and Conner 1996) although this is not necessarily so (Engstrom *et al.* 1996, Farrar 1996, W. D. Boyer, pers. comm.). In fact, W. D. Boyer (pers. comm.) states that the number of entries in longleaf stands under uneven-aged management can be fewer than in stands under even-aged management.

Application of prescribed fire is difficult or at least somewhat complex in uneven-aged stands of loblolly and shortleaf pines, and therefore hardwoods may become a problem (Rudolph and Conner 1996, Hedrick *et al.* 1998). Finally, selection systems, just like even-aged management, can result in the harvest of the old, large trees most valuable to red-cockaded woodpeckers. With careful application these drawbacks can be minimized.

Low Intensity Management

Some woodpecker populations exist in forests that are not managed for timber production. Low-intensity management for the primary purpose of biological conservation uses frequent growing season burns to control hardwoods, prepare the site for pine reproduction, and encourage beneficial native, site-appropriate groundcovers. Natural disturbances such as wind-throw and lightning strikes establish gaps in the canopy for reproduction and recruitment to occur. Hurricanes may occasionally create larger openings. Longleaf, shortleaf, and other pines on native sites are suited for low intensity management.

Some forests may require restoration prior to the application of this silvicultural method. Hardwood midstories and/or overstories may need reduction or removal. Herbaceous groundcovers may need to be restored, and dense pine stands will require thinning to densities suitable for red-cockaded woodpeckers.

Low intensity management is advantageous for red-cockaded woodpeckers because conservation is the primary goal. Low-intensity management offers aesthetic and recreational benefits as well, because the low tree density and healthy herbaceous layer are generally appealing to the public. Low-intensity management does not have the monetary benefits of timber production.

Pine Density

Pine densities generally recommended for timber production by uneven-aged management are 10.3 to 17.1 m^2 basal area per ha (45 to 75 ft^2/ac) in longleaf systems and somewhat higher for shortleaf and/or loblolly (Farrar 1996). Pine density before and after selection cutting generally remains within this range. Even-aged and two-aged management typically result in pine densities of 18.3 to 27.4 m^2/ha basal area (80 to 120 ft^2/ac) or more (Farrar 1996), and after cutting densities are often reduced to below 2.6

m^2/ha (20 ft^2/ac). In addition, second-growth forests are generally more dense than old growth woodlands (Ware *et al.* 1993, Masters *et al.* 1995, Noel *et al.* 1998).

For management of red-cockaded woodpeckers, it is important that densities of small and intermediate-sized pines (<35 cm, or 14 in dbh) be reduced, and the largest trees protected (Walters *et al.* 2000, 2002a, James *et al.* 2001). Two recent studies of foraging ecology in longleaf ecosystems documented increases in fitness of woodpeckers in more open habitat and at lower pine densities (Walters *et al.* 2000, 2002a, James *et al.* 2001). Thinning suppressed pines opens the forest structure, promotes desired herbaceous groundcovers, and increases effects of prescribed burning. However, further experimental research on silvicultural treatments, with adequate controls, is urgently needed to better understand the appropriate habitat structure to support healthy red-cockaded woodpecker populations (F. C. James, pers. comm.).

Further research is also necessary to assess effects of pine densities on foraging ecology of woodpeckers in shortleaf and loblolly systems. For shortleaf and loblolly forest types, pine densities below 18.4 m^2/ha (80 ft^2/ac), or an average spacing of at least 7.6 m (25 ft) between pines in mature stands, are very important in reducing risks of southern pine beetle infestations (Thatcher *et al.* 1980, Nebeker and Hodges 1985, Hicks *et al.* 1987, Belanger *et al.* 1988, Mitchell *et al.* 1991).

Priority for Leave Trees

Leave trees are those that remain standing after thinnings and harvests. Benefits to red-cockaded woodpeckers can be increased by preferentially leaving trees important to them. These important trees include old and very old pines (relict and remnant pines and flat-tops), potential cavity trees (pines over 60 years in age), and pines scarred by turpentine harvest or lightning.

Site Preparation

Regardless of the silvicultural system used, some form of site preparation is necessary to establish pine reproduction. Site preparation removes vegetation and other organic material to expose the mineral soil required for seed germination. Prescribed burning is the preferred method of site preparation, because it mimics natural processes, minimizes disturbance to the soil, and promotes native, site-appropriate herbaceous groundcovers beneficial to red-cockaded woodpeckers (see 2E). Prescribed burning during the growing season induces flowering of many native herbaceous plants (Platt *et al.* 1988a; see 2G) and enhances reproduction of longleaf pines much more so than winter burning (W. D. Boyer, pers. comm.).

Prescribed burning within one year of a good pine seed crop is generally the only site preparation needed, if hardwoods are well under control. If prescribed burning cannot be used, the Bracke scarifier-mounder or a roller drum chopper has fewer impacts on soil profiles and plant communities than do discing, root raking, windrowing, and bedding. Bracke-mounding is a relatively non-invasive technique by which small mounds rather than plow lines are created to expose the mineral soil. Chemical treatments are sometimes used for site preparation as well, but effects of herbicides on native groundcovers are largely unknown (Litt *et al.* 2000, 2001). Any method of site preparation that disturbs the soil will favor ruderal, disturbance-tolerant grasses and forbs over desired species such as wiregrass (Provencher *et al.* 1998, 1999, 2001b), and recovery of groundcovers can be exceedingly slow. For example, Provencher *et al.* (1997, 1998) estimated that recovery of groundcovers following selective harvest of longleaf pine can take 50 years in deep sandy soils.

F. PRESCRIBED BURNING

Because of fundamental changes in the landscape and natural fire regime of the southeast, prescribed burning is and will continue to be the primary means of restoring and maintaining fire in southern pine ecosystems (Frost 1998). Prescribed burning provides benefits for a suite of species characteristic of southern pine ecosystems, and is an essential management tool for the conservation and recovery of red-cockaded woodpeckers (Robbins and Myers 1992, Costa 1995a). By reducing dangerous fuel loads, prescribed burning is also a vitally important component in the protection of human life and property from extreme wildfire.

Red-cockaded woodpeckers are rightly termed an umbrella or flagship species, because their protection and management provides for the conservation of entire ecosystems and the hosts of associated species within. It is especially prescribed burning, but also retention of old growth and mature trees, that provides critical support for associated species. To maximize these benefits, the frequency, intensity, season, and variability of prescribed fire should mimic the historic natural fire regime as closely as possible (Masters *et al.* 1996).

In this section, we briefly review the benefits of prescribed burning to red-cockaded woodpeckers and other species of southern pine ecosystems, and then address concerns about possible negative effects on some animals. We also review the application of prescribed fire to the landscape and its use in habitat restoration. A general discussion of the history and role of fire in southern pine ecosystems is given in 2G. Guidelines for the use of prescribed burning are given in 8K.

Benefits of Prescribed Burning

Benefits to Red-cockaded Woodpeckers

Red-cockaded woodpeckers require open woodlands for nesting and roosting cavities. Hardwood encroachment eventually results in the abandonment of clusters and severe population decline or extirpation (Beckett 1971, Hopkins and Lynn 1971, Van

Balen and Doerr 1978, Locke *et al.* 1983, Hovis and Labisky 1985, Conner and Rudolph 1989, Costa and Escano 1989, Loeb *et al.* 1992, Masters *et al.* 1995). Encroachment of hardwoods and woody shrubs also degrades the quality of foraging habitat (James *et al.* 1997, Walters *et al.* 2000, 2002a). Prescribed burning, especially during the growing season, is a highly effective means of controlling such hardwood and shrub encroachment. Prescribed burning can effectively control hardwoods and shrubs without damaging the herbaceous layer and soils, and can be much less expensive than other restoration methods (Provencher *et al.* 2001b). Prescribed fire also has direct benefits to herbaceous plants in southern pine communities by initiating flowering (Platt *et al.* 1988a). Fire helps maintain a healthy native plant community, which in turn leads to increased fitness of red-cockaded woodpeckers (Hardesty *et al.* 1997, James *et al.* 1997, 2001). The mechanism for increased fitness of red-cockaded woodpeckers in the presence of abundant herbaceous groundcovers has not been documented, but one proposal for such a mechanism is increased abundance and/or nutrient content of prey (James *et al.* 1997).

Benefits to Associated Species

Many plants and animals associated with southeastern pine communities are threatened by loss of habitat through fire suppression and conversion to other land uses. Management for red-cockaded woodpeckers directly supports these sensitive, threatened, and endangered species. Currently, over 120 species of plants and 56 animal species associated with red-cockaded woodpecker habitats are on the regional list of proposed, endangered, threatened, and sensitive species (USFS 1995). Many more herbaceous plants of longleaf communities are rare in today's landscape (Walker 1993), nearly all of which are adapted to growing season fire. Thirty-five percent of the amphibians and reptiles inhabiting longleaf pine forests, and 56 percent of the longleaf pine specialist species, were listed by at least one conservation agency as being of special concern (Guyer and Bailey 1993). Fire suppression was identified as a primary cause of the decline of these species.

Fire benefits shortleaf pine communities as well, although these have not received as much research attention as longleaf systems. Masters *et al.* (1998) reported that species richness and diversity of small mammals increased in relation to midstory reduction and prescribed fire, and no species was adversely affected by fire. Similarly, King (1982) reported increased abundance and diversity of small mammals in loblolly/shortleaf pine forests of the Georgia Piedmont in response to frequent prescribed fires.

Prescribed burning directly benefits bird species associated with open pine woodlands such as Bachman's sparrows (*Aimophila aestivalis*), brown-headed nuthatches (*Sitta pusilla*), pine warblers (*Dendroica pinus*), prairie warblers (*D. discolor*), and red-headed woodpeckers (Engstrom *et al.* 1984, Jackson 1988, Wilson *et al.* 1995, Conner and Dickson 1997, Allen 2001). Bachman's sparrows, in particular, are in decline throughout most of their range and respond strongly to management for red-cockaded woodpeckers (Dunning and Watts 1990, Gobris 1992, Plentovich *et al.* 1998). Bird species associated with riparian habitats within open pine woodlands, such as Carolina wrens (*Thryothorus ludovicianus*), white-eyed vireos (*Vireo griseus*), common yellowthroats (*Geopthlypis thrichas*), and hooded warblers (*Wilsonia citrina*), can benefit from prescribed burning as well (Engstrom *et al.* 1984, Conner and Dickson 1997, Allen 2001). Riparian habitats within open pine forests, when frequently burned, support increased density and diversity of shrubs, a likely cause of increased abundance of associated bird species (Allen 2001). Additionally, many songbird species of southeastern pine communities prefer burned over unburned forests for nesting sites (White *et al.* 1999).

Concerns about Negative Effects

Increasing use of prescribed fire has prompted concern among some land managers, researchers, and the general public. A common anxiety is that prescribed burning during the growing-season may have detrimental effects on non-target species. Managers perceive negative impacts on game species, including losses of nests of ground-nesting birds such as northern bobwhites (*Colinus virginianus*) and wild turkeys (*Meleagris gallopavo*), and reduction of hard mast forage for game birds, white-tailed deer (*Odocoileus virginianus*), and black bear (*Ursus americanus*) among others. However, these concerns have not been substantiated. In fact, increases in abundance of bobwhites and wild turkeys after the introduction of growing season burns have been reported in many areas (Landers *et al.* 1995, Palmer and Hurst 1998). Prescribed burning and pine thinning benefit white-tailed deer by increasing the production of available forage and preferred woody browse to more than four times that of untreated areas (Masters *et al.* 1996).

One immediate effect of growing season fire is the destruction of nests, and this has caused some concern. However, for species associated with southeastern pine habitats, the benefits of prescribed burning far outweigh the occasional loss of nests. Improved habitat quality enables higher population densities, whereas fire suppression substantially lowers the abundance of these bird species (Allen 2001). Saving some nests through fire suppression can serve no purpose if the birds have no habitat in which to exist. In addition, many birds adapted to southeastern pine habitats, such as Bachman's sparrows, pine warblers, prairie warblers, and others, readily renest upon loss of a nest. Game birds such as wild turkeys and northern bobwhites also readily renest (Vangilder and Kurzejeski 1995, Harper and Exum 1999). This behavior acts to minimize any negative effect that fire can have.

There also has been some concern about possible effects of management for red-cockaded woodpeckers on neotropical-nearctic migratory birds. Some species of neotropical-nearctic migrants have experienced declines in recent decades (Robbins *et al.* 1989, Sauer and Droege 1992, Peterjohn and Sauer 1994). In response, conservation biologists and land managers have focused on these species. However, in the southeastern coastal plains, neotropical migrants of greatest management concern are largely associated with bottomland riparian forests (Hunter *et al.* 1994), whereas resident bird species of concern are associated with mature open pine forests and benefit from woodpecker management (Dunning and Watts 1990, Hunter *et al.* 1994, Wilson *et al.* 1995, Tucker *et al.* 1996). A study of the response of breeding bird communities to red-cockaded woodpecker management in southern Mississippi reported that 7 of the 9 bird species that benefited from woodpecker management were pine-grassland species under regional or national decline, whereas all 4 species benefiting from fire suppression were relatively common forest interior species exhibiting stable or increasing trends (Burger *et al.* 1998). In addition, almost all species of birds that increase abundance under fire suppression, such as red-eyed vireos (*V. olivaceous*), black-and-white warblers (*Mniotilta varia*), and Acadian flycatchers (*Empidonax virescens*), also use frequently burned riparian habitats within open pine ecosystems (Allen 2001). Finally, even species that are considered interior forest species may benefit from management for red-cockaded woodpeckers that includes prescribed fire. For example, Powell *et al.* (2000) reported increased abundance of wood thrushes (*Hylocichla mustelina*) on plots treated with pine thinning and prescribed fire relative to control plots in the Georgia Piedmont. The authors went on to suggest that such management contributed to the stability of the study population and recommended its use to stabilize other declining populations in the state.

Thus, management for red-cockaded woodpeckers benefits other resident bird species of concern without impacting those neotropical migrants that are in decline. Managers should not hesitate to conduct prescribed burns for fear of impacts to neotropical migratory birds. Neotropical-nearctic migrant species of concern will best be conserved not by fire suppression but by the protection of habitats most important to them, such as southeastern bottomland hardwoods and northeastern boreal forests.

Close proximity of human development to forests supporting red-cockaded woodpecker populations presents significant risks of natural fire to human property and human lives. Frequent prescribed burning is a critically important technique to reduce risk of extreme natural fire and increase human safety. Risks associated with prescribed burning can be reduced through careful application and other techniques (e.g., Feary and Neuenschwander 1998), and if properly planned and implemented prescribed burns can be safely used to manage natural habitats and protect human life and property. Benefits to human safety and to the entire ecosystem far outweigh risks, if fires are planned and conducted with caution and guidelines are followed (see 8K).

Season of Prescribed Burning

As stated above, the frequency, intensity, season, and variability of prescribed fire should mimic the historic natural fire regime as closely as possible (Masters *et al.* 1996). Growing season fire is emphasized throughout this document because it is commonly believed that most historic fires occurred during the lightning season. Early to mid growing season fire typically has stronger benefits for native, site-appropriate groundcovers than dormant season fire. Late growing season fire may have detrimental impacts on overstory pines and is not as effective in reducing midstory root stock and promoting native groundcovers (Sparks *et al.* 1998, 1999). Sparks *et al.* (1998, 1999) found late dormant season burns more effective than late growing season burns in reducing hardwoods and restoring herbaceous groundcovers in the Ouachita Highlands. Spring burns had much higher reproduction of longleaf pines and development of longleaf pine seedlings than did summer or winter burns in the Escambia Experimental Forest of Alabama, and hardwood development was virtually non-existent in stands undergoing spring burns (W. D. Boyer, pers. comm.). Season of prescribed burns may vary according to specific management objectives (e.g., initial fuel reduction), but the overriding goal of prescribed burning programs in southeastern pine ecosystems should be the institution of a fire regime that best recovers and maintains an abundant, diverse, native, and site-appropriate herbaceous layer to the ecosystem in question.

Application of Fire to the Landscape

Aerial and ground ignition are the two most common methods used to apply fire to the landscape. Ground ignition is the more common of the two because it requires less financial resources and training. However, aerial ignition is becoming increasingly popular because more area can be burned per unit time, and the smoke dispersal is improved.

Ground ignition is accomplished by one or more techniques. Hand-held drip torches are most common, either used alone or in combination with other techniques such as mechanical torches mounted to all-terrain vehicles (ATVs). Using all-terrain vehicles increases the efficiency of ground burning operations, but entails greater safety risks than hand held torches. Caution must be exercised when using ATVs in forest stands with excessive midstory, hidden stumps, or large amounts of downed timber, and operators should be trained in vehicle use. Recently, several safety improvements have been made to ATV-mounted torches, and managers considering their use should contact state and federal agencies to learn more about these improvements. Use of ATVs in areas supporting gopher tortoises may negatively impact that species.

Aerial ignition can be a very efficient method of burning large areas in a few hours. One example of a successful prescribed burning program using aerial ignition is that of the Carolina Sandhills National Wildlife Refuge (Ingram and Robinson 1998). Aerial ignition is generally accomplished through the use of a helicopter equipped with a helitorch or a plastic sphere dispenser (PSD). The helitorch uses a gel-like substance (alumi-gel) which is ignited and dispensed from a torch suspended from the helicopter. The PSD uses an apparatus mounted inside the helicopter that disperses individual spheres about 3.8 cm (1.5 in) in diameter; these spheres ignite in a few seconds once on the ground. The use of the PSD method requires a second person, other than the pilot, to operate the PSD machine. Over a thousand hectares (several thousand acres) can be burned per hour using either technique. Each technique has advantages and disadvantages; local experts should be contacted to discuss their use in various regions of the woodpecker's range.

Aerial ignition requires considerably greater protection of cavity trees than does ground ignition, because aerially ignited fires vary much more in fire intensity. If raking or mowing is used as a method of securing red-cockaded woodpecker cavity trees within an aerial-ignition burn unit, this should be done for a distance of 6.1 m (20 ft) or more from the cavity trees. Even greater distances may be required if the area has not already undergone frequent burning and the habitat requires restoration. In this case, all clusters should be burned using ground ignition before aerial ignition of the larger burning unit.

Restoration Burning and the Reintroduction of Fire

Restoring seriously degraded habitat is perhaps the most challenging application of prescribed fire in the management of red-cockaded woodpeckers, but it can be highly successful if performed with commitment and cooperation. Wade *et al.* (1998) describe four cases in which fire has been successfully reintroduced under seemingly insurmountable circumstances: (1) reintroduction of fire to an area that was not burned for over 50 years; (2) intentional use of a high-intensity stand replacement fire; (3) burning following a major hurricane, and (4) burning within a residential subdivision. Similarly, fuel reduction and restoration of plant communities has been accomplished in many state parks in Florida (Stevenson 1998).

Restoration burns are commonly used to reduce or remove dense hardwood midstories. These burns are usually more intense than other controlled burns, and it is especially important that adequate fire suppression equipment be on site in these instances. Clusters on deep, sandy soils, with a dense hardwood midstory and a sparse accumulation of ground fuels, can be effectively treated with a restoration burn during the growing season. Key to success of this management action is a thorough understanding of fire behavior in those fuel types under a variety of weather conditions. The use of fire for restoration purposes often requires burning under very specific weather parameters including those conditions identified as extreme fire weather conditions. Typically, these parameters include modest to high wind speeds, a low relative humidity, and low fuel moistures. Use of prescribed burns under these conditions requires extensive experience in the application of growing season fire and should only be attempted by experienced burners.

G. HABITAT RESTORATION

Ecological restoration is the process of returning ecosystem properties such as composition, structure, function, and dynamics to altered ecosystems. These properties are restored to within their estimated unaltered natural range of variation or, alternatively, to within ranges of variation that are capable of sustaining desired ecosystem components and processes. Thus, ecosystem restoration is rooted in the understanding and representation of natural variation in communities, ecosystems, and landscapes (White and Walker 1997). Identification of ecosystem composition, structure, function, and dynamics to be restored is achieved through the selection of appropriate reference criteria

(White and Walker 1997). A variety of reference information can be derived from existing reference sites, historical data, and on-site evidence (Meffe and Carroll 1997, White and Walker 1997). However, spatial scale is important in considering natural variation. Restoration should be performed with both regional and local variation under consideration.

For red-cockaded woodpeckers, restoration of good quality habitat is vital to the recovery of the species. Loss of habitat was primary among the original causes of decline (see 1A), and the widespread increases necessary for recovery cannot be achieved without large-scale restoration of habitat. Habitat loss was caused by removal of the original old growth forest, fire suppression, reproductive failure of longleaf pine, and conversion of longleaf and other native, site-appropriate pine species to plantations of off-site species. Methods of site preparation have also substantially altered native groundcovers in woodpecker habitats.

Reintroduction of a fire regime patterned after historic fires is central to the restoration of native southeastern pine ecosystems—that is, habitat for red-cockaded woodpeckers. Prescribed fire should mimic the frequency, intensity, seasonality, and variability of natural historic fire in order to maximize benefits to the fire-adapted species of southeastern pine communities. Restoration of fire to the landscape aids in restoring appropriate habitat structure and species composition. Prescribed fire facilitates the reproduction, growth, and maintenance of longleaf, shortleaf, and other native, site-appropriate pine species, and can reestablish highly diverse native groundcovers. The restoration of these species, in turn, facilitates frequent fire—an important function—in the system. Other important management tools in habitat restoration include thinning to restore historic pine densities; protecting, planting and seeding native, site-appropriate pines and groundcovers; and the use of site preparation methods that minimize soil disturbance.

One problem in specifying desired components and structure for ecosystem restoration is lack of information concerning historic communities and alteration of existing reference sites (White and Walker 1997, Walker 1998). Longleaf pine woodlands have been reduced to less than 5 percent of their original area, and longleaf ecosystems with intact groundcovers are even more rare (Frost 1993). Species lists and structural analyses of remnant longleaf pine ecosystems (e.g. Peet and Allard 1993, Noel *et al.* 1998) are critical. Other ecosystem types supporting red-cockaded woodpeckers, such as shortleaf and native slash pine communities, require further research attention as well. Despite these difficulties, researchers have assembled a body of information that can be used to identify general desired future conditions for southern pine ecosystems supporting red-cockaded woodpeckers. Key components of these conditions include: (1) native, site-appropriate canopy pine species, (2) old growth pines, (3) lower density of canopy pines than in most second and third-growth forests, and (4) healthy forb and bunchgrass groundcovers.

Restoration of Native Canopy Pines

Loss of native pines, especially longleaf but also shortleaf pine, has occurred throughout the range of red-cockaded woodpeckers. Loblolly and slash pines are native to the southeastern United States, but were restricted primarily to mesic sites and were rarely dominant in precolonial forests (White 1984, Christensen 2000). Restoration of native, site-appropriate pines is an important component of red-cockaded woodpecker management and recovery, primarily because these pines provide superior habitat and facilitate critical, frequent fire (Platt *et al.* 1988b). Restoration of native pine communities is a crucial aspect of ecosystem management also (see 3H). Restoration of longleaf pine has been identified as a high priority in the management of national forests. Over 40,000 ha (100,000 ac) of national forests were restored to longleaf pine between 1988 and 1997, a 20 percent increase over 1988 levels (McMahon *et al.* 1998). An additional 140,000 ha (350,000 ac) are to be restored over the next 90 years, representing a future increase of 60 percent over 1988 levels (McMahon *et al.* 1998). Expanded use of growing-season fire is an important part of this restoration program (McMahon *et al.* 1998).

Size of Restoration Areas

An important consideration in the restoration of native, site-appropriate pine species is the size of the area to be restored. Restoration work should not result in impacts to red-cockaded woodpeckers, either through direct loss of habitat or habitat fragmentation (Ferral 1998, F. James, pers. comm.). Clearcuts near active red-cockaded woodpecker clusters or recruitment clusters that are performed for this purpose should be no larger than 16 ha (40 ac), and use of smaller patches are recommended. Clearcuts as large as 32 ha (80 ac) are acceptable if they are at least 1.6 km (1 mi) from active or recruitment clusters.

Restoration Methods

General information about longleaf restoration is presented in Hermann (1993) and Kush (1998), and further details can be obtained from the Longleaf Alliance (Rt. 7, Box 171, Andalusia, AL, 36420; Gjerstad *et al.* 1998). In addition, the USDA Forest Service offers information and incentives to state managers and private landowners considering the restoration of native, site-appropriate pine species through the State and Private Forestry Programs (McMahon *et al.* 1998).

The first step in the restoration of site-appropriate pines to an area currently supporting off-site species is the removal of the off-site pines (typically loblolly and slash, but also Virginia and sand pines) through small clearcuts or group selection. Site preparation (preferably prescribed burning) rids the area of non-merchantable pines and undesirable hardwoods while establishing proper conditions for planting (see below and 8J for further discussions of site preparation). Seedlings or seeds to be planted in the site should be from an appropriate source for the local area to maintain genetic integrity and to enhance the likelihood of success (Schmidtling *et al.* 1998).

Restoration of Historic Pine Densities

Many of today's forests are densely stocked (Boyer and Farrar 1981, Landers *et al.* 1990, Noel *et al.* 1998). Density of pines in historic forests was substantially lower, as estimated from old survey data, travelers' accounts, and current old growth remnants (Foti and Glenn 1991, Masters *et al.* 1995, Noel *et al.* 1998). For example, precolonial densities for shortleaf pine forests in the Ouachita Mountains have been estimated at roughly 8 m^2 per ha (35 ft^2/ac) pine basal area and 6 m^2/ha (25 ft^2/ac) of hardwood basal area (Foti and Glenn 1991, Masters *et al.* 1995). Some old growth forests in rich sites may have carried pine basal areas near 23 m^2/ha (100 ft^2/ac) or more, but the overall structure was open because the individual pines were so large. Not only are second-growth stands more dense than old growth forests, but they typically have lower variability in density across the stand (Noel *et al.* 1998).

In the absence of active management, second-growth forests may not shift toward an old growth structure for decades or even centuries (Noel *et al.* 1998). Second-growth longleaf forests studied by Noel *et al.* (1998) contained an overrepresentation of pines 20.3 to 40.6 cm (8 to 16 in) in dbh, and trees of these sizes were characterized by extremely low mortality and very slow growth. Thus, change in habitat structure was unlikely to occur naturally in the near future. However, researchers and managers are not always sure of the best method or methods to restore appropriate pine densities. Selective removal of small groups of trees is recommended for xeric longleaf forests, but flatwoods longleaf may require more research to develop restoration methods (Noel *et al.* 1998). Prescribed burning, patterned after the historic fire regime, can contribute to long-term restoration of appropriate pine (and hardwood) densities (Noel *et al.* 1998).

Restoration of Native Groundcovers

Longleaf pine ecosystems are famous for their highly diverse groundcovers (Walker and Peet 1983, Simberloff 1993, Peet and Allard 1993, Glitzenstein *et al.* 1998b, Walker 1998). These fire-dependent ecosystems contain nearly one quarter of all the plant species in North America, including high numbers of endemic species (Mitchell *et al.* 2000). Restoring and maintaining this diversity is a primary goal of ecological restoration in the southeast. Native, site-appropriate groundcovers have important benefits to red-cockaded woodpeckers: native grasses are pyrogenic (Platt *et al.* 1988b, Noss 1989), and native groundcovers may support more diverse and abundant arthropods than encroaching hardwoods (Provencher *et al.* 1997, 1998, Collins 1998). Also, an ecosystem approach to managing red-cockaded woodpeckers and their habitat emphasizes the conservation of native, site-appropriate diversity.

Vegetation native to longleaf and shortleaf pine ecosystems may be best restored and maintained through the use of frequent growing season fire. Loss of groundcover diversity in the absence of fire is well documented (Christensen 1981, Ware *et al.* 1993, Peet and Allard 1993, Glitzenstein *et al.* 1998b, Walker 1998), and single fires are not sufficient to restore species diversity (Glitzenstein *et al.* 1998b). Prescribed fire is necessary to remove decades of litter accumulation and expose the mineral soil for seedling germination and early seedling growth (Walker 1998). In addition, prescribed fire opens the forest floor to sunlight, by reducing off-site hardwoods and shrubs and reducing the density and stature of on-site hardwoods and shrubs. Growing season fire stimulates flowering and fruit production of native groundcover plants (Platt *et al.* 1988a, Streng *et al.* 1993). Finally, benefits of fire may be increased by restoring natural variability in the fire regime (Walker 1998).

Hardwood Control

Key to restoration of native groundcovers is the initial control of existing hardwoods. Prescribed burning during early to mid-growing seasons may be the most cost-effective method of reducing hardwoods (Provencher *et al.* 2001b). In situations requiring rapid midstory removal, such as in clusters recently abandoned or supporting only a solitary male because of excessive hardwoods, mechanical and/or chemical methods of hardwood reduction may be in order (Conner 1989, Conner *et al.* 1995, Provencher *et al.* 2001b). However, such methods should be used with extreme caution to minimize disturbance to soils, pine tree roots, and desired native herbaceous species. If chemical and/or mechanical means of midstory reduction are used for rapid hardwood reduction, the area in question should soon be included in a prescribed fire program to restore and maintain appropriate herbaceous groundcovers.

Both herbicides and mechanical methods can result in increased abundance of disturbance-tolerant, ruderal species such as broom sedge (Provencher *et al.* 1998, 1999, 2001). In a study at Eglin Air Force Base, researchers compared three hardwood reduction treatments, including the commonly used herbicide, hexazinone, in a well-replicated large-scale experiment. They found that herbicide use increased disturbance-tolerant species while causing significant declines in common important species such as gopher apple (*Licania michauxii*), dwarf huckleberry (*Gaylussacia dumosa*), little bluestem (*Schizachyrium* spp.) and various legumes (e.g., Florida milk-pea, *Galactica floridana*). Some of these effects still persisted after four years and following the application of growing season fire (Provencher *et al.* 1999). Moreover, effects of herbicides on rare plant species are not known (Litt *et al.* 2000, 2001). In a recent review of all available studies on the impacts of herbicides on vegetation, only two, including Provencher *et al.* (1999), comprehensively documented the effects of herbicides across all species, including rare species (Litt *et al.* 2000, 2001). Litt *et al.* (2000, 2001) concluded that herbicide effects on plant species of management concern generally cannot be evaluated at this time. Use of herbicides to control hardwoods is also discussed in USFS (1989).

Handtools such as chainsaws or brushhooks will have minimal impacts on native species, but excessive use of heavy machinery should be avoided. In one study, repeated passes with a double drum chopper to remove scrub oaks (*Quercus* spp.) killed 50 percent of the existing wiregrass (Outcalt and Lewis 1990). In this same study, single passes with a light single drum chopper had little effect on groundcovers. Roller choppers may have increased effects on mesic sites (Glitzenstein *et al.* 1993). Use of heavy-duty mowers or grinders mounted on rubber-tired tractors may have fewer negative impacts than roller chopping.

With sufficient expertise, prescribed fire can be used to control even serious hardwood problems. Effects of fire vary with its intensity, frequency, and season, and although restoration of the historic fire regime is the desired goal, initial control of hardwoods may require manipulation of fire frequency, intensity, and season beyond those of historic fire (Robbins and Myers 1992). For example, Masters *et al.* (1995), in their recommendations for the reintroduction of fire into the shortleaf pine forests of the McCurtain County Wilderness Area in Oklahoma, called for initial use of dormant season burns to acclimate the old growth pines to fire. These were to be followed by high frequency growing season fires to remove small stems, and then by large-scale fires initiated after longer burn intervals to hasten return to precolonial conditions. Sparks *et al.* (1998, 1999) found late dormant season burns preferable to late growing season burns in reducing hardwood root stock and promoting grasses and forbs. To use fire successfully, managers must have solid understanding of the frequency, intensity, variability, and season of fire necessary to achieve management objectives, and specifically identify these in the planning of a prescribed burning program.

Site Preparation

As mentioned above, mechanical and/or chemical methods of site preparation can have detrimental effects on native groundcover plants (discussed in Glitzenstein *et al.* 1993, Provencher *et al.* 1999). Effects of site preparation methods can vary depending on characteristics of the specific site, especially soil moisture content. In general, mechanical and chemical site preparation increase weedy species, and repeated use can reduce or eliminate native species. Site preparation that leads to soil disturbance will favor more ruderal, weedy, disturbance-tolerant species at the cost of sensitive species (Provencher *et al.* 1998, 1999), and recovery rates for native groundcovers may approach 50 years in xeric soils (Provencher *et al.* 1997, 1998). Windrows and other methods that create piles are among the most destructive of mechanical site preparation methods. Roller chopping may have minimal impacts on xeric sites, especially if light machines are used (described above, Outcalt and Lewis 1990), but may be more damaging on wetter sites. Bracke-mounding has lower impacts than roller chopping. Bracke-mounding is a relatively non-invasive technique by which small mounds rather than plow lines are created to expose the mineral soil. Use of heavy-duty mowers or grinders mounted on rubber-tired tractors may also have lower impacts on soils and tree roots than roller chopping. However, site preparation is best performed using prescribed fire in order to minimize disturbance.

Direct Seeding and Planting

Not all of the desired plant species may return through the use of prescribed fire alone, depending on the degree of habitat alteration and the availability of natural seed sources. Progress has been made in the restoration of specific species using direct seeding and planting. For example, Hattenbach *et al.* (1998) reported successful use of direct seeding of wiregrass and several other groundcover species in the restoration of the Apalachian Bluffs and Ravines Preserve in Florida. Other examples of successful restoration of desired groundcover plants are described by Glitzenstein *et al.* (1998a, 1998b) and Bissett (1998). Researchers stress the need for frequent fire prior to and during restoration efforts to create required conditions for germination and to promote flowering. Direct seeding and planting is a labor-intensive technique conducted at very small scales. Thus, protection of existing native groundcovers should always be the first option.

H. ECOSYSTEM MANAGEMENT

Ecosystem management has been defined in many ways (reviewed by Meffe and Carroll 1997), but its various definitions contain common themes. In general, ecosystem management is an expansion of single-species or traditional management methods to include broader ecological, socioeconomic, and institutional perspectives. Meffe and Carroll (1997), in their review of ecosystem management, have developed the following composite definition:

> Ecosystem management is an approach to maintaining or restoring the composition, structure, and function of natural and modified ecosystems for the goal of long-term sustainability. It is based on a collaboratively developed vision of desired future conditions that integrates ecological, socioeconomic, and institutional perspectives, applied within a geographic framework defined primarily by natural ecological boundaries.

This definition summarizes important aspects of ecosystem management common to various definitions (e.g., Grumbine 1994, Christensen *et al.* 1996), including:

1. *Conservation of biological diversity and ecological integrity.* Targets of conservation include all natural levels of organization, from genes through landscapes; the complex interactions among these levels; natural disturbance regimes; and ecosystem functions. Both natural and modified landscapes have these conservation targets.

2. *Long-term sustainability.* Sustainability, over generations and centuries, is of overwhelming importance. It should always be a clearly identified objective that is incorporated into management planning.

3. *Collaboration.* Successful ecosystem management requires cooperation among federal, state, and local agencies, tribal governments, corporations, and individuals.

4. *Desired future conditions.* Desired future conditions are determined based on historical, ecological, and cultural considerations. This vision should be specifically identified and incorporated into management planning.

5. *Ecological perspective.* Excellent science is a foundation of ecosystem management.

6. *Socioeconomic perspective.* Ecosystem management recognizes that humans are a fundamental component of the natural world, and that conservation must protect human rights as well as biological diversity. Local and indigenous people should be involved in decision-making at the outset and throughout the management process, and impacts of management actions on people must always be evaluated. Excellent social science, therefore, is also a foundation of ecosystem management.

7. *Institutional perspective.* Institutions must be flexible, to respond to changing needs and new information. Flexible administration and legislation that properly reflects human values is the third foundation of ecosystem management.

8. *Natural ecological boundaries.* Precise definitions of ecosystems are not required for ecosystem management; rather, boundaries should reflect some natural border of interest (such as a watershed or mountain range, Meffe and Carroll 1997). Therefore, ecosystem management is generally conducted at larger geographic scales than traditional management. Also, management across political boundaries can be conducted only through cooperative efforts.

9. *Adaptive management.* An important component of ecosystem management not specifically identified in Meffe and Carroll's (1997) definition is its ability to adapt to changing environmental conditions and new information. The fundamental basis of adaptive management is experimental research, complete with adequate reference sites and controls. Adaptive management requires feedback from consistent and intensive biological monitoring, and indicator species must be carefully chosen to reflect management goals.

Ecosystem Management and Red-cockaded Woodpeckers

Current management for red-cockaded woodpeckers is, in many ways, an ecosystem approach. Long-term sustainability is the primary objective of management recommended in this recovery plan, and desired future conditions that will support long-term sustainability are identified herein. Cooperation among federal agencies (specifically, the U.S. Fish and Wildlife Service, the U.S. Forest Service, the U.S. Departments of Defense and Energy, and the National Park Service) is required in the management of core and essential support recovery populations. Cooperation of federal, state, and local agencies, corporations, and individuals is being fostered for the management of red-cockaded woodpeckers on state and private lands. Finally, ecological borders are used for recovery units and form the basis of the translocation strategy.

Moreover, management for red-cockaded woodpeckers provides strong benefits for entire ecosystems. Such benefits are mainly the result of broad-scale prescribed burning programs and broad-scale silviculture that restores open conditions and retains old trees throughout the landscape. In addition, cavities created by red-cockaded woodpeckers or supplied to them through management are used by a host of secondary cavity species. Ecologically, single-species management of red-cockaded woodpeckers merges with ecosystem management for three main reasons: (1) red-cockaded woodpeckers are an indicator species whose population trends can mark the health of southern pine ecosystems (Provencher *et al.* 2001a); (2) red-cockaded woodpeckers are an umbrella species, whose protection provides simultaneous protection for many associated species; and (3) red-cockaded woodpeckers are a keystone species whose presence influences the presence and/or abundance of other species (secondary cavity users) in the community.

However, some aspects of current woodpecker management have not yet been expanded to the level of the ecosystem. One example of current management that is not consistent with an ecosystem approach is management of predation and cavity kleptoparasitism. Managers of several red-cockaded populations have instituted predator and kleptoparasite control programs, but no research has assessed management impacts on these other species or on indirect interactions among community members. Ecosystem management protects viable populations of all native species in the region. More information concerning the population dynamics of predators and cavity kleptoparasites, and their impacts on red-cockaded woodpeckers in general, is required before methods of control can be considered part of an adaptive, ecosystem-based strategy. At present, the U.S. Fish and Wildlife Service is recommending that methods of control be non-lethal, and used only in critically small populations of red-cockaded woodpeckers (see 8G).

The primary example of current management that is not consistent with an ecosystem approach is the continued focus of most management actions, especially prescribed burning and retention of old trees, within the cluster rather than throughout the landscape. Burning and retaining old trees only in small patches provides only limited benefits to other members of southern pine communities. Moreover, such patch-based management has had detrimental effects on red-cockaded woodpeckers as well, including decreased value of foraging habitat (James *et al.* 1997, Walters *et al.* 2000, 2002a), increased cavity damage by pileated woodpeckers (Saenz *et al.* 1998), and increased mortality of cavity trees due to pests such as southern pine beetles (Conner *et al.* 1997a). Fundamental change in the scale of prescribed burning and beneficial silvicultural practices is required for both ecosystem management and the recovery of red-cockaded woodpeckers.

Some management actions must continue to be applied at the level of individual territories or aggregations of territories rather than at a landscape scale. That is, some aspects of single-species management continue to be critical to the recovery of red-cockaded woodpeckers. Chief among these are cavity management (see 8E), establishment of strategically placed recruitment clusters (8B), and translocation (8H). Predator and cavity kleptoparasite control is a single-species management technique also, but it differs from those listed above in that it can potentially disrupt natural ecosystem processes and impact other native species.

Thus, at present red-cockaded woodpeckers are best managed with a combination of single-species and ecosystem management. In addition, other members of southern pine communities benefit substantially from such management. Once red-cockaded woodpeckers attain recovery, single-species methods may not be required. Currently, we hope that ecosystem management by itself, including continued monitoring of red-cockaded woodpeckers, will provide long-term sustainability for all members of southern pine communities. However, at this time we simply do not know what management will be needed after delisting. Our understanding of future management needs will increase as the species recovers.

4. CURRENT STATUS AND CONSERVATION INITIATIVES

A. PRIVATE LANDS

Conservation of red-cockaded woodpeckers on privately owned lands is an important part of species recovery (Costa 1995b, 1997, Bonnie and Bean 1996, Bonnie 1997), although primary support for recovery is provided by federal properties (4C). Red-cockaded woodpeckers on private lands have inherent ecological, cultural, and historical value. Groups and populations of red-cockaded woodpeckers on private lands also have substantial value as reservoirs of genetic resources, sources of immigration for other populations, and as stepping stones to facilitate dispersal between other populations. In addition, prior to species recovery, many populations on private lands will have a key role in translocation programs, as either donors or recipients of red-cockaded woodpeckers. Currently, 23 percent of all red-cockaded woodpecker groups are located on private lands. However, other than the prohibition against take (below), nothing in the Endangered Species Act requires private landowners to participate in active conservation. Thus the role of private landowners in species recovery is important but voluntary.

The voluntary nature of active conservation on the part of private landowners has some benefits. Private lands conservation arising from local participants can be more meaningful and longer lasting than attempts at regulating private land use by federal authorities. The most successful conservation programs are those that strike a balance between voluntary participation and federal control. For endangered species, private landowners require a mechanism for resolving land use conflicts; however, mitigation to help offset adverse impacts to listed species must be adequate and federally supervised (Bean and Wilcove 1997). Flexibility, with appropriate boundaries, can foster genuine conservation interest on the part of local landowners and reduce the resentment that is a common result of enforcement of federal regulations (Bean and Wilcove 1997, Bonnie 1997). For example, volunteer participants in Safe Harbor programs (below) have shown increased concern for red-cockaded woodpeckers on their lands (Bonnie 1997). Raising awareness, incentives, and the removal of disincentives are key factors facilitating the rise of conservation among private individuals (USFWS 1979, 1985, Bonnie and Bean 1996, Kennedy *et al.* 1996).

These benefits of voluntary conservation were recognized, encouraged, and incorporated into a private lands conservation strategy by the U.S. Fish and Wildlife Service during the 1990's (Costa 1995b; described below). Some early efforts may have fallen short of conservation goals (Bonnie 1997), but with continual improvements the private lands conservation strategy of the U.S. Fish and Wildlife Service has shown remarkable success.

The Endangered Species Act and Private Landowners

Federal law does not require private landowners to participate in the recovery of threatened and endangered species but does prohibit their 'take' (Section 9a of the Act). The term, take, means to "harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct" (Section 3.18 of the Act). Habitat destruction and alteration may be considered forms of take where they are the proximate and foreseeable cause of death or injury to members of the species, following a Supreme Court ruling on this issue (Sweet Home vs. Babbitt). The Endangered Species Act does provide a mechanism for take of endangered species on private lands if that take is "incidental to, and not the purpose of, the carrying out of an otherwise lawful activity" (Section 10a of the Act). Incidental take may be permitted by the U.S. Fish and Wildlife Service only after the applicant submits a detailed Habitat Conservation Plan (HCP) that includes steps to be taken to minimize and mitigate impacts from the proposed actions (Section 10a). Thus, the U.S. Fish and Wildlife Service has formulated guidelines for mitigation of impacts to red-cockaded woodpecker groups (below). Still, incidental take permits are issued rarely, because generally alternatives to incidental take exist, and the Act requires the evaluation of alternatives and their use if appropriate (Section 10a). Federal properties are not involved in the incidental take permitting process, but rather must consult with the U.S. Fish and Wildlife Service on proposed actions that may have the potential to result in incidental take (Section 7a of the Act).

Recent Trends and Current Status

Despite continued protection under the Endangered Species Act, the decline and local extirpation of red-cockaded woodpeckers on private lands has been well documented across their range. Reports from North Carolina (Carter 1974, 1990, Carter *et al.* 1983, 1995), South Carolina (Cely and Ferral 1995), Georgia (Baker 1981, 1995), Arkansas (James and Neal 1989), Texas (Ortego and Lay 1988), Florida (Baker 1983), and range wide (Thompson 1976, Ligon *et al.* 1986, James 1995) show declines and local extirpations into the early 1990's. These losses are the result of a variety of factors including loss and fragmentation of habitat, fire suppression and resultant changes in habitat structure, and vulnerability to environmental and demographic stochasticity because of small population size. Currently, there are 1296 known active clusters on private lands in 11 states (Costa and Walker 1995, USFWS unpublished), and the existence of up to 280 additional groups is considered likely.

The Private Lands Conservation Strategy

The private lands conservation strategy was developed by the U.S. Fish and Wildlife Service in response to the realization that red-cockaded woodpeckers on private lands were important to the recovery of the species, and that their loss was a significant biological problem (Costa 1995b, 1997). Moreover, the U.S. Fish and Wildlife Service recognized that conservation of red-cockaded woodpeckers on private lands would require a multi-faceted approach based on conservation science and innovative conservation partnerships (Costa 1995b, 1997). The strategy has been aggressively implemented, modified as necessary based on new scientific findings, and regularly evaluated to ensure goals are being achieved. Five primary objectives of the private lands strategy are to (1) increase the acreage of private land under management for red-cockaded woodpeckers; (2) maintain or increase the larger populations on private lands, (3) establish healthy, spatially aggregated, and protected groups of woodpeckers to offset losses, (4) foster and develop corporate partnerships between and among federal, state, and private parties responsible for and interested in red-cockaded woodpecker recovery and (5) increase, via translocation, the size of populations on state and federal lands (Costa 1995b). This last objective does not imply that federal properties are appropriate mitigation sites, but private lands do occasionally contribute birds to public properties as part of the regional translocation strategy.

The implementation of the private lands strategy between the U.S. Fish and Wildlife Service and private land conservation partners since 1992 has helped to slow, stabilize, and in some cases reverse population declines among woodpeckers on privately owned lands. It has resulted in significantly increased protection for many woodpecker groups and their habitat on privately owned lands, and raised the possibility that such protection can become the normal standard rather than the exception. Finally, the private lands strategy has resulted in the creation of strong and effective partnerships with a multitude of diverse partners. Currently, 509 red-cockaded woodpecker groups on 140,608 ha (347,439 ac) of private lands are protected, in agreements involving 139 private landowners. These agreements provide protection for 40 percent of the known red-cockaded woodpeckers on private lands. Additionally, several landowners in signed and pending agreements have agreed to increase their existing populations. These increases could result in 71 additional groups.

The development of the private lands strategy began in the early 1990's, with initial attempts to protect woodpeckers on forest industry lands (Costa 1995b). In 1992, the first Memorandum of Agreement (below) was signed with an industrial forest landowner in an effort to protect approximately 90 groups in Arkansas and Louisiana (Wood and Kleinhofs 1995). Seven other Memoranda of Agreement followed (Costa 1997). These are ‘no-take’ agreements under which a corporation agrees to protect occupied habitat and conduct some habitat management (Bonnie 1997, Costa 1997). Since 1995, the U.S. Fish and Wildlife Service has shifted from Memoranda of Agreement to Habitat Conservation Plans (HCPs; Bonnie 1997, Costa 1997), in which incidental take of existing and/or future woodpecker groups is permitted in exchange for management of occupied and unoccupied habitat. Habitat Conservation Plans, authorized under Section 10 of the Endangered Species Act, can involve a variety of landowners, including timber and other corporations, private citizens, and developers. Two forms of HCPs currently exist: individual plans and statewide plans. More recently, Safe Harbor agreements have become the primary tool for conservation of red-cockaded woodpeckers on private lands (Bonnie 1997, Costa and Kennedy 1997, Costa 1999, Costa *et al.* in press).

Memoranda of Agreement

Memoranda of Agreement (MOAs) are legal conservation agreements between the U.S. Fish and Wildlife Service and corporate landowners. The agreement outlines management actions by which the corporation can satisfy responsibilities under the Endangered Species Act and the U.S. Fish and Wildlife Service’s guidelines for habitat management, and meet corporate objectives for land management. These management actions typically include population monitoring, management and retention of current and future nesting habitat, maintenance of adequate foraging habitat, and research and educational initiatives. Several MOAs also include state or other federal agencies as cooperators. Motivation to enter into such agreements includes reduced risk of litigation, prestige and satisfaction associated with conservation efforts, and consolidation of populations and responsibility (Costa and Edwards 1997). Currently, over 12,990 ha (32,100 ac) of habitat and 83 active woodpecker clusters are managed under Memoranda of Agreement.

Individual Habitat Conservation Plans

Individual Habitat Conservation Plans allow the ‘incidental take’ of red-cockaded woodpecker groups with mitigation, as authorized under the Endangered Species Act. Both the plan and the associated mitigation are funded by the landowner. Early HCPs for individual landowners were criticized because the mitigation required was not considered sufficient to offset the permitted loss of groups (Bonnie 1997). These critics correctly identified two major faults of early mitigation efforts. First, occupation of the newly established clusters was not assured. Second, the creation of clusters on federal properties did not truly mitigate damage to privately owned clusters, because federal agencies are already required to conserve (recover) their populations. In response to these criticisms, the current policies governing the use of mitigation (below) require that one occupied cluster be established for each active cluster harmed or removed. In addition, new groups are established on private lands when possible (below).

TABLE 5. Number of active red-cockaded woodpecker clusters (ACT, 2000) on private properties that harbor or are capable of harboring ten or more active clusters and are currently under partnerships with the U.S. Fish and Wildlife Service. These properties are all designated significant support populations (see 7). Also listed are the property owners, property population goal, and type of agreement.

Property (State)	**Owner**	**ACT 2000**	**Goal**	**Type**[1]
Arcadia Plantation (SC)	Private Landowner	11	11	SH
Avalon Plantation (FL)	Turner Endangered Species Fund	7	25+	MOA
Bates Hill Plantation (SC)	Private Landowner	12	12	SH
Brookgreen Gardens (SC)	Brookgreen Gardens	6	10	SH[2]
Brosnan Forest (SC)	Norfolk Southern Railroad	75	100	SH
Brushy Creek (TX)	International Paper	3	20	SH
Calloway Tract (NC)	The Nature Conservancy	5	10	SH
Crossett Forest (AR/LA)	Plum Creek Timber Company	82	92	MOA
Curtis H. Stanton Energy Center (FL)	Orlando Utilities	7	10	----
Friendfield Plantation (SC)	Private Landowner	10	14	SH
Good Hope Plantation (SC)	Private Landowner	12	12	SH
Hobcaw Barony (SC)	B. W. Baruch Foundation	23	23	SH
J. W. Jones Ecological Research Center (GA)	Ichauway, Inc.	6	10+	SH
Medway Plantation (SC)	Private Landowner	14	14	SH
Palmetto-Peartree Preserve (NC)	Conservation Fund	25	25+	CE
Piney Grove Preserve (VA)	The Nature Conservancy	3	10+	SH
Plum Creek Conservation Area (AR)	Plum Creek Timber Company	26	30	HCP
Potlach Corporation Lands (AR)	Potlach Corporation	20	30	HCP
Prince George (SC)	Prince George Foundation	3	10	SH
Red Hills (GA/FL)	Various Landowners	180	180	SH[3]
Scrappin' Valley (TX)	Temple Inland Corporation	8	14	SH
Southern Pines/Pinehurst (NC)	Various Landowners	47	47	SH
Southlands Experimental Forest (GA)	International Paper	8	30	HCP
TOTAL: 22 Properties in 8 States		**588**	**729**	

[1]Safe Harbor (SH), Memorandum of Agreement (MOA), Conservation Easement (CE), or Habitat Conservation Plan (HCP). See text for more detail.

[2] Pending.

[3] Over 30 landowners harbor 180 active clusters, some of which are enrolled in Safe Harbor, some are pending enrollment, and more enrollments are anticipated.

Since 1995, the U.S. Fish and Wildlife Service has authorized ten incidental take permits for non-industrial forest landowners. Under these permits, 27 groups of red-cockaded woodpeckers may be impacted or removed, pending completion of mitigation. Mitigation for these groups includes the probable establishment of 52 new groups through creation of recruitment clusters and/or translocation of juveniles to unoccupied clusters (Costa 1997).

The U.S. Fish and Wildlife Service has also issued three individual HCPs for industrial forest landowners. These plans provide current protection for 64 groups and potential long-term protection for 90 groups of red-cockaded woodpeckers.

Statewide Habitat Conservation Plans

Currently, statewide Habitat Conservation Plans (not including statewide Safe Harbor, below) permit the incidental take of demographically isolated groups only. Defining demographic isolation for this purpose is not an easy task. It is known that isolation of red-cockaded woodpecker groups results in decreased likelihood of group survival. However, research into the isolation of groups has been designed to identify spatial arrangements that increase population persistence, not to identify a statewide standard for incidental take (Bonnie 1997). Establishing a threshold measure of isolation above which groups would be available for statewide incidental take is a matter of some debate, and requires further research attention.

Safe Harbor

The Safe Harbor program has been an immense success for both landowners and red-cockaded woodpeckers (Bonnie 1997, Costa 1997, 1999, Costa *et al.* in press). Red-cockaded woodpecker Safe Harbor permits have been issued for the sates of Texas, South Carolina, and Georgia, the six-county Sandhills region of North Carolina, and a Nature Conservancy preserve in Virginia (Lohr 2000, Costa *et al.* in press). Louisiana and Alabama have draft plans, Florida has initiated the plan development process, and two individual landowners in Florida and Mississippi are working on agreements with the U.S. Fish and Wildlife Service (Costa *et al.*, in press). Under a Safe Harbor agreement, a landowner agrees to actively manage nesting and foraging habitat (i.e., a safe harbor) for the number of active red-cockaded woodpecker clusters equal to those present when the agreement is initiated (i.e., the baseline). Landowners must also agree to enhance existing habitat and/or improve additional potential woodpecker habitat, typically through the use of prescribed fire and cavity management. In turn, the landowner receives an incidental take permit, authorizing a land use change, for any additional woodpecker groups that may occupy the property in the future as a result of beneficial management practices. Thus, private landowners are free to manage their properties with prescribed fire, thinnings, lengthened timber rotations, or other actions that may benefit red-cockaded woodpeckers without fear of additional land-use restrictions.

Eligible landowners enrolled in Safe Harbor agreements may choose to enter into mitigation banking (below), and increase their baseline in exchange for a mitigation fee. This can be a powerful incentive for private landowners to join a Safe Harbor program and aggressively manage their lands for red-cockaded woodpeckers (Bonnie and Bean 1996, Kennedy *et al.* 1996, Costa and Kennedy 1997). Mitigation banks can be established only by following the guidelines presented below.

As of 2001, 191 groups, 48 landowners, and 58,005 ha (143,272 ac) in South Carolina, 50 groups, 53 landowners, and 14,354 ha (35,455 ac) in North Carolina, 17 groups, 19 landowners, and 6,029 ha (14,891 ac) in Texas, 8 groups, 3 landowners, and 13,142 ha (32,461 ac) in Georgia, and 3 groups, 2 landowners, and 734 ha (1,812 ac) in Virginia were enrolled in Safe Harbor agreements (Costa *et al*. in press). Many of these groups provide important support for nearby recovery populations.

Mitigation

No Net Loss of Groups

The philosophy guiding mitigation policy is that there be no net loss of red-cockaded woodpecker groups, and a primary objective is to assure that the status of the species as a whole is better following mitigation than before. Mitigation of impacts to red-cockaded woodpeckers is generally achieved through the establishment of a woodpecker group in another location, for every group that is affected by the proposed action. In general, the minimum required ratio of newly established to impacted groups is one to one. For the ten HCP permits issued to date, this ratio has been two to one (Costa 1997). Preservation credits, discussed below, are an exception to the required one to one ratio.

Mitigation Site

The location in which new groups are established is known as the mitigation site. This term refers to both the actual recruitment clusters and the population that contains the newly established groups. Four factors are important to the choice of mitigation sites: geographic location, ownership class (i.e., prior commitment to recovery), degree of protection in place, and amount of available habitat (i.e., maximum future population size). Mitigation within the recovery unit is preferred, to serve ecological goals and reduce costs. However, the Fish and Wildlife Service may approve mitigation outside recovery units on a case-by-case basis.

The first priority for ownership class of mitigation sites is private and state lands. When all opportunities to mitigate on private and state lands within the above geographic restrictions have been exhausted, federal lands shall be considered. Mitigation on federal properties will be conducted only if it is the sole appropriate option within the recovery unit. In general, the use of federal properties as mitigation sites for impacts on private lands is strongly discouraged. Additionally, the U.S. Fish and Wildlife Service prefers that mitigation sites have a degree of protection greater than that of impacted groups.

Mitigation sites must have sufficient habitat to support at least 10 groups of red-cockaded woodpeckers in territories that are aggregated, not isolated, in space. Only with a highly aggregated spatial structure do populations of 10 woodpecker groups have any reasonable chance of persisting over periods of 20 years or more (Crowder *et al.* 1998, Walters et al. 2002b). Mitigation sites may consist of multiple, adjacent properties under private or state ownership. Potential mitigation sites directly adjacent to red-cockaded woodpecker populations on federally owned lands may qualify even if the site has a capacity of less than 10 groups, providing the site and federally owned population has a combined capacity of 10 or more groups.

Mitigation Groups

Mitigation groups are those newly established in exchange for permission to impact groups, on a one-to-one basis as discussed above. Mitigation groups must have equivalent breeding status as impacted groups. In other words, if an impacted group consists of a solitary male, then only a solitary male needs to be established for mitigation, but if an impacted group consists of a potential breeding group, then a potential breeding group must be established as the mitigation group. Helpers do not need to be “replaced”.

Mitigation groups are typically established prior to the impact on existing groups. However, incidental take may occur prior to successful mitigation if legally binding implementation agreements and performance bonds are in place. A mitigation group is considered established if evidence of breeding is detected or if the same potential breeding group or solitary male remain in the mitigation cluster for six months including a breeding season (April – July).

Mitigation Credits, Mitigation Banks, and Preservation Credits

Several tools to facilitate mitigation exist, including mitigation credits, mitigation banks, and preservation credits. A mitigation credit is earned once a mitigation group has been established (one credit is equal to one group), and is used by impacting an existing group. A mitigation credit can be used immediately after earning or stored in a mitigation bank to be used in the future. Mitigation credits stored in a bank can also be made available for sale to third parties requesting a permit to impact an existing group or groups. A mitigation bank is the mitigation site in which new groups are established. Guidelines for mitigation sites (above) apply to mitigation banks. Mitigation banks may be owned by a single or multiple landowners, but must have approved habitat management plans including regular prescribed burning and cavity management in place.

Finally, a preservation credit is earned by increasing the protection of one to three existing groups in exchange for the incidental take of one group. Increased protection may take the form of private land conservation easements, direct land acquisition, and subsequent transfer to protected/managed public land agencies or other conservation programs that ensure protection, but must be in place for perpetuity. In addition, preservation groups must benefit from population monitoring and habitat management, including frequent prescribed burning (8K), cavity and cluster management (8E, 8F), and provision of foraging habitat that meets the recovery standard (8I). Perpetual protection of one to three groups in excellent habitat in exchange for the loss of one group is considered an improvement in the conditions faced by red-cockaded woodpeckers as a whole, in agreement with the overall objective of mitigation policy.

The specific ratio for preservation credits is determined on a case-by-case basis. Variables used to calculate this ratio include location, population size, trend, viability, and ownership, forest type, breeding status, and available foraging habitat. The final ratio is based on a careful comparison of the status of these variables for both the impacted population and the mitigation site. These variables are used to ensure that the biological value of the group being impacted is replaced or improved upon by the mitigation group.

Funding for Mitigation

Mitigation is funded by the landowner performing the action that will impact woodpecker groups. Mitigation costs include a management endowment sufficient to cover habitat management, such as prescribed burning, for the mitigation groups for 5 years (one full generation for red-cockaded woodpeckers). Other costs include the initial provisioning of cavities and initial midstory control in the recipient cluster as well as the costs of translocating juvenile birds to create mitigation groups and translocating resident adults from affected clusters upon successful mitigation.

Other Incentive Programs

Several programs other than Safe Harbor Agreements are available to assist private landowners in management of their lands, but unlike Safe Harbor these are not designed directly for red-cockaded woodpeckers. However, programs that could potentially benefit woodpeckers are available through the Farm Services Agency, Natural Resources Conservation Service, U.S. Fish and Wildlife Service, and state forestry and wildlife agencies. Local offices of the administering agency or organization should be contacted for information about future sign-ups and eligibility requirements.

Farm Service Agency

The Conservation Reserve Program offers annual rental payments and cost-share assistance to plant permanent areas of grass and trees on land that is subject to erosion, and to improve soil, water, and wildlife resources. Assistance for up to 50 percent of costs is available for the 10 to 15 year contracts. This program is most applicable to agricultural lands. However, some management practices implemented under these programs could benefit red-cockaded woodpeckers.

Natural Resources Conservation Service

Landowners who participate in the Wetlands Reserve Program may sell a conservation easement or enter into a cost-share restoration agreement to restore and protect wetlands. Landowners receive financial incentives to enhance wetlands in exchange for retiring marginal agricultural land. In addition to farmland, eligible lands include production forestland where hydrology has been altered, riparian areas that link protected wetlands, and lands adjacent to protected wetlands that contribute significantly to wetland functions and values. The program offers landowners three options: permanent easements, 30-year easements, and restoration cost-share agreements of at minimum 10-year duration. Landowners continue to control access to the land—and may lease the land—for hunting, fishing, and other recreational activities requiring no development.

The Wildlife Habitat Incentives Program is designed to help private landowners develop and improve wildlife habitat on their lands. Participating landowners work with the Natural Resources Conservation Service to prepare a wildlife habitat development plan in consultation with the local conservation district. The plan describes the landowner's goals for improving wildlife habitat, a list of practices, a schedule for installing them, and steps necessary to maintain the habitat for the life of the agreement. The participant enters into a cost-share agreement usually lasting at least 10 years. The landowner agrees to maintain the cost-shared practices and allows monitoring to judge the effectiveness of the practice. The U.S. Department of Agriculture agrees to provide technical assistance and pay up to 75 percent of the cost of identified practices.

The Environmental Quality Incentives Program is for farmers and ranchers who face serious threats to soil, water, and related natural resources. The program offers financial, educational, and technical help to install or implement structural, vegetative, and management practices called for in 5 to 10-year contracts. Eligible lands include cropland, rangeland, pasture, forestland, and other farm or ranch lands where the program is delivered. Cost-sharing may provide up to 75 percent of the funds for certain conservation practices.

The Forestry Incentives Program is intended to assure the nation's ability to meet future demand for sawtimber, pulpwood, and quality hardwoods. The program pays cost sharing of up to 65 percent (with a limit of $10,000 per person per year) for tree planting, timber stand improvement, and site preparation for natural regeneration. The state forester provides technical advice in developing a management plan and helps find approved vendors, if needed, for completing the work. Private, non-industrial landowners who own less than 4,047 ha (1,000 ac) are eligible to participate in the program. However, this program is available only in selected counties.

U.S. Fish and Wildlife Service

The Partners for Wildlife Program provides technical and financial assistance to private landowners that are restoring and enhancing fish and wildlife habitat. Program emphasis is on restoration of historic vegetation and hydrology. Seventy percent of the project area must reflect the historic vegetation and hydrology while 30 percent may consist of wildlife enhancement activities. Landowners must sign a minimum of 10-year agreement for some projects, and a 25-year agreement for restoration projects.

State Forestry Agencies

The Forestry Stewardship Program is intended to stimulate management of non-industrial, private forestland using multiple-use concepts. This technical assistance program provides management recommendations to fit the landowner’s objectives for forest management. Wildlife habitat, water quality, and soil protection are examples of objectives that can be incorporated into the landowner’s management plan. The Stewardship Incentives Program is intended to reimburse landowners for 75 percent of the cost of certain forest management practices, including those intended to improve habitat for endangered species. However, cost-share funding through the Stewardship Incentives Program is currently unavailable in many states.

State incentive programs administered by the respective state forestry agencies often emphasize reforestation. Through reforestation, however, other objectives of the landowner, such as creation or enhancement of habitat for red-cockaded woodpeckers, can be addressed. Some state wildlife agencies also administer incentive programs. Examples include Kentucky’s Habitat Improvement Program and Arkansas’ Acres for Wildlife Program. Not all state forestry or wildlife agencies within the range of the red-cockaded woodpecker offer incentive programs.

B. State Lands

Status and Distribution

As of 2000, there were an estimated 631 active clusters of red-cockaded woodpeckers on 44 state-owned properties in 7 states (USFWS, unpublished; Table 6). Largest concentrations of woodpeckers on state lands occur in Florida, North Carolina, and South Carolina.

During the 1970's, Jackson (1978b) found that approximately 300 clusters, or 8.6 percent of all reported clusters, were located on lands owned by state or local governments. These clusters were distributed across ten states, with the largest concentrations occurring in Florida and South Carolina. Seven of the remaining eight states had less than 12 clusters on state or local lands. Costa and Walker (1995) estimated that 384 active clusters occurred on state lands in 8 states. Although it is clear that several states have, by 2000, lost all woodpeckers on state lands, comparison of current population sizes with those from the 1970's is hampered by inconsistent survey techniques and increasing survey effort across time (Cely and Ferral 1995, Ortego *et al.* 1995, J. Cely, pers. comm.).

Conservation of woodpeckers on state lands is improving, but much progress remains to be made. Habitat management plans, including population goals, have not yet been established for all state lands. Through interviews with state land managers and biologists, J. Hovis (pers. comm.) found that most state agencies have implemented a prescribed burning regime on their lands inhabited by red cockaded woodpeckers. Beyond this, however, the level of management and population monitoring varies considerably both within and among states. For example, some state lands have never been surveyed completely for cavity trees, whereas others have been surveyed but the demography of the resident red-cockaded woodpecker population is unknown. Today, only a few populations on state lands have been intensively managed and/or monitored on a long-term basis. These include the McCurtain County Wilderness Area in Oklahoma (M. Howery, pers. comm.), the Sandhills Game Lands in North Carolina (Walters *et al.* 1988a), and the Sand Hills State Forest in South Carolina (Ferral 1998).

Recovery Role

State lands can contribute to the recovery of the red-cockaded woodpecker in numerous ways. Some state lands will contribute by being part of a designated recovery population. For example, in North Carolina the Holly Shelter Game Lands is part of a primary core population and the Sandhills Game Lands is part of an essential support population. In South Carolina, the Sand Hills State Forest is part of a secondary core population. Several state properties in South/Central Florida are designated essential support populations (see 7). Other state lands throughout the range of red-cockaded woodpeckers contribute to the conservation and recovery of the species as significant and important support populations (see 7).

Finally, state lands can contribute to recovery as mitigation sites (see 4A). Through the mitigation process, red-cockaded woodpecker populations on state lands could be enhanced or restored. Establishing state lands as mitigation sites, however, would require a commitment from the state agencies involved to monitor and manage their woodpecker populations on a long-term basis. Unfortunately, many state agencies have neither the personnel nor funds required to fill such a commitment. Although mitigation monies could be used to finance some management and monitoring activities,

TABLE 6. Number of active red-cockaded woodpecker clusters (ACT, 2000) on state properties, by state. Also listed is estimated potential size (number of active clusters). Except where noted, potential size is based on an agency estimate or property goal identified in a draft or approved red-cockaded woodpecker management plan, or submitted in an Annual Report (2000).

State	Property Full Name	ACT 2000	Potential Size[2]
Arkansas	Pine City Natural Area	1	2[1]
	subtotal	1	2
Florida	Babcock/Webb Wildlife Management Area	27	240[1]
	Blackwater River State Forest	26	≥45
	Camp Blanding Training Site	14	25
	Central Florida Reception Center – South Unit	1	1[1]
	Goethe State Forest	30	150
	Hal Scott Preserve	7	15[1]
	J. W. Corbett/Dupuis Wildlife Management Area	13	90[1]
	Kicco Wildlife Management Area	1	1[1]
	Ochlockonee River State Park	3	3[1]
	Picayune Strand State Forest	3	25[1]
	Platt Branch Mitigation Park	4	7[1]
	St. Sebastian River State Buffer Preserve	8	25
	Tate's Hell State Forest	29	400[1]
	Three Lakes Wildlife Management Area	51	125[1]
	Withlacoochee State Forest - Citrus Tract	46	100
	Withlacoochee State Forest - Croom Tract	5	30
	subtotal	268	1282
Louisiana	Alexander State Forest	5	5
	subtotal	5	5
North Carolina	Bladen Lakes State Forest	3	3[1]
	Holly Shelter Game Lands	38	38
	Johnston Community College	1	1
	Jones Lake State Park	1	4
	McCain Tract	5	7
	Sandhills Game Lands	134	160
	Singletary Lake State Park	4	6
	Weymouth Woods State Nature Preserve	7	13
	subtotal	193	232
Oklahoma	McCurtain County Wilderness Area	12	44
	subtotal	12	44

Table continued next page.

TABLE 6 (cont.). Number of active red-cockaded woodpecker clusters on state properties.

State	Property Full Name	ACT 2000	Potential Size[2]
South Carolina	Cheraw State Fish Hatchery	1	1
	Cheraw State Park	7	25
	Hampton Plantation State Park	1	1[1]
	Lewis Ocean Bay Heritage Preserve	2	10[1]
	Longleaf Pine Heritage Preserve	2	4[1]
	Manchester State Forest	3	3[1]
	Persanti Island	3	3[1]
	Sand Hills State Forest	51	~143[1]
	Sandy Island	32	35[1]
	Santee Coastal Reserve	8	16
	Santee State Park	1	7[1]
	Webb Wildlife Center	12	30[1]
	Wedge Plantation	2	2[1]
	Yawkey Wildlife Center	8	15[1]
	subtotal	133	295
Texas	Huntsville State Fish Hatchery	1	1[1]
	I. D. Fairchild State Forest	4	7
	W. G. Jones State Forest	14	14
	subtotal	19	22
	TOTAL	**631**	**1882**

[1]Potential size based on U.S. Fish and Wildlife Service or responsible agency's estimate derived by dividing the area of currently or potentially suitable upland pine on the property by 81 ha (200 ac) per cluster.

[2] Except for those potential sizes identified as goals in approved agency management plans, all other potential population sizes are non-binding and subject to change pending approval of site-specific management plans.

long-term programs on state lands will require additional funding. Accordingly, state agencies should be encouraged to seek Section 6 funds through the U.S. Fish and Wildlife Service to initiate or enhance their activities on state lands with red-cockaded woodpeckers.

Conservation of Biodiversity within States

Whereas recovery of red-cockaded woodpeckers as a species is founded on distribution of large populations throughout the species range, biologists and managers working at the state level must set priorities for conservation of biodiversity based on political (state) boundaries. We emphasize that small populations with a minor designated role in species recovery may be critical in conserving biodiversity at the state level.

C. Federal Lands

Conservation of red-cockaded woodpeckers as a species depends primarily on the conservation of populations on federal lands, for several reasons. First, the vast majority of red-cockaded woodpeckers in existence today are on federal lands (Costa and Walker 1995, James 1995; see Table 7). Second, federal properties contain most of the land that can reasonably be viewed as potential habitat for red-cockaded woodpeckers (USFWS 1985). Third, existing legislation, especially the Endangered Species Act (Section 7) but also the National Forest Management Act and others, require that federal agencies conserve listed species and maintain biodiversity within their lands. In the Endangered Species Act (Section 3), conservation is defined as “the use of all methods and procedures necessary to bring an endangered species or threatened species to the point at which the measures provided pursuant to this act are no longer necessary.” Thus, to the extent that legislation reflects public perception, it is the public’s view that recovery of endangered species and conservation of biodiversity is a responsibility of the federal government to be conducted primarily on publicly owned lands under federal control. This is a difficult task, as it requires the protection of biodiversity at or near precolonial levels on minute remnants of the habitat base. Private landowners can contribute substantially to conservation, but such contributions above the required protection against direct harm (take) are voluntary (see 4A).

Federal properties supporting populations of red-cockaded woodpeckers include national forests, military installations, national wildlife refuges, a national preserve, and a Department of Energy property. As of 2000, there were an estimated 3698 active clusters of red-cockaded woodpeckers on 55 federally owned properties in 9 states (USFWS, unpublished; see Table 7). National forests support the majority of core woodpecker populations required for delisting and therefore have a uniquely important role in the recovery of red-cockaded woodpeckers. Second to national forests in recovery importance are the military installations. National wildlife refuges have a smaller but important role in woodpecker recovery, as do the remaining occupied federal properties.

National Forests

Current Status and Trends

Currently, there are 24 populations of red-cockaded woodpeckers partly or wholly supported by national forests (see map insert and Table 7), ranging in size from 6 active clusters (Shoal Creek Ranger District of the Talladega National Forest) to 486 active clusters (Apalachicola Ranger District, Apalachicola National Forest). An additional national forest property, the Talladega Ranger District of the Talladega National Forest, currently harbors no active clusters but red-cockaded woodpeckers will soon be re-established there. The Apalachicola Ranger District, together with the Wakulla Ranger District and other adjoining properties, supports the largest woodpecker population in existence (665 active clusters; see 7, Table 8).

Numbers of active clusters on national forest properties over the past three years are presented in Table 7. Most populations on national forests appear to be stable or increasing, and a few are in decline. In contrast, most populations on national forests were declining until the mid 1980's, and a few were stable (Costa and Escano 1989). Management efforts during the past decade, especially prescribed burning and cavity management, have stabilized most of these populations and led to increases in many. It is very encouraging that the widespread declines have been stabilized. Our challenge now is to increase the populations to sizes necessary for species recovery.

Recent declines have occurred on four national forest properties. On the Talladega Ranger District, the Kisatchie Ranger District, and the Francis Marion National Forest, poor habitat resulting from lack of fire and suitable cavities is considered the primary factor in these recent declines (R. Costa, pers. comm.). The decline in the Vernon Unit, Calcasieu Ranger District is surprising, given the apparent health of the population and its habitat. The reason for this decline is not presently known, but may be the result of differences in field survey and census methods over time, and/or record keeping. Each of these populations has a substantial role in recovery (below, Table 7; see also 7, Table 8) and these declining trends must be reversed.

Role in Recovery

National forests have a vital role in recovery of red-cockaded woodpeckers, because most core populations within recovery units (see 7) are located in national forests. National forests (or ranger districts) containing all or part of a primary core population are the Angelina, Apalachicola (Apalachicola and Wakulla Ranger Districts), Bienville, Croatan, Francis Marion, Kisatchie (Vernon Unit of the Calcasieu Ranger District), Osceola, Sabine, and Sam Houston. Each of these national forests (or ranger districts) will support a population of at least 350 potential breeding groups at the time and after the species is recovered. National forests (or ranger districts) containing all or part of a secondary core population are the Catahoula, Conecuh, Davy Crockett, DeSoto (Chickasawhay and DeSoto Ranger Districts, separately), Homochitto, Oconee, Ouachita, and Talladega (Oakmulgee Ranger District). Each of these national forests (or ranger districts) will support a population of at least 250 potential breeding groups at the time and after the species is recovered. Two national forests—the Ocala in South/Central Florida and the Talladega (Shoal Creek/Talladega Ranger Districts) in the Cumberlands—harbor a support population designated essential to recovery of the species because of the importance of conserving red-cockaded woodpeckers in those regions. Populations on all other national forests, not designated as primary core, secondary core, or essential support populations, are designated significant support populations (see 7). As federally managed support populations, they are required to be increasing at least until the species is recovered. These populations are valuable because they protect against demographic, environmental, and catastrophic events, contain important genetic resources, and facilitate natural dispersal among populations. Because of these contributions, support populations are necessary to bring the species to recovery but will not be required for species viability once core populations reach population goals identified in delisting criteria (see 6A).

Military Installations

Current Status and Trends

At present there are 15 military installations harboring red-cockaded woodpeckers (see map insert and Table 7), ranging from 1 active cluster on Charleston Naval Weapons Station to 301 active clusters on Eglin Air Force Base and 350 active clusters on Fort Bragg. All of these populations appear to be stable or increasing, with the exception of Dare County Bombing Range. Like the populations on national forests, widespread declines among populations on military installations have been stabilized, but substantial increases in population sizes are still required for recovery. In general, the military is managing red-cockaded woodpeckers very effectively. Rates of increase reported from Marine Corps Base Camp Lejeune and Fort Stewart during the 1990’s are among the highest yet documented (in the absence of translocation), an encouraging result of intensive, well-planned, and well-executed management.

Role in Recovery

Military installations have a substantial role in recovery and continuing conservation of red-cockaded woodpeckers. Six military installations contain all or part of six primary core populations: Eglin Air Force Base, Fort Benning, Fort Bragg, Fort Polk, Fort Stewart, and Marine Corps Base Camp Lejeune. These primary core populations will contain at least 350 potential breeding groups at the time of and after the species is delisted. Avon Park Air Force Range is a designated essential support population because it supports one of the largest remaining populations in the ecologically unique South/Central Florida Recovery Unit (see 7). Dare County Bombing Range and Camp Mackall are likewise part of essential support populations because of unique or important habitat types. Seven other military installations contain significant support populations, whose increases are important to bringing the species to recovery for reasons described above; however, population goals for these populations are not included in delisting criteria.

National Wildlife Refuges

Current Status and Trends

There are currently 13 populations of red-cockaded woodpeckers partially or wholly contained on national wildlife refuges (see map insert and Table 7), ranging in size from 1 active cluster (Upper Ouachita, Pee Dee, and Black Bayou National Wildlife Refuges) to 116 active clusters (Carolina Sandhills National Wildlife Refuge). Most appear to be stable; several appear to be declining, including Carolina Sandhills, D'Arbonne, and Pocosin Lakes. Substantial increases are required for recovery.

Role in Recovery

National wildlife refuges have a small but important role in recovery of red-cockaded woodpeckers. One refuge (Okefenokee National Wildlife Refuge) contains part of a primary core population, and two refuges contain part of two secondary core populations (Carolina Sandhills and Piedmont National Wildlife Refuges). In addition, two refuges in northeastern North Carolina (Alligator River and Pocosin Lakes National Wildlife Refuges) contain part of a support population designated essential to recovery because of the importance of conserving red-cockaded woodpeckers in the unique habitat type there. The remaining populations partially or wholly on refuge lands are important or significant support populations (see 7) and should be managed for increasing populations. Big Branch Marsh National Wildlife Refuge, containing 15 active clusters at the present time, is notable among support populations on refuge lands because of its location in an ecoregion (Gulf Coast Prairies and Marshes) that currently contains no other woodpeckers.

Other Federal Lands

Two populations of red-cockaded woodpeckers occur on federal lands other than national forests, military installations, and national wildlife refuges. Big Cypress National Preserve harbors a population of 42 active clusters in the ecologically unique native hydric slash pine habitat of south Florida (see map insert and Table 7). Because of its unique habitat, this population is designated an essential support population. The Savannah River Site, controlled by the Department of Energy, contains an increasing population of 34 active clusters and is a secondary core population (see map insert and Table 7). This population will hold at least 250 potential breeding groups at the time of and after delisting.

TABLE 7. Number of active red-cockaded woodpecker clusters (ACT) on federal and tribal properties in 1998, 1999, and 2000, by responsible agency. Also indicated is property goal based on habitat designated for red-cockaded woodpeckers [usually 81 ha (200 ac) per cluster] in agency or site-specific management plans.

		ACT			
Federal Agency	**Property Full Name**	**1998**	**1999**	**2000**	**Goal**
National Park Service	Big Cypress National Preserve	40	41	42	42
	subtotal	40	41	42	42
U.S. Air Force	Avon Park Air Force Range	21	21	21	68
	Dare County Bombing Range	6	9	3	46
	Eglin Air Force Base	280	295	301	500
	Poinsett Weapons Range	5	6	6	30
	subtotal	312	331	331	644
U.S. Army	Camp Mackall	9	11	11	11
	Fort Benning	187	186	219	450
	Fort Bragg	309	350	350	436
	Fort Gordon	2	3	5	25
	Fort Jackson	13	21	24	126
	Fort Polk	45	44	46	179
	Fort Stewart	189	198	212	500
	Military Ocean Terminal Sunny Point	6	6	9	17
	Peason Ridge	25	25	23	120
	subtotal	785	844	899	1864
U.S. Dept of Energy	Savannah River Site	29	31	34	418
	subtotal	29	31	34	418
U.S. Forest Service	Angelina NF	30	30	29	252
	Apalachicola Ranger District, Apalachicola NF	505	486	486	500
	Bienville NF	106	106	104	500
	Catahoula Ranger District, Kisatchie NF	29	31	32	317
	Chickasawhay Ranger District, DeSoto NF	10	13	15	502
	Conecuh NF	13	14	18	309
	Croatan NF	60	58	62	169
	Davy Crockett NF	48	51	53	330
	DeSoto Ranger District, DeSoto NF	6	6	7	368
	Evangeline Unit, Calcasieu Ranger District, Kisatchie NF	68	70	72	231
	Francis Marion NF	368	334	344	453
	Homochitto NF	67	45	51	254
	Kisatchie Ranger District, Kisatchie NF	56	57	29	292
	Oakmulgee Ranger District, Talladega NF	123	115	110	394

Table continued next page.

TABLE 7 (cont.). Number of active red-cockaded woodpecker clusters on federal and tribal properties in 1998, 1999, and 2000.

		ACT			
Federal Agency	**Property Full Name**	**1998**	**1999**	**2000**	**Goal**
U.S. Forest Service (cont.)	Ocala NF	13	18	22	179
	Oconee NF	17	18	20	250
	Osceola NF	54	63	63	462
	Ouachita NF	15	16	21	400
	Sabine NF	22	25	28	262
	Sam Houston NF	168	168	168	541
	Shoal Creek Ranger District, Talladega NF	2		6	~125
	Talladega Ranger District, Talladega NF	1	5	0	~110
	Vernon Unit, Calcasieu Ranger District, Kisatchie NF	196	146	152	302
	Wakulla Ranger District, Apalachicola NF	125	125	138	506
	Winn Ranger District, Kisatchie NF	14	16	18	263
	subtotal	2116	2016	2048	8271
U.S. Fish and Wildlife Service	Alligator River NWR	2	2	3	~20+
	Big Branch Marsh NWR	8	9	15	20
	Black Bayou NWR			1	1
	Carolina Sandhills NWR	125	118	116	193
	D'Arbonne NWR	5	4	2	5
	Felsenthal NWR	15	15	15	34
	Noxubee NWR	37	38	44	88
	Okefenokee NWR	26	29	37	86
	Pee Dee NWR	1	1	1	10
	Piedmont NWR	35	37	39	96
	Pocosin Lakes NWR	4	1	1	50
	St. Marks NWR	6	6	9	71
	Upper Ouachita NWR	1	1	1	1
	subtotal	265	261	284	675
U.S. Marine Corps	Marine Corps Base Camp Lejeune	47	49	59	173
	subtotal	47	49	59	173
U.S. Navy	Charleston Naval Weapons Station	2	2	1	12
	subtotal	2	2	1	12
	TOTAL, FEDERAL PROPERTIES	**3596**	**3575**	**3698**	**12099**
Tribe					
Alabama-Coushatta	Alabama-Coushatta Tribe of Texas			2	2
	TOTAL, FEDERAL AND TRIBAL PROPERTIES			**3700**	**13101**

In summary, federal lands have a fundamental role in the recovery of red-cockaded woodpeckers. Advances in management of red-cockaded woodpeckers on federal lands have led to stabilization of most populations and increases in many. A few populations are still declining. For most populations designated as primary core, secondary core, or essential support populations, substantial increases are required before recovery population goals are reached.

D. NATIVE AMERICAN TRIBAL TRUST LANDS

Currently, there is one Native American Tribe with lands supporting active clusters of red-cockaded woodpeckers. Lands belonging to the Alabama-Coushatta Tribe of Texas presently support two active clusters, and the Alabama-Coushatta Tribal Forestry Department is actively managing for red-cockaded woodpeckers. Native American Tribes have no specifically designated role in recovery of red-cockaded woodpeckers, but are encouraged to participate in recovery efforts to the fullest possible extent.

PART II. RECOVERY

5. RECOVERY GOAL

The ultimate recovery goal is species viability. This goal is represented by delisting. Once delisting criteria are met, it is believed that the size, number, and distribution of red-cockaded woodpecker populations will be sufficient to counteract threats from demographic, environmental, genetic, and catastrophic stochasticity. Therefore, upon delisting the species will be viable over the long-term, at least under the current understanding of these stochastic processes. An interim goal is downlisting from endangered to threatened status.

6. RECOVERY CRITERIA

Population sizes identified in recovery criteria are measured in the number of potential breeding groups. A potential breeding group is an adult female and adult male that occupy the same cluster, with or without one or more helpers, whether or not they attempt to nest or successfully fledge young. A traditional measure of population size has been number of active clusters. Potential breeding groups is a better measure of population status, because this is the basis of population dynamics in this species, and number of active clusters can include varying proportions of solitary males and captured clusters. Estimates of all three parameters—number of active clusters, proportion of solitary males, and proportion of captured clusters—are required to support estimates of potential breeding groups.

To assist in the transition between these two measures, we have provided a range of numbers of active clusters considered the likely equivalents of the required number of potential breeding groups. Estimated number of active clusters is likely to be at least 1.1 times the number of potential breeding groups, but it is unlikely to be more than 1.4 times this number. Thus, an estimated 400 to 500 active clusters will be necessary to contain 350 potential breeding groups, depending on the proportions of solitary males and captured clusters and also on the estimated error of the sampling scheme. It is expected that all recovery populations will have sampling in place that is adequate to judge potential breeding groups. If this is not the case, only the highest number of active clusters in the range given can be substituted to meet the required population size.

A. DELISTING

Delisting shall occur when each of the following criteria is met. A brief rationale for each criterion is given immediately following this list, and a detailed discussion of species and population viability is presented in 2C. Discussion of the five listing factors identified in the Endangered Species Act (Section 4(a)(1)), and how they are related to red-cockaded woodpecker recovery, is also presented in this section. Definitions and descriptions of terms used in delisting criteria, such as recovery units, primary and secondary core populations, and essential support populations, are given in the next section (7). See Table 8 for population designation. All properties identified as part or all of a recovery population (Table 8) should be managed for maximum size that the habitat designated for red-cockaded woodpeckers will allow. (Maximum size is generally based on 200 ac [81 ha] per group).

Criterion 1. There are 10 populations of red-cockaded woodpeckers that each contain at least 350 potential breeding groups (400 to 500 active clusters), and 1 population that contains at least 1000 potential breeding groups (1100 to 1400 active clusters), from among 13 designated primary core populations, and each of these 11 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size.

Criterion 2. There are 9 populations of red-cockaded woodpeckers that each contain at least 250 potential breeding groups (275 to 350 active clusters), from among 10 designated secondary core populations, and each of these 9 populations is not dependent on continuing installation of artificial cavities to remain at or above this population size.

Criterion 3. There are at least 250 potential breeding groups (275 to 350 active clusters) distributed among designated essential support populations in the South/Central Florida Recovery Unit, and six of these populations (including at least two of the following: Avon Park, Big Cypress, and Ocala) exhibit a minimum population size of 40 potential breeding groups that is independent of continuing artificial cavity installation.

Criterion 4. There is one stable or increasing population containing at least 100 potential breeding groups (110 to 140 active clusters) in northeastern North Carolina and southeastern Virginia, the Cumberlands/Ridge and Valley recovery unit, and the Sandhills recovery unit, and these populations are not dependent on continuing artificial cavity installation to remain at or above this population size.

Criterion 5. For each of the populations meeting the above size criteria, responsible management agencies shall provide (1) a habitat management plan that is adequate to sustain the population and emphasizes frequent prescribed burning, and (2) a plan for continued population monitoring.

Rationale for Delisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift. One primary core population has the potential to harbor 1000 potential breeding groups within the near future; this criterion is included because such a large population may well be resistant to loss of genetic variation through drift. Eleven of 13 primary core populations are required for delisting because it is recognized that at any given time, one or two may be suffering hurricane impacts. Thirteen primary core populations are designated because of available habitat and because this number, together with 10 secondary core populations (below), may serve to facilitate natural dispersal among populations and maximize retention of genetic variability. Primary and secondary core populations provide for the conservation of the species within each major physiographic unit in which it currently exists, with the exception of South/Central Florida. This unit is represented by several, smaller, essential support populations (below). Populations that depend on continuing artificial cavity installation to maintain stable or increasing trends are barred from meeting delisting criteria because this management technique is considered appropriate for short-term management only.

Criterion 2. A population size of 250 potential breeding groups is the minimum size considered robust to environmental stochasticity, and is well above the size necessary to withstand inbreeding and demographic stochasticity. Nine of 10 designated secondary core populations are required for delisting to allow for hurricane impacts.

Criterion 3. This unique habitat type is represented to the extent that available habitat allows. Unique genetic resources are conserved as much as reasonably possible. Because of small size, some of these populations will remain vulnerable to extinction threats and may eventually be lost. The likelihood of extirpation of small populations is minimized by enhancing the spatial arrangement of territories so that they are highly aggregated.

Criterion 4. These unique habitats, and genetic resources contained within this population, will be represented at the time of delisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. Continued habitat management and population monitoring are necessary to ensure that the species does not again fall to threatened or endangered status.

Delisting Criteria and Listing Factors Identified in the Endangered Species Act

The Endangered Species Act (Section 4(a)(1)) identified five factors that threaten or endanger a species, any one of which is justification for listing. At delisting, therefore, none of these factors can exist. We discuss each of these factors below and describe the means by which, if this recovery plan is fully implemented, these factors will not threaten red-cockaded woodpeckers at time of delisting.

Listing Factor A: *the present or threatened destruction, modification, or curtailment of a species' habitat or range*. Red-cockaded woodpeckers are vulnerable to habitat loss and habitat degradation. Habitat loss and degradation were primary factors in the species' original decline (see 1A); these factors resulted from direct conversion of habitat to other land uses, fire suppression, and loss of mature pines within pine woodlands. Direct conversion of habitat no longer occurs on public lands, which form the basis of recovery for red-cockaded woodpeckers. However, currently, lack of frequent fire and mature pines continue to threaten the species on public and private lands (1B). Red-cockaded woodpeckers are most vulnerable to loss and degradation of nesting habitat (2D), but are also vulnerable to loss and degradation of foraging habitat (2E). Addressing these threats is a primary objective of this recovery plan.

Management actions such as artificial cavity installation, prescribed burning, and silviculture that protects old pines are powerful tools critical to restoration of habitat and recovery of the species. As such, these actions are heavily emphasized in management guidelines (8E, 8K, 8J), recovery tasks (9), and throughout the document. Moreover, these critical actions are represented in delisting criteria: a prescribed burning program is explicitly required as part of habitat management plans that must be in place for delisting (criterion 6), whereas a stable or increasing population trend, independent from continuing artificial cavity installation, is required for populations to meet their size requirements (criteria 1-5). A stable or increasing trend independent of continuing artificial cavity installation can only be achieved once large old pines are available in abundance.

Listing Factor B: *overutilization for commercial, recreational, scientific, or educational purposes.* Overutilization was not a factor in the original decline of red-cockaded woodpeckers and it is not currently a threat to species recovery.

Listing Factor C: *disease or predation.* Disease and predation were not factors in the original decline of red-cockaded woodpeckers and neither is currently a threat to species recovery.

Listing Factor D: *inadequacy of existing regulatory mechanisms*. Existing regulatory mechanisms, specifically the Endangered Species Act and the National Forest Management Act, are adequate to ensure the recovery of red-cockaded woodpeckers, assuming this recovery plan is fully implemented.

Listing Factor E: *other natural or manmade factors affecting its continued existence.* Other natural or manmade factors affecting the continued existence of red-cockaded woodpeckers include habitat fragmentation and the threats to viability inherent to small populations. Addressing these threats is a primary objective of this recovery plan.

Habitat fragmentation can result in loss of population viability through disrupted dispersal. Further fragmentation of habitat is safeguarded against by appropriate silvicultural methods (3E, 8J). In addition, management guidelines emphasize maintaining or developing beneficial arrangements of red-cockaded woodpecker groups in space, to enhance dispersal within populations (8B, 8H). Translocation (8H) and installation of recruitment clusters (8B) are important management actions used to create such beneficial spatial arrangements. Threats to viability inherent to small populations are discussed in detail in section 2C. Resistance to these threats is the fundamental basis for target population sizes identified in delisting criteria (1 – 5). The set of populations that will exist at delisting will not be vulnerable to effects of habitat fragmentation nor to stochastic events that threaten small populations. Once delisting criteria have been met, the species will be viable to the fullest degree possible given current scientific understanding.

B. DOWNLISTING

Downlisting shall occur when each of the following criteria is met. Rationale for each criterion is presented immediately following this list. See Table 8 for population designation. All populations identified in downlisting criteria should be managed for maximum size that the habitat designated for red-cockaded woodpeckers will allow. (Maximum size is generally based on 200 ac [81 ha] per group).

Criterion 1. There is one stable or increasing population of 350 potential breeding groups (400 to 500 active clusters) in the Central Florida Panhandle.

Criterion 2. There is at least one stable or increasing population containing at least 250 potential breeding groups (275 to 350 active clusters) in each of the following recovery units: Sandhills, Mid-Atlantic Coastal Plain, South Atlantic Coastal Plain, West Gulf Coastal Plain, Upper West Gulf Coastal Plain, and Upper East Gulf Coastal Plain.

Criterion 3. There is at least one stable or increasing population containing at least 100 potential breeding groups (110 to 140 active clusters) in each of the following recovery units: Mid-Atlantic Coastal Plain, Sandhills, South Atlantic Coastal Plain, and East Gulf Coastal Plain.

Criterion 4. There is at least one stable or increasing population containing at least 70 potential breeding groups (75 to 100 active clusters) in each of four recovery units, Cumberlands/Ridge and Valley, Ouachita Mountains, Piedmont, and Sandhills. In addition, the Northeast North Carolina/Southeast Virginia Essential Support Population is stable or increasing and contains at least 70 potential breeding groups (75 to 100 active clusters).

Criterion 5. There are at least four populations each containing at least 40 potential breeding groups (45 to 60 active clusters) on state and/or federal lands in the South/Central Florida Recovery Unit.

Criterion 6. There are habitat management plans in place in each of the above populations identifying management actions sufficient to increase the populations to recovery levels, with special emphasis on frequent prescribed burning during the growing season.

Rationale for Downlisting Criteria

Criterion 1. A population size of 350 potential breeding groups is considered highly robust to threats from environmental stochasticity as well as inbreeding and demographic stochasticity. It is the lowest current estimate of the minimum size necessary to offset losses of genetic variation through genetic drift.

Criterion 2. This population size, 250 potential breeding groups, is sufficient to withstand extinction threats from environmental uncertainty, demographic uncertainty, and inbreeding depression. These 6 populations, in combination with the single population identified in criterion (1), will represent each major recovery unit.

Criterion 3. A second population in these coastal recovery units will decrease the species' vulnerability to hurricanes. The West Gulf Coastal Plain is excluded because there are no candidate populations there. The lower size, 100 potential breeding groups, is considered sufficient to withstand threats from demographic uncertainty and inbreeding depression, and is much more quickly attained than 250 potential breeding groups thought necessary to withstand environmental stochasticity.

Criterion 4. These special habitats will be represented at the time of downlisting. This population size is midway in estimates of sizes necessary to withstand threats from inbreeding depression and is considered robust to demographic stochasticity if territories are moderately aggregated in space.

Criterion 5. This unique region will be represented at the time of downlisting. Forty potential breeding groups is at the lower end of estimates of sizes necessary to withstand inbreeding depression and are considered robust to demographic stochasticity if territories are highly aggregated in space.

Criterion 6. These habitat management plans are necessary to ensure progress toward delisting.

7. RECOVERY UNITS

Recovery units are geographic or otherwise identifiable subunits of the listed entity that individually are necessary to conserve genetic robustness, demographic robustness, important life history stages, or some feature necessary for long-term sustainability of the overall listed entity. The recovery units established for red-cockaded woodpeckers are a surrogate for likely genetic variation and adaptation to local environments, because they are based on changing environmental conditions, i.e., they are geographic areas delineated according to ecoregions (physiographic provinces; see discussion below and map insert). Substantial genetic variation has been documented in red-cockaded woodpeckers across their range, although distinct boundaries for this variation have not been identified. Red-cockaded woodpeckers exhibit a correlation between genetic variation and geographic distance, meaning the farther apart populations are geographically, the greater the genetic variation between or among them. This has been documented using both randomly amplified polymorphic DNA (used as a genetic marker; Haig et al. 1994a, 1996) and allozyme data (Stangel et al. 1992, Stangel and Dixon 1995). As molecular markers gain resolution, we may be able to identify more distinct genetic boundaries, but the correlation between genetic variation and geographic distance is a classic characteristic of species that were once distributed primarily as a continuous population.

Names of recovery units are the same as their respective ecoregion, with one exception (South/Central Florida). There are eleven designated recovery units for red-cockaded woodpeckers. All but two recovery units contain one or more core recovery populations and one or multiple support populations (map insert). The remaining two recovery units contain support populations only. Core populations are classified as primary or secondary based on available habitat and population size required for delisting. In addition to primary and secondary core populations, several support populations are considered essential to species recovery and as such are identified in delisting and downlisting criteria. These essential support populations are not designated primary or secondary cores because of habitat limitations. All other support populations (below) are necessary to protect and maximize genetic and demographic health until the species is delisted.

Maintaining viable populations within each recovery unit is essential to the survival and recovery of red-cockaded woodpeckers as a species, across their range. Conservation of populations in all habitats, forest types, and ecoregions, represented within and by recovery units is critical to species survival and recovery because these varied populations have crucial ecological and genetic values. The loss, or reduction of the likelihood of survival and recovery, of core and essential support populations within one or more of the designated recovery units could not only jeopardize the recovery goals for the individual recovery unit(s), but also jeopardize the recovery of the entire species in several ways.

First, without immigration, no red-cockaded woodpecker population (with the possible exception of the Central Florida Panhandle population) will be large enough to avoid loss of genetic variability through genetic drift. Loss of genetic variation may reduce a species' ability to adapt and persist in a changing environment (ecoregion), and thereby reduce its viability over long time periods. One practical way to reduce the threat of genetic drift is to promote immigration, both natural (dispersal) and artificial (via translocation). Multiple recovery units, harboring all of the habitat types and representing all ecoregions in which red-cockaded woodpeckers currently exist, provide the means to ensure that natural and artificial immigration can occur and be managed.

Second, the vast majority of red-cockaded woodpecker populations are threatened today by demographic stochasticity and will remain so for the foreseeable future. Therefore, the short-term survival of many individual populations in most recovery units is dependent on translocated birds from other recovery units. Because donor populations for many small (less than 30 potential breeding groups), at-risk populations are in adjacent recovery units, actions adversely affecting donor populations in one recovery unit can jeopardize the survival and recovery of populations in other recovery units, thereby jeopardizing the entire species.

A third and significant threat to red-cockaded woodpecker populations are catastrophes, including hurricanes and outbreaks of southern pine beetles, which point to several reasons for identifying and conserving multiple recovery units. First, red-cockaded woodpecker populations in similar habitats/forest types and with more closely related genetic resources may occur in recovery units adjacent to those impacted by the catastrophic event, thus helping ensure that the ability of the species to adapt to these ecological conditions of habitat and forest type would be protected. Second, by maintaining a number of recovery units, with their associated populations, that are broadly spaced geographically, and including as many inland populations as possible, the threat from catastrophic loss is substantially reduced. Additionally, when losses do occur in one recovery unit, other recovery units can be relied upon to supply birds for population restoration programs, thereby ensuring the continued likelihood of survival and recovery of the species.

To achieve and maintain species viability, we must maintain a network of interacting populations within and between recovery units. This strategy will promote natural immigration from support and core populations, over the long-term, within and between recovery units, thereby reducing species' susceptibility to loss of genetic variability through genetic drift. If, in the future, natural immigration rates are determined to be inadequate to reach or maintain genetic variability, artificial immigration (via translocation) within and between recovery units will be necessary to ensure the survival and recovery of red-cockaded woodpeckers. Similarly, the recovery unit system provides the means today and into the future to overcome the threats of demographic stochasticity through translocation. Additionally, the recovery unit system provides the opportunity to respond aggressively to stabilize and restore recovery units and populations impacted by catastrophic events. Thus, the system of recovery units, with respective primary core, secondary core, and support populations, provides the foundation of the strategy to recover red-cockaded woodpeckers.

Recovery Units as the Basis for Jeopardy Analysis in Interagency Consultation

In the past, exceptions from applying the jeopardy standard to an entire species were granted by a U.S. Fish and Wildlife Service Director's memorandum, dated March 3, 1986, for specific populations of a species. Since the mid-1980's, in compliance with the Director's memorandum, we conducted jeopardy analyses for red-cockaded woodpeckers at the level of the population.

Our guidance on this topic changed with the release of our Consultation Handbook in 1998 (USFWS 1998). The Handbook states that when determining whether an action jeopardizes the continued existence of the species, we are to analyze the total impacts of the proposed project on the entire species. However, the Handbook acknowledges that for some wide-ranging species, this analysis can be facilitated by the establishment of recovery units in a final recovery plan. The Consultation Handbook notes that species' recovery plans provide the best available scientific information relative to the areas and environmental elements needed for the species to recover, and may even describe recovery units essential to recovering the species. Given that actions that appreciably impair or preclude the capability of such a recovery unit from providing the survival and recovery functions identified for it in a recovery plan may therefore represent jeopardy to the species, the Consultation Handbook indicates the jeopardy standard may be applied to individual recovery units identified as necessary for survival and recovery of the species in an approved final recovery plan. Thus, the designation of recovery units in recovery plans facilitates recovery both by focusing the species' recovery program on the need to conserve the geographic, demographic, and genetic features of the recovery unit for its contribution to the whole species, and by facilitating the evaluation of potential jeopardy to the species when the survival and recovery of an individual recovery unit is in question.

Ecoregions

Ecoregions (physiographic provinces; Bailey 1983, Bailey *et al.* 1994) are a system of classification based on physiography, the study of the natural features of the earth's surface. Important to physiography and the designation of ecoregions are characteristics of land formation, climate, air and sea currents, and distribution of flora and fauna. Ecoregions are a more finely grained system of classification than the world biome system (Clements and Shelford 1939), for example, but not as fine as classifications according to ecosystems or communities. Although the natural boundaries of ecoregions are generally gradual rather than distinct, for the purposes of classification distinct boundaries have been delineated.

Ecoregions can be used to represent varying climatic and edaphic factors that have likely influenced species evolution over time. For red-cockaded woodpeckers, ecoregions reflect broad areas within which local adaptations and genetic coadaptation have likely occurred. (Genetic coadaptation is the evolution of gene complexes that together impart greater fitness than the sum of each individual gene's contribution. A coadapted gene's effect depends on the presence of one or more other genes; Templeton *et al.* 1986). Thus, major objectives in the use of ecoregions as a basis for recovery units are to identify likely genetic variation and to assure that this variation is conserved to the fullest extent possible.

Translocation

Translocations between populations (see 3D) will be conducted within recovery units and between adjacent recovery units except in rare cases. These rare exceptions include (1) previous agreements between the U.S. Fish and Wildlife Service, private landowners, and state and federal agencies, and (2) no donor population available in the same or adjacent recovery unit. This guideline applies to all translocations, including those intended for population augmentation (3D) and mitigation (4A). The primary objectives, and major benefits, of this guideline are the retention of genetic integrity and the protection of each unit's progress toward recovery. Translocation and/or mitigation must not result in genetic pollution or cause a net loss of groups within any given recovery unit. In addition, controlling maximum distances for translocation will minimize cost, logistical difficulties, and the stress on the birds from transport.

Primary and Secondary Core Populations

Primary Core Populations

Primary core populations are those that will harbor at least 350 potential breeding groups at the time of and after delisting. Populations of this size are above the minimum size considered necessary to withstand threats of extirpation from demographic stochasticity, environmental stochasticity, and inbreeding depression (2C). Populations of this size may not be capable of retaining sufficient genetic variability for long-term viability in the absence of immigration (Lande 1995; 2C), but because retention of genetic variability is a direct function of population size, these primary core populations will retain more variation than secondary core and support populations. Conservation of within-population genetic diversity is a major function of primary core populations.

One primary core population (Central Florida Panhandle) will harbor 1000 potential breeding groups at delisting. This population size may well be resistant to loss of genetic variation through genetic drift.

Although a minimum population size of primary core populations is necessarily identified in delisting criteria, primary core populations should expand to the maximum sizes the habitat designated for red-cockaded woodpeckers will allow, to retain as much genetic variation within the populations as possible (2C). (Maximum size is generally based on 200 ac [81 ha] per group). At downlisting, primary core populations may not necessarily contain 350 potential breeding groups.

There are 12 designated primary core populations, located on federal lands including national forests, military installations, and one national wildlife refuge (see map insert). Some state properties, such as Holly Shelter Game Lands in North Carolina, support important segments of primary core populations.

Secondary Core Populations

Secondary core populations are those that will hold at least 250 potential breeding groups at the time of and after delisting. This population size is the minimum estimate considered necessary to withstand threats of extirpation from environmental stochasticity, and is considered highly robust to threats from demographic stochasticity and inbreeding depression. These populations are not large enough to withstand threats to long-term viability from the process of genetic drift unless immigration is maintained. Secondary core populations should be expanded to maximum population goals based on available habitat to protect genetic resources as much as possible and to provide maximum resilience to environmental effects. Habitat limitations for secondary core populations prevent their designation as primary core populations. Secondary core populations may not necessarily harbor 250 potential breeding groups at the time of downlisting.

There are 11 secondary core populations, located on federal lands including national forests, national wildlife refuges, and Department of Energy lands (see map insert). State lands, such as the Sand Hills State Forest in South Carolina, support important segments of secondary core populations.

Benefits of the Primary and Secondary Core Population Strategy

The 12 primary and 11 secondary core populations of red-cockaded woodpeckers are well distributed throughout the species' range. This widespread distribution serves several critical ecological objectives. First, such a distribution conserves red-cockaded woodpeckers in varied habitats and geographic regions in which they currently exist (above). Second, the wide distribution and relatively high number of populations reduces threat of species extinction from catastrophic events such as hurricanes (see 2C). Finally, secondary and primary core populations together create a network which, when population goals are reached, may facilitate the natural dispersal among populations that is critical to long-term genetic viability (2C).

Red-cockaded woodpeckers are capable of long-distance movements between populations (Walters *et al.* 1988b, Conner *et al.* 1997c, Ferral *et al.* 1997; see 2B), although under present conditions these dispersal events are rare. With increasing population size, natural movements between populations are expected to increase. Primary and secondary core populations at and after delisting will be large and healthy; thus, natural dispersal among recovered core populations may be sufficient to maintain species-wide genetic variability. If not, translocation may have to be conducted to achieve this objective. In the meantime, support populations (below) play a vital role in facilitating gene flow through natural dispersal and translocation.

Primary core, secondary core, and essential support (below) populations are delineated by estimated biological population boundaries. Most of these designated populations are currently functioning, or will function at recovery, as one demographic and genetic unit. If this were not the case, expected resistance to stochastic threats would be compromised. There are four cases, however, in which a defined recovery population may continue to be a composite of relatively isolated subpopulations: (1) Angelina/Sabine Primary Core, (2) Coastal North Carolina Primary Core, (3) Osceola/Okefenokee Primary Core, and (4) Northeast North Carolina/Southeast Virginia Essential Support. For these cases, it remains to be seen whether, as isolated subpopulations grow in size, these designated populations can begin to function as single biological units.

Support Populations

All populations not designated a primary or secondary core are designated support populations. There are three classifications for support populations:

1. Essential support populations are those populations, identified in recovery criteria, that represent unique or important habitat types that cannot support a larger, core population. They are located on federal, state, and, in two cases, private lands in agreement with the U.S. Fish and Wildlife Service (Table 3).

2. Significant support populations are populations, not identified in recovery criteria, that contain and/or have a population goal of 10 or more active clusters. (A population size of 10 active clusters, if highly aggregated in space, has a good probability of persistence over a 20-year time period; Crowder *et al.* 1998, Walters et al. 2002b.) They are located on federal and state lands and on private lands enrolled in agreements with the U.S. Fish and Wildlife Service (see Tables 5 and 9).

3. Important support populations are populations, not identified in recovery criteria, that contain and have a population goal of less than 10 active clusters. They are located on federal and state lands (Table 9) and on private lands enrolled in agreements with the U.S. Fish and Wildlife Service.

All populations of red-cockaded woodpeckers have intrinsic ecological, cultural, and historical value. In addition to these intrinsic values, support populations aid in the conservation and recovery of the species. Support populations are important reservoirs of genetic resources. They help represent natural variation in habitats occupied by red-cockaded woodpeckers. Support populations are an important source of immigrants for core populations to increase retention of genetic variation and could potentially provide a buffer against stochastic loss of core populations. These functions are especially critical now, because many core populations are currently well below the population sizes necessary to withstand threats of environmental, demographic, and genetic uncertainty. Because of small population size of most support populations, extirpation of some due to stochastic events is expected.

Significant and important support populations identified within this plan are defined by ownership, rather than biological population boundaries. Some of the populations listed below may be functioning as part of larger populations. Recovery populations—primary core, secondary core, and essential supports—are defined by estimated biological boundaries rather than ownership.

Management prescriptions for all support populations on public lands will be the same as those applied in core populations. Managers should increase their populations to the maximum the habitat base will support, using the level of monitoring recommended based on population size (see 8C) and the recovery standard for foraging habitat (8I). Management plans for federal and state lands are approved by the U.S. Fish and Wildlife Service (contact the Recovery Coordinator for further information). Support populations on private lands will be managed under Memoranda of Agreement, Habitat Conservation Plans, Safe Harbor Agreements or other management instruments approved by the U.S. Fish and Wildlife Service (contact the Recovery Coordinator for further information). Management prescriptions for these populations depend on agreements.

Individual Recovery Units

For each recovery unit, we list populations identified in delisting criteria below. See Tables 5, 6, and 7, and the map insert, for other populations including those on private, state, and federal properties.

Cumberlands/Ridge and Valley Recovery Unit

The Cumberlands/Ridge and Valley Recovery Unit (Table 8, map insert) contains one essential support population: Talladega/Shoal Creek, which consists of the Talladega and Shoal Creek Ranger Districts of the Talladega National Forest.

East Gulf Coastal Plain Recovery Unit

The East Gulf Coastal Plain Recovery Unit (Table 8, map insert) contains three primary core populations: (1) Central Florida Panhandle, consisting of Apalachicola and Wakulla Ranger Districts of the Apalachicola National Forest, Ochlockonee River State Park, St. Mark's National Wildlife Refuge, and Tate's Hell State Forest; (2) Chickasawhay Ranger District of the DeSoto National Forest, and (3) Eglin Air Force Base. The Central Florida Panhandle Primary Core will harbor 1000 potential breeding groups at delisting. This recovery unit also contains three secondary core populations: (1) Conecuh/Blackwater, consisting of Conecuh National Forest and Blackwater River State Forest, (2) DeSoto Ranger District of the DeSoto National Forest, and (3) Homochitto National Forest.

Mid-Atlantic Coastal Plain Recovery Unit

The Mid-Atlantic Coastal Plain Recovery Unit (Table 8, map insert) contains two primary core populations: (1) Coastal North Carolina, consisting of Croatan National Forest, Holly Shelter Game Lands, and Marine Corps Base Camp Lejeune; and (2) Francis Marion National Forest. It also contains one essential support population: Northeast North Carolina/Southeast Virginia, consisting of Alligator River National Wildlife Refuge, Dare County Bombing Range, Palmetto-Peartree Preserve (owned by the Conservation Fund), Pocosin Lakes National Wildlife Refuge, and Piney Grove Preserve (owned by The Nature Conservancy).

Ouachita Mountains Recovery Unit

The Ouachita Mountains Recovery Unit (Table 8, map insert) contains one secondary core population, Ouachita National Forest.

Piedmont Recovery Unit

The Piedmont Recovery Unit (Table 8, map insert) contains one secondary core population: Oconee/Piedmont, consisting of Oconee National Forest and Piedmont National Wildlife Refuge.

Sandhills Recovery Unit

The Sandhills Recovery Unit (Table 8, map insert) contains two primary core populations: (1) North Carolina Sandhills East[1], consisting of Calloway Tract (owned by The Nature Conservancy), Carver's Creek Tract (owned by The Nature Conservancy), Fort Bragg, McCain Tract, and Weymouth Woods State Nature Preserve; and (2) Fort Benning. This unit contains one secondary core population: the South Carolina Sandhills, consisting of Carolina Sandhills National Wildlife Refuge and Sand Hills State Forest. This unit also contains one essential support population: North Carolina Sandhills West[11], consisting of Camp Mackall and the Sandhills Game Lands.

South Atlantic Coastal Plain Recovery Unit

The South Atlantic Coastal Plain Recovery Unit (Table 8, map insert) contains two primary core populations: (1) Fort Stewart, and (2) Osceola/Okefenokee, consisting of Osceola National Forest and Okefenokee National Wildlife Refuge. This recovery unit contains a single secondary core population, the Savannah River Site.

South/Central Florida Recovery Unit

The South/Central Florida Recovery Unit (Table 8, map insert) is one of two recovery units that do not contain a primary or secondary core population, because no

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[1] Additional private properties acquired and/or managed under the provisions of the cooperative agreement between the Department of the Army and The Nature Conservancy, or protected in perpetuity through other mechanisms, will be considered as contributing to the total number of potential breeding groups in the North Carolina Sandhills East and North Carolina Sandhills West populations, as appropriate given property location.

federal properties in this unit have sufficient land base to support populations of this size. For this reason, the 1985 Recovery Plan (USFWS 1985) did not include south and central Florida in species recovery. However, maintaining populations of red-cockaded woodpeckers in south and central Florida is essential to the recovery of the species. These populations are associated with unique habitat types such as native hydric slash pine (Beever and Dryden 1992) and critically endangered sand ridge communities. South/central Florida populations contain a high degree of among-population genetic variation and at least one unique allele (Haig *et al.* 1996). In addition, south and central Florida served as the source of the longleaf pine/scrub oak community roughly 5000 to 8000 years ago (Watts 1971, Watts *et al.* 1992). The region was a refuge for red-cockaded woodpeckers during the Wisconsin Glaciation just prior to the longleaf advance, and it is likely that red-cockaded woodpeckers evolved here during a previous glacial event (Jackson 1971, Conner *et al.* 2001). Therefore, red-cockaded woodpeckers in south and central Florida are considered an essential component of the species.

All populations on state and federal lands in this unit that have the capacity to harbor 10 or more active clusters are designated essential support populations. Support populations within the South/Central Florida Recovery Unit are included in criteria for delisting (see 6). It is recognized that this recovery unit will not in itself sustain viable populations and that one or more of these populations may be lost to stochastic events. Translocation among populations within this unit is likely to be necessary for long-term maintenance of genetic variation.

Essential support populations within the South/Central Florida Recovery Unit are (1) Avon Park, consisting of Avon Park Air Force Range and Kicco Wildlife Management Area, (2) Babcock/Webb Wildlife Management Area, (3) Big Cypress National Preserve, (4) Camp Blanding Training Site, (5) Goethe State Forest, (6) Hal Scott Preserve, (7) Corbett/Dupuis, consisting of J. W. Corbett Wildlife Management Area and Dupuis Wildlife Management Area, (8) Ocala National Forest, (9) Picayune Strand State Forest, (10) St. Sebastian River State Buffer Preserve, (11) Three Lakes Wildlife Management Area, (12) Withlacoochee State Forest – Citrus Tract, and (13) Withlacoochee State Forest – Croom Tract. Currently, there are no private lands enrolled in agreements with the U.S. Fish and Wildlife Service in this recovery unit.

Upper East Gulf Coastal Plain Recovery Unit

The Upper East Gulf Coastal Plain (Table 8, map insert) contains one primary core population, Bienville National Forest, and one secondary core population, Oakmulgee Ranger District of the Talladega National Forest.

Upper West Gulf Coastal Plain Recovery Unit

The Upper West Gulf Coastal Plain (Table 8, map insert) contains one primary core population, the Sam Houston National Forest. This unit contains no secondary core populations.

West Gulf Coastal Plain Recovery Unit

The West Gulf Coastal Plain Recovery Unit (Table 8, map insert) contains two primary core populations: (1) the Angelina/Sabine National Forests and (2) Vernon/Fort Polk, consisting of the Vernon Unit of the Calcasieu Ranger District of Kisatchie National Forest, and Fort Polk. This recovery unit contains two secondary core populations: (1) Davy Crockett National Forest and (2) Catahoula Ranger District/Winn Ranger District (portion) of Kisatchie National Forest. These secondary core populations were chosen from among several federal properties that can hold populations of 250 potential breeding groups, and were selected to create a stepping-stone pattern in the hopes of enhancing natural dispersal.

Gulf Coast Prairies and Marshes Ecoregion

The Gulf Coast Prairies and Marshes ecoregion (Table 8, map insert) is not considered a recovery unit because there is only a single, small population within it and habitat for red-cockaded woodpeckers is limited. Big Branch National Wildlife Refuge is a significant support population. Because of its unusual habitat type, Big Branch National Wildlife Refuge should be conserved to the fullest extent possible.

Mississippi Alluvial Plain

The Mississippi Alluvial Plain ecoregion (Table 8, map insert) is likewise not considered a recovery unit because there is only a single, small population within it and habitat is limited. Pine City Natural Area is an important support population which, because of its unusual habitat type (pure, site-appropriate loblolly), should be conserved to the fullest extent possible.

TABLE 8. Primary core, secondary core, and essential support populations, and the properties that comprise these populations, by recovery unit. Each of these populations has a designated role in recovery. Also listed is minimum size at delisting (potential breeding groups; PBG), current size (active clusters in 2000; ACT), state, ownership type, and responsible agency. Number of active clusters is generally equal to 1.1 to 1.4 times the number of potential breeding groups. See 10 (Table 16) for key to agency abbreviations.

Recovery Unit / **Population** / **Property**	**Size at Delisting (PBG)**	**Current Size (ACT)**	**State**	**Type**	**Agency**
Cumberlands/Ridge and Valley					
Talladega/Shoal Creek Essential Support	100				
Shoal Creek Ranger District, Talladega NF		6	AL	Federal	USFS
Talladega Ranger District, Talladega NF		0	AL	Federal	USFS
East Gulf Coastal Plain					
Central Florida Panhandle Primary Core	1000				
Apalachicola Ranger District, Apalachicola NF		486	FL	Federal	USFS
Ochlockonee River State Park		3	FL	State	FPS
St. Mark’s National Wildlife Refuge		9	FL	Federal	USFWS
Tate's Hell State Forest		29	FL	State	FDF
Wakulla Ranger District, Apalachicola NF		138	FL	Federal	USFS
Chickasawhay Primary Core	350				
Chickasawhay Ranger District, Desoto NF		15	MS	Federal	USFS
Conecuh/Blackwater Secondary Core	250				
Blackwater River State Forest		26	FL	State	FDF
Conecuh National Forest		18	AL	Federal	USFS
DeSoto Secondary Core	250				
DeSoto Ranger District, DeSoto NF		7	MS	Federal	USFS
Eglin Primary Core	350				
Eglin Air Force Base		301	FL	Federal	USAF
Homochitto Secondary Core	250				
Homochitto National Forest		51	MS	Federal	USFS
Mid-Atlantic Coastal Plain					
Coastal North Carolina Primary Core	350				
Croatan National Forest		62	NC	Federal	USFS
Holly Shelter Game Lands		38	NC	State	NCWRC
Marine Corps Base Camp Lejeune		59	NC	Federal	USMC
Francis Marion Primary Core	350				
Francis Marion National Forest		344	SC	Federal	USFS
Northeast North Carolina/Southeast Virginia Essential Support	100				
Alligator River National Wildlife Refuge		3	NC	Federal	USFWS
Dare County Bombing Range		3	NC	Federal	USAF
Palmetto-Peartree Preserve		25	NC	Private	
Piney Grove Preserve		3	NC	Private	
Pocosin Lakes National Wildlife Refuge		1	NC	Federal	USFWS

Table continued next page.

TABLE 8 (cont.). Primary core, secondary core, and essential support populations.

Recovery Unit Population Property	Size at Delisting (PBG)	Current Size (ACT)	State	Type	Agency
Ouachita Mountains					
Ouachita Secondary Core	250				
Ouachita National Forest		21	AR	Federal	USFS
Piedmont					
Oconee/Piedmont Secondary Core	250				
Oconee National Forest		20	GA	Federal	USFS
Piedmont National Wildlife Refuge		39	GA	Federal	USFWS
Sandhills					
Fort Benning Primary Core	350				
Fort Benning		219	GA	Federal	USARMY
North Carolina Sandhills East Primary Core	350				
Calloway Tract		5	NC	Private	TNC
Carver's Creek Tract		4	NC	Private	TNC
Fort Bragg		350	NC	Federal	USARMY
McCain Tract		5	NC	Federal	NCDA
Weymouth Woods State Nature Preserve		7	NC	State	NCDENR
North Carolina Sandhills West Essential Support	100				
Camp Mackall		11	NC	Federal	USARMY
Sandhills Game Lands		134	NC	State	NCWRC
South Carolina Sandhills Secondary Core	250				
Carolina Sandhills National Wildlife Refuge		116	SC	Federal	USFWS
Sand Hills State Forest		51	SC	State	SCFC
South Atlantic Coastal Plain					
Fort Stewart Primary Core	350				
Fort Stewart		212	GA	Federal	USARMY
Osceola/Okefenokee Primary Core	350				
Okefenokee National Wildlife Refuge		37	GA	Federal	USFWS
Osceola National Forest		63	FL	Federal	USFS
Savannah River Secondary Core	250				
Savannah River Site		34	SC	Federal	DOE
South/Central Florida					
Avon Park Essential Support	40				
Avon Park Air Force Range		21	FL	Federal	USAF
Kicco Wildlife Management Area		1	FL	State	FFWCC
Babcock/Webb Essential Support	40				
Babcock/Webb Wildlife Management Area		27	FL	State	FFWCC
Big Cypress Essential Support	40				
Big Cypress National Preserve		42	FL	Federal	NPS

Table continued next page.

TABLE 8 (cont.). Primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Size at Delisting (PBG)	Current Size (ACT)	State	Type	Agency
South/Central Florida (cont.)					
Camp Blanding Essential Support	25[1]				
Camp Blanding Training Site		14	FL	Federal	FDMA
Corbett/Dupuis Essential Support	40				
J. W. Corbett/Dupuis Wildlife Management Area		13	FL	State	FFWCC/ SFWMD
Goethe Essential Support	40				
Goethe State Forest		30	FL	State	FDF
Hal Scott Essential Support	15[1]				
Hal Scott Preserve		7	FL	State	SJRWMD
Ocala Essential Support	40				
Ocala National Forest		22	FL	Federal	USFS
Picayune Strand Essential Support	25[1]				
Picayune Strand State Forest		3	FL	State	FDF
St. Sebastian River Essential Support	25[1]				
St. Sebastian River State Buffer Preserve		8	FL	State	SJRWMD
Three Lakes Essential Support	40				
Three Lakes Wildlife Management Area		51	FL	State	FFWCC
Withlacoochee Citrus Tract Essential Support	40				
Withlacoochee State Forest - Citrus Tract		46	FL	State	FDF
Withlacoochee Croom Tract Essential Support	30[1]				
Withlacoochee State Forest - Croom Tract		5	FL	State	FDF
Upper East Gulf Coastal Plain					
Bienville Primary Core	350				
Bienville National Forest		104	MS	Federal	USFS
Oakmulgee Secondary Core	250				
Oakmulgee Ranger District, Talladega NF		110	AL	Federal	USFS
Upper West Gulf Coastal Plain					
Sam Houston Primary Core	350				
Sam Houston National Forest		168	TX	Federal	USFS
West Gulf Coastal Plain					
Angelina/Sabine Primary Core	350				
Angelina National Forest		29	TX	Federal	USFS
Sabine National Forest		28	TX	Federal	USFS

Table continued next page.

TABLE 8 (cont.). Primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	**Size at Delisting (PBG)**	**Current Size (ACT)**	**State**	**Type**	**Agency**
Catahoula Secondary Core	250				
Catahoula Ranger District, Kisatchie NF		32	LA	Federal	USFS
Winn Ranger District (portion), Kisatchie NF		5	LA	Federal	USFS
Davy Crockett Secondary Core	250				
Davy Crockett National Forest		53	TX	Federal	USFS
Vernon/Fort Polk Primary Core	350				
Fort Polk		46	LA	Federal	USARMY
Vernon Unit, Calcasieu Ranger District, Kisatchie NF		152	LA	Federal	USFS

[1]These populations each have an estimated potential size of less than 40 potential breeding groups but can contribute significantly to the delisting criterion of 250 potential breeding groups (275-350 active clusters) in the South/Central Florida Recovery Unit overall.

TABLE 9. Significant and important support populations on state and federal properties, by recovery unit. Also listed are location (state), current size (number of active clusters in 2000) and potential size (number of active clusters). Except where noted, potential size is based on an agency estimate or property goal identified in a draft or approved red-cockaded woodpecker management plan, or submitted in an Annual Report (2000). See Table 5 for significant support populations on private properties.

Recovery Unit Property	State	Designation	Current Size	Potential Size[2]
Mid-Atlantic Coastal Plain				
Bladen Lakes State Forest	NC	Important Support	3	3[1]
Hampton Plantation State Park	SC	Important Support	1	1[1]
Jones Lake State Park	NC	Important Support	1	4
Lewis Ocean Bay Heritage Preserve	SC	Significant Support	2	10[1]
Longleaf Pine Heritage Preserve	SC	Important Support	2	4[1]
Military Ocean Terminal Sunny Point	NC	Significant Support	9	17
Sandy Island	SC	Significant Support	32	35[1]
Santee Coastal Reserve	SC	Significant Support	8	16
Singletary Lake State Park	NC	Important Support	4	6
Wedge Plantation	SC	Important Support	2	2[1]
Yawkey Wildlife Center	SC	Significant Support	8	15[1]
subtotal			72	113
Ouachita Mountains				
McCurtain County Wilderness Area	OK	Significant Support	12	44
subtotal			12	44
Piedmont				
Pee Dee National Wildlife Refuge	NC	Significant Support	1	10
Johnston Community College	NC	Important Support	1	1
subtotal			2	11
Sandhills				
Cheraw State Fish Hatchery	SC	Important Support	1	1
Cheraw State Park	SC	Significant Support	7	25
Fort Gordon	GA	Significant Support	5	25
Fort Jackson	SC	Significant Support	24	126
Manchester State Forest	SC	Important Support	3	3[1]
Poinsett Weapons Range	SC	Significant Support	6	30
subtotal			46	210
South Atlantic Coastal Plain				
Charleston Naval Weapons Station	SC	Significant Support	1	12
Persanti Island	SC	Important Support	3	3[1]
Santee State Park	SC	Important Support	1	7[1]
Webb Wildlife Center	SC	Significant Support	12	30[1]
subtotal			17	52

Table continued next page.

TABLE 9 (cont.). Significant and important populations on state and federal properties.

Recovery Unit Property	State	Designation	Current Size	Potential Size[2]
South/Central Florida				
Central Florida Reception Center - South Unit	FL	Important Support	1	1[1]
Platt Branch Mitigation Park	FL	Important Support	4	7[1]
subtotal			5	8
Upper East Gulf Coastal Plain				
Noxubee National Wildlife Refuge	MS	Significant Support	44	88
subtotal			44	88
Upper West Gulf Coastal Plain				
D'Arbonne National Wildlife Refuge	LA	Important Support	2	5
Felsenthal National Wildlife Refuge	AR	Significant Support	15	34
Huntsville State Fish Hatchery	TX	Important Support	1	1[1]
I. D. Fairchild State Forest	TX	Important Support	4	7
Upper Ouachita National Wildlife Refuge	LA	Important Support	1	1
W. G. Jones State Forest	TX	Significant Support	14	14
subtotal			37	62
West Gulf Coastal Plain				
Alabama-Coushatta Tribe of Texas	TX	Important Support	2	2[1]
Alexander State Forest	LA	Important Support	5	5
Black Bayou National Wildlife Refuge	LA	Important Support	1	1
Evangeline Unit, Calcasieu Ranger District, Kisatchie National Forest	LA	Significant Support	72	231
Kisatchie Ranger District, Kisatchie National Forest	LA	Significant Support	29	292
Peason Ridge	LA	Significant Support	23	120
Winn Ranger District, Kisatchie National Forest	LA	Significant Support	18	263
subtotal			150	914
Outside Recovery Units:				
Pine City Natural Area	AR	Important Support	1	2[1]
Big Branch Marsh National Wildlife Refuge	LA	Significant Support	15	20
subtotal			16	22
TOTAL			**401**	**1524**

[1]Property goal based on U.S. Fish and Wildlife Service or responsible agency's estimate derived by dividing the area of currently or potentially suitable upland pine on the property by 81 ha (200 ac) per cluster.

[2] Except for those potential sizes identified as property goals in approved agency management plans, all other potential sizes are non-binding and subject to change pending approval of site-specific management plans.

8. MANAGEMENT GUIDELINES

The following management guidelines are fundamental to conservation and recovery of red-cockaded woodpeckers. We strongly encourage and recommend the application of these guidelines to the management of all woodpecker populations, including those on private lands. Managers of private lands may choose to substitute guidelines given in Appendix 5 (Private Lands Guidelines) for comparable sections below, but again are encouraged to follow the management guidelines given in this section as these have been designed specifically for population and species recovery.

A. ASSESSING PROGRESS TOWARD RECOVERY

Trends of all populations, but particularly for those identified in recovery criteria, will be monitored closely by the Red-cockaded Woodpecker Recovery Coordinator to ensure that significant progress toward recovery is being made. This assessment is a critical aspect of species conservation, management, and recovery. In this section, we define recommended rate of increase and critical rates of population decline. We identify the schedule by which assessments will be made. We also describe actions to be taken if populations are not increasing at the recommended rate or if populations are declining at a rate equal to or greater than the identified critical values. Monitoring for population size and trend is described in 3A, and population monitoring guidelines are given in 8C.

Guidelines

1. Recommended Rate and Assessment of Population Increase.

Populations are to be increasing at a rate of 5 percent per year. Population trend will be assessed by the Red-cockaded Woodpecker Recovery Coordinator annually using the U.S. Fish and Wildlife Service Annual Report. Depending on the results of annual assessments, and specifically for those populations not increasing at the recommended rate, more thorough 5-year population trend assessments and analyses will be conducted as necessary (see below).

2. Management Review for Populations Not Increasing

For those populations not increasing at the recommended rate, an investigation of which factors are restricting potential increases will be undertaken. Factors to be investigated include:

> 1.1.1. Condition of nesting habitat within active clusters, including number of suitable cavities and presence of hardwood midstory in clusters.

1.1.2. Condition of foraging habitat corresponding to active clusters, including age, size, and density of pines, height and density of pine and hardwood midstory, percent of canopy hardwoods, and presence of herbaceous groundcover.

1.1.3. Number of recruitment clusters available, and their placement within the landscape.

1.1.4. Condition of recruitment clusters, including condition of nesting and foraging habitat as indicated by variables listed in 1.1.1. and 1.1.2.

Once factors potentially limiting population growth have been identified, implementation of management plans will be changed accordingly. If management plans require adjustment, re-initiation of consultation with the U.S. Fish and Wildlife Service will be strongly recommended.

3. Critical Rate and Assessment of Population Decline

It is essential to conservation and recovery of red-cockaded woodpeckers that population declines be detected quickly and accurately. Population declines can occur in various forms, such as a sudden large drop or a small, slow, steady decrease in size. We therefore define critical population decline in two different ways. A population is considered declining if either of the following criteria is met:

(1) number of active clusters decreases by 10% from one year to the next.
(2) number of active clusters decreases by 10% within five years.

Captured clusters must not be included in this calculation. Each year, the Red-cockaded Woodpecker Recovery Coordinator will assess population trend for evidence of critical decline.

4. Re-initiation of Consultation for Critically Declining Populations

If populations are found to be declining at or above these critical rates, re-initiation of consultation with the US Fish and Wildlife Service will be strongly recommended. Review and adjustment of management plans and their implementation is the only appropriate response to such evidence. Declining populations are not eligible to act as a donor population for translocation (8H). Ineligibility will remain in place until populations once again meet the criteria for donor populations (8H).

Early indicators of population decline include a decreasing proportion of groups that contain potential breeding groups, increasing proportions of solitary males and/or captured clusters, and decreases in mean group size. Currently, a population exhibiting an increasing proportion of solitary males, captured clusters, or a decline in mean group size will not be formally considered critically declining populations, if number of active clusters is not declining as described above. However, this is important evidence of a population in poor health and managers are strongly encouraged to review and adjust management actions accordingly. In the future, the U.S. Fish and Wildlife Service may develop an additional definition of a critically declining population based on number of potential breeding groups, which would give an earlier indication of decline than current definitions.

5. Annual Reporting

Assessing progress toward recovery is highly dependent on conscientious reporting. Managers and researchers are required to submit an Annual Report to the Red-cockaded Woodpecker Recovery Coordinator. The Annual Report contains results of annual population monitoring and a description of management actions, including management of cavities and clusters, management and restoration of foraging habitat, and translocation if used.

TABLE 10. Worksheet to assess population trend for all primary core, secondary core, and essential support populations, sorted by recovery unit. This table presents expected population size (number of active clusters; ACT) at 5-year intervals under 5 percent annual increase through estimated time of delisting. Populations are to be increasing at this rate until the species is delisted or until the property goal is reached. Property goals are derived directly from agency or site-specific management plans, except where noted. Also listed is minimum population size required for delisting (potential breeding groups). Number of active clusters is equivalent to 1.1 – 1.4 times the number of potential breeding groups. Updates of this table will be provided on the Red-cockaded Woodpecker Recovery web page (http://rcwrecovery.fws.gov).

Recovery Unit / Population / Property	**Delisting Size (PBG)**	**Expected Size Based on Recommended Rate of Increase (ACT)**																
		2000	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**	**2065**	**2070**	**2075**	**2080**
Cumberlands/Ridge and Valley																		
Talladega/Shoal Creek	100																	
Shoal Creek RD		6	8	10	12	16	20	26	33	42	54	69	88	112	125	125	125	125
Talladega RD		0	5	6	8	10	13	17	22	28	35	45	57	73	93	110	110	110
East Gulf Coastal Plain																		
Central Florida Panhandle	1000																	
Apalachicola RD		486	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500	500
Ochlockonee River SP[1]		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
St. Mark’s NWR		9	11	15	19	24	30	39	50	63	71	71	71	71	71	71	71	71
Tate's Hell SF[1]		29	37	47	60	77	98	125	160	204	261	333	400	400	400	400	400	400
Wakulla RD		138	176	225	287	366	467	506	506	506	506	506	506	506	506	506	506	506
Chickasawhay	350																	
Chickasawhay RD		15	19	24	31	40	51	65	83	106	135	172	220	280	358	456	502	502
Conecuh/Blackwater	250																	
Blackwater River SF		26	33	42	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Conecuh NF		18	23	29	37	48	61	78	99	127	162	206	263	309	309	309	309	309
DeSoto	250																	
DeSoto RD		7	9	11	15	19	24	30	39	49	63	80	102	131	167	213	272	347[2]
Eglin	350																	
Eglin Air Force Base		301	384	490	500	500	500	500	500	500	500	500	500	500	500	500	500	500

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
East Gulf Coastal Plain (cont.)																		
Homochitto	250																	
Homochitto NF		51	65	83	106	135	173	220	254	254	254	254	254	254	254	254	254	254
Mid-Atlantic Coastal Plain																		
Coastal North Carolina	350																	
Croatan NF		62	79	101	129	165	169	169	169	169	169	169	169	169	169	169	169	169
Holly Shelter Game Lands		38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38	38
MCB Camp Lejeune		59	75	96	123	157	173	173	173	173	173	173	173	173	173	173	173	173
Francis Marion	350																	
Francis Marion NF		344	439	453	453	453	453	453	453	453	453	453	453	453	453	453	453	453
Northeast North Carolina/ Southeast Virginia	100																	
Alligator River NWR		3	4	5	6	8	10	13	17	20	20	20	20	20	20	20	20	20
Dare Co. Bombing Range		3	4	5	6	8	10	13	17	21	17	34	44	46	46	46	46	46
Palmetto-Peartree Preserve		25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Piney Grove Preserve		3	4	5	6	8	10	10	10	10	10	10	10	10	10	10	10	10
Pocosin Lakes NWR		1	1	2	2	3	3	4	6	7	9	11	15	19	24	30	39	50
Ouachita Mountains																		
Ouachita	250																	
Ouachita NF		21	27	34	44	56	71	91	116	148	189	241	307	392	400	400	400	400

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit Population Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
Piedmont																		
Oconee/Piedmont	250																	
Oconee NF		20	26	33	42	53	68	86	110	141	176	176	176	176	176	176	176	176
Piedmont NWR		39	50	64	81	96	96	96	96	96	96	96	96	96	96	96	96	96
Sandhills																		
Fort Benning	350																	
Fort Benning		219	280	357	450	450	450	450	450	450	450	450	450	450	450	450	450	450
North Carolina Sandhills East	350																	
Calloway Tract		5	6	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Carver's Creek Tract		4	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Fort Bragg		350	436	436	436	436	436	436	436	436	436	436	436	436	436	436	436	436
McCain Tract		5	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Weymouth Woods SNP		7	9	11	13	13	13	13	13	13	13	13	13	13	13	13	13	13
North Carolina Sandhills West	100																	
Camp Mackall		11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
Sandhills Game Lands		134	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160	160
South Carolina Sandhills	250																	
Carolina Sandhills NWR		116	148	189	193	193	193	193	193	193	193	193	193	193	193	193	193	193
Sand Hills SF[1]		51	65	83	106	135	143	143	143	143	143	143	143	143	143	143	143	143
South Atlantic Coastal Plain																		
Fort Stewart	350																	
Fort Stewart		212	271	345	441	500	500	500	500	500	500	500	500	500	500	500	500	500
Osceola/Okefenokee	350																	
Okefenokee NWR		37	47	60	77	86	86	86	86	86	86	86	86	86	86	86	86	86
Osceola NF		63	80	103	131	167	213	272	348	444	462	462	462	462	462	462	462	462

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit Population Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
South Atlantic Coastal Plain (cont.)																		
Savannah River	250																	
Savannah River Site		34	43	55	71	90	115	147	188	239	305	390	418	418	418	418	418	418
South/Central Florida																		
Avon Park	40																	
Avon Park Air Force Range		21	27	34	44	56	68	68	68	68	68	68	68	68	68	68	68	68
Kicco WMA[1]		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Babcock/Webb	40																	
Babcock/Webb WMA[1]		27	34	44	56	72	91	117	149	190	240	240	240	240	240	240	240	240
Big Cypress	40																	
Big Cypress NP		42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42	42
Camp Blanding	25																	
Camp Blanding Training Site		14	18	23	25	25	25	25	25	25	25	25	25	25	25	25	25	25
Corbett/Dupuis	40																	
J. W. Corbett/Dupuis WMA[1]		13	17	21	27	34	44	56	72	90	90	90	90	90	90	90	90	90
Goethe	40																	
Goethe SF		30	38	49	62	80	102	130	150	150	150	150	150	150	150	150	150	150
Hal Scott	15																	
Hal Scott Preserve[1]		7	9	11	15	15	15	15	15	15	15	15	15	15	15	15	15	15
Ocala	40																	
Ocala NF		22	28	36	46	58	74	95	121	155	179	179	179	179	179	179	179	179
Picayune Strand	25																	
Picayune Strand SF[1]		3	4	5	6	8	10	13	17	21	25	25	25	25	25	25	25	25

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	Delisting Size (PBG)	Expected Size Based on Recommended Rate of Increase (ACT)																
		2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050	2055	2060	2065	2070	2075	2080
South/Central Florida (cont.)																		
St. Sebastian River	25																	
St. Sebastian River SBP		8	10	13	17	21	25	25	25	25	25	25	25	25	25	25	25	25
Three Lakes	40																	
Three Lakes WMA[1]		51	65	83	106	125	125	125	125	125	125	125	125	125	125	125	125	125
Withlacoochee – Citrus Tract	40																	
Withlacoochee – Citrus		46	59	75	96	100	100	100	100	100	100	100	100	100	100	100	100	100
Withlacoochee –Croom Tract	30																	
Withlacoochee – Croom		5	6	8	10	13	17	22	28	30	30	30	30	30	30	30	30	30
Upper East Gulf Coastal Plain																		
Bienville	350																	
Bienville NF		104	133	169	216	276	352	449	500	500	500	500	500	500	500	500	500	500
Oakmulgee	250																	
Oakmulgee RD		110	140	179	229	292	372	394	394	394	394	394	394	394	394	394	394	394
Upper West Gulf Coastal Plain																		
Sam Houston	350																	
Sam Houston NF		168	214	274	349	446	541	541	541	541	541	541	541	541	541	541	541	541
West Gulf Coastal Plain																		
Angelina/Sabine	350																	
Angelina NF		29	37	47	60	77	98	125	160	204	252	252	252	252	252	252	252	252
Sabine NF		28	36	46	58	74	95	121	154	197	252	262	262	262	262	262	262	262

Table continued next page.

TABLE 10 (cont.). Worksheet to assess population trend for all primary core, secondary core, and essential support populations.

Recovery Unit / Population / Property	**Delisting Size (PBG)**	**Expected Size Based on Recommended Rate of Increase (ACT)**																
		2000	**2005**	**2010**	**2015**	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**2055**	**2060**	**2065**	**2070**	**2075**	**2080**
West Gulf Coastal Plain (cont.)																		
Catahoula	250																	
Catahoula RD		32	41	52	67	85	108	138	177	225	288	317	317	317	317	317	317	317
Winn RD (portion)		5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Davy Crockett	250																	
Davy Crockett NF		53	68	86	110	141	179	229	292	330	330	330	330	330	330	330	330	330
Vernon/Fort Polk	350																	
Fort Polk		46	59	75	96	122	156	179	179	179	179	179	179	179	179	179	179	179
Vernon Unit		152	194	248	302	302	302	302	302	302	302	302	302	302	302	302	302	302

[1]For these properties for which no management plan is available, property goals are non-binding estimates only and are subject to change when management plans are drafted and approved.

[2]Population goal is 386. However, 347 active clusters will provide at least the 250 potential breeding groups needed for delisting.

B. USE OF RECRUITMENT CLUSTERS

Substantial increases in population sizes are required to achieve recovery of red-cockaded woodpeckers (see 8A). Proper management of the nesting and foraging habitat of existing groups (see 8E, 8F, 8I) is a prerequisite for population increase, but recent research and experience strongly indicate that management of existing groups by itself is not sufficient to bring about the rates of increase necessary for recovery. Because population dynamics of red-cockaded woodpeckers are regulated by the number of potential breeding groups (see 2B), substantial increases in population size are best obtained through continued addition of recruitment clusters. Therefore, we have developed the following guidelines for the use of recruitment clusters in all populations being managed for increasing population size. Recruitment clusters are clusters of artificial cavities in habitat containing mature and old pines (greater than 60 years in age), with little or no hardwood midstory and a healthy grass and forb groundcover (see 2D for discussion of cluster ecology and 8F for cluster management guidelines).

Guidelines

1. Recommended Number of Recruitment Clusters: To achieve recommended rates of increase (8A), provide a constant supply of unoccupied recruitment clusters equal to 10 percent of total active clusters in the population. As recruitment clusters become occupied, establish additional recruitment clusters on an annual basis to sustain the required pool of unoccupied recruitment clusters. Do not establish more recruitment clusters than can reasonably be occupied within 1 to 3 years.

An exception to this guideline is made for recruitment clusters used in reintroductions or the development of new population segments (a set of clusters in suitable habitat somewhat removed from other groups). For these purposes, a number of recruitment clusters greater than 10 percent of active clusters may be used. These management actions will always be conducted using translocations of multiple potential pairs. Typically, for translocations of multiple potential pairs, two recruitment clusters will be established for each pair of birds being translocated.

2. Placement of Recruitment Clusters: Placement of recruitment clusters is critical to successful use. Place recruitment clusters no closer than 0.4 km (0.25 mi) to existing active clusters, to reduce the likelihood of capture by an existing group. Place recruitment clusters no farther than 3.2 km (2 mi), and preferably no farther than 1.6 km (1 mi), from existing active clusters to facilitate occupation and to develop beneficial spatial arrangements and densities within the population (see 2C).

Recruitment clusters for use in reintroduction or for developing a new segment of a population are exempt from this recommendation. Recruitment clusters for these purposes must be highly aggregated.

Recent research performed with a spatially explicit, individual based model of population dynamics (see 2C) has indicated that edges of populations are particularly vulnerable to decay from disrupted dispersal. Maintain group densities as high as possible throughout the population, and pay particular attention to population edges.

3. Recruitment Cluster Requirements:

a. Nesting and Roosting Habitat. Provision recruitment clusters with three suitable cavities and two starts, or four suitable cavities, when first installed. Once the cluster is occupied, ensure that a minimum of four suitable cavities is maintained. See 3B and 8E for further details concerning the definition of suitable cavities and recommended methods for constructing artificial cavities and starts.

b. Foraging Habitat. We anticipate that much of the foraging habitat assigned to recruitment clusters may not meet all elements of good quality foraging habitat as described under the recovery standard (8I). If the recovery standard is not met, then assign each recruitment cluster at least 49 ha (120 ac) of foraging habitat that meets elements (b, c, d, f, g, h, and i), and additionally, stands should contain no more than 70 ft^2/ac basal area in total. Within this habitat, restore habitat structure and encourage the development of old pines so that all elements of the recovery standard can be met in the future.

C. POPULATION MONITORING

Population monitoring is an essential aspect of red-cockaded woodpecker management and recovery. Only through accurate monitoring can we determine the success and failure of our management actions, and adapt these actions accordingly. Appropriate intensity of monitoring varies with population size, role in recovery, and management objectives. In section 3A and Appendix 2 we describe basic monitoring techniques. In this section, we present guidelines for determining recommended monitoring levels for individual populations.

Guidelines

1. In primary core, secondary core, and essential support populations, monitor number of active clusters and number of potential breeding groups so that population trend and size can be determined. Follow directions for monitoring number of active clusters and potential breeding groups given in 3A. Use random sampling without replacement to select a sample of the size recommended in Table 11. For populations in which no banding is being conducted, select random samples annually. For populations in which some groups are banded, select random samples at 5-year intervals; within this five-year

period, samples remain fixed. Use stratified random sampling whenever appropriate (see 3A).

2. In critically small populations (less than 30 potential breeding groups) on federal and state lands, monitor number of active clusters, number of potential breeding groups, group size, and reproductive success. Follow directions for monitoring number of active clusters and potential breeding groups in 3A, and for group size and reproductive success given in Appendix 2. Sample the population completely. These populations are to be completely color-banded, to enable the monitoring of group size and reproductive success. In addition, this level of monitoring is required to receive translocated birds from donor populations.

3. In populations containing mitigation sites, monitor number of active clusters and number of potential breeding groups as recommended for recovery populations (see above). In addition, monitor group size and reproductive success in the neighborhood of the mitigation site both before and after the installation of mitigation sites, until successful mitigation is completed. Follow directions for monitoring number of active clusters and potential breeding groups in 3A, and for group size and reproductive success given in Appendix 2.

4. In populations serving as mitigation banks or planned as future mitigation banks, monitor number of active clusters and number of potential breeding groups as recommended for recovery populations (see above). In addition, monitor group size and reproductive success by maintaining a completely color-banded population. Follow directions for monitoring number of active clusters and potential breeding groups in 3A, and for group size and reproductive success given in Appendix 2.

5. For other populations, publicly or privately owned, we strongly recommend that the above monitoring guidelines be followed.

TABLE 11. Recommended sample sizes for monitoring number of active clusters (ACT) and potential breeding groups (PBG) in red-cockaded woodpecker populations, by population size.

	Population Size (PBG)				
Parameter	**<30**	**30 - 99**	**100 – 249**	**250 - 349**	**≥ 350 or at approved property goal**
ACT	100% of potentially active clusters per year	100% per year	100% per year	100% every 2 yrs.	consult with FWS
PBG	100% of potentially active clusters per year	100% per year	50% per year	33% per year	consult with FWS

6. For those populations and or forests that have suffered catastrophic losses of habitat and or red-cockaded woodpeckers, individualized habitat and population monitoring programs will be developed in consultation with the U.S. Fish and Wildlife Service.

D. HABITAT MONITORING

The primary cause of species decline was sharp decreases in the quantity and quality of habitat (1A), and habitat limitations remain a major threat to species recovery (1B). It is therefore critical to species recovery that quantity and quality of habitat be closely monitored. We give specific guidelines for habitat monitoring in several different sections of this plan. Here we briefly summarize them and refer the reader to relevant sections.

1. Monitoring Nesting/Roosting Habitat

a. Number of Suitable Cavities per Cluster. Assess number of suitable cavities in each cluster at recommended frequencies based on population size. See 8E for sampling frequency and definition of a suitable cavity. These assessments are best conducted during cluster activity checks (March – July). If populations with a designated recovery role are not increasing at recommended rates (8A), or if they are found to be declining at or above the identified critical values of decline (8A), number of suitable cavities per cluster will be reviewed by the Red-cockaded Woodpecker Recovery Coordinator.

b. Habitat Structure within Clusters. Maintain clusters that are free of pine and hardwood midstory, as described in 8F. If populations with a designated recovery role are not increasing at recommended rates (8A), or if they are found to be declining at or above the identified critical values of decline (8A), habitat structure within clusters will be reviewed by the Red-cockaded Woodpecker Recovery Coordinator.

2. Monitoring Foraging Habitat

Assess quality and quantity of foraging habitat at a minimum frequency of once every 10 years, with the exception of midstory which is to be assessed at a minimum frequency of once every 5 years. More frequent assessments are encouraged. Evaluate foraging habitat for all habitat elements described within the recovery standard (8I), including ages of pines, pine size class distribution, presence of hardwood midstory, and percent native, site-appropriate, herbaceous groundcover. More information on monitoring these elements is given in 8I. Ensure that substantial progress toward meeting all elements put forth in the recovery standard is made. If populations with a designated recovery role are not increasing at recommended rates (8A), or if they are found to be declining at or above the identified critical values of decline (8A), quality and quantity of foraging habitat will be reviewed by the Red-cockaded Woodpecker Recovery Coordinator.

3. Documenting Prescribed Fire

Keep accurate and detailed records of all prescribed burns.

4. Reporting

Report results of all habitat monitoring and history of prescribed burns to the Red-cockaded Woodpecker Recovery Coordinator using the Annual Report.

E. Cavity Management, Artificial Cavities, and Restrictor Plates

Maintaining an adequate number of suitable cavities in each woodpecker cluster is fundamental to the recovery of the species. Loss of cavity trees was a major factor in the species' decline (see 1A), and availability of cavity trees currently limits many populations. This limitation will remain in effect until large old pines are restored throughout the lands managed for red-cockaded woodpeckers. Until large old pines become widely available, artificial cavities and restrictor plates are essential management tools that can bring about population increases, if used carefully and in suitable habitat.

Here we present guidelines for the use of artificial cavities and restrictor plates. The role of cavities in population dynamics and the cooperative breeding system of red-cockaded woodpeckers is discussed in 2B. Further information concerning nesting ecology is provided in 2D. Descriptions of artificial cavity construction techniques and their usefulness are given in 3B. Restrictor plates are also discussed in 3B, and cavity enlargement in general is described in sections 2F and 3B.

Guidelines

1. Monitor the cavity resource. Assess the number of suitable cavities in each potentially active cluster at a frequency determined by the size of the population (Table 12). Conduct these assessments in March – July. A suitable cavity has a single entrance, an entrance tunnel that is not enlarged, a cavity chamber that is not enlarged, a solid base, and is dry and free of debris. In addition, the cavity plate must not contain large amounts of dead wood. Relict, enlarged, or any suspect cavities must not be considered suitable for use by red-cockaded woodpeckers. Suitable cavities may be either naturally excavated or artificially constructed. If a restrictor is present, it must be inspected for safety during cavity suitability assessments.

To conduct this assessment, examine all unenlarged cavities internally by climbing the tree or using a video 'peeper'. An enlarged cavity is unsuitable unless a restrictor is installed and the cavity is otherwise found to be suitable by internal inspection.

TABLE 12. Frequency of cavity suitability assessment by population size and trend (see 8A for definitions of trend).

Population Size (potential breeding groups)		
< 100	**100 to 349**	**≥ 350 or at approved property goal**
100% of all cavities per year	50% of all cavities if not increasing at recommended rate	50% of all cavities if decreasing by the critical rate or more

2. Maintain the recommended number of suitable cavities in each cluster.

   a. Maintain at least four suitable cavities in each active cluster, in all populations not meeting population size goals identified in delisting criteria (6) or in approved management plans. However, ensure there are sufficient cavities for all group members post-breeding season.

   b. Maintain at least four suitable cavities (or three suitable cavities and two starts) in each unoccupied recruitment cluster, in all populations not meeting population goals identified in delisting criteria (6) or in approved management plans.

   c. Do not provision excessive numbers of artificial cavities within active or recruitment clusters. Count natural suitable cavities first, then install artificial cavities as necessary to make four to six suitable cavities.

3. Use the appropriate method of cavity construction. See 3B for more information.

   a. Use the Copeyon-drilled method when heartwood is sufficient to house the cavity.

   b. Use drilled starts when heartwood is insufficient to house the cavity and cavities are not needed for a year or more. Provide more than one start for each new cavity desired.

   c. Use cavity inserts when heartwood is insufficient to house a drilled cavity and cavities are needed as soon as possible. Inserts must always be used with full restrictor plates, and all inserts must be coated with a thick layer of non-toxic sealant such as non-toxic polyurethane glue (e.g. EXCEL ONE) or wood putty. Annual maintenance of cavity inserts prolongs their suitability and minimizes potential injury or mortality to red-cockaded woodpeckers.

   d. Avoid using the modified-drilled method (see 3B).

4. Install artificial cavities as close to existing cavity trees as possible, preferably within 71 m (200 ft.).

5. If installing a cavity insert, select a tree that is greater than 45 years old but not a relict, flat-top, or very old pine.

6. Select the appropriate location on the tree. Place artificial drilled cavities as high as heartwood diameter of the recipient tree will allow. Do not place cavities above or below the range of natural cavity heights in the surrounding area. Orient entrances so that they are facing west, if possible.

7. Protect the birds from sap leakage. Ensure that no artificial cavity has resin leaking into the chamber or entrance tunnel.

a. Prior to installation, coat all inserts with a thick layer of non-toxic sealant such as non-toxic polyurethane glue or wood putty. Do not use toxic coatings or inserts without coatings.

b. Screen all drilled starts and drilled cavities with heavy wire mesh (0.64 by 0.64 cm [0.25 by 0.25 in]) for at least four weeks following installation.

c. Inspect cavity interiors when the screens are removed. If resin leaks are detected, keep the screens on and conduct additional checks. Persistent resin leaks into entrance tunnels can be treated with repeated scraping, application of wood putty, replacement of veneer, or redrilling. If severe leaks continue, block the cavity with a wooden plug at least 7.6 cm (3 in) long, and construct a replacement cavity.

d. Construct artificial cavities and starts between August and March to reduce likelihood of leaks.

e. Check all new artificial cavities and starts for resin leaks during or just prior to the first breeding season following installation, and screen or plug those found to be leaking.

f. During cavity suitability assessment (1, above), replace, screen, or plug any insert found to be dangerously faulty (i.e., containing or likely to contain resin in the interior).

8. Use cavity restrictors judiciously to control cavity enlargement.

a. Use only when necessary on active cavities. Do not restrict all cavities. Slightly enlarged cavities may be restricted but do not use to repair excessively enlarged cavities.

b. Use restrictors on a cluster-by-cluster basis to minimize potential damage to any cavity, natural or artificial, by pileated woodpeckers. Only use restrictors if there is a known problem with enlargement by pileated woodpeckers or there is a good possibility, based on past experience, that cavities may be damaged.

c. Use full restrictors on all cavity inserts and previously installed modified-drilled cavities.

d. Inspect all restrictors at least once each year and repair if loose or out of place. Do not use restrictors if annual inspections cannot be performed.

e. Do not use on unenlarged cavities for the purpose of excluding cavity kleptoparasites.

F. Clusters and Cavity Trees

Conservation and recovery of red-cockaded woodpeckers in today's second- and third-growth forests requires skillful management of their cavity trees and clusters. Successful cluster management consists of three main programs: (1) protection of existing cavity trees, (2) development and protection of sufficient large, old pines for future cavity trees, and (3) restoration and maintenance of appropriate habitat structure, including no hardwood midstory, low densities of small pines, low to moderate densities of large pines, and abundant native grass and forb groundcovers. We recommend the removal of excessive overstory hardwoods in regions where fire suppression has resulted in the establishment of large hardwood trees. We also recommend that human disturbance within the cluster be minimized.

In this section, we provide guidelines for management of cavity trees and clusters. Information concerning nesting ecology is given in 2D. Any discussion of nesting ecology is not complete without considering fire. The role of fire in the southeastern pine ecosystem, prescribed burning as a management tool, and guidelines for the use of prescribed fire are discussed in sections 2G, 3F, and 8K, respectively.

To facilitate management and conservation, we use a management-based definition of a cluster for these guidelines. Here, the cluster is the minimum convex polygon containing all cavity trees in use by a group of red-cockaded woodpeckers *and* a 61 m (200 ft) wide buffer of continuous forest surrounding the minimum convex polygon. The cluster must contain a minimum of 4.0 ha (10 ac). Recommendations for cluster management apply to the entire cluster; that is, these guidelines apply to the buffer as well as the minimum convex polygon containing all cavity trees.

Guidelines

1. Protect existing cavity trees.

   a. Reduce risk of accidental damage or removal. Mark cavity trees for easy identification.

   b. Protect against fire damage. The application of regular, frequent fire in the clusters is the best method of protecting cavity trees against damage from fires (prescribed or wild) that are too intense. Until cavity trees are no longer a limiting resource, use one or more additional methods of protecting individual cavity trees presented in 8K.

   c. Protect cavity tree roots. Prohibit, with rare exceptions, the use of heavy machinery and vehicles within 15.25 m (50 ft) of cavity trees, and do not use at all within 15.25 m (50 ft) of cavity trees in wet areas. Do not establish plow lines within 61 m (200 ft) of cavity trees.

   d. Protect against southern pine beetle infestations. Thin dense loblolly and shortleaf pine forests regularly to maintain basal areas of less than 18.4 m^2/ha (80 ft^2/ac) or to maintain a minimum average spacing of 7.6 m (25 ft) between trees. Minimize physical disturbance to soil and roots during management operations such as thinning, midstory reduction, and prescribed burning.

   e. Reduce risk of damage from high winds. Retain a 61 m (200 ft) wide buffer of continuous forest around the minimum convex polygon containing each group's set of cavity trees, as part of the cluster. Consider retaining an additional buffer and minimize the establishment of openings adjacent to the cluster. Over time, risk of wind damage can be reduced by the development of an open habitat structure that encourages the growth of wind-resistant trees. Conversion to longleaf pine, where appropriate, also can reduce risk from winds.

2. Develop sufficient large and old pines to serve as cavity trees.

   a. Retain all potential cavity trees (pines greater than 60 years in age) within clusters, unless pine basal area is above 11.5 m^2/ha (50 ft^2/ac) and all trees are above 60 years in age.

   b. Supply trees for future cavity trees and clusters in abundance. Grow large, old pines throughout the landscape managed for red-cockaded woodpeckers (see 3E, 8J).

c. If potential cavity trees are rare, consider protecting them from fire, root damage, and other potential risks as described above for existing cavity trees.

3. Restore and maintain appropriate habitat structure.

a. Control hardwood and pine midstory. Apply prescribed fire to the entire cluster every one to five years, preferably during the growing season. This will maintain a cluster that is relatively free of midstory. If necessary, remove excessive hardwoods by hand (with chainsaws and brushhooks), mechanical means such as brush-hogging or mulching, one-time application of herbicides to live trees or stumps, or a combination of these methods. Mechanized equipment for the purpose of hardwood control will not be used within the cluster when woodpeckers are nesting. Broadcasting herbicides by hand within the cluster is permitted during nesting season. Recently abandoned clusters should be managed with the same intensity as active clusters.

b. Foster native grasses and forbs. Native grasses and forbs facilitate prescribed burning and are maintained by prescribed burning. Apply frequent growing season fire and avoid soil disturbance that negatively impacts fragile ground covers. Restrict vehicle use to existing roads and prohibit use of off-road vehicles in clusters.

c. Reduce excessive overstory hardwoods within the cluster. Overstory hardwoods within the cluster should not total more than 2.3 m^2/ha (10 ft^2/ac) in basal area. Remove all hardwoods within 50 ft. of cavity trees.

Retain natural oak inclusions of upland species, such as post, blackjack, turkey, and bluejack oak, within the cluster if they are considered a historic component of the site prior to fire suppression. The area occupied by these oaks is not counted toward the required minimum 4.0 ha (10 ac). These historic oak inclusions should be managed with prescribed fire and artificial cavities should not be installed near them. Overstory trees of mesic hardwood species such as sweetgum (*Liquidambar styraciflua*) and maples (*Acer* spp.) are generally considered undesirable components of fire suppression and are to be removed from red-cockaded woodpecker clusters.

d. Locate recruitment clusters away from stream drainages whenever possible. Although some clusters naturally occur in wetland habitats, use of upland sites as recruitment clusters whenever possible can reduce midstory encroachment associated with mesic hardwoods.

e. Retain dead and dying cavity trees and all other snags, unless they present a safety hazard.

4. Reduce human disturbance within clusters as much as possible, especially during nesting season. As a minimum, follow these guidelines:

a. Restrict vehicle use to existing roads. Avoid construction of new roads and trails (for motorized and unmotorized use) within clusters.

b. Limit pine and hardwood silvicultural and cultural operations to daylight hours; avoid these activities within at least one or two hours of dawn and dusk.

c. Military training activities are restricted to those specified in installation-specific management plans approved through consultation with the U.S. Fish and Wildlife Service.

d. Use of mechanized equipment in a cluster is permitted during the non-breeding season for red-cockaded woodpecker management activities only (e.g., mechanical midstory reduction).

e. Habitat management activities other than prescribed burning, for example timber thinning and hardwood midstory control, are prohibited during the breeding season (April – July).

G. Predators and Cavity Kleptoparasites

Red-cockaded woodpecker populations that are healthy and of medium to large size require no predator control and few measures to combat cavity kleptoparasites. Predators and cavity kleptoparasites were not among the original causes of decline (see 1A), and their removal will not result in population increases. Occasional loss of nests to predators does not affect population size or trend in larger populations. Maintaining good quality nesting and foraging habitat, and retaining snags throughout the landscape, are the recommended management tools to control kleptoparasitism in all but the smallest populations.

Managers of critically small populations of red-cockaded woodpeckers (less than 30 potential breeding groups), especially those in shortleaf and loblolly pine habitats, may choose to use exclusion devices and other methods for predator/kleptoparasite control. A less invasive technique, bark-shaving, may be employed in any population to protect newly installed artificial cavities. However, further research into direct and indirect species interactions is necessary before the full consequences of such control are understood.

We present guidelines for the use of predator and kleptoparasite control below. Research supporting these guidelines is described in detail in 2F. The techniques themselves are described in 3C. Control of cavity enlargement through the use of restrictor plates is required in many populations regardless of population size, and is discussed in 3B and 8E.

Guidelines

1. Use methods of predator control only in small populations (less than 30 potential breeding groups).

2. If snake control measures are considered necessary, use the bark-scraping procedure or metal snake excluders and restrict this use to trees containing newly installed artificial cavities or to active trees with minimal resin that are likely to be used as nest sites. Do not use snake nets—their use is prohibited because of risk to red-cockaded woodpeckers.

3. If flying squirrel control measures are considered necessary, avoid lethal methods if possible; use flying squirrel excluder devices or removal.

4. Retain snags in clusters and throughout the landscape, and consider the protection of snags in active clusters during prescribed burns.

5. Consider using nest boxes for species other than red-cockaded woodpeckers.

H. TRANSLOCATION

Translocation is an important management tool for small or disjunct populations to be used only in conjunction with aggressive management of nesting and foraging habitat. All translocations should serve to enhance the spatial structure of the population. Potential breeding groups should be developed in locations carefully chosen to link isolated groups or population segments and increase territory density. We refer to this critical management concern as strategic recruitment. Strategic recruitment is accomplished by translocating birds from within or outside the population to (1) unoccupied recruitment clusters or (2) clusters containing solitary birds.

Translocation of birds within populations is conducted solely for the purpose of strategic recruitment. Translocation of birds from donor to recipient populations may be used for population augmentation (increasing the size of the recipient population), mitigation (see 4A), and reintroduction (establishment of a population). Again, translocation for population augmentation, mitigation, or reintroduction must also serve to create beneficial spatial arrangements of groups. See 8B for guidelines governing the use of recruitment clusters. See 3D for background information concerning translocation. Use of translocation for any purpose requires permits from the U.S. Fish and Wildlife Service as discussed in Appendix 1. Use of reintroduction requires consultation with the U.S. Fish and Wildlife Service.

Guidelines

1. Populations Eligible for Within-population Translocation.— Birds can be translocated within a population if the population meets each of the following requirements:

a. Full administrative support, including valid state and federal permits and staff well trained in the handling, banding, and transport of birds;

b. A management plan approved by the U.S. Fish and Wildlife Service that includes each of the following.

i. Population monitoring at recommended levels (3A, 8C).

ii. A prescribed burning program for both nesting and foraging habitat in place.

iii. Specific identification of objectives and locations of the proposed translocations. Objective of proposed translocations should include definitions of target areas (the area in which birds must be found for the translocation to be judged successful; see 3D).

c. Recipient clusters that are in excellent condition, with a minimum of four suitable cavities per cluster, no or very low midstory within the cluster, and suitable foraging habitat (see 8B, 8E, 8I). Generally, provide no more than two recruitment sites for each potential pair moved (but see 3B).

2. Populations Eligible for Augmentation. A population can receive birds from a donor population (augmentation) if the receiving population or a demographically isolated population segment of the receiving population contains fewer than 30 potential breeding groups, has a population goal of and current habitat capacity to support at least 10 active clusters, and meets criteria a, b, and c listed above.

Not all populations eligible for augmentation will receive birds, because available birds are limited. Whether or not a population receives birds is decided annually based on population need and importance to species recovery.

3. Populations Eligible to Donate Birds. Eligibility criteria for donor populations differ by role in recovery.

a. Populations designated as recovery populations may donate birds for translocation if one of the following conditions is met:

i. The population has reached the size required for delisting, and population trend is stable or increasing,

ii. The population is within 75 percent of its population goal (based on designated habitat), at least 50 active clusters in size, and population trend is increasing at 3 percent annually or more, or

iii. The population is at least 100 active clusters in size and population trend is stable or increasing, or

iv. The population contains multiple properties and the donor property has attained its property goal.

b. Populations not designated as recovery populations may donate birds for translocation if one of the following conditions is met:

i. The population goal (based on designated habitat) has been met, and population trend is stable or increasing,

ii. The population is within 75 percent of its goal (based on designated habitat), at least 50 active clusters in size, and population trend is increasing at 3 percent annually or more, or

iii. The population is at least 100 active clusters in size and population trend is stable or increasing.

Populations that do not meet one or more of the criteria identified above (3a, 3b) may serve as donor populations on a case-by-case basis to be evaluated through consultation with the U.S. Fish and Wildlife Service. Factors considered during the consultation process will include, but not be limited to: (1) benefit to recovery, (2) value to the recipient population, and (3) agency or landowner objectives, and (4) population size and trend.

4. Matching Recipient Populations with Appropriate Donors. Translocations will be conducted within recovery units whenever possible. This is to maintain genetic integrity and enhance translocation success by accommodating local adaptations of translocated birds, to the maximum extent possible. Translocations between non-adjacent recovery units are prohibited, except in extenuating circumstances to be determined by consultation with the U.S. Fish and Wildlife Service.

5. Recipient Clusters. Translocate birds only to clusters that are:

a. Within 3.2 km (2 mi) of an occupied cluster. This guideline applies to all translocations, whether the translocation is within a population, between populations, to an unoccupied cluster, or to a cluster containing a solitary individual. The only exception to this guideline is translocation of multiple potential pairs into the same target area, which may be unoccupied or sparsely occupied. The purpose of this guideline, and its exception, is to ensure that all translocations serve to develop a beneficial, highly aggregated spatial arrangement of groups.

b. In excellent condition prior to receiving birds, as stated above. Recipient clusters must have a minimum of four suitable cavities per cluster, no or very low midstory within the cluster, and suitable foraging habitat. Generally, provide no more than two recruitment sites for each potential pair moved (but see 3B).

6. Impacts to Donor Populations. Impacts of translocation on donor populations require further research before specific guidelines can be developed. Currently, we recommend that managers refrain from removing excessive numbers of birds. Number of individuals removed should be no more than 25 percent of potential breeding groups within the donor population or population segment. Exceptions to this may be made on a case-by-case basis through consultation with the U.S. Fish and Wildlife Service. To be considered for this exception a population must be undergoing intensive monitoring and be increasing in size. Stable populations that have met their population goals will also be considered as possible exceptions to the 25 percent guideline, pending approval by consultation. Individuals moved within a population are not counted as part of this 25 percent.

7. Birds Eligible for Translocation. Determine which birds may be removed for translocation by following these guidelines:

a. Remove only subadult males or subadult females. A subadult is less than 12 months in age.

b. Remove birds only from their natal territory.

c. Do not remove any males unless there will be at least one male helper or male fledgling remaining in the group after the individual is removed. Do not remove more than two subadult males from any group within any one year.

d. Do not remove more than two subadult females from any group.

e. Translocation of any birds not meeting these criteria (above) must be approved on a case-by-case basis through consultation with the Red-cockaded Woodpecker Recovery Coordinator.

8. When to Translocate Birds. Translocations can be performed from September 15 through January 1. Translocations in the fall may have lower success, because translocated birds will also experience winter mortality. Translocations after January 1 may have higher impacts on the donor neighborhood and donor populations,

because females that have survived the early winter have a high likelihood of becoming breeders in their native population. More research on the effects of season on translocation is required before more specific recommendations can be made. Exceptions to this time period may be made on a case-by-case basis through consultation with the Red-cockaded Woodpecker Recovery Coordinator.

9. Procedures for Capture, Transport, and Release. Procedures for the capture, transport, and release of translocated birds are provided in Appendix 3. Translocation is not to be conducted when air temperature is below 32 degrees Fahrenheit (0 degrees Celsius) or during wet weather.

10. Monitoring, Evaluation of Success, and Reporting. Adequate population monitoring, evaluation of success, and reporting are required for regulatory compliance with permits authorizing translocations. Follow these guidelines:

a. Monitor all populations in which translocation is used at recommended levels (above, 3A, 8C, Appendix 2).

b. Determine success of all translocations by presence or absence of translocated birds within target areas in the following breeding season. Management objectives (identified in management plans) dictate target areas. For example:

i. The objective of mate provisioning is successful only if the translocated bird is found in the target cluster in the following breeding season.

ii. The objective of population augmentation is successful if the translocated bird is found anywhere within the target area in the following breeding season.

c. Report all translocations and translocation attempts, both within and between populations, to the Red-cockaded Woodpecker Recovery Coordinator using the Annual Report. Include a description of the management objective, the target area, and the success of the translocation.

I. FORAGING HABITAT

Recent research has expanded our understanding of the foraging ecology of red-cockaded woodpeckers considerably (2E). We know that the structure of foraging habitat is important to fitness of red-cockaded woodpeckers as well as influencing habitat selection. Fitness increases if foraging habitat is burned regularly, has an open character and herbaceous groundcovers, and contains large old trees. Selection of habitat increases with these same characteristics. This structure constitutes good quality foraging habitat for the species. Quality of foraging habitat also affects home range size: as quality increases, the amount of foraging habitat used decreases. We base the following guidelines for the management of foraging habitat on what we now know about both habitat quality and quantity.

We provide two sets of guidelines for the management of foraging habitat: the recovery standard (below) and the standard for managed stability (Appendix 5). Under section 7(a)(1) of the Endangered Species Act, federal agencies have a responsibility to (i.e., "federal agencies shall") use their authorities to carry out programs for the conservation (i.e., recovery) of listed species. Use of the recovery standard by federal agencies will facilitate recovery. Additionally, we strongly recommend that all state properties, particularly those involved in recovery, manage under the recovery standard. We also recommend this standard for those populations on private lands that landowners wish to manage for increasing population size.

The second set of guidelines, referred to as the standard for managed stability, should be used for instances in which a landowner cannot manage to the recovery standard. If a private landowner follows the standard for managed stability, the U.S. Fish and Wildlife Service will not recommend that the landowner needs, or applies for, an incidental take permit, based on the amount of foraging habitat remaining post-project. However, other project-related impacts, for instance, disturbance in the cluster during the nesting season, may require an incidental take permit. The standard for managed stability is presented in Appendix 5, the Private Lands Guidelines. The standard for managed stability is not designed to increase population size. Additionally, its wide-scale implementation, or application, will: (1) not provide future nesting habitat or good quality foraging habitat, (2) result in population fragmentation with subsequent problems related to demographic stochasticity, and (3) based on (1) and (2) above, not maintain that population's long-term viability.

A general discussion of foraging ecology is presented in 2E, and a detailed rationale for each component of the recovery standard is given in Table 13 (below). The recovery standard includes a discussion of habitat variation. Following the recovery standard, we present guidelines on foraging habitat assessment, including general habitat monitoring. We then provide a brief description of foraging habitat partitioning. Guidelines for silvicultural methods to implement the recovery standard are given in 8J.

Guidelines

Part A. Recovery Standard

We recommend this standard for all populations on federal lands, state lands, and those populations on private lands being managed for increasing population size.

1. Area Provided by Site Productivity

a. In systems of medium to high site productivity (site index 60 or more, for the dominant pine species), provide each group of woodpeckers 49 ha (120 ac) of good quality habitat as defined below. A specific exception to this area requirement is made for longleaf and shortleaf habitat types under group selection silviculture; see below for details.

b. In systems of low site productivity (site index below 60, for the dominant pine species), provide each group of woodpeckers 80 to 120 ha (200 to 300 ac) of good quality habitat as defined below. (We recognize that some aspects of the following definition of good quality habitat may not be achievable on extremely dry or wet sites. See discussions below on geographic variation in habitat for more information.)

2. Definition of Good Quality Foraging Habitat. Good quality foraging habitat has some large old pines, low densities of small and medium pines, sparse or no hardwood midstory, and a bunchgrass and forb groundcover. Based on results of studies described in 2E and Table 13, good quality habitat has all of the following characteristics:

a. There are 45 or more stems/ha (18 or more stems/ac) of pines that are $\geq$ 60 years in age *and* $\geq$ 35 cm (14 in) dbh. Minimum basal area for these pines is 4.6 m^2/ha (20 ft^2/ac). Recommended minimum rotation ages apply to all land managed as foraging habitat.

b. Basal area of pines 25.4 – 35 cm (10 – 14 in) dbh is between 0 and 9.2 m^2/ha (0 and 40 ft^2/ac).

c. Basal area of pines < 25.4 cm (< 10 in) dbh is below 2.3 m^2/ha (10 ft^2/ac) *and* below 50 stems/ha (20 stems/ac).

d. Basal area of all pines $\geq$ 25.4 cm (10 in) dbh is at least 9.2 m^2/ha (40 ft^2/ac). That is, the minimum basal area for pines in categories (a) and (b) above is 9.2 m^2/ha (40 ft^2/ac).

e. Groundcovers of native bunchgrass and/or other native, fire-tolerant, fire-dependent herbs total 40 percent or more of ground and midstory plants and are dense enough to carry growing season fire at least once every 5 years.

f. No hardwood midstory exists, or if a hardwood midstory is present it is sparse and less than 2.1 m (7 ft) in height.

g. Canopy hardwoods are absent or less than 10 percent of the number of canopy trees in longleaf forests and less than 30 percent of the number of canopy trees in loblolly and shortleaf forests. Xeric and sub-xeric oak inclusions that are naturally existing and likely to have been present prior to fire suppression may be retained but are not counted in the total area dedicated to foraging habitat.

h. All of this habitat is within 0.8 km (0.5 mi) of the center of the cluster, and preferably, 50 percent or more is within 0.4 km (0.25 mi) of the cluster center.

i. Foraging habitat is not separated by more than 61 m (200 ft) of non-foraging areas. Non-foraging areas include (1) any predominantly hardwood forest, (2) pine stands less than 30 years in age, (3) cleared land such as agricultural lands or recently clearcut areas, (4) paved roadways, (5) utility rights of way, and (6) bodies of water.

3. Discussion of Foraging Habitat Types.

a. Longleaf Pine. Longleaf pine communities vary from highly xeric to mesic and seasonally wet (see 2E), and each of these can support red-cockaded woodpeckers if the habitat structure is suitable. Red-cockaded woodpeckers in some highly xeric sites, such as Eglin Air Force Base in Florida, have very large home ranges, sparse groundcovers, and low density of large old trees that may result from low productivity and past management practices. Thus, we recommend that between 80 to 120 ha (200 and 300 ac) of good quality foraging habitat be provided each group in such sites. Note that this number of hectares (acres) does not refer to home range size in this habitat type, but the recommended amount of good quality foraging habitat within the home range. The latter may be much larger, due to unsuitable areas and home range overlap.

Extremely dry and extremely wet longleaf habitats may be unable to support some of the characteristics identified for good quality habitat. Pine sizes, pine density, and groundcover density may be below those specified above. Failure to meet these three criteria in extremely dry and extremely wet sites is understandable, as long as habitats are burned frequently and conscientious restoration is underway. Further research will help determine the extent of the natural ability of these habitats to support longleaf pines, native groundcovers, and red-cockaded woodpeckers at higher densities.

b. Shortleaf Pine. Historically, shortleaf pine communities included those without hardwoods, those with a small hardwood component, and those dominated by hardwoods. For red-cockaded woodpeckers, some shortleaf habitats, especially those on upland areas, should be free or almost free of hardwoods. Other habitats, such as those grading into mesic sites and north facing slopes, may support more hardwood overstory (up to 20 percent) and still be important red-cockaded woodpecker foraging habitat. Overstory hardwoods should not be removed entirely from communities in which they were historically present; however, neither should they be allowed to dominate a historic pine site. Stands with an overstory hardwood component greater than 30 percent are not considered suitable foraging habitat for red-cockaded woodpeckers.

c. Loblolly Pine. Because of fire sensitivity, loblolly pine was historically much less widespread than today. Prior to fire suppression, loblolly pine was a minor component of riparian and other mesic forests in the coastal plain and a secondary component of mixed pine and pine hardwood forests in the interior uplands. Forests dominated by loblolly were rare and restricted to a part of southern Arkansas and perhaps eastern Virginia and northeastern North Carolina. Currently, because of the fire suppression of the past century, loblolly pine is the dominant pine throughout the southeast, in areas that were historically covered by longleaf pine, shortleaf pine, and shortleaf/loblolly pine forests. These off-site loblolly pine forests provide important resources for red-cockaded woodpeckers. Loblolly pine does not provide as high quality habitat as do longleaf and shortleaf pines, because it produces less resin and is more sensitive to fire, southern pine beetles, and windthrow. These characteristics also render the management of loblolly for use by red-cockaded woodpeckers somewhat more difficult. However, with care, loblolly pine can be successfully managed to provide important habitat for red-cockaded woodpeckers. Additionally, there may be opportunities to carefully restore loblolly stands to site-appropriate pines. Foraging habitat for red-cockaded woodpeckers in loblolly forests should be managed according to the recovery standard, with the additional recommendation that total stand basal area in off-site loblolly forests be kept below 18.4 m^2/ha (80 ft^2/ac).

d. South Florida Slash Pine. Foraging ecology of red-cockaded woodpeckers in native slash pine (*Pinus elliottii* var. *densa*) communities in south Florida has received little research attention. It is clear, though, that home ranges of red-cockaded woodpeckers in native slash pines are unusually large. It is also clear that hydric slash pine flatwoods do not support the size of pines, and may not support the pine density, recommended in the Recovery Standard (above). Until further information is available, we can make only intermediate provisions for these populations. Each group in south Florida slash pine habitat is to be provided at least 80 to 120 ha or more (200 to 300 ac) of good quality foraging habitat containing mature and old pines and healthy native groundcovers that are frequently burned. Again, this is not the home range size but the amount of good quality habitat to be provided. Further research will help determine the density to which south Florida slash pines can be restored, as well as the specific requirements of red-cockaded woodpeckers in this unique habitat type.

e. Slash Pine. Historically, slash pine (*Pinus elliottii* var. *elliottii*) was typically found in transitional mesic sites within longleaf pine forests, such as in narrow drainages and along pond margins. Slash pine is now much more widespread than historically, as a result of fire suppression and aggressive planting. Foraging habitat for red-cockaded woodpeckers in slash pine (var. *elliottii*) forests should be managed according to the recovery standard.

f. Pond Pine. Ecology of red-cockaded woodpeckers in pond pine communities is virtually unknown. Catastrophic natural fire regimes of these communities confound red-cockaded woodpecker management. Certainly, reintroduction of fire and restoration of an open habitat structure are important. We recognize that the above definition of good quality habitat may not apply to this habitat type but can offer no alternative at this time. Further research is necessary before more specific recommendations can be made for this habitat type.

4. Population-specific Guidelines.

Managers may formulate population-specific foraging guidelines in consultation with the U.S. Fish and Wildlife Service. Population-specific guidelines must be based on site-specific research consisting of multi-year (typically 3-5 years) data on red-cockaded woodpecker group and population health and their relationships to quantity and quality of foraging habitat. Such guidelines must still meet or exceed recommendations put forth in the recovery standard concerning these habitat elements: (1) herbaceous groundcover, (2) hardwood midstory, (3) canopy hardwoods, and (4) distance from cluster center. Site-specific guidelines may deviate from the recovery standard in these habitat elements: (1) pine basal area, (2) pine age, and (3) the size class distribution and stem density of pines. Again, deviations must be based on sound science and meet approval through consultation with the U.S. Fish and Wildlife Service.

5. Multiple Ownership.

For those situations in which more than one property is included within the foraging partition of an active cluster, each property owner shall be responsible for providing foraging habitat in proportion to the area of their property currently containing foraging habitat within the partition.

TABLE 13. Rationale for foraging guidelines based on habitat structure[1] (recovery standard).

	Recommendation	Rationale	Source
1a	49 ha (120 ac) good quality habitat	Home range/foraging habitat required decreased with habitat quality.	Walters *et al.* 2000, 2002a
		51 ha (126 ac) good quality habitat recommended.	James *et al.* 2001
		Average home range of groups with access to old growth foraging (Wade Tract, GA) was 47 ha (116 ac), including overlap.	Engstrom and Sanders 1997
1b	More foraging required for sites of low productivity	Large home ranges in Eglin Air Force Base and South/Central Florida.	DeLotelle *et al.* 1987 Beever and Dryden 1992 Hardesty *et al.* 1977
2a	$\geq$ 45 pines/ha (18/ac) that are at least 35 cm dbh (14 in) and 60 yrs in age. Minimum basal area for these pines is 4.6 m^2/ha (20 ft^2/ac).	Group size and reproduction increased with density of large pines; recommended 40 35 cm pines per ha (16 14 in pines/ac).	James *et al.* 2001
		RCWs selected stands with 50 or more pines at least 35 cm in dbh per ha (20 or more pines at least 14 in dbh/ac).	Walters *et al.* 2000, 2002a
		Group size increased with number of flat-tops per acre.	Walters *et al.* 2000, 2002a
		Pines and patches of pines selected if over 60 yrs. in age.	Zwicker and Walters 1999 Walters *et al.* 2000, 2002a

Table continued next page.

TABLE 13 (cont.). Rationale for foraging guidelines based on habitat structure[1] (recovery standard).

	Recommendation	Rationale	Source
2a (cont.)		RCWs selected large old pines in greater proportion than their availability.	Hooper and Lennartz 1981 DeLotelle *et al.* 1983, 1987 Hooper and Harlow 1986 Porter and Labisky 1986 Jones 1994 Epting *et al.* 1995 Engstrom and Sanders 1997 Hardesty *et al.* 1997 Bowman *et al.* 1998 Doster and James 1998 Zenitsky 1999 Zwicker and Walters 1999 Walters *et al.* 2000, 2002a
2b	Basal area of pines 25.4 – 35 cm (10 – 14 in) dbh is between 0 and 9.2 m^2/ha (0 and 40 ft^2/ac).	High pine density negatively affected group size and productivity.	James *et al.* 1997 Hardesty *et al.* 1997 Walters *et al.* 2000, 2002a James *et al.* 2001
2c	Basal area of pines $\geq$ 25 cm (10 in) dbh < 2.3 m^2/ha (10 ft^2/ac) *and* below 50 stems/ha (20 stems/ac).	High densities of small pines negatively affected group size and productivity.	James *et al.* 1997 James *et al.* 2001
		High densities of small pines negatively affected selection of stands for foraging.	Porter and Labisky 1986 Bradshaw 1995 Walters *et al.* 2000, 2002a
2d	Basal area of all pines $\geq$ 25.4 cm (10 in) dbh is at least 2.3 m^2/ha (40 ft^2/ac).	RCWs avoided patches with basal areas below these ranges.	Walters *et al.* 2000, 2002a
2e	Herbaceous groundcovers $\geq$ 40% of groundcovers.	Group size and reproduction increased with herbaceous groundcovers; this level recommended.	Hardesty *et al.* 1997 James *et al.* 1997 James *et al.* 2001

Table continued next page.

TABLE 13 (cont.). Rationale for foraging guidelines based on habitat structure[1] (recovery standard).

	Recommendation	Rationale	Source
2f	Hardwood midstory below 2.1 m (7 ft).	Patches with midstory below 2.1 m (7 ft) were preferred. Stand use decreased with midstory above 2.1 m (7 ft).	Walters *et al.* 2000, 2002a
		Patch and stand use decreased with midstory in general.	Hooper and Harlow 1986 Jones 1994 Epting *et al.* 1995 Bradshaw 1995 Doster and James 1998
2g	Canopy hardwoods < 10% of canopy trees in longleaf stands and < 30 % of canopy trees in loblolly and shortleaf stands.	Large hardwoods negatively affected habitat selection; Jones (1994) found a negative effect above 10%.	Jones 1994 Bradshaw 1995
2h, 2i	Within 0.8 km (0.5 mi), not separated by more than 61 m (200 ft) non-forested land.	Fragmentation of foraging habitat negatively affected RCWs.	Conner and Rudolph 1991b Rudolph and Conner 1994 Conner and Dickson 1997 Ferral 1998

[1]Foraging guidelines are based on structural components rather than total number of pines $\geq$ 10 dbh because of the evidence presented in this table and because no relationship has been found between this variable and group size or reproduction (Hooper and Lennartz 1995, Beyer *et al.* 1996, Wigley *et al.* 1999).

Part B. Assessment of Foraging Habitat

Assessment of foraging habitat is an important component of red-cockaded woodpecker conservation and recovery. Improvements in quality of foraging habitat are necessary for the recovery of the species, and progress in improving foraging habitat is to be assessed through general habitat monitoring. Also, foraging habitat assessment is required prior to executing any projects that may impact foraging habitat. Here we first discuss partitioning, which is the allocation of foraging habitat to specific woodpecker clusters. We then describe general habitat monitoring and interim guidelines for assessment of project impacts in foraging partitions (below) not meeting recommendations for foraging habitat set forth in the recovery standard.

1. Allocating Foraging Habitat

Foraging habitat is best allocated to a specific cluster by performing follows on individual groups, to ascertain which portions of forest stands a particular group is using. Acquiring such data-intensive knowledge is generally far beyond the resources of managers and researchers, but may be required for some projects.

An alternative approach has been developed using geographic information systems (GIS), based on the recommendation within previous foraging guidelines (USFWS 1985) that all foraging habitat be within 0.8 km (0.5 mi) of the center of the cluster. The technique consists of first creating 0.8 km (0.5 mi) foraging circles around the center of each cluster, then applying tabular data of stand characteristics to determine availability of foraging habitat within the newly created circular polygon. Where foraging circles overlap, the area of overlap is partitioned into equal sections and allocated accordingly. Technical resources are available to assist managers and researchers in partitioning the complex overlaps that are common in areas with high cluster densities (Lipscomb and Williams 1996, 1998). Complete and partitioned foraging circles are referred to as foraging partitions.

Revised foraging guidelines (this document) recommend that all foraging habitat be within 0.8 km (0.5 mi) of the center of the cluster, and that, preferably, 50 percent or more be within 0.4 km (0.25 mi) of the cluster center. Foraging partitions should therefore include a second, smaller circle denoting the 0.4 km (0.25 mi) radius. Because cavity tree clusters are spatially dynamic, foraging partitions should be reevaluated periodically as described below.

2. General Monitoring of Foraging Habitat

a. Monitor quality and quantity of all foraging habitat dedicated to red-cockaded woodpecker groups and recruitment clusters at a minimum frequency of 10 years, with the exception of midstory which is to be monitored at a minimum frequency of 5 years. Begin monitoring foraging habitat as soon as possible. Substantial change in habitat quality should be made during each ten-year interval until all habitat elements put forth in the recovery standard are met. Once the recovery standard is met, continued habitat monitoring will ensure that habitat quality and quantity are maintained.

b. Record, for each territory or foraging partition associated with active and recruitment clusters, the following information:

i. the number of ha (ac) of foraging habitat that meets all elements of good quality habitat identified in the recovery standard (above).

ii. the number of ha (ac) of foraging habitat that meets all elements but one, and for each forest stand, identify the missing element.

iii. the number of ha (ac) of foraging habitat that meets all elements but two, and for each forest stand, identify the missing elements.

c. Use appropriate management techniques to increase the number of ha (ac) in categories (i) and (ii) above, and to move toward meeting the standard of 49 ha (120 ac) in category (i).

d. To monitor groundcover, estimate percent native, site-appropriate herbaceous cover using as simple standard technique such as that presented by James and Shugart (1970) and proportional sampling based on the size of the stand. If necessary, more specific recommendations for groundcover monitoring will be formulated by the U.S. Fish and Wildlife Service.

e. To monitor pine size and density, use standard forestry techniques. Age of pines can be determined by coring a sample and determining the relationship between age and size for each habitat type.

3. Interim Guidelines. Here we discuss interim guidelines for assessment of project impacts in territories or foraging partitions not meeting foraging habitat recommendations. The major theme of these recommendations is that if reasonable progress toward meeting the recovery standard can be demonstrated, most projects can be implemented.

a. Demonstration of Reasonable Progress. Reasonable progress toward meeting the recovery standard is best demonstrated by increases in the area of foraging habitat that meets all of the elements of good quality habitat as set forth in the recovery standard (above). Reasonable progress can also be demonstrated by increasing habitat area that meets all elements but one, with no corresponding decrease in the habitat area meeting all elements. Finally, reasonable progress can also be demonstrated if one or more of the individual components are being moved toward the desired condition. For example, if managers can document that an area once supporting no herbaceous groundcover now supports 20 percent native herbaceous cover, reasonable progress is being made. Any of these improvements in foraging habitat have to be current (within the past 3 years) to be considered reasonable progress.

b. Guidance on Specific Projects - Cluster-level Analysis

i. If the project itself (e.g. pine thinning) will move the habitat dedicated to specific clusters toward the desired structure identified in the recovery standard, project concurrence is provided.

ii. If the project **will not** impact the best 49 ha (120 ac) dedicated to foraging habitat (or the best 80 – 120 ha (200-300 ac) in sites of low productivity), and that dedicated foraging habitat is being actively moved toward the desired structure by demonstration of reasonable progress, then project (e.g., a land use change) concurrence is provided. Here we use the term 'best' to refer to those hectares (acres) that best reflect the desired habitat structure and important habitat elements put forth in the recovery standard.

iii. If the project **will** impact some of the best 49 ha (120 ac) dedicated to foraging habitat (or the best 80 – 120 ha (200-300 ac) in sites of low productivity), and will not move the habitat directly toward the desired structure, then the project will typically require reconsideration and modification prior to concurrence. However, in some cases such as restoration of site-appropriate pine species, the project may continue at a reduced level (e.g., group selection or very small patches) so that impacts to foraging are minimized and weighed against future benefits. Such concurrence requires a case-by-case review.

c. Guidance on Specific Projects - Neighborhood-level Analysis

Foraging habitat loss or alteration can have direct effects on group size and reproduction (cluster-level analysis, above). Additionally, by affecting landscape configuration, projects may affect the health and distribution of red-cockaded groups at a neighborhood scale. Habitat fragmentation affects dispersal of individuals in adjacent or nearby groups, and the likelihood that breeding vacancies become filled. Demographic viability of groups, neighborhoods, and populations is primarily dependent on the ability of group members to disperse. If dispersal opportunities are limited or inhibited by a project, even if adequate foraging habitat remains post-project, group status, group size, and reproduction may be affected. It is important that these neighborhood effects be assessed during analysis of project impacts.

J. SILVICULTURE

Silviculture is an important tool for conservation, management, and recovery of red-cockaded woodpeckers. We describe silvicultural methods and techniques in 3E. We present general guidelines for silviculture below (Part A). These general guidelines are based on research documenting the importance of old pines and impacts of habitat fragmentation on red-cockaded woodpeckers (see 2D, 2E). We also present some approaches to satisfying foraging guidelines (8I) under various silvicultural systems currently in use. These approaches reflect our new understanding of foraging ecology (2E) and current silviculture in general; they are not based on research of the effects of these silvicultural treatments on red-cockaded woodpeckers. Experimental research into effects of specific silvicultural treatments on fitness of red-cockaded woodpeckers is a critical research need.

Guidelines

Part A. General Guidelines for Silviculture

1. Use two-aged management, uneven-aged management, or low intensity management to manage habitat for red-cockaded woodpecker populations on public lands. These guidelines are to be applied throughout the habitat managed for red-cockaded woodpeckers, unless otherwise noted.

a. If two-aged management is used, then

i. Use rotation intervals not less than 120 years for longleaf and shortleaf pines and 100 years for loblolly, slash, and pond pines. An exception to this for loblolly and shortleaf stands under high risk of mortality due to insects, disease, or other site-related problems may be given on a case-by-case basis through consultation with the U.S. Fish and Wildlife Service. These rotation intervals are considered the minimum intervals compatible with red-cockaded woodpecker conservation.

ii. Limit regeneration areas to less than 10 ha (25 ac) in populations of less than 100 potential breeding groups, and to less than 16 ha (40 ac) in populations of 100 potential breeding groups or more.

iii. Leave a minimum of 15 – 25 pines on each ha (6 – 10 pines on each ac).

iv. Retain all flat-tops, turpentine pines, and other relict pines.

b. If uneven-aged management is used, then

i. Retain 12 or more pines on each hectare (5 or more on each acre) of the oldest pines present, to establish very old pines throughout the landscape at this minimum density.

ii. Retain all flat-tops, turpentine pines, and other relict pines.

c. If low-intensity management is used, ensure that the appropriate habitat structure, as described in foraging (8I) and cluster management guidelines (8F), is maintained.

2. Use even-aged, two-aged, and/or uneven-aged management systems to restore off-site pines to native pine species. Generally, limit size of regeneration areas for restoration to 16 ha (40 ac) or less. However, regeneration areas up to 32 ha (80 ac) are acceptable for native pine restoration if such stands are at least 1.6 km (1 mi) from active or recruitment clusters.

3. Use the least invasive form of site preparation possible given habitat conditions. In most instances, prescribed burning is the preferred method.

4. Protect against infestation of southern pine beetles by practicing Integrated Pest Management, including thinning pines to maintain adequate spacing (7.6 m or 25 ft among canopy pines) and minimizing disturbance. For more specific information consult the U.S. Forest Service's Final Environmental Impact Statement for the Suppression of the Southern Pine Beetle (USFS 1987).

Part B. Silvicultural Systems and Implementation of Foraging Guidelines

Here we present a brief description of how foraging guidelines can be satisfied in forests managed under modified two-aged or uneven-aged silviculture. See 3E for more information concerning silviculture.

1. Modified Two-aged Management

a. Loblolly, Slash, and Pond Pines. Forests of these pine types are to be managed on a minimum rotation of 100 years. An exception to the minimum may be permitted in forests under high risk of infestation by southern pine beetles through consultation with the U.S. Fish and Wildlife Service. To implement foraging guidelines under a minimum rotation of 100 years, follow these recommendations:

i. Retain a minimum basal area of 4.6 m^2/ha (20 ft^2/ac) in leave trees.

ii. Do not count stands with dense, young regeneration as foraging habitat. Stands that do not meet criterion (c) in the Recovery Standard (above) cannot be counted as foraging habitat.

iii. Once regeneration reaches 25.4 cm (10 in) dbh, thin the regeneration to a maximum basal area of 9.2 m^2/ha (40 ft^2/ac) and protect or restore herbaceous groundcover. The stand should then meet the criteria of good quality habitat (above) and can be counted as foraging habitat.

b. Longleaf and Shortleaf Pines. Longleaf and shortleaf pine woodlands under modified two-aged silviculture are to be managed with a minimum rotation of 120 years. An exception to the minimum may be obtained in shortleaf forests under high risk of disease (e.g. little-leaf disease). There are at least three options for implementing the recovery standard in these woodlands. The first is to extend the rotation interval to 150 years for woodpecker groups maintained at a current or projected density of 81 ha (200 ac) per group. This would provide 49 ha (120 ac) of good quality habitat in each foraging partition. The second option is to follow the approach described above for loblolly/slash/pond pine forests under modified two-aged silviculture. However, some managers may consider leaving a minimum of 4.6 m^2/ha (20 ft^2/ac) of basal area in leave pines unrealistic in longleaf woodlands because of the shade intolerance of the species. These managers may consider a third option, which is to extend the projected density of red-cockaded woodpecker groups to 97 ha (240 ac) per group. Under this third option, regeneration areas (still requiring 15 – 25 leave pines/ha, or 6 to 10 pines/ac) are not counted as foraging habitat until the regeneration reaches at least 60 years in age and 35 cm (14 in) dbh.

2. Uneven-aged Management

Uneven-aged silviculture includes both single tree and group selection. Both silvicultural methods are compatible with management for red-cockaded woodpeckers. If single tree selection is applied appropriately, the entire forest can meet all elements of good quality foraging habitat as put forth in the recovery standard. However, when group selection is applied, small patches of regeneration (< 0.8 ha, or 2 ac) are interspersed throughout the managed forest. These individual patches of regeneration may be included within the area identified as good quality foraging habitat once the regenerating pines are at least 25.4 cm (10 in) dbh, the density of these pines is 9.2 m^2/ha (40 ft^2/ac), and the appropriate percentage of native groundcovers is present. Once the regenerating pines are 35 cm (14 in) in dbh or greater, regeneration areas should meet all elements of the recovery standard.

If red-cockaded woodpecker groups are being managed at a density of 81 ha (200 ac) per group, this approach to satisfying the recovery standard in forests under group selection will result in 40 ha (100 ac) of good quality habitat and an additional 20 ha (50 ac) of small patches that meet all elements of good quality habitat except the requirement for pines 35 cm (14 in) and larger. This is the only acceptable exception to the minimum area requirement of 49 ha (120 ac) of good quality habitat put forth in the recovery standard. This exception is considered acceptable because of the spatial distribution and size of regenerating patches (that is, regenerating patches that lack pines 35 cm (14 in) dbh and larger are small and interspersed throughout the forest).

K. PRESCRIBED BURNING

Prescribed burning is basic to the management, conservation, and recovery of red-cockaded woodpeckers. In addition, prescribed burning provides benefits for a long list of species associated with southern pine/bunchgrass ecosystems, many of which are rare, threatened, or endangered. Discussions of the integral role of fire in southern pine ecosystems and the use of prescribed fire are given in 2G and 3F. Prescribed burning should mimic natural fire regimes as closely as possible, but must be carefully planned and conducted to reduce the likelihood of damage to nesting and foraging habitat. In general, managers are to work toward a prescribed burning program of early to mid-growing season burns on a 1 to 5 year return interval. Habitat with excessive hardwood midstory is to be restored to one with an herbaceous groundcover, preferably by burning at a frequency of 1 to 3 years. Longer intervals are appropriate only for habitat that can be maintained with recommended herbaceous groundcover at those longer burn frequencies.

Guidelines

1. Planning a Prescribed Burning Program. In planning a prescribed burning program to benefit red-cockaded woodpeckers, consider the following guidelines:

a. Prioritize areas of the forest in need of burning.

i. Review the status of red-cockaded woodpeckers throughout the forest.

ii. Give first priority to maintaining active clusters that support healthy herbaceous groundcovers.

iii. Give second priority to restoring herbaceous groundcovers in active clusters with excessive hardwood midstory.

iv. Give third priority to recently inactive clusters with excessive midstory.

b. As special needs are being addressed, move to implement an effective broad-scale burning program to maintain and enhance quality of nesting and foraging habitat.

2. Burn Prescriptions. Prepare burn prescriptions for each burn unit prior to conducting prescribed burning based on habitat evaluations for individual woodpecker groups. Each prescription should include:

a. The management objective of the burn, such as habitat restoration, habitat maintenance, or fuel reduction.
b. The parameter values necessary to achieve the objective, including season of burn, fuel moisture, wind speed and direction, and relative humidity.

c. Maps indicating the location of all cavity trees within the burn unit as well as specific directions for protecting each of these cavity trees.

In light of stringent laws regulating smoke management, it is imperative that all prescribed burns comply with state and federal regulations.

3. Season of Prescribed Burning. Determine the appropriate season for prescribed burns based on management objectives. Consider the following guidelines when determining appropriate season:

a. Strive for a program of frequent early to mid-growing season burns to maintain and enhance quality of nesting and foraging habitat.

b. Apply dormant season fire prior to growing season burns when reintroducing fire to fire-suppressed habitats, but be aware that fires conducted during the late growing season and into the fall can result in increased pine mortality. Growing season burns can be used as a method of habitat restoration in some sites (see 3G and below).

c. Do not rely on dormant season fire. Once hazardous fuel accumulations have been reduced by dormant season burns, place the area on a growing season fire rotation.

d. Bear in mind geographic variation in the timing of the seasons.

e. Remember that regardless of the season, heavy fuels are very dangerous to cavity trees. During dormant season as well as growing season burns, thick duff layers surrounding pines can result in deadly smolder fires.

4. Size of Burn Units. Size of prescribed burns can vary from single clusters to over a thousand hectares (several thousand acres). In general, larger burns have a lower cost per hectare (acre) and provide the greatest benefit to the ecosystem. However, cost efficiency should not be the sole factor in determining the size of burn units. The prescribed burn should be large enough to accomplish the primary objective of the burn without reducing the burn boss's ability to maintain control of the fire's intensity.

5. Cavity Tree Protection. Protect cavity trees within and in close proximity to the burn unit, following these guidelines:

a. Ensure that all members of the burn crew have maps detailing the location and status of all cavity trees within and in close proximity to the burn unit. Information distributed to each crew member should include activity status, cavity height, and relative amount of resin present, as determined by surveys performed within one year of the burn date.

b. Determine the appropriate level of protection for cavity trees, according to the following:

i. Protect active cavity trees, inactive cavity trees, and relict pines (flat-tops, very old pines, and turpentine pines) within the burn unit if one or more of the following conditions exist: (1) the population consists of less than 30 potential breeding groups; (2) fire intensity of the prescribed burn would likely result in ignition of an unprotected tree; or (3) potential cavity trees (i.e., pines over 60 years in age, including relict pines) are limited.

ii. Protect only active cavity trees within the burn unit if all of the following conditions exist: (1) the population consists of 30 or more potential breeding groups; (2) the area proposed for burning has been burned in recent years (3 – 5 years or less) and the fuel loads have been reduced to acceptable limits; and (3) potential cavity trees are not limited.

c. Protect individual cavity trees by reducing fuels at the base of cavity trees for a minimum distance of 3 m (10 ft) from the trunk. The necessary distance varies depending on fuel types, fuel loads, amount of resin present, cavity heights, and firing technique as well as on the objective of the burn. Restoration burns require a greater distance of fuel reduction than less intense maintenance burns. Use maximum distances during the nesting season and when protecting cavity trees with turpentine scars and resin low on the bole.

d. Use one or more of the following methods of cavity tree protection:

i. Small preparation burns. Conduct preparation burns of the cluster or areas surrounding individual cavity trees before conducting the larger burn. Preparation burns can be performed immediately before or several weeks ahead of the larger burn. Carefully monitor and extinguish preparation burns to avoid damage to cavity trees or unintentional ignition of the larger burn unit. A strong advantage of this method is that it benefits groundcover plants that are harmed by other methods such as raking and mowing (below).

ii. Raking. Rake fuels far enough from the trunk to prevent cavity tree ignition. Avoid the formation of mounds or rings of concentrated fuels (such as pine straw); such piles of fuels can cause greater mortality than if no action had been taken. Remove small trees and shrubs by hand prior to raking fuels.

iii. Mowing. Mowing is effective, but heavy machinery can compact soils and damage tree roots. To reduce these negative impacts, avoid repeated mowing and use of heavy equipment, and minimize use of machinery in wet sites. Weed-whipping is a low impact alternative.

iv. Light bark scraping. Lightly scraping off the loose bark from ground to breast height can improve the effectiveness of other methods such as raking and mowing.

v. Wetting the cavity trees. A solution of water and foaming agent applied to the base of cavity trees is currently being tested as a method for cavity tree protection. This may become available for widespread use in the future. Foam may be especially effective in combination with mowing or raking.

vi. Plow lines as cavity tree protection are prohibited. Never install circular plow lines around individual cavity trees because such plow lines can cause the death of the tree.

6. Method of Ignition. Apply fire to the landscape using aerial or ground ignition. Ground ignition may require less financial resources and training. Aerial ignition increases the area burned per unit time, and improves dispersal of smoke. Either technique is suitable, and both are discussed in 3F.

If using aerial ignition, provide a greater degree of cavity tree protection than normally provided for burns ignited on the ground. Rake, mow, or burn for a distance of at least 6.1 m (20 ft) or more from the cavity trees. Even greater protection is necessary if the area has not been burned frequently and the habitat requires restoration. If restoration is required, we recommend a prescribed burn of the cluster ignited on the ground prior to igniting the larger burning unit from the air.

7. Restoration Burning. Restoration burning and the reintroduction of fire can be used to reduce or remove dense hardwood midstories. When applying restoration burns, have fire suppression equipment on site in case the fire crosses control lines. Clusters on deep, sandy soils, with a dense hardwood midstory and a sparse accumulation of ground fuels, can be effectively treated with a restoration burn during the growing season.

Key to success of this management action is a thorough understanding of fire behavior in those fuel types under a variety of weather conditions. The use of fire for restoration purposes often requires burning under very specific weather conditions, which may include moderate winds, low relative humidity, and low fuel moistures. Use of prescribed burns under these conditions requires extensive experience in the application of growing season fire and must be conducted only by qualified burners. Again, it is imperative that all prescribed burns comply with state and federal regulations.

8. Consider the use of wildland fire to accomplish management objectives in appropriate areas. Protect public safety and property if implementing this policy. Protect cavity trees from ignition, and ensure that emergency fire suppression personnel are familiar with cavity protection methods and the need to protect cavity tree roots from plow lines and other firebreaks.

9. RECOVERY TASKS

The following recovery tasks are presented as a stepdown outline, a format required by the U.S. Fish and Wildlife Service's recovery planning guidelines. Ecology and management techniques relevant to these tasks are described in the Introduction. Management guidelines are given in detail in previous sections of Recovery. Specific guidelines relevant to tasks are referred to in parentheses.

1. Increase existing populations on all federal lands, and on those state lands identified in recovery criteria, until population objectives are reached.

1.1. Protect existing active clusters.

1.1.1. Apply prescribed burns every 1 to 5 years, preferably during the growing season (included in task 1.7., see 8K).

1.1.2. Provide and maintain four suitable cavities per cluster, if necessary using artificial cavities and/or restrictor plates (8E).

1.1.3. Control midstory and overstory hardwoods using means other than prescribed fire as necessary, but minimize disturbance to soil and native herbaceous groundcovers (8F, 8K).

1.1.4. Retain and protect active and inactive cavity trees and potential cavity trees (8F, 8K).

1.1.5. Practice integrated pest management to limit risk of damage by southern pine beetles.

1.2. Provide and maintain a sufficient number of recruitment clusters to achieve an annual average rate of population increase between 5 and 10 percent (8A).

1.2.1. Choose strategic locations for recruitment clusters, to facilitate occupation and develop beneficial spatial arrangements of groups (8B).

1.2.2. Restore suitable habitat structure prior to the installation of artificial cavities in recruitment clusters, using prescribed fire and other means as necessary to remove midstory and overstory hardwoods. Conduct pine thinning if densities are too high. Minimize disturbance to soils and native herbaceous groundcovers (8B, 8E, 8F, 8K).

1.2.3. Provision a number of recruitment clusters equal to 10 percent of potential breeding groups (or number of active clusters, if potential breeding groups is unknown). For each recruitment cluster, provide 3 artificial cavities and two drilled starts, or four artificial cavities (8A, 8B).

1.2.4. Apply prescribed burns to unoccupied recruitment clusters every 1 to 5 years, preferably during the growing season (8K).

1.2.5. When occupied, manage recruitment clusters as in 1.1 above.

1.3. Provide suitable quality and quantity of foraging habitat for each active and recruitment cluster, following the recovery standard (8I).

1.3.1. Apply prescribed fire to foraging habitat every 1 to 5 years, preferably during the growing season, to protect and restore native herbaceous groundcovers and control densities of midstory hardwoods and pines (8I, 8K).

1.3.2. Use means other than prescribed fire, if necessary, to control densities of midstory and overstory hardwoods and small and medium-sized pines (8I, 8K).

1.3.3. Protect and/or develop an old growth or mature pine component within the foraging habitat, at recommended densities (8I, 8J).

1.3.4. Provide suitable quantity of good quality foraging habitat (8I).

1.3.5. Practice integrated pest management to limit risk of damage by southern pine beetles.

1.4. Combat effects of fragmentation on demography and genetic resources.

1.4.1. Locate newly developed recruitment clusters of artificial cavities in strategic locations to enhance natural dispersal (same as task 1.2.1).

1.4.2. Use within-population translocation when appropriate to stabilize and increase isolated sub-populations (8H).

1.4.3. Consider population augmentation if your population is less than 30 potential breeding groups, through enrolling in a regional translocation program (8H). Provide high quality nesting and foraging habitat prior to translocation (8B, 8E, 8F, 8I).

1.4.4. Avoid further fragmentation of forests managed for red-cockaded woodpeckers (8J).

1.5. Provide additional habitat for population growth to achieve population objectives.

1.5.1. Use appropriate silvicultural techniques to produce suitable foraging and nesting habitat for future population expansion (8J).

1.5.2. Restore historic vegetation type (e.g., longleaf and shortleaf pine communities) where appropriate (8J).

1.6. Monitor woodpecker populations using recommended monitoring intensity (8C).

1.7. Apply prescribed fire to all habitat managed for red-cockaded woodpeckers at least every 1 to 5 years (tasks 1.1.1, 1.2.4, and 1.3.1).

2. Maintain and/or increase populations on state lands not identified in recovery criteria.

2.1. Provide regulatory and economic incentives for state managers to participate in recovery efforts.

2.2. Enlist managers in statewide and regional recovery programs and partnerships.

2.3. Protect existing active clusters and encourage population increase (see tasks 1.1-1.7).

3. Maintain and/or increase populations on private lands, and establish new populations.

3.1. Provide regulatory and economic incentives for private landowners to participate in recovery efforts.

3.2. Enroll private landowners in management, conservation, and recovery programs, including Safe Harbor, Habitat Conservation Plans, and Memoranda of Agreement.

3.3. Provide awards to private landowners, both citizens and corporations, for exemplary conservation efforts.

3.4. Protect existing active clusters and encourage population increase (see tasks 1.1-1.7.).

4. Increase awareness of stakeholders and the general public.

4.1. Increase awareness of red-cockaded woodpecker ecology, status, and recovery.

4.2. Increase awareness of the role of fire in southeastern ecosystems and the need for prescribed burning.

4.3. Increase awareness of the need to restore an old growth pine component to federal, state, and private lands of the south.

5. Conduct research to further our understanding of woodpecker ecology, management, and recovery.

5.1. Explore and evaluate best management practices to increase populations at a rate appropriate for the recovery potential and habitat availability of individual populations.

5.2. Expand current understanding of relationships between condition of foraging habitat (structure, age, and species composition) and measures of group fitness and population health, for various habitat types such as mesic and xeric longleaf pine, south Florida slash pine, pond pine, off-site and site-appropriate loblolly, and shortleaf pine systems.

5.3. Expand current understanding of the relationships between condition of nesting habitat (density of pines, age of cavity trees, and groundcover composition) and measures of group fitness and population health.

5.4. Research conditions and factors that promote territorial budding and pioneering.

5.5. Further evaluate genetic threats.

5.6. Gain a better understanding of effects of cavity kleptoparasitism and predation on population dynamics, for various population sizes and habitat conditions.

5.7. Further research juvenile dispersal, especially factors promoting movements between populations.

5.8. Identify the thresholds at which quantity and quality of foraging habitat affect population trends, to better evaluate management of woodpeckers on private lands.

5.9. Further evaluate the relative benefits and drawbacks of artificial cavity installation methods.

5.10. Further assess the value of translocation as a management tool, including research on impacts to donor populations, benefits to receiving populations, and best techniques to increase success. Determine if translocation among recovery populations is warranted for genetic conservation (informed by results of tasks 5.5 and 5.7) or if drawbacks outweigh potential benefits of this action.

5.11. Further research the relationships among bark beetles, red-cockaded woodpeckers, and habitat management, including the extent and cause of elevated mortality of cavity trees infested with bark beetles, effects of habitat management on risk of infestation, and reasons why cavity trees attract bark beetles. Develop measures to prevent or reduce beetle-induced mortality of cavity trees.

5.12. Research the impacts of exotic species such as melaleuca and fire ants on red-cockaded woodpeckers.

6. Explore costs, benefits, and feasibility of moving from management based on single clusters to landscape level management.

6.1. On federal lands.

6.2. On state lands.

6.3. On private lands.

6.4. On tribal lands.

10. IMPLEMENTATION SCHEDULE AND ESTIMATED COSTS

We present several tables in this section. First are tables of estimated time to delisting (Table 14) and downlisting (Table 15), as calculated by projecting a 5 percent annual increase. Next is the implementation schedule and estimated costs for each recovery task (Table 16). These costs are given per unit (e.g., per active cluster, or per unit area). Finally, there are tables that illustrate estimated costs, by recovery population and responsible agency, for three recovery tasks: cavity maintenance (Table 17), cavity installation in recruitment clusters (Table 18), and frequent prescribed burning of all woodpecker habitat (Table 19).

TABLE 14. Estimated time (years, to the nearest 5 years) for each recovery population to meet size specified in delisting criteria, by recovery unit. Also listed is current size (number of active clusters in 2000, ACT) and minimum size required at delisting (potential breeding groups, PBG). Each estimated time is calculated based on a recommended 5% annual growth rate and a ratio of 1.4 active clusters per potential breeding group. Estimated time to delisting is 75 years, the maximum time in this table.

Recovery Unit	**Population**	**Current Size (ACT)**	**Size at Delisting (PBG)**	**Time to Required Size (yrs)**
Cumberlands/Ridge and Valley	Talladega/Shoal Creek	6	100	55
East Gulf Coastal Plain	Central Florida Panhandle	665	1000	50
	Chickasawhay	15	350	75
	Conecuh/Blackwater	44	250	60
	DeSoto	7	250	75
	Eglin	301	350	10
	Homochitto	51	250	35
Mid-Atlantic Coastal Plain	Coastal North Carolina	159	350	25
	Francis Marion	344	350	10
	Northeast North Carolina/Southeast Virginia	35	100	50
Ouachita Mountains	Ouachita	21	250	60
Piedmont	Oconee/Piedmont	59	250	45
Sandhills	Fort Benning	219	350	15
	North Carolina Sandhills East	371	350	15
	North Carolina Sandhills West	145	100	0
	South Carolina Sandhills	167	250	25
South Atlantic Coastal Plain	Fort Stewart	212	350	20
	Osceola/Okefenokee	100	350	40
	Savannah River	34	250	50
South/Central Florida	Avon Park	21	40	20
	Babcock/Webb	27	40	15
	Big Cypress	42	40	5
	Camp Blanding	14	25[1]	15
	Corbett/Dupuis	13	40	30
	Goethe	30	40	15
	Hal Scott	7	15[1]	15
	Ocala	22	40	20
	Picayune Strand	3	25[1]	45
	St. Sebastian River	8	25[1]	30
	Three Lakes	51	40	5
	Withlacoochee - Citrus Tract	46	40	5
	Withlacoochee - Croom Tract	5	30[1]	40
Upper East Gulf Coastal Plain	Bienville	104	350	35
	Oakmulgee	110	250	25
Upper West Gulf Coastal Plain	Sam Houston	168	350	25

Table continued next page.

TABLE 14 (cont.). Estimated time for each recovery population to meet size specified in delisting criteria.

Recovery Unit	Population	Current Size (ACT)	Size at Delisting (PBG)	Time to Required Size (yrs)
West Gulf Coastal Plain	Angelina/Sabine	57	350	45
	Catahoula	37	250	55
	Davy Crockett	53	250	40
	Vernon/Fort Polk	198	350	15

[1]These populations each have an estimated potential size of less than 40 potential breeding groups but can contribute significantly to the delisting criterion of 250 potential breeding groups (275-350 active clusters) in the South/Central Florida Recovery Unit overall.

TABLE 15. Estimated minimum time (years, to the nearest 5 years) for each recovery unit to meet downlisting criteria, assuming the currently largest populations within each recovery unit fulfill downlisting criteria first. Estimated time is calculated based on a recommended 5% annual growth rate and a ratio of 1.4 active clusters per potential breeding group. Estimated time to downlisting is 50 years.

Recovery Unit	**Time to Meet Downlisting Criteria (yrs)**
Cumberlands/Ridge and Valley	50
East Gulf Coastal Plain	0
Mid-Atlantic Coastal Plain	25
Ouachita Mountains	30
Piedmont	15
Sandhills	0
South Atlantic Coastal Plain	15
South/Central Florida	15
Upper East Gulf Coastal Plain	25
Upper West Gulf Coastal Plain	20
West Gulf Coastal Plain	15

TABLE 16. Implementation schedule and estimated costs by recovery task. See key below for explanation of abbreviations and cost estimates. For more information on costs and implementation schedule for select recovery tasks, see Tables 17, 18, and 19. See key (below) for explanation of column headings and abbreviations.

Task	Task No.	P	D	Responsible Parties	Cost Estimates ($1) FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Increase All Federal and Specific State Populations														
Nesting Habitat, Active Clusters														
Prescribed burning	1.1.1	1	C	AGENCY	50/ha[1]	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Cavity installation and restriction (see Table 17)	1.1.2	1	D	AGENCY	200/ACT[2]	200/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT	100/ACT
Other hardwood control	1.1.3	1	C	AGENCY	0-250/ha[3]	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha
Protect cavity trees	1.1.4	1	C	AGENCY	*Included in prescribed burning costs above*									
Practice IPM	1.1.5	1	C	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Nesting Habitat, Recruitment Clusters														
Strategic locations	1.2.1	1	D	AGENCY	0	0	0	0	0	0	0	0	0	0
Initial habitat restoration	1.2.2	1	D	AGENCY	0-250/ha[3]	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha
Cavity installation (see Table 18)	1.2.3	1	D	AGENCY	800/RC[4]	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC	800/RC
Maintenance burning	1.2.4	1	D	AGENCY	50/ha[1]	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Appropriate management when occupied (task 1.1)	1.2.5	1	C	AGENCY	*Included in task 1.1*									
Foraging Habitat														
Prescribed burning	1.3.1	1	C	AGENCY	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Other hardwood or pine control	1.3.2	1	C	AGENCY	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha	0-250/ha
Develop mature pines	1.3.3	1	C	AGENCY	0	0	0	0	0	0	0	0	0	0
Provide suitable quantity	1.3.4	1	C	AGENCY	0	0	0	0	0	0	0	0	0	0
Practice IPM	1.3.5	1	C	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Table continued next page.

TABLE 16 (cont.). Implementation schedule and estimated costs by recovery task.

Task	Task No.	P	D	Responsible Parties	Cost Estimates ($1) FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Increase All Federal and Specific State Populations (cont.)														
Combat Fragmentation				AGENCY										
Strategically locate recruitment clusters (1.2.1)	1.4.1	1	D	AGENCY	0	0	0	0	0	0	0	0	0	0
Within-pop. translocation	1.4.2	2	D	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Population augmentation, pops. < 30 PBG only	1.4.3	1	D	AGENCY	3000-9000 /new PBG[5]	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG	3000-9000 /new PBG
Avoid fragmentation	1.4.4	1	C	AGENCY	0	0	0	0	0	0	0	0	0	0
Develop Additional Habitat														
Silviculture	1.5.1	1	D	AGENCY	0	0	0	0	0	0	0	0	0	0
Habitat restoration	1.5.2	1	D	AGENCY	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Monitor Populations	1.6	1	C	AGENCY	750/ACT[6]	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT	750/ACT
Burn All Habitat in HMA at least every 1-5 yrs. (1.1.1, 1.2.4, 1.3.1; see Table 19)	1.7	1	C	AGENCY	50/ha[1]	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha	50/ha
Maintain and/or increase all other state populations														
Provide incentives	2.1	2	C	STATES &USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Enlist in programs	2.2	2	D	STATES & USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Protect existing clusters, encourage increases	2.3	2	C	STATES & USFWS	*See tasks 1.1 – 1.7*									
Maintain and/or increase populations on private lands														
Provide incentives	3.1	2	C	STATES & USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Enlist in programs	3.2	2	D	STATES & USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Provide awards	3.3	2	D	USFWS	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Protect existing clusters, encourage increases	3.4	2	C	STATES & USFWS	*See tasks 1.1 – 1.7*									
Increase public awareness														
Ecology, status, recovery	4.1	2	C	ALL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Importance of fire	4.2	2	C	ALL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD
Importance of old pines	4.3	2	C	ALL	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD	TBD

Table continued next page.

TABLE 16 (cont.). Implementation schedule and estimated cost by recovery task.

Task	Task No.	P	D	Resp. Parties	Cost Estimates ($1*1000) FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Research needs														
Best management to increase populations	5.1	1	TBD	PI	200	200	200	200	200	200	200	200	200	200
Foraging habitat & fitness, in various habitat types	5.2	1	TBD	PI	200	200	200	200	200	200	100	100	100	100
Nesting habitat & fitness	5.3	1	TBD	PI	100	100	100	100	100	100	0	0	0	0
Budding & pioneering	5.4	2	TBD	PI	100	100	100	100	0	0	0	0	0	0
Genetic threats	5.5	2	TBD	PI	50	50	50	50	50	50	0	0	0	0
Cavity kleptoparasitism & predation	5.6	3	TBD	PI	30	30	30	30	0	0	0	0	0	0
Dispersal	5.7	2	TBD	PI	100	100	100	100	100	100	0	0	0	0
Foraging & private lands	5.8	2	TBD	PI	200	200	200	200	0	0	0	0	0	0
Cavity installation methods	5.9	3	TBD	PI	30	30	30	30	30	30	30	30	0	0
Translocation	5.10	2	TBD	PI	50	50	50	50	50	50	0	0	0	0
Bark Beetles	5.11	1	TBD	PI	100	100	100	100	100	100	0	0	0	0
Threats from exotic species	5.12	3	TBD	PI	30	30	30	30	0	0	0	0	0	0

Key to Column Headings and Abbreviations:

Task: Recovery task from stepdown outline, section 9. See section 8 for guidelines.
Task No.: Task number identified in stepdown outline (see 9).
P: Priority assigned to recovery task, including (1) tasks that must be completed to meet delisting criteria; (2) tasks that should be done to help meet recovery objective; and (3) tasks that should be done to enhance management of the species.
D: Duration of recovery task. Two levels are identified here: (C) continuous, up to and after delisting; and (D) until delisting.
Resp. Parties: Agencies and other parties responsible for the completion of recovery task. Abbreviations are as follows:

AGENCY **-** all agencies responsible for properties identified in delisting criteria, i.e. the following:
Florida Department of Military Affairs (FDMA)
Florida Division of Forestry (FDF)
Florida Fish and Wildlife Conservation Commission (FFWCC)
Florida Park Service (FPS)
National Park Service (NPS)
North Carolina Department of Agriculture (NCDA)
North Carolina Department of Environment and Natural Resources (NCDENR)
North Carolina Wildlife Resources Commission (NCWRC)

Key to Column Headings and Abbreviations (cont.):

South Carolina Forestry Commission (SCFC)
South Florida Water Management District (SFWMD)
Saint John's River Water Management District (Florida; SJRWMD)
U.S. Air Force (USAF)
U.S. Army (USARMY)
U.S. Department of Energy (USDOE)
U.S. Forest Service (USFS)
U.S. Fish and Wildlife Service (USFWS)
U.S. Marine Corps (USMC)
U.S. Navy (USNAVY)

PI	Principal investigators
STATES	All state agencies with occupied properties
ALL	All federal and state agencies with occupied properties and principal investigators

Cost Estimates: The figures in this column represent the estimated annual cost of each task. Further information is given in the following notes and in Tables 17, 18, and 19.
[1]Estimate for prescribed burning is a well-known figure in the field.
[2]Estimate for artificial cavity installation includes salary, equipment, overhead, and associated costs.
[3]Estimate for chemical and mechanical control varies within this range, well-known in the field.
[4]Estimate for cavity installation in recruitment clusters is four times the cost per cavity (4 x $200).
[5]Estimate for translocation for population augmentation is based on price per bird ($1500), success rate (varies between 25 and 50%), and movement of one or two birds; it does not include costs of constructing recruitment clusters.
[6]Estimate for monitoring is based on survey of federal properties' annual expenditures.

Abbreviations under Cost Estimates:

ACT	active cluster
FY	fiscal year
PBG	potential breeding group
RC	recruitment cluster
TBD	to be determined

TABLE 17. Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*) by responsible agency, for all federal properties and those state properties identified in recovery criteria. See key to Table 16 for agency abbreviations. Annual estimated cost = $200 x number of active clusters for the first 2 years, then $100 x number of active clusters for the remaining time period[1]. Estimated cost per artificial cavity = $200. Number of active clusters (ACT, 2000) is projected over 10 years with an annual population increase of 5 percent[1] until property goal is met. Properties that reach their goal are considered to require the same level of cavity maintenance over these ten years, with the exception of the Apalachicola Ranger District. Properties will require cavity maintenance until the average age of potential cavity trees is at least 80 and 100 years for loblolly and longleaf pine, respectively.

Responsible		**ACT**	**Property**	**Estimated Annual Cost ($1) for Cavity Maintenance**									
Agency	**Property**	**2000**	**Goal[2]**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
FDF	Blackwater River SF	26	45	5600	5800	3100	3200	3400	3500	3700	3900	4100	4300
	Goethe SF	30	150	6400	6800	3500	3700	3900	4100	4300	4500	4700	4900
	Picayune Strand SF	3	25	800	800	400	400	400	500	500	500	500	500
	Tate's Hell SF	29	400	6200	6400	3400	3600	3800	3900	4100	4300	4500	4800
	Withlacoochee - Citrus Tract	46	100	9800	10200	5400	5600	5900	6200	6500	6800	7200	7500
	Withlacoochee - Croom Tract	5	30	1200	1200	600	700	700	700	800	800	800	900
	subtotal	139	750	30000	31200	16400	17200	18100	18900	19900	20800	21800	22900
FDMA	Camp Blanding Training Site	14	25	3000	3200	1700	1800	1800	1900	2000	2100	2200	2300
	subtotal	14	25	3000	3200	1700	1800	1800	1900	2000	2100	2200	2300
FFWCC	Babcock/Webb WMA	27	240	5800	6000	3200	3300	3500	3700	3800	4000	4200	4400
	J.W. Corbett/Dupuis WMA[3]	13	90	2800	3000	1600	1600	1700	1800	1900	2000	2100	2200
	Three Lakes WMA	51	125	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
	subtotal	91	455	19400	20400	10800	11100	11800	12400	12900	13600	14300	15000
FPS	Ochlockonee River SP	3	3	600	600	300	300	300	300	300	300	300	300
	subtotal	3	3	600	600	300	300	300	300	300	300	300	300
NCDA	McCain Tract	5	7	1200	1200	600	700	700	700	700	700	700	700
	subtotal	5	7	1200	1200	600	700	700	700	700	700	700	700

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible		**ACT Property**		**Estimated Annual Cost ($1) for Cavity Maintenance**									
Agency	**Property**	**2000**	**Goal[2]**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
NCDENR	Weymouth Woods State NP	7	13	1600	1600	900	900	900	1000	1000	1100	1100	1200
	subtotal	7	13	1600	1600	900	900	900	1000	1000	1100	1100	1200
NCWRC	Holly Shelter Game Lands	38	38	7600	7600	3800	3800	3800	3800	3800	3800	3800	3800
	Sandhills Game Lands	134	160	28200	29600	15600	16300	17200	18000	18900	19800	20800	21900
	subtotal	172	198	35800	37200	19400	20100	21000	21800	22700	23600	24600	25700
NPS	Big Cypress NP	42	42	8400	8400	4200	4200	4200	4200	4200	4200	4200	4200
	subtotal	42	42	8400	8400	4200	4200	4200	4200	4200	4200	4200	4200
SCFC	Sand Hills SF	51	143	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
	subtotal	51	143	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
SFWMD	Kicco WMA	1	1	200	200	100	100	100	100	100	100	100	100
	St. Sebastian River SBP	8	25	1800	1800	1000	1000	1100	1100	1200	1200	1300	1400
	subtotal	9	26	2000	2000	1100	1100	1200	1200	1300	1300	1400	1500
SJRWMD	Hal Scott Preserve	7	15	1600	1600	900	900	900	1000	1000	1100	1100	1200
	subtotal	7	15	1600	1600	900	900	900	1000	1000	1100	1100	1200
USAF	Avon Park AFR	21	68	4600	4800	2500	2600	2700	2900	3000	3200	3300	3500
	Dare County Bombing Range	3	46	800	800	400	400	400	500	500	500	500	500
	Eglin AFB	301	500	63400	66400	34900	36600	38500	40400	42400	44500	46700	49100
	Poinsett Weapons Range	6	30	1400	1400	700	800	800	900	900	900	1000	1000
	subtotal	331	644	70200	73400	38500	40400	42400	44700	46800	49100	51500	54100

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
				Estimated Annual Cost ($1) for Cavity Maintenance									
USARMY	Camp Mackall	11	11	2200	2200	1100	1100	1100	1100	1100	1100	1100	1100
	Fort Benning	219	450	46000	48400	25400	26700	28000	29400	30900	32400	34000	35700
	Fort Bragg	350	436	73600	77200	40600	42600	43600	43600	43600	43600	43600	43600
	Fort Gordon	5	25	1200	1200	600	700	700	700	800	800	800	900
	Fort Jackson	24	126	5200	5400	2800	3000	3100	3300	3400	3600	3800	4000
	Fort Polk	46	179	9800	10200	5400	5600	5900	6200	6500	6800	7200	7500
	Fort Stewart	212	500	44600	46800	24600	25800	27100	28500	29900	31400	32900	34600
	MOT Sunny Point	9	17	2000	2000	1100	1100	1200	1300	1300	1400	1400	1500
	Peason Ridge	23	120	5000	5200	2700	2800	3000	3100	3300	3400	3600	3800
	subtotal	899	1864	189600	198600	104300	109400	113700	117200	120800	124500	128400	132700
USDOE	Savannah River Site	34	418	7200	7600	4000	4200	4400	4600	4800	5100	5300	5600
	subtotal	34	418	7200	7600	4000	4200	4400	4600	4800	5100	5300	5600
USFS	Angelina NF	29	252	6200	6400	3400	3600	3800	3900	4100	4300	4500	4800
	Apalachicola RD	486	500	0	0	0	0	0	0	0	0	0	0
	Bienville NF	104	500	22000	23000	12100	12700	13300	14000	14700	15400	16200	17000
	Catahoula RD	32	317	6800	7200	3800	3900	4100	4300	4600	4800	5000	5300
	Chickasawhay RD	15	502	3200	3400	1800	1900	2000	2100	2200	2300	2400	2500
	Conecuh NF	18	309	3800	4000	2100	2200	2300	2500	2600	2700	2800	3000
	Croatan NF	62	169	13200	13800	7200	7600	8000	8400	8800	9200	9700	10100
	Davy Crockett NF	53	330	11200	11800	6200	6500	6800	7200	7500	7900	8300	8700
	DeSoto NF	7	368	1600	1600	900	900	900	1000	1000	1100	1100	1200
	Evangeline RD	72	231	15200	16000	8400	8800	9200	9700	10200	10700	11200	11800
	Francis Marion NF	344	453	72400	76000	39900	41900	44000	45300	45300	45300	45300	45300

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
				Estimated Annual Cost ($1) for Cavity Maintenance									
USFS (cont.)	Homochitto NF	51	254	10800	11400	6000	6200	6600	6900	7200	7600	8000	8400
	Kisatchie RD	29	292	6200	6400	3400	3600	3800	3900	4100	4300	4500	4800
	Oakmulgee RD	110	394	23200	24400	12800	13400	14100	14800	15500	16300	17100	18000
	Ocala NF	22	179	4800	5000	2600	2700	2900	3000	3100	3300	3500	3600
	Oconee NF	20	176	4200	4600	2400	2500	2600	2700	2900	3000	3200	3300
	Osceola NF	63	462	13400	14000	7300	7700	8100	8500	8900	9400	9800	10300
	Ouachita NF	21	400	4600	4800	2500	2600	2700	2900	3000	3200	3300	3500
	Sabine NF	28	262	6000	6200	3300	3500	3600	3800	4000	4200	4400	4600
	Sam Houston NF	168	541	35400	37200	19500	20500	21500	22600	23700	24900	26100	27400
	Shoal Creek RD	6	125	1400	1400	700	800	800	900	900	900	1000	1000
	Talladega RD	0	110	200	400	300	400	500	600	600	600	700	700
	Vernon Unit	152	302	32000	33600	17600	18500	19400	20400	21400	22500	23600	24800
	Wakulla RD	138	506	29000	30600	16000	16800	17700	18500	19500	20400	21500	22500
	Winn RD	18	263	3800	4000	2100	2200	2300	2500	2600	2700	2800	3000
	subtotal	2048	8197	330600	347200	182300	191400	201000	210400	218400	227000	236000	245600
USFWS	Alligator River NWR	3	20	800	800	400	400	400	500	500	500	500	500
	Big Branch Marsh NWR	15	20	3200	3400	1800	1900	2000	2000	2000	2000	2000	2000
	Black Bayou NWR	1	1	200	200	100	100	100	100	100	100	100	100
	Carolina Sandhills NWR	116	193	24400	25600	13500	14100	14900	15600	16400	17200	18000	18900
	D'Arbonne NWR	2	5	600	600	300	300	300	300	300	300	400	400
	Felsenthal NWR	15	34	3200	3400	1800	1900	2000	2100	2200	2300	2400	2500
	Noxubee NWR	44	88	9400	9800	5100	5400	5700	5900	6200	6600	6900	7200
	Okefenokee NWR	37	86	7800	8200	4300	4500	4800	5000	5300	5500	5800	6100
	Pee Dee NWR	1	10	400	400	200	200	200	200	200	200	200	200

Table continued next page.

TABLE 17 (cont.). Estimated annual cost and schedule for implementation of recovery task 1.1.2 (*maintain four suitable cavities in each active cluster*).

Responsible Agency	Property	ACT Property 2000	Goal[2]	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
				Estimated Annual Cost ($1) for Cavity Maintenance									
USFWS (cont.)	Piedmont NWR	39	96	8200	8600	4600	4800	5000	5300	5500	5800	6100	6400
	Pocosin Lakes NWR	1	50	400	400	200	200	200	200	200	200	200	200
	St. Marks NWR	9	71	2000	2000	1100	1100	1200	1300	1300	1400	1400	1500
	Upper Ouachita NWR	1	1	200	200	100	100	100	100	100	100	100	100
	subtotal	284	675	60800	63600	33500	35000	36900	38600	40300	42200	44100	46100
USMC	MCB Camp Lejeune	59	173	12400	13200	6900	7200	7600	8000	8400	8800	9200	9700
	subtotal	59	173	12400	13200	6900	7200	7600	8000	8400	8800	9200	9700
USNAVY	Charleston Naval Weapons Station	1	12	400	400	200	200	200	200	200	200	200	200
	subtotal	1	12	400	400	200	200	200	200	200	200	200	200
	TOTAL	**4196**	**13660**	**785600**	**822800**	**432000**	**452300**	**473700**	**494000**	**512900**	**533300**	**554400**	**577400**

[1]Methods of rounding can substantially affect estimates of future population sizes and costs. Here, number of active clusters was not rounded in projections of future population size but future population size was then rounded up for cost estimates. For example, estimated population size in 2001 for Charleston Naval Weapons Station was 1.05 in 2001, rounded up to 2, and the cost estimate was thus $400 for that year. Cost estimate for Upper Ouachita NWR, as a second example, remained at $100/year throughout 2003-2010 because the property has reached its goal of 1 active cluster.

[2]Some property goals are non-binding estimates; see notes for Tables 6 and 9 for further information.

[3]Dupuis WMA is managed by SFWMD.

TABLE 18. Estimated annual cost for implementation of recovery task 1.2.3 (*provision recruitment clusters equal to 10 percent of population, 4 artificial cavities each*), for all federal properties and those state properties identified in recovery criteria. See key (Table 16) for agency abbreviations. Annual estimated cost = $800 x (0.1 x number of active clusters). Number of recruitment clusters to be provisioned annually is adjusted at 5-year intervals, based on a population size increasing at 5 percent annually[1]. Populations at or above property goal[2] require no more recruitment clusters. This estimate does not include habitat restoration (see Tables 16 and 19).

Responsible Agency	Property	ACT 2000	Property Goal[2]	Recruitment Clusters/Yr 2001-2006	Cost/Yr ($1) 2001-2006	Recruitment Clusters/Yr 2006-2010	Cost/Yr ($1) 2006-2010
FDF	Blackwater River SF	26	45	3	2400	4	3200
	Goethe SF	30	150	3	2400	5	4000
	Picayune Strand SF	3	25	1	800	1	800
	Tate's Hell SF	29	400	3	2400	4	3200
	Withlacoochee - Citrus Tract	46	100	5	4000	7	5600
	Withlacoochee - Croom Tract	5	30	1	800	1	800
	subtotal	139	750	16	12800	22	17600
FDMA	Camp Blanding Training Site	14	25	2	1600	2	1600
	subtotal	14	25	2	1600	2	1600
FFWCC	Babcock/Webb WMA	27	240	3	2400	4	3200
	J. W. Corbett/Dupuis WMA[3]	13	90	2	1600	2	1600
	Three Lakes WMA	51	125	6	4800	7	5600
	subtotal	91	455	11	8800	13	10400
FPS	Ochlockonee River SP	1	3	0	0	0	0
	subtotal	1	3	0	0	0	0
NCDA	McCain Tract	5	7	1	800	1	800
	subtotal	5	7	1	800	1	800
NCDENR	Weymouth Woods State NP	7	13	1	800	1	800
	subtotal	7	13	1	800	1	800
NCWRC	Holly Shelter Game Lands	38	38	0	0	0	0
	Sandhills Game Lands	134	160	14	11200	0	0
	subtotal	172	198	14	11200	0	0
NPS	Big Cypress NP	42	42	0	0	0	0
	subtotal	42	42	0	0	0	0
SCFC	Sand Hills SF	51	143	6	4800	7	5600
	subtotal	51	143	6	4800	7	5600

Table continued next page.

TABLE 18 (cont.). Estimated annual cost for implementation of recovery task 1.2.3 (*provision recruitment clusters equal to 10 percent of population, 4 artificial cavities each*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	Recruitment Clusters/Yr 2001-2006	Cost/Yr ($1) 2001-2006	Recruitment Clusters/Yr 2006-2010	Cost/Yr ($1) 2006-2010
SFWMD	Kicco WMA	1	1	0	0	0	0
	St. Sebastian River SBP	8	25	1	800	2	1600
	subtotal	9	26	1	800	2	1600
SJRWMD	Hal Scott Preserve	7	15	1	800	1	800
	subtotal	7	15	1	800	1	800
USAF	Avon Park AFR	21	68	3	2400	3	2400
	Dare County Bombing Range	3	46	1	800	1	800
	Eglin AFB	301	500	31	24800	41	32800
	Poinsett Weapons Range	6	30	1	800	1	800
	subtotal	331	644	36	28800	46	36800
USARMY	Camp Mackall	11	11	0	0	0	0
	Fort Benning	219	450	22	17600	30	24000
	Fort Bragg	350	436	35	28000	0	0
	Fort Gordon	5	25	1	800	1	800
	Fort Jackson	24	126	3	2400	4	3200
	Fort Polk	46	179	5	4000	7	5600
	Fort Stewart	212	500	22	17600	29	23200
	MOT Sunny Point	9	17	1	800	2	1600
	Peason Ridge	23	120	3	2400	4	3200
	subtotal	899	1864	92	73600	77	61600
USDOE	Savannah River Site	34	418	4	3200	5	4000
	subtotal	34	418	4	3200	5	4000
USFS	Angelina NF	29	252	3	2400	4	3200
	Apalachicola RD	486	500	49	39200	0	0
	Bienville NF	104	500	11	8800	14	11200
	Catahoula RD	32	317	4	3200	5	4000
	Chickasawhay RD	15	502	2	1600	3	2400
	Conecuh NF	18	309	2	1600	3	2400
	Croatan NF	62	169	7	5600	9	7200
	Davy Crockett NF	53	330	6	4800	8	6400
	DeSoto NF	7	368	1	800	1	800
	Evangeline RD	72	231	8	6400	10	8000
	Francis Marion NF	344	453	35	28000	0	0
	Homochitto NF	51	254	6	4800	7	5600

Table continued next page.

TABLE 18 (cont.). Estimated annual cost for implementation of recovery task 1.2.3 (*provision recruitment clusters equal to 10 percent of population, 4 artificial cavities each*).

Responsible Agency	Property	ACT 2000	Property Goal[2]	Recruitment Clusters/Yr 2001-2006	Cost/Yr ($1) 2001-2006	Recruitment Clusters/Yr 2006-2010	Cost/Yr ($1) 2006-2010
USFS (cont.)	Kisatchie RD	29	292	3	2400	4	3200
	Oakmulgee RD	110	394	11	8800	15	12000
	Ocala NF	22	179	3	2400	3	2400
	Oconee NF	20	176	2	1600	3	2400
	Osceola NF	63	462	7	5600	9	7200
	Ouachita NF	21	400	3	2400	3	2400
	Sabine NF	28	262	3	2400	4	3200
	Sam Houston NF	168	541	17	13600	23	18400
	Shoal Creek RD	6	125	1	800	1	800
	Talladega RD	0	110	8	6400	8	6400
	Vernon Unit	152	302	16	12800	21	16800
	Wakulla RD	138	506	14	11200	19	15200
	Winn RD	18	263	2	1600	3	2400
	subtotal	2048	8197	224	179200	180	144000
USFWS	Alligator River NWR	3	20	1	800	1	800
	Big Branch Marsh NWR	15	20	2	1600	0	0
	Black Bayou NWR	1	1	0	0	0	0
	Carolina Sandhills NWR	116	193	12	9600	16	12800
	D'Arbonne NWR	2	5	1	800	1	800
	Felsenthal NWR	15	34	2	1600	3	2400
	Noxubee NWR	44	88	5	4000	6	4800
	Okefenokee NWR	37	86	4	3200	5	4000
	Pee Dee NWR	1	10	1	800	1	800
	Piedmont NWR	39	96	4	3200	6	4800
	Pocosin Lakes NWR	1	50	1	800	1	800
	St. Marks NWR	9	71	1	800	2	1600
	Upper Ouachita NWR	1	1	0	0	0	0
	subtotal	284	675	34	27200	42	33600
USMC	MCB Camp Lejeune	59	173	6	4800	8	6400
	subtotal	59	173	6	4800	8	6400
USNAVY	Charleston Naval Weapons Station	1	12	1	800	1	800
	subtotal	1	12	1	800	1	800
	TOTAL	**4194**	**13660**	**448**	**358400**	**405**	**324000**

[1]Population size was not rounded for size projections but was rounded up to calculate recruitment clusters.

[2]Some property goals are non-binding estimates; see notes for Table 6 for further information.

[3]Dupuis WMA is managed by SFWMD.

TABLE 19. Estimated annual cost for implementation of recovery task 1.7 (*burn entire area managed for red-cockaded woodpeckers at least once every 1 to 5 years*), for all federal properties and those state properties identified in recovery criteria. See key (Table 16) for agency abbreviations. Annual estimated cost = $49.4 x (1/3 total ha), or $20 x (1/3 total ac), assuming all habitat is burned once every 3 years. Estimated available habitat is based on property goal; see notes in Table 6 for further information on property goals.

Responsible Agency	**Property**		**Estimated Available Habitat [ha (ac)]**		**Estimated Annual Cost ($1)**
FDF	Blackwater River SF		3640	(9000)	60000
	Goethe SF		12140	(30000)	200000
	Picayune Strand SF		2020	(5000)	3330
	Tate's Hell SF		32380	(80000)	533330
	Withlacoochee - Citrus Tract		8090	(20000)	133330
	Withlacoochee - Croom Tract		2430	(6000)	40000
		subtotal	60700	(150000)	999990
FDMA	Camp Blanding Training Site		2020	(5000)	33330
		subtotal	2020	(5000)	33330
FFWCC	Babcock/Webb WMA		19420	(48000)	320000
	J. W. Corbett/Dupuis WMA[1]		7280	(18000)	120000
	Three Lakes WMA		10120	(25000)	166670
		subtotal	36820	(91000)	606670
FPS	Ochlockonee River SP		240	(600)	4000
		subtotal	240	(600)	4000
NCDA	McCain Tract		570	(1400)	9330
		subtotal	570	(1400)	9330
NCDENR	Weymouth Woods State NP		1050	(2600)	17330
		subtotal	1050	(2600)	17330
NCWRC	Holly Shelter Game Lands		3080	(7600)	50670
	Sandhills Game Lands		12950	(32000)	213330
		subtotal	16030	(39600)	264000
NPS	Big Cypress NP		3400	(8400)	56000
		subtotal	3400	(8400)	56000
SCFC	Sand Hills SF		11570	(28600)	190670
		subtotal	11570	(28600)	190670

Table continued next page.

TABLE 19 (cont.). Estimated annual cost for implementation of recovery task 1.7 (burn entire area managed for red-cockaded woodpeckers at least once every 1 to 5 years).

Responsible Agency	Property		Estimated Available Habitat [ha	(ac)]	Estimated Annual Cost ($1)
SFWMD	Kicco WMA		80	(200)	13330
	St. Sebastian River SBP		2020	(5000)	33330
		subtotal	2100	(5200)	46660
SJRWMD	Hal Scott Preserve		1210	(3000)	20000
		subtotal	1210	(3000)	20000
USAF	Avon Park AFR		5500	(13600)	90670
	Dare County Bombing Range		3720	(9200)	61330
	Eglin AFB		40470	(100000)	666670
	Poinsett Weapons Range		2430	(6000)	40000
		subtotal	52120	(128800)	858670
USARMY	Camp Mackall		890	(2200)	14670
	Fort Gordon		2020	(5000)	33330
	Fort Bragg		35290	(87200)	581330
	Fort Jackson		10200	(25200)	168000
	Fort Stewart		40470	(100000)	666670
	Fort Benning		36420	(90000)	600000
	Fort Polk		14490	(35800)	238670
	MOT Sunny Point		1380	(3400)	22670
	Peason Ridge		9710	(24000)	160000
		subtotal	150870	(372800)	2485330
USDOE	Savannah River Site		33830	(83600)	557330
		subtotal	33830	(83600)	557330
USFS	Angelina NF		20400	(50400)	336000
	Apalachicola RD		40470	(100000)	666670
	Bienville NF		40470	(100000)	666670
	Catahoula RD		25660	(63400)	422670
	Chickasawhay RD		40630	(100400)	669330
	Conecuh NF		25010	(61800)	412000
	Croatan NF		13680	(33800)	225330
	Davy Crockett NF		26710	(66000)	440000
	DeSoto NF		29790	(73600)	490670
	Evangeline RD		18700	(46200)	308000
	Francis Marion NF		36670	(90600)	604000
	Homochitto NF		20560	(50800)	338670
	Kisatchie RD		23630	(58400)	389330

Table continued next page.

TABLE 19 (cont.). Estimated annual cost for implementation of recovery task 1.7 (*burn entire area managed for red-cockaded woodpeckers at least once every 1 to 5 years*).

Responsible Agency	**Property**		**Estimated Available Habitat [ha (ac)]**		**Estimated Annual Cost ($1)**
USFS (cont.)	Oakmulgee RD		31890	(78800)	525330
	Ocala NF		14490	(35800)	238670
	Oconee NF		14250	(35200)	234670
	Osceola NF		37390	(92400)	616000
	Ouachita NF		32380	(80000)	533330
	Sabine NF		21210	(52400)	349330
	Sam Houston NF		43790	(108200)	721330
	Shoal Creek RD		10120	(25000)	166670
	Talladega RD		8900	(22000)	146670
	Vernon Unit		24440	(60400)	402670
	Wakulla RD		40960	(101200)	674670
	Winn RD		21290	(52600)	350670
		subtotal	645200	(1594200)	10628010
USFWS	Alligator River NWR		1620	(4000)	26670
	Big Branch Marsh NWR		1620	(4000)	26670
	Black Bayou NWR		80	(200)	1330
	Carolina Sandhills NWR		15620	(38600)	257330
	D'Arbonne NWR		400	(1000)	6670
	Felsenthal NWR		2750	(6800)	45330
	Noxubee NWR		7120	(17600)	117330
	Okefenokee NWR		6960	(17200)	114670
	Pee Dee NWR		810	(2000)	13330
	Piedmont NWR		7770	(19200)	128000
	Pocosin Lakes NWR		4050	(10000)	66670
	St. Marks NWR		5750	(14200)	94670
	Upper Ouachita NWR		80	(200)	1330
		subtotal	54630	(135000)	900000
USMC	MCB Camp Lejeune		14000	(34600)	230670
		subtotal	14000	(34600)	230670
USNAVY	Charleston Naval Weapons Station		970	(2400)	16000
		subtotal	970	(2400)	16000
		TOTAL	**1005860**	**(2500000)**	**16569330**

[1] Dupuis WMA is managed by SFWMD.

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GLOSSARY OF TERMS

Active cavity	A completed cavity or start exhibiting fresh pine resin associated with cavity maintenance, cavity construction, or resin well excavation by red-cockaded woodpeckers.
Active cavity tree	Any tree containing one or more active cavities.
Active cluster	A cluster containing one or more active cavity trees.
Adaptive management	The process of implementing flexible management and policy that is responsive to results of continuous biological monitoring and scientific experimentation.
Allozyme	An enzyme that has different forms, resulting from different alleles at the locus encoding the enzyme.
Augmentation	Increasing the size of a population by translocating individuals between populations.
Basal area	The area of a horizontal cross section of a tree's stem, generally measured at breast height.
Breeding dispersal	Movement of individuals between consecutive breeding locations.
Budding	One of two processes of new group formation in red-cockaded woodpeckers (see also pioneering), referring to the splitting of one territory into two.
Canopy	The uppermost layer of foliage in a forest or forest stand.
Captured cluster	A cluster that does not support its own group of red-cockaded woodpeckers, but contains active cavity trees in use or kept active by birds from a neighboring cluster.
Catastrophe	A random environmental event of great consequence.
Clayhills	Pine communities on clay soils, especially in northwestern Florida, eastern Alabama, and southwestern Georgia.
Clearcut	An area in which all trees have been removed in one cutting.
Cluster	The aggregation of cavity trees previously and currently used and defended by a group of woodpeckers, or this same aggregation of cavity trees *and* a 61 m (200 ft) wide buffer of continuous forest. Here, the second definition is used. For management purposes, the minimum area encompassing the cluster is 4 ha (10 ac). Use of the term cluster is preferred over colony because colony implies more than one nest (as in colonial breeder).
Cluster, active	See active cluster.
Cluster, captured	See captured cluster.

Coadapted gene complexes	Genes, having evolved together, that as a unit confer higher fitness than the sum of the individual genes' contributions. A coadapted gene's fitness effect depends on the genetic environment (the presence of other genes).
Coastal plain	In the United States, an ecoregion or physiographic province located near the Atlantic Ocean or Gulf of Mexico.
Cooperative breeding	A breeding system in which one or more adults assist a breeding pair in rearing of young. These extra adults, called helpers, delay their own dispersal and reproduction and are generally related to the offspring of the breeding pair.
Critical rate of decline	Critical rate of population decline identified in this recovery plan is 10% decrease in number of active cluster clusters from one year to the next, or within 5 years.
Decreasing population trend	See critical rate of decline.
Demographic stochasticity	Randomly occurring events affecting individuals.
Demography	Vital rates, including birth, death, and dispersal rates, and the analysis of population size and trend.
Dispersal	Movement of individuals from natal to first breeding location (natal dispersal), or between consecutive breeding locations (breeding dispersal).
Ecoregion	A system of classification based on physiography.
Effective population size	The size of the ideal, hypothetical population in which all individuals mate randomly and all contribute equally to reproduction. Variation in reproductive success and other processes in a real population affect how many genes are conserved in subsequent generations. The concept of effective population size is used to control for the effects of such processes when discussing genetic conservation.
Environmental stochasticity	Random changes in environmental conditions and their effects on populations.
Even-aged management	A silvicultural method designed primarily for timber production, in which all trees in a stand are of one age/size class. The forest is regulated by developing equal areas in each age/size class.
Extirpation	Loss of a population or all populations within a specified region.
Flatwoods	Mesic pine communities on the Gulf and Atlantic coastal plains with a well-developed woody shrub or midstory layer.
Floater	An adult bird not associated with a breeding group.
Forb	A herbaceous plant that has broad leaves, not a grass.
Fragmentation	Habitat loss that results in isolated patches of remaining habitat.
Gene flow	The movement of genetic material among populations or within a population.

Genetic drift	Random sampling of genetic resources within a population from one generation to the next. In populations of finite size, this sampling will always result in loss of variation. In populations of large size, such loss may be offset by new variation arising through mutation.
Genetic stochasticity	Random changes in gene frequencies.
Group	The social unit in red-cockaded woodpeckers, consisting of a breeding pair with one or more helpers, a breeding pair without helpers, or a solitary male.
Habitat selection	Use of a resource above what is expected based on the availability of that resource.
Heartwood	The inner, inactive core of a tree.
Helper	An adult that delays its own reproduction to assist in the rearing of another breeding pair's young. Typically, helpers are related to the breeding pairs that they assist.
Herbs	Grasses and forbs.
Herbaceous	Non-woody.
Heterozygosity	Genetic diversity within an individual or population, as measured by the proportion of loci containing two different alleles.
Home range	The area supporting the daily activities of an animal, generally throughout the year.
Homozygosity	Genetic similarity within an individual or population, as measured by the proportion of loci containing two identical alleles.
Immigration	Movement of one or more individuals into a population.
Inbreeding	Mating between relatives.
Inbreeding depression	Loss of fitness due to the increase in homozygosity that results from inbreeding.
Increasing population trend, recommended rate of	Five percent increase in active clusters from one year to the next.
Kleptoparasitism	Theft by one species of resources procured by another species, resulting in positive effects for the parasite and negative effects for the species being parasitized. Generally this term is applied to theft of food, but has recently been expanded to include theft of spatial resources.
Local adaptation	Traits conferring higher fitness in a local environment.
Metapopulation	A set of interacting populations.
Midstory	A layer of foliage intermediate in height between canopy and groundcover, litter layer, or soil surface.

Mitigation	Reduction of negative impacts.
Mutation	A heritable change in a DNA molecule.
Natal dispersal	Movement of individuals from their place of birth to their first breeding location.
Pioneering	One of two processes of new group formation in red-cockaded woodpeckers (see also budding), by which a group colonizes previously unoccupied areas. Because of the difficulty of cavity excavation, this process occurs at very low frequencies.
Plate	On a cavity tree, the area surrounding the cavity entrance with bark removed by red-cockaded woodpeckers. Newly formed cavities may not exhibit a well-developed plate.
Pocosin	A wetland dominated by a dense cover of evergreen and deciduous shrubs.
Population	A group of individuals of the same species occupying a given area. Methods of specifying such an area may differ according to purpose. A common specification is the area within which gene flow is sufficient to avoid genetic differentiation.
Population augmentation	Translocation between populations to increase population size.
Population dynamics	Properties of a population such as trend and regulation of population size.
Population trend	See increasing population trend, decreasing population trend, and stable population trend.
Potential breeding group	An adult female and adult male that occupy the same cluster, whether or not they are accompanied by a helper, attempt to nest, or successfully fledge young.
Predation	The acquisition of food by killing and eating another organism.
Prescribed burning	Fire applied to the landscape to meet specific management objectives.
Primary cavity nester	Species that nest in cavities they created.
Primary core population	A population identified in recovery criteria that will hold at least 350 potential breeding groups at the time of and after delisting. Defined by biological boundaries.
RAPD	Randomly amplified polymorphic DNA; used as a genetic marker.
Recovery	Species viability.
Recovery population	One of a set of populations designated necessary to the recovery of the species.
Recovery unit	One of a set of geographical areas, delineated according to ecoregions, that likely represent broad-scale geographic and genetic

	variation in red-cockaded woodpeckers. Viable populations in each recovery unit, to the fullest extent that available habitat allows, are considered essential to the recovery of the species.
Recruitment	The addition of individuals into a breeding population through reproduction and/or immigration and attainment of a breeding position.
Recruitment cluster	A cluster of artificial cavities in suitable nesting habitat, located close to existing groups.
Regeneration	A silvicultural method of simultaneously harvesting, and establishing reproduction in, a stand of trees.
Regulation	A process of implementing silvicultural techniques to establish equal areas of tree size classes, to sustain a given level of timber production over time.
Reintroduction	Translocation of individuals from a captive or wild population to previously occupied but currently unoccupied habitat.
Resinosis	A process through which injured sapwood in a pine tree becomes saturated with hardened resin, reducing and eventually preventing loss of resin.
Resin well	A wound in a pine tree’s cambium, created and maintained by red-cockaded woodpeckers, for the purpose of resin production.
Restrictors	Metal plates used to prevent or repair enlargement of cavity entrances.
Rotation	In even-aged management of forests, the number of years between regeneration events.
Sandhills	Xeric and sub-xeric longleaf pine communities on deep sandy soils. Also, the ecoregion encompassing the fall-line sandhills communities, between the mid- and south-Atlantic coastal plains and Piedmont.
Sapwood	The outer, active layer of tissue in a tree, lying just inside the cambium.
Savannah	A mesic and seasonally wet pine community, often transitional between xeric pine systems and wetlands, characterized by diverse grass and forb groundcovers.
Secondary cavity nester	Species that inhabit cavities they did not create.
Secondary core population	A population identified in recovery criteria that will hold at least 250 potential breeding groups at the time of and after delisting. Defined by biological boundaries.
Seed-tree	A method of timber regeneration in which most trees in a site are cut, and tree seedlings become established under remnant large trees. Remnant large trees are retained at lower densities than under the shelterwood method.

Selection cutting	A method of timber regeneration in which single trees or patches of trees (0.8 ha or less, 2 ac or less) are cut.
Shelterwood	A method of timber regeneration in which many but not all trees in a site are cut, and tree seedlings become established under remnant large trees. Remnant large trees are retained at higher densities than under the seed-tree method.
Silviculture	The theory and practice of controlling the establishment, composition, structure, and growth of forests to achieve management objectives. Silviculture was developed primarily for the purpose of timber production, but can be used for other purposes including biological conservation.
Snag	A standing, dead tree.
SNEDs	Snake excluder devices.
Solitary male	An unpaired male that is the sole resident of a cluster.
SQEDs	Squirrel excluder devices.
Stable population	A population that exhibits neither an increasing or decreasing population trend.
Stand	A silvicultural term for an area of trees that is or has been treated as a single management unit.
Start	An incomplete cavity.
Strategic recruitment	Placement of recruitment clusters in locations strategically chosen to enhance the spatial arrangement of breeding groups. Breeding groups aggregated in space rather than isolated are beneficial to population dynamics and viability.
Stochasticity	Random events.
Support population	All known populations not designated a primary or secondary core are designated support populations. Support populations (other than essential supports) are defined by ownership rather than biological boundaries. There are three classifications for support populations: 1. Essential support populations are those populations, identified in recovery criteria, that represent unique or important habitat types that cannot support a larger, core population. They are located on federal and state lands and two private properties. 2. Significant support populations are populations, not identified in recovery criteria, that contain and/or have a population goal of 10 or more active clusters. They are located on federal and state lands and on private lands enrolled in agreements with the U.S. Fish and Wildlife Service. 3. Important support populations are populations, not identified in recovery criteria, that contain and have a population goal of less than 10 active clusters. They are located on federal and state lands and on

	private lands enrolled in agreements with the U.S. Fish and Wildlife Service.
Take	As defined by the Endangered Species Act, take means to “harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or to attempt to engage in any such conduct” (Section 3.18 of the Act). Habitat destruction and alteration are considered forms of take, following a Supreme Court ruling on this issue (Sweet Home vs. Babbitt).
Taxonomy	Hierarchical classification system for all life forms.
Territory	A region within an animal’s home range that is defended from conspecifics.
Thinning	A silvicultural treatment removing some trees in a stand to reduce tree density.
Translocation	The artificial movement of wild organisms between or within populations to achieve management objectives. Originally, translocation referred to the movement of animals from captive to wild populations, but the term has been expanded to include movements (by artificial means) within and between wild populations.
Two-aged management	A silvicultural method designed primarily for timber production, in which trees of two age/size classes are present in the same stand. The forest is regulated by developing equal areas in each age/size class.
Uneven-aged management	A silvicultural method designed primarily for timber production, in which trees of at least three age classes are present in the same stand. Stands are regulated by size class structure or volume.
Viability	The ability of a population or species to persist over time.

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APPENDIX 1. PERMITS, TRAINING, AND COMPLIANCE REQUIREMENTS

The objectives of the permitting and compliance program are to: (1) identify, standardize, and, as needed, modify training/certification procedures to ensure the safety of and minimize death and injury to red-cockaded woodpeckers; (2) standardize permit reporting requirements; (3) ensure compliance with all permit requirements, including reporting; (4) ensure that a coordinated specimen disposal program exists, and (5) facilitate distribution of research findings resulting from permit activities. The permit process is an important component of adaptive management. Permitted activities may be modified or eliminated based on research findings and/or an evaluation of their biological costs versus conservation benefits. The primary objective of establishing certification procedures, including "hands-on" protocols, is to minimize the potential for injury or death. Ultimately, it is our responsibility as individuals and as federal and state agency regulators to ensure that biological and ethical protocols are established and followed when conducting activities that have the potential to harm or harass red-cockaded woodpeckers.

The following activities associated with the monitoring and management of red-cockaded woodpeckers require an exemption from the prohibitions of Section 9 of the Endangered Species Act. This exemption is usually authorized via a Section 10(a)(1)(A) permit. The U.S. Fish and Wildlife Service considers that these activities have the potential to harass or result in death or injury to an individual red-cockaded woodpecker or to raise concern about possession of endangered wildlife contrary to laws and regulations.

1. installation and/or modification of artificial nesting cavities.
2. installation of cavity restrictors.
3. manipulation (removal or modification) of red-cockaded woodpecker cavities or cavity trees, including installation of SNEDs, SQEDs, cameras, etc.
4. capturing and handling (for any purpose, including banding or color marking) nestling and adult birds.
5. placing radiotelemetry devices on red-cockaded woodpeckers.
6. visual examination of active cavities with a mirror and droplight or a video probe (“peeper”).
7. salvage of addled eggs, and/or determining viability of eggs.
8. collection and retention of red-cockaded woodpecker specimens or their body parts (including eggs, blood or feathers) for scientific and other purposes consistent with the species' conservation strategy.
9. interstate commerce of dead or living birds or their body parts, including sale or bartering for financial gain.
10. translocation and/or temporary confinement of adults, fledglings, chicks, or eggs.
11. any other activity or practice that may be construed to harm or harass red-cockaded woodpeckers during any life stage.

In addition, the following activities involving red-cockaded woodpeckers are likely to require a Section 10(a)(1)(A) permit unless you are an employee or agent of the

U.S. Fish and Wildlife Service, any other federal land management agency, or a state conservation agency who is designated by his agency for the following purposes:

1. aid to a sick, injured, or orphaned specimen.
2. disposal of a dead specimen.
3. salvage of a dead specimen which may be useful for scientific study.

(Federal or state employees and agents must notify the U.S. Fish and Wildlife Service, Division of Law Enforcement within 5 days of undertaking these activities and must receive concurrence from the U.S. Fish and Wildlife Service on the disposition of these specimens.)

Those individuals placing aluminum bands and/or auxiliary markers (including colored leg bands) on red-cockaded woodpeckers, require a permit (in addition to a U.S. Fish and Wildlife Service Section 10(a)(1)(A) permit) for each of those activities from the U.S. Geological Survey, Biological Resources Division's National Bird Banding Lab, Route 197, Laurel, Maryland 20708; telephone: (301) 498-0428. Most, if not all, states harboring red-cockaded woodpeckers also require permits for some of the activities listed above, including translocating birds from and to their state. Contact state wildlife agencies for endangered/threatened species permit requirements. Each permit has a specific purpose and provides important information to the agency legally responsible for issuing the permit.

Reporting Requirements

Every Section 10(a)(1)(A) permit requires an annual report to the U.S. Fish and Wildlife Service. The Annual Report fulfills this requirement, and must be completed and submitted to the Recovery Coordinator (original) and the U.S. Fish and Wildlife Service’s Regional Office (copy) annually by January 31st. Agencies or individuals not submitting completed reports will not have their permits re-authorized. This reporting system ensures that this critical recovery program is evaluated annually for its conservation value, and is modified as needed in response to new information.

Training

Prior to issuing any Section 10(a)(1)(A) permit, the U.S. Fish and Wildlife Service must meet several criteria, including the determination of the applicant’s ability to successfully accomplish the authorized activities. Because of the potential for direct injury or death to red-cockaded woodpeckers from the above activities, all individuals involved in any of these activities must be trained and certified for each activity prior to receiving a permit or sub-permit under someone else's permit. Potential applicants must be trained by an individual who has the proper permits for and extensive experience in the activity in question. Several federal and state biologists, consultants, and researchers are considered "trainers" or "certifiers" by the U.S. Fish and Wildlife Service for one or more of the above activities. Upon satisfactory completion of training (as determined by the trainer and the Service), the trainer certifies in writing to the Service that the individual is competent and qualified to perform the activity or activities in question. Contact the Red-cockaded Woodpecker Recovery Coordinator to arrange training with certified trainers.

Training for Installation of Artificial Cavities and Restrictors

Training prior to installation of artificial cavities and restrictors is considered adequate if the following criteria are met:

a. A period of apprenticeship is completed under the direction of a person that has held appropriate permits for at least three years and has been involved in the activities in question throughout that time.

b. The apprentice has installed at least 10 restrictors, 10 drilled cavities, 10 starts, and 10 inserts under direct supervision of the permit holder.

c. The apprentice has learned the maintenance and inspection procedures for cavities and restrictors.

d. The permit holder has certified in writing to the U.S. Fish and Wildlife Service Regional Permits Coordinator and the Red-cockaded Woodpecker Recovery Coordinator that the apprentice completed the required training. If the permit holder determines that additional training of the apprentice is necessary or that the apprentice should not be issued a permit, he or she should certify such in writing to the apprentice and the coordinators listed above.

Training for Monitoring, Capture, Banding, Etc.

Safe and accurate monitoring of red-cockaded woodpeckers requires skill, normally acquired through years of experience with red-cockaded woodpeckers and their habitat. Apprenticeship training by a recognized expert in the biology of red-cockaded woodpeckers can accelerate the acquisition of appropriate monitoring skills. The Red-cockaded Woodpecker Recovery Coordinator maintains a list of recognized experts who are willing to serve as trainers. Persons seeking the endangered species and bird banding permits necessary for red-cockaded woodpecker monitoring will document their *need* in writing to the Red-cockaded Woodpecker Recovery Coordinator and the Regional Permits Coordinator. If both Coordinators concur that the monitoring need is legitimate and that the permit applicant is the appropriate entity to conduct the monitoring, the applicant will be referred to the list of qualified trainers. In reaching the referral decision the Recovery Coordinator or Permits Coordinator may conduct background inquiries as they deem necessary.

The applicant will select a red-cockaded woodpecker trainer from the provided list, contact that person, and arrange for training to occur. The cost of training will be borne by the applicant. The red-cockaded woodpecker expert will personally supervise the training of the applicant. The training period will be at the discretion of the trainer, but will not be less than:

a. 50 cavities correctly assessed for stage and activity,

b. 15 cavity trees climbed and cavity contents checked,

c. 10 adult red-cockaded woodpeckers captured and banded (with appropriate data taken) without injury to the birds,

d. 20 nestlings captured, aged and banded (with appropriate data taken) without injury to the birds,

e. 20 free ranging red-cockaded woodpeckers correctly identified by color-bands,

f. 10 sub-adults translocated without injury or mortality (including all associated activities such as feeding during transport, etc.), and

g. 10 red-cockaded woodpeckers treated for any other handling technique (such as bleeding, etc.).

Once at least the minimum amount of training, as described above or as otherwise dictated by the Recovery Coordinator, is accomplished to the satisfaction of the trainer, he or she will certify such in writing to the Recovery Coordinator and the Regional Permits Coordinator. The trainer will only conduct training and certification in areas of expertise in which he or she is certified. The trainer is under no obligation to certify anyone if in his or her opinion the applicant has not completed training adequately. If such is the case, the trainer will document the deficiencies in writing to the applicant, the Recovery Coordinator and the Regional Permits Coordinator, and recommend either more training or permit denial. Certification may be issued for some techniques and withheld for others. A person receiving certification cannot in turn train and certify other individuals until he or she has at least 3 years of experience in the certified techniques, has all required permits in good order and has been placed on the Recovery Coordinator's list of red-cockaded woodpecker trainers.

APPENDIX 2. PROTOCOL FOR MONITORING REPRODUCTIVE SUCCESS, GROUP SIZE, AND GROUP COMPOSITION (COLOR-BANDING)

Monitoring reproductive success and group size is accomplished by periodic visits to the nest, color-banding all nestlings and unbanded adults, conducting fledgling checks and/or late-nestling checks, and identifying all banded adults throughout the breeding season. This appendix provides information on: (1) nest checks, (2) aging nestlings according to Ligon age characteristics, (3) capturing and color-banding nestlings, (4) capturing and color-banding adults, (5) fledgling or late nestling checks, (6) color-band observation, (7) determining group composition, and (8) data management.

1. Nest Checks

Nest checks consist of repeated visits to the cluster on a 7 to 11 day cycle until a nest is found. More frequent nest checks subject the birds to unnecessary disturbance for little additional information. Less frequent nest checks greatly increase the likelihood that nestlings will be too old to band when found, and nest failures may go undetected.

Each active cavity tree in the cluster is a potential nest site, although nests are typically found in the most active cavity tree and often in the most recently completed cavity. Locate nests by observing adult behavior (e.g., flushing from a cavity during the day, tending nestlings) and/or inspecting contents of active cavities using Swedish ladders or a video probe. Once a nest is located, observe and record contents, including number of eggs or nestlings and nestling age (see below), as well as other relevant information such as date, time, and cavity, cavity tree, and cluster identification numbers. Schedule the following nest visit by optimal banding age (see below). If a discovered nest contains eggs, return to the cluster in 7 to 11 days. After nestlings are banded, it is not necessary to return to the site until the late/nestling check or fledgling check, whichever is used (see below).

If a nest fails before nestlings have fledged, return the cluster to the nest check cycle to detect renesting. If no nest is observed within a cluster, conduct a morning follow of group members (3A) and survey for new cavity trees within suitable habitat in and near the cluster (3A).

During nest checks, identify all adults present by color-band observation and record their color-band combination and activity (e.g., incubating, feeding nestlings, conflicting with other adults). This information is important to determining group composition (see below).

2. Aging Nestlings

Nestlings are aged according to descriptive characteristics set out by Ligon (1970; Table 20). Aging of nestlings is done with extreme care and attention to detail.

TABLE 20. Nestling characteristics indicative of nestling age, in number of days.

Nestling Age	Character	Description
DAY 0	SKIN	Loose and pink
	BILL	Mandible roughly 2mm longer that maxilla; diamond-shaped egg-tooth on maxilla
	WINGS	Permanently extended and used to remain upright
	RETRICES	Bumps
	FEET	Heel pad greatly enlarged
	SIZE	Appears small enough to fit back into egg
DAY 1	SIZE	Appears that the body would fit back into shell, but not the head
DAY 3	REMIGES	Dots visible
DAY 4	SKIN	Tail darkening
	BILL	Turning black except for egg tooth
	TRACTS	Back, wing, and scapular tracks visible
DAY 5	SKIN	Skin darkening
	TRACTS	Crown, lower neck, and most of spinal, femoral, and ventral tracks visible
DAY 6	BILL	Maxilla almost as long as mandible
	EARS	Open
	RETRICES	Bristles visible
DAY 7	TRACTS	Crural tracts visible
	FEET	Increasing in size
DAY 8	SKIN	Darker
	BILL	Maxilla and mandible are about equal in length
	RETRICES	Protruding
	REMIGES	Quills protruding from skin
	FEET	Darkening
DAY 9	EYE	Opening
	RETRICES	Exposed short distance
	FEET	Extended toes 34 mm
DAY 10	REMIGES	Quills showing
	TRACTS	Well developed; feather tips exposed at tail, rump, slightly on breast, and on lower abdominal tract. Quills of middle and lesser coverts, humeral tract, and spinal tract showing.
	FEET	Feet and tarsi dark, heel pads light, losing knobs and tubercles
DAY 11	BILL	Maxilla slightly longer than mandible, culmen 11 – 12 mm
	REMIGES	1^{st} secondary 8mm, 2^{nd} primary 7 mm
	TRACTS	Feather tips of spinal, scapulars, anterior ventral and crural tracts showing
	BEHAVIOR	Call changes to more adult-like
DAY 13	RETRICES	Quills 6.5 – 7.5 mm
	REMIGES	Outer primary quills about 25 mm; longest primary 18 – 25 mm

Table continued next page.

TABLE 20 (cont.). Nestling characteristics indicative of nestling age, in number of days.

Nestling Age	Character	Description
DAY 15	RETRICES	Quills 16 – 18 mm
	TRACTS	Feathers still largely sheathed
DAY 16	BILL	Culmen 14 mm
	REMIGES	Longest primary 27 mm (sheath 20 mm)
	TRACTS	Erupted feathers covering much of body surface
DAY 17	TRACTS	Feather sheaths on pileum of males broken away except for those of red crown patch
DAY 19	RETRICES	Longest feather 29 mm and quills beginning to break away
	REMIGES	Longest primary 45 mm and quills beginning to break away
	TRACTS	Body covered with feathers except for abdomen and flanks
	BEHAVIOR	Active and pecking at observer’s hand

3. Capturing and Color-banding Nestlings

Nestlings are banded between the ages of 5 to 10 days old. Banding nestlings older than 10 days in age is prohibited because of greatly increased risk of injury and mortality. Banding nestlings younger than 5 days old is not possible because they cannot accommodate three color-bands on one leg. In southerly parts of the range, nestling 5 or 6 days in age may not be large enough to wear three color-bands. In these regions, narrow the window of banding opportunity to 7 to 10 days in age.

Nestlings are captured and carefully removed from the nest cavity using a soft noose liberally lubricated with cornstarch (Jackson 1982). Nestlings must be kept warm and dry, and out of direct sunlight, while out of the nest.

Each individual is banded with a unique combination of color-bands (size XB) and a U.S. Geological Survey aluminum band (size 1A). Nestlings and adults (see below) are banded with three color-bands on one leg and the aluminum band, with or without an additional color-band, on the other leg. Birds are not to be banded with one or two color-bands alone on a leg, because color-bands that move excessively can cause injury to toes. Birds are not to be banded with more than a single color-band on the leg carrying the aluminum band. Therefore, we recommend that both legs be banded. If only one leg is banded, color-band combinations are reduced to a single color-band and the aluminum band.

Once nestlings are banded, check the accuracy of the band combination several times. Record necessary data on banding sheets. Return nestlings to the cavity.

4. Capturing and Banding Adults

Adults are captured for banding or color-band replacement following the breeding season, or at any time other than the breeding season, unless the bird in question cannot be caught except during breeding (e.g., a female without a roost cavity). Aluminum bands are never replaced, and are only removed if the band is causing injury. Color-bands may sometimes need replacement, but capture of adults should be minimized to the fullest possible extent.

Adults are typically captured at the roost cavity at dawn or dusk with a net attached to a telescoping pole. Adults will not be caught at night, except those captured for translocation that evening and for specific research needs with appropriate permits. Adults will also not be caught during wet weather; handling wet birds can kill them. Adults are banded in the same way as nestlings: three color-bands on one leg, and the aluminum band with or without an additional color-band on the other leg.

5. Fledgling or Late Nestling Checks

Fledgling checks or late nestling checks are performed to determine how many nestlings survived to fledging, and the sex of those individuals. Fledgling checks are preferable to late nestling checks because the accuracy of survival estimates are improved and because fledgling checks are an important time to identify adult members of the group. However, late nestling checks may be substituted if time and personnel are constrained.

Conduct fledgling checks for each banded nest between 2 and 14 days after the projected fledging date (26 days after estimated hatching date). Fledgling checks last a minimum of one hour or until all nestlings banded are seen as fledglings. Record number of fledglings, their color band combinations, and their sex. Determine sex by unobstructed views of the fledgling's entire crown: females have a black crown and males have a red crown patch. If a banded nestling is not detected as a fledgling during the one-hour fledgling check, conduct a second check within ten days. If no fledglings are detected in these two checks, examine active cavity trees for an additional nest attempt.

Conduct late nestling checks before the 21^{st} day after estimated hatching date. If nestlings are disturbed at age 21 days or older, they may fledge prematurely. During a late nestling check, identify, count, and sex all nestlings and record these data.

6. Color-band Observation

Using spotting scopes, identify and count adults whenever they are encountered. Most observations are made during nest and fledgling checks. Do not count birds by sound alone. Record color-band combinations, cluster, date, and behavioral data such as tending young or conflicting with other adults present. Verify unexpected color-band combinations.

7. Determining Group Composition

Group composition is determined using color-band observations described above. Breeding male status can be assigned to a male if any one of the following criteria are met: (1) he is the only male in the group, (2) he is the oldest male in the group, (3) he roosts in the nest cavity, or (4) he was the breeding male in the previous year. Once the breeding male has been determined, other adult males present are assigned helper status if they are on their natal territory or if they were seen incubating, tending young, or interacting peacefully with other adult members of the group. Breeding female status is assigned to a female if (1) she is the only female, (2) she is the oldest female in the group, or (3) she was the breeding female in that group in the previous year. Other adult females are assigned helper status only if they are on their natal territory.

Birds that are observed in conflict with group members are intruders from a nearby group or non-breeding adults without a group (floaters). Extra adult females that peacefully interact with a group, but are not on their natal territory, sometimes occur. The role of these auxiliary females deserves further research.

In cases where group composition or individual status remains uncertain, conduct a morning follow (3A) or roost check. This will enable determination of which bird roosts in the nest cavity as well as locate breeders or helpers not seen previously. Old breeding males, for example, may be especially hard to observe during nest and fledgling checks. If it appears that an old breeding male is no longer present, a morning follow or roost check is recommended to verify his disappearance.

8. Data Management

We recommend that data be stored using database management software rather than spreadsheets or other software types. Of course, data management will vary according to research and species management needs.

However, for monitoring reproductive success and group size, it is useful to keep at least these two separate data sets: (1) the first containing one record for each individual in each breeding season, and including information such as color-band combination, age or minimum age, status (e.g. helper or breeder), cluster, and year; and (2) the second containing one record per group per year, including information such as the number of eggs, nestlings, and fledglings produced, whether or not a nest was attempted, and group size. Group size should not include fledglings. Managers may consider creating a third data set that contains one record for every time a bird was observed, although this is time-consuming. Other data sets can be created as needed.

APPENDIX 3. PROTOCOL FOR TRANSLOCATION EVENTS

This appendix describes general protocol for confirmation of cluster status and the capture, transport, and release of birds for the purposes of translocation. Translocation guidelines (8H) must be followed for all translocation events. If a bird is being translocated to a cluster containing a solitary bird (mate provisioning), solitary status in the recipient cluster is to be confirmed by a morning follow (i.e., morning roost check, see 3A) just prior to the translocation event.

Part A. Confirmation of Cluster Status

1. Confirm status of the recipient cluster one to three days before the translocation event, by a morning follow (i.e., morning roost check; see 3A). This is conducted in all clusters receiving birds, to determine:

   a. if the cluster is inactive, for translocations of potential pairs;
   b. if the cluster contains a solitary bird, for translocations of potential mates;
   c. if the cluster contains a potential breeding group, contrary to expectations;
   d. the suitability of cavities and cluster habitat structure.

If the intended recipient cluster contains a potential breeding group, or does not have suitable cavities and habitat structure, cancel the translocation. If cluster status is confirmed as expected and the translocation can proceed, ensure that the cluster and target cavity trees are easily found at night and flag a route if necessary.

2. Confirm status of potential donor clusters one to three days before the translocation event, by a morning follow (3A). Ensure, for all clusters donating birds, that the birds intended for translocation are actually available. Follow guidelines for bird availability given in 8H. Have several potential donor clusters for every one bird to be translocated, in case a bird cannot be captured or bird availability status has changed.

Part B. Capture, Transport, and Release of Individuals

1. Plan the capture of the birds based on transport time.

1. Observe roosting of the birds to be translocated. Capture the birds that night or the following morning with a net and telescoping pole. Birds should be trapped at night if transport time is not expected to exceed 5 or 6 hours, and in the new cavity by midnight; if not, morning captures are used. Double-check the aluminum band numbers to ensure that the correct birds were captured.

2. Transport the birds in covered, well-ventilated cages placed in the interior of unheated and quiet vehicles. Never transport more than one bird in each cage. Be certain that you

always know the location of each captured bird, but keep disturbance to an absolute minimum. Feed crickets and mealworms to birds every 45 to 60 minutes if transported during daytime.

3. Put the birds safely, quickly, and quietly into recipient cavities. Screen cavity entrances with ½in hardware cloth tacked firmly but lightly so that the screen can be easily removed in the morning. Drop a string from the screen to the ground so that the screen can be removed without climbing. If the cluster contains a solitary bird prior to translocation, take care not to flush it.

4. Arrive at the cluster at first light. If a solitary male roosts in the cluster, release the translocated potential mate when the resident male exits his cavity. If a potential pair has been moved, wait until both are pecking at the screen, and release them simultaneously. Have ladders present in case the tree has to be climbed to remove the screen.

5. A cassette of red-cockaded woodpecker calls played just after release may help increase the likelihood that birds encounter each other.

6. Once the birds are released, wait at least one week before returning to the cluster for any follow-up check. Follow-up checks are not necessary; no further observations are required until the next breeding season. During the next breeding season, the cluster and surrounding clusters should be monitored to determine the presence of potential breeding groups and the location of translocated birds. In populations undergoing translocation for the purpose of population augmentation (i.e., receiving birds from donor populations), all clusters are monitored for group size and reproductive success (Appendix 2).

Part C. Other Methods of Translocation

Other techniques for the translocation of individuals may prove more successful than current methods (e.g. Wallace and Buchholz 2001), but are not approved for general use at this time.

APPENDIX 4. SURVEY PROTOCOL

Guidelines for Surveys to Assess Potential Project Impacts to Red-cockaded Woodpecker Nesting and/or Foraging Habitat

Surveys are used to determine whether the nesting and/or foraging habitat of a red-cockaded woodpecker group will be adversely impacted by a proposed project, such as a timber sale or development activity, on a particular tract of land. This is an important part of the conservation and management of this endangered species, and therefore the Fish and Wildlife Service has developed standard survey and analysis procedures for such determinations. These determinations must be undertaken prior to the initiation of any project within the southeastern United States that calls for removal of pine trees 30 years or older; typically such trees will be at least 25.4 cm (10 in) dbh or larger. The procedure is also used following new land acquisition by state and federal agencies in the southeast or any other circumstance in which the presence or absence of red-cockaded woodpeckers is to be assessed.

The first step in the survey procedure is to determine if suitable nesting or foraging habitat exists within the area to be impacted by the project. If no suitable nesting or foraging habitat is present within the project impact area, further assessment is unnecessary and a "no effect" determination is appropriate. If no suitable nesting habitat is present within the project impact area, but suitable foraging habitat is present and will be impacted, potential use of this foraging habitat by groups outside the project boundaries must be determined. This is accomplished by identifying any potential nesting habitat within 0.8 km (0.5 mi) of the suitable foraging habitat that would be impacted by the project. Any potential nesting habitat is then surveyed for cavity trees. This procedure is described in greater detail below. If no active clusters are found, then a "no effect" determination is appropriate. If one or more active clusters are found, a foraging habitat analysis is conducted (see 8I) to determine whether sufficient amounts of foraging habitat will remain for each group post-project.

For nesting and foraging habitat surveys within project impact areas and within 0.8 km (0.5 mi) of the project site, potential habitat is assessed at the level of the stand. A stand is a term often used to refer to a wooded area receiving past or current silvicultural treatment as a single management unit. Here we expand the term to include any subset of a tract of wooded land, divided by biological community type, management history, or any other reasonable approach. A small tract of land may be considered a single stand.

Identification of Suitable Foraging Habitat

For the purpose of surveying, suitable foraging habitat consists of a pine or pine/hardwood stand of forest, woodland, or savannah in which 50 percent or more of the dominant trees are pines and the dominant pine trees are generally 30 years in age or older. These characteristics do not necessarily describe good quality foraging habitat (see 2E, 8I); rather, this is a conservative description of potentially suitable habitat.

Identification of pine and pine/hardwood stands can be made using cover maps that identify pine and pine/hardwood stands, aerial photographs interpreted by standard techniques, or a field survey conducted by an experienced forester or biologist. Age of stands can be determined by aging representative dominant pines in the stands using an increment-borer and counting annual growth rings. Stand data describing size classes may be substituted for age if the average size of 30 year-old pines is known, i.e., at least 25.4 cm (10 in) dbh or larger, for the local area and habitat type.

If no suitable foraging habitat is present within the project area (that is, no pines 30 years or older will be impacted), then further evaluation is unnecessary and red-cockaded woodpeckers are considered absent. If the project area contains any suitable foraging habitat that will be impacted by the project, that habitat, if it contains any 60 year old trees or older, and all other suitable nesting habitat within 0.8 km (0.5 mi) of the project site, regardless of ownership, must be surveyed for the presence of red-cockaded woodpeckers.

Identification of Suitable Nesting Habitat

For the purpose of surveying, suitable nesting habitat consists of pine, pine/hardwood, and hardwood/pine stands that contain pines 60 years in age or older and that are within 0.8 km (0.5 mi) of the suitable foraging habitat to be impacted at the project site (see above). Additionally, pines 60 years in age or older may be scattered or clumped within younger stands; these older trees within younger stands must also be examined for the presence of red-cockaded woodpecker cavities. These characteristics do not necessarily describe good quality nesting habitat (see 2D, 8E, 8F); rather, this is a conservative description of potential nesting habitat.

Determination of suitable nesting habitat may be based on existing stand data, aerial photo interpretation, and/or field reconnaissance. All stands meeting the above description, regardless of ownership, are surveyed for cavity trees.

Surveying for Red-cockaded Woodpecker Cavity Trees

Once suitable nesting habitat is identified (above), it must be surveyed for cavity trees of red-cockaded woodpeckers by personnel experienced in management and/or monitoring of the species. Potential nesting habitat is surveyed by running line transects through stands and visually inspecting all medium-sized and large pines for evidence of cavity excavation by red-cockaded woodpeckers. Transects must be spaced so that all trees are inspected. Necessary spacing will vary with habitat structure and season from a maximum of 91 m (100 yards) between transects in very open pine stands to 46 m (50 yards) or less in areas with dense midstory. Transects are run north-south, because many cavity entrances are oriented in a westerly direction, and can be set using a hand compass.

When cavity trees are found, their location is recorded in the field using a Global Positioning System (GPS) unit, aerial photograph, and/or field map. Activity status, cavity stage (start, advanced start, or complete cavity), and any entrance enlargement are assessed and recorded at this time. Again, it is extremely important to have all surveys and cavity tree assessments performed by experienced personnel.

If cavity trees are found, more intense surveying within 457 m (1500 ft) of each cavity tree is conducted to locate all cavity trees in the area. Cavity trees are later assigned into clusters based on observations of red-cockaded woodpeckers as described in 3A. Any cavity trees or other evidence of red-cockaded woodpecker activity is reported to the Fish and Wildlife Service, at either a local office or the Clemson Field Office, Clemson, South Carolina.

APPENDIX 5. PRIVATE LANDS GUIDELINES

Private landowners have different responsibilities than do public land managers for endangered species conservation under the Endangered Species Act. Because of this, we provide specific guidance here for private landowners to follow on lands occupied by red-cockaded woodpeckers. However, private landowners are strongly encouraged to follow general guidelines for red-cockaded woodpecker management given in section 8 of this document.

Here, we first list activities that have the potential for harass and/or harm under the definition of "take" in the Act. These activities cannot be conducted within clusters and foraging habitat of red-cockaded woodpeckers without concurrence and/or a permit (see 4A) from the U.S. Fish and Wildlife Service. We then present guidelines for the management of foraging habitat on private lands. Finally, we give guidance on monitoring the activity status of red-cockaded woodpecker clusters specific to private landowners.

Potentially Harmful Activities

Because of the potential for harass and/or harm under the definition of 'take' in the Endangered Species Act, the following activities require concurrence and/or a permit from the U.S. Fish and Wildlife Service.

1. Removing any red-cockaded woodpecker cavity tree, through cutting, bulldozing, or any other activity.

2. Damaging an active cavity tree which results in the death of that tree. Damage includes, but is not limited to, injury to the bole or root system (generally due to heavy equipment use), exposure to herbicides, and fire scorch to the crown due to inadequate protective measures during prescribed burning. Pines are best protected from damage by intense fires through frequent low-intensity prescribed burns (see 8K).

3. Using insecticides on any standing pine tree. Prevention and control of disease and insect infestations is encouraged. Infestations of insects such as southern pine beetles are best prevented by maintaining open structure and adequate spacing between pines (see 8J). Control of active infestations often includes the cutting of infested trees. If such control will result in losses of trees below recommended foraging guidelines (below), or in the removal of cavity trees, the U.S. Fish and Wildlife Service must be contacted prior to the action.

4. Constructing roads and utility rights-of-way within a cluster. Use of existing roads, improved or unimproved, generally does not adversely affect red-cockaded woodpeckers and therefore is permitted. If, in the landowner’s opinion, there is no reasonable alternative to construction of new roads, either improved or unimproved, or if there is no reasonable alternative to placing a utility right-of-way within the cluster, the U.S. Fish

and Wildlife Service must be contacted before construction or clearing activities are initiated.

5. Construction of facilities including, but not limited to, buildings, campgrounds, recreational developments, residential dwellings, and industrial or business complexes. If, in the landowner's opinion, extenuating circumstances require a facility to be constructed in an active cluster, the U.S. Fish and Wildlife Service must be contacted during the planning phase and prior to any construction activity.

6. Planting of shrubs and/or ornamental plants that will exceed 2.1 m (7 ft) in height within 15.24 m (50 ft) of active and inactive cavity trees. If cavities are 3.05 m (10 ft) or less in height, planting any shrubs within 15.24 m (50 ft) of cavity trees may adversely affect red-cockaded woodpeckers. Construction equipment and construction material cannot be stored within 61 m (200 ft) of cavity trees. Landscaping within clusters should be accomplished with hand tools or lightweight power equipment rather than tractor-mounted equipment.

Foraging Habitat

We present two sets of guidelines for the management of foraging habitat. The first, named the recovery standard, is presented in 8I, and scientific reasoning underlying these guidelines is explained in 2E. However, because of differing responsibilities of private landowners and public land managers under the Endangered Species Act, it may be unreasonable to expect that private landowners manage their foraging habitat at the same level of quality at which public land managers are expected to manage their lands. Populations on public lands are required to be increasing, whereas many populations on private lands are managed for stability. For those private landowners that wish to increase the size of their population, we strongly encourage that the recovery standard be followed. However, we present an alternative set of foraging guidelines for groups in populations on private lands managed to maintain existing population size. Because our understanding of foraging requirements is not yet sufficient to identify the specific level of foraging resources at which a population changes from stable to increasing (see recovery task 5.8.), these guidelines are based on existing minimum amounts of foraging resources of groups known to be surviving and reproducing over at least short time periods.

Red-cockaded woodpeckers can benefit by the establishment of lower guidelines for populations in which only stability rather than increasing trends is required, because lower guidelines can encourage private landowners to enroll in conservation agreements and participate in active management. Flexibility in guidelines, within appropriate boundaries, is an important component of successful conservation on private lands because it fosters cooperation rather than resentment (see 4A). But, these guidelines are presented with a caveat: stability of small populations cannot be attained without additional management (such as use of artificial cavities and/or translocation; see 3B, 3D, 8E, 8H). Additionally, the standard for managed stability is not designed to increase population size nor is its wide-scale implementation within a population adequate to maintain that population's viability over the long-term. It does not provide future nesting habitat or suitable, i.e., good quality, foraging habitat over the long-term. Its wide-scale implementation will result in population fragmentation with subsequent problems related to demographic stochasticity and perhaps genetic variability. Again, private landowners are strongly encouraged to manage at or toward the recovery standard, and should provide at least the standard for managed stability. The standard for managed stability is as follows:

1. Provide each group of red-cockaded woodpeckers a minimum of 689 m^2 (3000 ft^2) of pine basal area, including only pines $\geq$ 25.4 cm (10 in) dbh.

2. Provide the above pine basal area on a minimum of 30.4 ha (75 ac).

3. Count only those pine stands in suitable habitat that, for this standard only, has each of the following characteristics:

   a. Stands that are at least 30 years old and older.

   b. An average pine basal area of pines $\geq$ 25.4 cm (10 in) between 9.2 and 16.1 m^2/ha (40 and 70 ft^2/ac).

   c. An average pine basal area of pines < 25.4 cm (10 in) less than 4.6 m^2/ha (20 ft^2/ac).

   d. No hardwood midstory or if a hardwood midstory is present, it is sparse and less than 2.1 m (7 ft) in height.

   e. Total stand basal area, including overstory hardwoods, less than 23.0 m^2/ha (80 ft^2/ac).

   f. We recommend that all land counted as foraging habitat be within 0.4 km (0.25 mi) of the cluster, and that any stand counted as foraging habitat be within 61 m (200 ft) of another foraging stand or the cluster itself.

   g. Frequent prescribed burning of foraging habitat, especially during the growing season, is strongly recommended. Development and protection of herbaceous groundcovers facilitates prescribed burning and benefits red-cockaded woodpeckers.

As stated above, the standard for managed stability can benefit red-cockaded woodpeckers on ownerships not legally required to recover the species, because it encourages cooperation between landowners and the U.S. Fish and Wildlife Service. Previous guidelines for privately owned lands facilitated the development of successful

Safe Harbor Agreements and Memoranda of Agreement (see 4A). Again, research to date does not adequately support the designation of foraging habitat that will result in stable vs. increasing populations, so these guidelines have been developed using minimum observed values for successfully reproducing groups. For the most part, the standard for managed stability reflects previous guidelines for private lands. Changes include requirements of slightly more minimum acreage, lower maximum pine densities, and higher minimum pine densities. These modifications were made based on results of recent research described in detail in 2E.

We stress the importance of adequate stand structure. Stands cannot be considered suitable as foraging habitat unless they have an "open" character. A pine stand that is 30 years in age and has an average tree diameter of 25.4 cm (10 in) or more does not necessarily qualify as suitable foraging habitat. If such a stand has not been prescribed burned (or otherwise treated to control hardwood midstory) and has not been thinned to a basal area of 16.1 m^2/ha (70 ft^2/ac) or less, it will not satisfy the "open" condition criterion. Dense stands of young pine and pine/hardwood are typical of unmanaged plantations and natural regeneration areas (particularly loblolly seedtree harvests) that have not been thinned or frequently burned. Such stands cannot be considered suitable foraging habitat simply because they have the required total and stand basal area and average stem diameter. Stand quality, as measured by an open structure, is a critical factor determining suitability and use of foraging habitat and must be considered when acceptable foraging habitat is identified.

Development, with concurrence from the U.S. Fish and Wildlife Service, can occur within the 0.8 km (0.5 mi) radius surrounding the cluster. However, the level of development cannot reduce the available foraging substrate below the required standard of managed stability. Although residential and commercial facilities and their associated infrastructures (roads, right-of-way, parking areas, recreational complexes, etc.) are permitted, all reasonable measures will be taken to minimize the impact of these developments on the foraging habitat available to the red-cockaded woodpecker. In other words, developments will strive to minimize clearing for rights-of-way, road widths, residential dwellings, and commercial and/or industrial complexes. If development would result in foraging habitat losses below the recommended guidelines, a permit (see 4A) is required. Landscaping, whenever possible, should use existing natural vegetation and will not involve extensive hardwood tree plantings.

Monitoring Activity Status of Clusters

Private landowners are encouraged to monitor the number of active clusters on their property and report this information annually to the Red-cockaded Woodpecker Recovery Coordinator. A description of monitoring number of active clusters, and further information concerning the Annual Report, is given in 3A. Private landowners are not responsible for the protection and maintenance of inactive or abandoned clusters, but must adequately document that a cluster is no longer active. This section defines inactive and abandoned clusters and explains how to adequately document cluster activity status.

For the purposes of these private lands guidelines, an abandoned cluster is one that has not shown any evidence of activity by red-cockaded woodpeckers for three years or more. An inactive cluster is one that is not currently supporting any red-cockaded woodpeckers and shows no evidence of red-cockaded woodpecker activity.

Declaring a cluster inactive or abandoned requires the expertise of a knowledgeable biologist or other individual familiar with the identification, life history, and ecology of red-cockaded woodpeckers. The individual must have ample experience with red-cockaded woodpeckers to recognize, and interpret, the sometimes confusing and subtle differences associated with cavity status. One visit is not sufficient to determine activity status, because of several of the species' life history traits. Therefore a cluster-specific monitoring program must be established for at least each cluster in question, and preferably for all clusters on the property.

The objective is to determine whether any red-cockaded woodpeckers are using any cavities within the cluster. Clusters are monitored for red-cockaded woodpecker activity during early morning and/or early evening hours. The number of monitoring days and/or periods (morning/evening) required to document the use or non-use of the cluster by red-cockaded woodpeckers will depend on several factors.

These factors include, but are not limited to,

1. The existing number and condition of cavities. If at least one cavity tree has fresh resin, the cluster is active. If all cavity trees appear as if abandoned for several years, one additional visit at dawn or dusk is generally sufficient to verify the absence of red-cockaded woodpeckers. In contrast, if the cluster appears possibly active, or active within the last few months, several visits may be necessary to document the presence or absence of birds.

2. Distance from, and numbers of, other known active clusters. Active clusters nearby (within a few km, or mi) increase the probability that the cluster in question is active. The number of visits to the cluster should be increased if there are active clusters nearby.

3. Time of year that cluster status is determined. Red-cockaded woodpeckers may not spend as much time in the fall and winter on cavity and resin well maintenance; additionally, resin flow is not as vigorous during the non-growing season. Both of these factors should be considered if cluster status is being determined during the fall/winter period.

Ultimately, a significant amount of professional judgment is required when deciding upon an acceptable monitoring strategy. In general, the monitoring program should be designed to meet individual needs, to the degree necessary, to accurately determine whether or not red-cockaded woodpeckers are using the cluster. Landowners are encouraged to obtain the assistance of red-cockaded woodpecker biologists, consultants, and other qualified individuals to help them certify the status of their particular cluster(s).

As general guidance, when it is not obvious that the cluster has been abandoned for a long time (several to many years), monitoring for either: (1) an extended period of consecutive days, with a mix of morning and evening periods or (2) a series of randomly selected days, spread over several weeks or months, will be necessary to determine the cluster's status. If new evidence, such as a change in appearance of cavities or resin wells, arises during the monitoring period, even though red-cockaded woodpeckers were not observed, the existing monitoring strategy must be revised to include additional visits to the cluster.

Because of the variability and uncertainties associated with individual red-cockaded woodpecker behavior, no single monitoring strategy can be designed for all situations. Strategies will be developed on a case-by-case basis and discussed with the Red-cockaded Woodpecker Recovery Coordinator for adequacy and acceptability. Flexibility in design and implementation of red-cockaded woodpecker cluster status monitoring programs is important and will be emphasized with each landowner.

Appendix C-5: West Indian Manatee Recovery Plan

Florida Manatee Recovery Plan

(*Trichechus manatus latirostris*)
Third Revision

U.S. Fish and Wildlife Service
Southeast Region

FLORIDA MANATEE RECOVERY PLAN

(Trichechus manatus latirostris)

THIRD REVISION

Original Approval: April 15, 1980
First revision approved: July 24, 1989
Second revision approved: January 29, 1996

Southeast Region
U.S. Fish and Wildlife Service
Atlanta, Georgia

Approved: Sam D. Hamilton

Sam D. Hamilton, Regional Director, Southeast Region,
U.S. Fish and Wildlife Service

Date: 10/30/01

DISCLAIMER

Recovery plans delineate reasonable actions believed to be required to recover and/or protect listed species. Plans published by the U.S. Fish and Wildlife Service (FWS), are sometimes prepared with the assistance of recovery teams, contractors, state agencies, and other affected and interested parties. Recovery teams serve as independent advisors to FWS. Plans are reviewed by the public and submitted to additional peer review before they are adopted by FWS. Objectives of the plan will be attained and any necessary funds made available subject to budgetary and other constraints affecting the parties involved, as well as the need to address other priorities. Recovery plans do not obligate other parties to undertake specific tasks and may not represent the views nor the official positions or approval of any individuals or agencies involved in the plan formulation, other than FWS. They represent the official position of FWS only after they have been signed by the Regional Director as approved. Approved recovery plans are subject to modification as dictated by new findings, changes in species status, and the completion of recovery tasks.

By approving this document, the Regional Director will certify that the data used in its development represent the best scientific and commercial data available at the time it was written. Copies of all documents reviewed in development of the plan are available in the administrative record located at U.S. Fish and Wildlife Service, 6620 Southpoint Drive, South, Suite 310, Jacksonville, Florida 32216. (904) 232-2580.

LITERATURE CITATION SHOULD READ AS FOLLOWS:

U.S. Fish and Wildlife Service. 2001. Florida Manatee Recovery Plan, (*Trichechus manatus latirostris*), Third Revision. U.S. Fish and Wildlife Service. Atlanta, Georgia. 144 pp. + appendices.

ADDITIONAL COPIES MAY BE OBTAINED FROM:

Fish and Wildlife Reference Service
5430 Grosvenor Lane, Suite 110
Bethesda, Maryland 20814
(301) 492-6403 or 1-800-582-3421

Fees for plans vary depending upon the number of pages.

ACKNOWLEDGMENTS

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Save the Manatee Club

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Save the Manatee Club

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***Appointed Recovery Team members have an asterisk by their name.**

EXECUTIVE SUMMARY

CURRENT SPECIES STATUS

Endangered. The near and long term threats from human-related activities are the reasons for which the Florida manatee currently necessitates protection under the Endangered Species Act. The focus of recovery is not on how many manatees exist, but instead the focus is on implementing, monitoring and addressing the effectiveness of conservation measures to reduce or remove threats which will lead to a healthy and self-sustaining population. The Florida manatee could be considered for reclassification from endangered to threatened provided that threats can be reduced or removed, and that the population trend is stable or increasing for a sufficient time period.

HABITAT REQUIREMENTS AND LIMITING FACTORS

The Florida manatee lives in freshwater, brackish and marine habitats. Submerged, emergent, and floating vegetation are their preferred food. During the winter, cold temperatures keep the population concentrated in peninsular Florida and many manatees rely on the warm water from natural springs and power plant outfalls. During the summer they expand their range and on rare occasions are seen as far north as Rhode Island on the Atlantic coast and as far west as Texas on the Gulf coast.

The most significant problem presently faced by manatees in Florida is death or injury from boat strikes. The long-term availability of warm-water refuges for manatees is uncertain if minimum flows and levels are not established for the natural springs on which many manatees depend, and as deregulation of the power industry in Florida occurs. Their survival will depend on maintaining the integrity of ecosystems and habitat sufficient to support a viable manatee population.

RECOVERY GOAL

The goal of this revised recovery plan is to assure the long-term viability of the Florida manatee in the wild, allowing initially for reclassification to threatened status and, ultimately, removal from the List of Endangered and Threatened Wildlife.

RECOVERY CRITERIA

This plan sets forth criteria, which when met, will ensure a healthy, self-sustaining population of manatees in Florida by reducing or removing threats to the species' existence.

The following criteria must be met prior to **reclassification of the Florida manatee from endangered to threatened (downlisting)**:

1. Reduce threats to manatee habitat or range, as well as threats from natural and manmade factors by:
   - identifying minimum spring flows;
   - protecting selected warm-water refuge sites;
   - identifying for protection foraging habitat associated with the warm-water refuge sites;
   - identifying for protection other important manatee areas; and
   - reducing unauthorized human caused "take."

2. Achieve the following population benchmarks in each of the four regions over the most recent 10 year period of time:
   - statistical confidence that the average annual rate of adult survival is 90% or greater;
   - statistical confidence that the average annual percentage of adult female manatees accompanied by first or second year calves in winter is at least 40%; and
   - statistical confidence that the average annual rate of population growth is equal to or greater than zero.

The following criteria must be met prior to **removal of the Florida manatee from the List of Endangered and Threatened Wildlife (delisting)**:

1. Reduce or remove threats to manatee habitat or range, as well as threats from natural and manmade factors by enacting and implementing federal, state or local regulations that:
   - adopt and maintain minimum spring flows;
   - protect warm-water refuge sites;
   - protect foraging habitat associated with select warm-water refuge sites;
   - protect other important manatee areas; and
   - reduce or remove unauthorized human caused "take."

2. Achieve the following population benchmarks in each of the four regions for an additional 10 years after reclassification:
   - statistical confidence that the average annual rate of adult survival is 90% or greater;
   - statistical confidence that average annual percentage of adult female manatees accompanied by first or second year calves in winter is at least 40%; and
   - statistical confidence that average annual rate of population growth is equal to or greater than zero.

ACTIONS NEEDED

1. Minimize causes of manatee disturbance, harassment, injury and mortality.
2. Determine and monitor the status of the manatee population.
3. Protect, identify, evaluate, and monitor manatee habitats.
4. Facilitate manatee recovery through public awareness and education.

DATE OF RECOVERY

Currently, in some regions of the state, there are only reliable population data for the past 6 years. Therefore, full recovery may not be possible for at least another 14 years in order to meet the standard of assessing the population over the most recent 10 years of data for reclassification from endangered to threatened status and for an additional 10 years after reclassification for removal from the List of Endangered and Threatened Wildlife. Time is also needed to establish and implement management initiatives to reduce or remove the threats.

TOTAL ESTIMATED COST OF RECOVERY

Based on information provided by our recovery partners, current annual estimated budget expenditures for recovery approach $10,000,000.

TABLE OF CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

The following standard abbreviations for units of measurements and other scientific/technical acronyms and terms are found throughout this document:

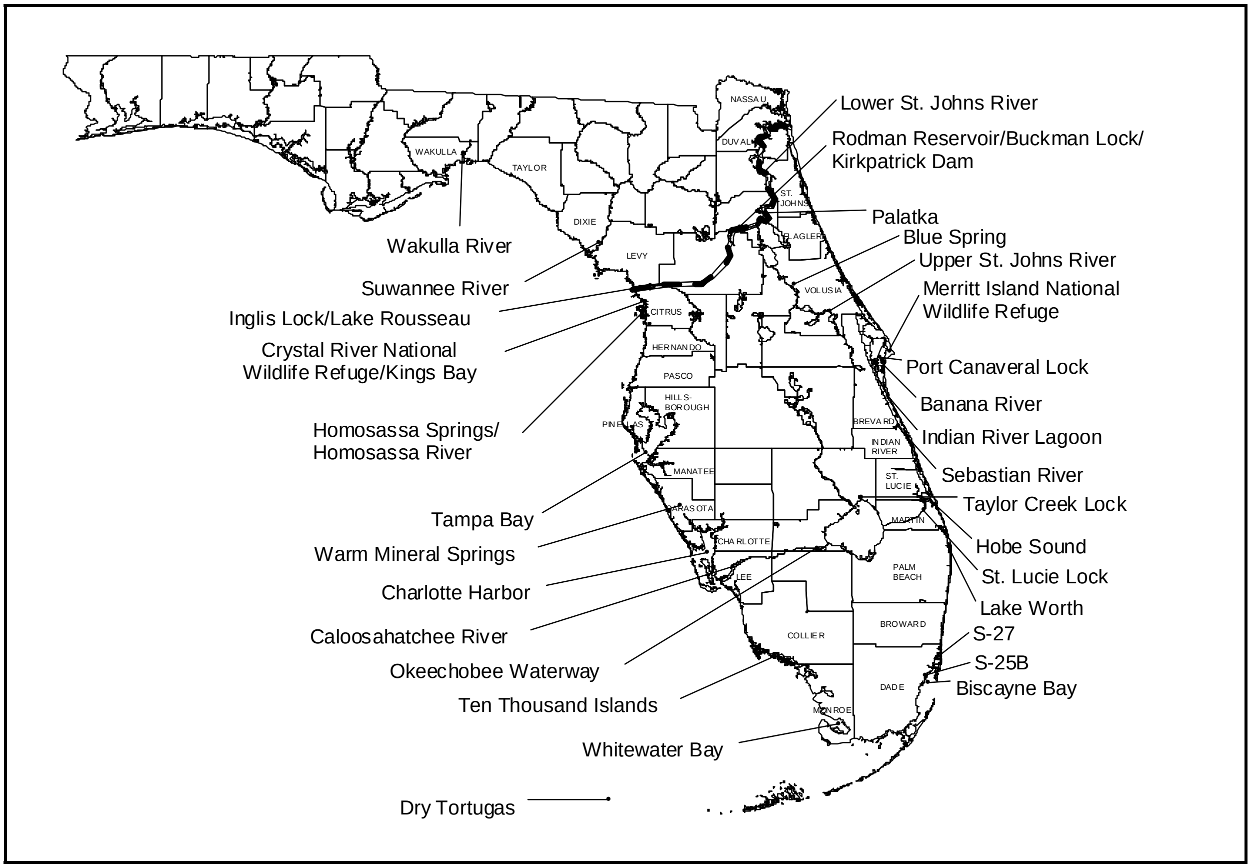
BPSM	Florida Fish and Wildlife Conservation Commission, Bureau of Protected Species Management
CERP	Comprehensive Everglades Restoration Plan
CFR	Code of Federal Regulations
COE	U.S. Army Corps of Engineers
CZS	Chicago Zoological Society
DERM	Miami-Dade Department of Environmental Resources Management
EPA	U.S. Environmental Protection Agency
ESA	Endangered Species Act of 1973, as amended
FDEP	Florida Department of Environmental Protection
FDNR	Florida Department of Natural Resources
FIND	Florida Inland Navigation District
FMRI	Florida Fish and Wildlife Conservation Commission, Florida Marine Research Institute
FPL	Florida Power and Light Company
FR	Federal Register
FWC	Florida Fish and Wildlife Conservation Commission
FWC-DLE	Florida Fish and Wildlife Conservation Commission Division of Law Enforcement
FWS	U.S. Fish and Wildlife Service
GDNR	Georgia Department of Natural Resources
GIS	Geographic Information System
GPS	Global Positioning System
HBOI	Harbor Branch Oceanographic Institute
HWG	Habitat Working Group
IOWG	Interagency Oceanaria Working Group

LOA	Letter of Authorization
LE	Law Enforcement
MIPS	Manatee Individual Photo-Identification System
MML	Mote Marine Laboratory
MMPA	Marine Mammal Protection Act of 1972, as amended
MMPL	Marine Mammal Pathology Lab
MNPL	Maximum net productivity level
MPP	Manatee Protection Plan
MPS	Manatee protection system
MPSWG	Manatee Population Status Working Group
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPS	National Park Service
NSAV	Native submerged aquatic vegetation
NWR	National Wildlife Refuge
OC	The Ocean Conservancy (formerly the Center for Marine Conservation)
OSP	Optimum Sustainable Population
PIT	Passive Integrated Transponder
SAV	Submerged aquatic vegetation
SMC	Save the Manatee Club
USCG	U.S. Coast Guard
USGS-Sirenia	U.S. Geological Survey, Sirenia Project
USN	U.S. Navy
VHF	Very high frequency
WMD's	Water Management Districts

C Fish Industry	Commercial Fishing Industry
Local Gov'ts	Local Governments
M Industry	Marine Industries
Oceanaria	Cincinnati Zoo, Columbus Zoo, Homosassa Springs State Wildlife Park, Living Seas, Lowry Park Zoo, Miami Seaquarium, Mote Marine Laboratory, Sea World Florida and California, South Florida Museum
Photo-ID	Photo-identification
P Industry	Power Industries
R Fish Industry	Recreational Fishing Industry

C	Centigrade
cm	centimeters
ft	feet
hrs	hours
K	carrying capacity
kg	kilograms
km	kilometers
lbs	pounds
m	meters
mi	miles
min	minutes
ppm	parts per million
%	percent
≤	less than or equal to
°	degrees

Florida Coastal Counties and Other Sites Referenced in the Florida Manatee Recovery Plan



PREFACE

This Florida Manatee Recovery Plan revision adds new and refines existing recovery program activities for the next five years. The Recovery Plan is composed of four major sections:

1. Introduction: This section acquaints the reader with the Florida manatee, its status, the threats it faces, and past and ongoing conservation efforts. It also serves as a review of the biological literature for this subspecies.

2. Recovery: This section describes the goal of the plan; outlines an upcoming status review; presents reclassification and delisting criteria based upon the five listing/recovery factors and population benchmarks to assist in evaluating the status; objectives, strategy and actions or tasks needed to achieve recovery. These recovery tasks are presented in step-down outline format for quick reference and in a narrative outline, organized by four major objectives: (1) minimize causes of manatee disturbance, harassment, injury and mortality; (2) determine and monitor the status of the manatee population; (3) protect, identify, evaluate, and monitor manatee habitats; and (4) facilitate manatee recovery through public awareness and education.

3. Implementation Schedule: This section presents the recovery tasks from the step down outline in table format; assigns priorities to the tasks; estimates the time necessary to complete the tasks; identifies parties with authority, responsibility, or expressed interest in implementation of the tasks; and estimates the cost of the tasks and recovery program.

4. Appendices: This section presents additional information utilized by the FWS and Recovery Team to draft this revision.

PART I. INTRODUCTION

The Endangered Species Act of 1973, as amended (16 U.S.C. 1531 *et seq*.) (ESA), establishes policies and procedures for identifying, listing and protecting species of wildlife that are endangered or threatened with extinction. The ESA defines an "endangered species" as "any species which is in danger of extinction throughout all or a significant portion of its range." A "threatened species" is defined as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range."

The West Indian manatee, *Trichechus manatus*, was listed as endangered throughout its range for both the Florida and Antillean subspecies (*T. manatus latirostris* and *T. manatus manatus*) in 1967 (32 FR 4061) and received federal protection with the passage of the ESA in 1973. It should be noted that since the manatee was designated as an endangered species prior to enactment of the ESA, there was no formal listing package identifying threats to the species, as required by Section 4(a)(1) of the ESA. Critical habitat was designated in 1976 for the Florida subspecies, *Trichechus manatus latirostris* (50 CFR Part 17.95(a)). This was one of the first ESA designations of critical habitat for an endangered species and the first for an endangered marine mammal.

The Secretary of the Interior is responsible for administering the ESA's provisions as they apply to this species. Day-to-day management authority for endangered and threatened species under the Department's jurisdiction has been delegated to the U.S. Fish and Wildlife Service (FWS). To help identify and guide species recovery needs, section 4(f) of the ESA directs the Secretary to develop and implement recovery plans for listed species or populations. Such plans are to include: (1) a description of site-specific management actions necessary to conserve the species or population; (2) objective measurable criteria which, when met, will allow the species or populations to be removed from the List; and (3) estimates of the time and funding required to achieve the plan's goals and intermediate steps. Section 4 of the ESA and regulations (50 CFR Part 424) promulgated to implement its listing provisions, also set forth the procedures for reclassifying and delisting species on the federal lists. A species can be delisted if the Secretary of the Interior determines that the species no longer meets the endangered or threatened status based upon these five factors listed in Section 4(a)(1) of the ESA:

(1) the present or threatened destruction, modification, or curtailment of its habitat or range;
(2) overutilization for commercial, recreational, scientific, or educational purposes;
(3) disease or predation;
(4) the inadequacy of existing regulatory mechanisms; and
(5) other natural or manmade factors affecting its continued existence.

Further, a species may be delisted, according to 50 CFR Part 424.11(d), if the best scientific and commercial data available substantiate that the species or population is neither endangered nor threatened for one of the following reasons: (1) extinction; (2) recovery; or (3) original data for classification of the species were in error.

West Indian manatees also are protected under the Marine Mammal Protection Act (MMPA) of 1972, as amended (16 U.S.C. 1461 *et seq*.). The MMPA establishes, as national policy, maintenance of the health and stability of marine ecosystems, and whenever consistent with this primary objective, obtaining and maintaining optimum sustainable populations of marine mammals. It also establishes a moratorium on the taking of marine mammals, which includes harassing, hunting, capturing, killing, or attempting to harass, hunt, capture, or kill any marine mammal. Section 101(a)(5)(A) of the MMPA allows FWS, upon request, to authorize by specific regulation the incidental, unintentional take of marine mammals by persons engaged in identified activities within specific geographic areas, if FWS determines that such taking would have a negligible impact on the species or stock. Since the West Indian manatee, which is comprised of the Florida and Antillean manatee stocks, is currently listed as "endangered" under ESA, they are thus considered "depleted" under the MMPA. Section 115(b) of the MMPA requires that conservation plans be developed for marine mammals considered "depleted." Such plans are to be modeled after recovery plans required under section 4(f) of the ESA, as described above. The purpose of a conservation plan is to identify actions needed to restore species or stocks to optimum sustainable population levels as defined under the MMPA. Thus, in the case of the Florida manatee, this plan addresses conservation planning under MMPA and recovery planning under the ESA.

FWS developed the initial recovery plan for the West Indian manatee in 1980. This initial plan focused primarily on manatees in Florida, but included Antillean manatees in Puerto Rico and the United States Virgin Islands. In 1986, FWS adopted a separate recovery plan for manatees in Puerto Rico. To reflect new information and planning needs for manatees in Florida, FWS revised the original plan in 1989 and focused exclusively on the Florida manatee. This first revision covered a 5-year planning period ending in 1994. FWS revised and updated the plan again in 1996, which again covered a 5-year planning period ending in 2000. In 1999, FWS initiated the process to revise the plan for a third time. A 18-member recovery team (see Acknowledgment Section), consisting of representatives of the public, agencies, and groups that have an interest in manatee recovery and/or could be affected by proposed recovery actions, was established to draft this revision.

In the 20 years since approval of the original recovery plan, a tremendous amount of knowledge of manatee biology and ecology has been obtained, and significant protection programs have been implemented, through the guidance provided by the recovery planning process. This third revision of the Florida Manatee Recovery

Plan reflects many of those accomplishments, addresses current threats and needs, and specifically addresses the planning requirements of both the ESA and MMPA through 2006. This plan was developed with the assistance of the Florida Manatee Recovery Team. Henceforth in this document, unless otherwise specified, the term "manatee" refers to *Trichechus manatus latirostris*, the Florida manatee subspecies of the West Indian manatee.

OVERVIEW

In the southeastern United States, manatees occur primarily in Florida and southeastern Georgia, but individuals can range as far north as Rhode Island on the Atlantic coast (Reid 1996), and probably as far west as Texas on the Gulf coast. This population appears to be divided into at least two somewhat isolated areas, one on the Atlantic coast and the other on the Gulf of Mexico coast of Florida and into two regional groups on each coast: Northwest, Southwest, Atlantic, and Upper St. Johns River (Fig. 1).

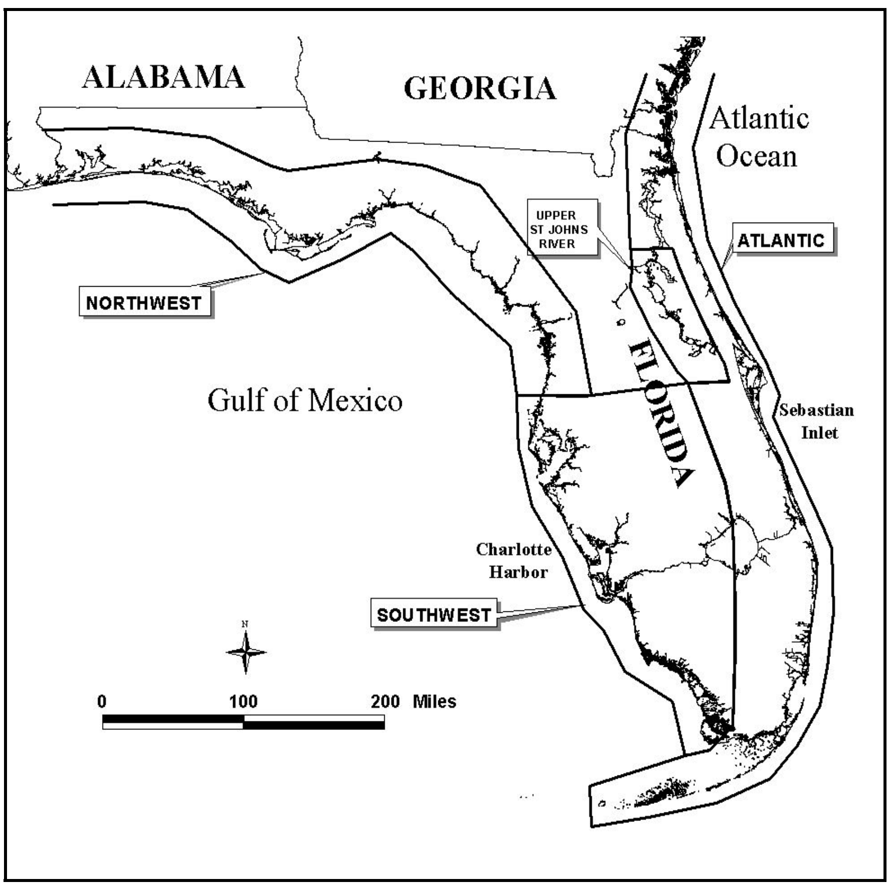


Figure 1. Florida manatee generalized regions: Northwest, Southwest, Upper St. Johns River and Atlantic coast.

Florida manatees have a low level of genetic diversity (Garcia-Rodriguez *et al*. 1998). Historical accounts and archeological evidence of manatees prior to the first half of the 20th century are poor and often contradictory (Domning *et al*. 1982; O'Shea 1988). The record indicates that manatees probably are almost as geographically widespread today as they were historically; however, they appear to be less abundant in many regions (Lefebvre et al. 2001). They were hunted by pre-Columbian societies, but the extent to which they were taken is unclear. After Spanish occupation, Florida's human population increased, and manatees probably were taken in greater numbers. Commercial and subsistence hunting, particularly in the 1800s, probably reduced the population significantly. In 1893, the State of Florida passed legislation prohibiting the killing of manatees.

The major threats faced by manatees today are many fold. Collisions with watercraft account for an average of 24 percent (%) of known manatee deaths in Florida annually (1976-2000), with 30% in 1999 and 29% in 2000. Deaths attributed to water control structures and navigational locks represents 4% of known deaths. The future of the current system of warm-water refuges for manatees is uncertain as deregulation of the power industry in Florida occurs, and if minimum flows and levels are not established and maintained for the natural springs on which many manatees depend. There are also threats to habitat caused by coastal development throughout much of the manatee's Florida range. Florida's human population has grown by 130% since 1970 (6.8 to 15.7 million) and is expected to exceed 18 million by 2010 and 20 million by the year 2015 (Florida Office of Economic and Demographic Research 2000). It is also projected that by 2010, 13.7 million people will reside in the 35 coastal counties (Florida Office of Economic and Demographic Research 2000). There are also threats from natural events such as red tide and cold events. The challenge for managers has increasingly become how to modify human, not manatee, behavior (Reynolds 1999). Yet, since the first Manatee Recovery Plan in 1980, well-coordinated interagency and non-governmental efforts to recover the Florida manatee have been extraordinary, making recovery an achievable goal (Domning 1999).

Based on the highest minimum count of the southeastern United States manatee population (Table 1), Florida manatees constitute the largest known group of West Indian manatees anywhere in the species' range. Outside the United States, manatees occur in the Greater Antilles, on the east coast of Mexico and Central America, along the North and Northeastern coast of South America, and in Trinidad (Lefebvre *et al*. 2001). In most of these areas, remaining populations are believed to be much smaller than the United States population and are subject to poaching for food, incidental take in gillnets, and habitat loss. Manatee protection programs in many countries are not well organized or supported and, in this context, protection of the Florida population takes on international significance.

Table 1. Estimates of manatee life history traits and related statistics. Except as noted, information was obtained from O'Shea *et al*. 1995.

Life-history trait		**Data**
Maximum determined age		59 years
Gestation		11-14 months
Litter size		1
% twins	Blue Spring	1.79%
	Crystal River	1.40%
Sex ratio at birth		1:1
Calf survival	Blue Spring	60%
	Crystal River	67%
Annual adult survival	Atlantic coast	90%
	Blue Spring	96%
	Crystal River	96%
Age of first pregnancy (female)		3-4 years
Mean age at first reproduction (female)		5 years
Age of spermatogenesis (male)		2-3 years
Proportion pregnant	Salvaged carcasses	33%
	Blue Spring (photo-ID)	41%
Proportion nursing - 1st-year calves during winter	Mean	36%
	Blue Spring	30%
	Crystal River	36%
	Atlantic coast	38%
Calf dependency		1.2 years
Interbirth interval		2.5 years
Highest number of births		May-September
Highest frequency in mating herds		February-July
No. verified carcasses in Florida[a]		4,043 (1974-2000)
No. documented in ID catalog		>1,200 (1975-2000)
Highest minimum count (aerial surveys)[a]		3,276 in Jan 5-6, 2001

[a] Data provided by the Florida Marine Research Institute, FWC.

A. TAXONOMY

The West Indian manatee, *Trichechus manatus* Linnaeus, 1758, is one of four living species of the mammalian Order Sirenia. The other three sirenians are the West African manatee (*T. senegalensis*), the Amazonian manatee (*T. inunguis*), and the dugong (*Dugong dugon*). All four species are aquatic herbivores listed as endangered or threatened throughout their ranges by FWS. A fifth species, Steller's sea cow (*Hydrodamalis gigas*), existed in sub-Arctic waters of the Bering Sea. Hunted to extinction within 27 years of its discovery in 1741, Steller's sea cow was a toothless sirenian that fed on kelp and reached lengths of up to 8 m (26 ft) (Reynolds and Odell 1991).

Two subspecies of West Indian manatee are now recognized: the Florida manatee, *T. manatus latirostris*, which occurs in the southeastern United States, and the Antillean manatee, *T. manatus manatus*, found throughout the remainder of the species' range. The Florida manatee was first described by Harlan (1824) as a separate species, *Manatus latirostris*. Later, Hatt (1934) recognized Florida manatees as a subspecies of *T. manatus* Linnaeus. Although subsequent researchers (Moore 1951; Lowery 1974) questioned the validity of the subspecies status, Domning and Hayek (1986) carefully examined morphological characteristics and concluded that the distinction was warranted. The historical ranges of the two subspecies may overlap on the coast of Texas, where the origin of occasional strays (from Florida or Mexico) is uncertain.

B. SPECIES DESCRIPTION

West Indian manatees are massive fusiform-shaped animals with skin that is uniformly dark grey, wrinkled, sparsely haired, and rubber-like. Manatees possess paddle-like forelimbs, no hind limbs, and a spatulate, horizontally flattened tail. Females have two axillary mammae, one at the posterior base of each forelimb (Fig. 2). Their bones are massive and heavy with no marrow cavities in the ribs or long bones of the forearms (Odell 1982). Adults average about 3.0 m (9.8 ft) in length and 1,000 kg (2,200 lbs) in weight, but may reach lengths of up to 4.6 m (15 ft) (Gunter 1941) and weigh as much as 1,620 kg (3,570 lbs) (Rathbun *et al*. 1990). Newborns average 1.2 to 1.4 m (4 to 4.5 ft) in length and about 30 kg (66 lbs) (Odell 1981). The nostrils, located on the upper snout, open and close by means of muscular valves as the animals surface and dive (Husar 1977; Hartman 1979). A muscular flexible upper lip is used with the forelimbs to manipulate food into the mouth (Odell 1982). Bristles are located on the upper and lower lip pads. Molars designed to crush vegetation form continuously at the back of the jaw and move forward as older ones wear down (Domning and Hayek 1986). The eyes are very small, close with sphincter action, and are equipped with inner membranes that can be drawn across the eyeball for protection. Externally, the ears are minute with no pinnae. Internally, the ear structure suggests that they can hear sound within a relatively narrow low frequency range, that their hearing is not acute, and that they have difficulty in localizing sound (Ketten *et al*. 1992). This indirect "structured" evidence is not entirely concordant with actual electro physiological measurements. Gerstein (1995) suggested that manatees may have a greater low-frequency sensitivity than the other marine mammal species that have been tested.

Figure 2. Mother manatee nursing a calf. (*Photograph by G. Rathbun*)

C. POPULATION BIOLOGY

Information on manatee population biology was reviewed during a technical workshop held in February 1992 (O'Shea *et al.* 1992). The objectives of the workshop were to synthesize existing information, evaluate the strengths and weaknesses of current data sets and research methods, and make recommendations for future research, particularly for constructing new population models (O'Shea *et al*. 1995). The population and life history information published in the workshop proceedings suggests that the potential long-term viability of the Florida manatee population is good, provided that strong efforts are continued to curtail mortality, ensure warm-water refuges are protected, maintain and improve habitat quality, and offset potential catastrophes (Lefebvre and O'Shea 1995).

The value of maintaining long-term databases was emphasized in the 1992 workshop. The collection of manatee reproduction, sighting history, life history, carcass salvage, and aerial survey data has continued, and improved techniques for estimating trends in important population characteristics have been developed.

Such measures include estimation of adult manatee survival (probabilities based on photo-identification) (Langtimm *et al*. 1998), determination of population trends from aerial survey data (Craig *et al*. 1997; Eberhardt *et al*. 1999), and development of population models (Eberhardt and O'Shea 1995). Population modeling will be an ongoing process that evolves as databases and modeling tools improve.

POPULATION SIZE Despite considerable effort in the early 1980s, scientists have been unable to develop a useful means of estimating or monitoring trends in the size of the overall manatee population in the southeastern United States (O'Shea 1988; O'Shea *et al*. 1992; Lefebvre *et al.* 1995). Even though many manatees aggregate at warm-water refuges in winter (Fig. 3) and most if not all such refuges are known, direct counting methods (i.e., by aerial and ground surveys) have been unable to account for uncertainty in the number of animals that may be away from these refuges at any given time, the number of animals which are not seen because of turbid water, and other factors. The use of mark-resighting techniques to estimate manatee population size based on known animals in the manatee photo identification database also has been impractical, as the proportion of unmarked manatees cannot be estimated.

Figure 3. Manatee aggregated during a winter cold front at a power plant warm-water outfall in Titusville, Florida. (*Photograph by B. Bonde*)

The only data on population size have been uncalibrated indices based on maximum counts of animals at winter refuges made within one or two days of each other. Based on such information in the late 1980s, the total number of manatees throughout Florida was known to be at least 1,200 animals (Reynolds and Wilcox 1987). Because aerial and ground counts at winter refuges are highly variable depending on the weather, water clarity, manatee behavior, and other factors (Packard *et al.* 1985; Lefebvre *et al*. 1995), interpretation of analyses for temporal trends is difficult (Packard and Mulholland 1983; Garrott *et al*. 1994). Strip-transect aerial surveys are used routinely to estimate dugong population size and trends (Marsh and Sinclair 1989); however, they are difficult to adapt to manatees because of the species' much more linear (coastal and riverine) distribution. This survey method was tested in the Banana River, Brevard County, and recommended for use in that area to monitor manatee population trends (Miller *et al*. 1998). This approach may also have utility in the Ten Thousand Islands-Everglades area.

Beginning in 1991, the former Florida Department of Natural Resources (FDNR) initiated a statewide aerial survey program to count manatees in potential winter habitat during periods of severe cold weather (Ackerman 1995). These surveys are much more comprehensive than those used to estimate a minimum population during the 1980s. The highest two-day minimum count of manatees from these winter synoptic aerial surveys and ground counts is 3,276 manatees in January 2001 (Fig. 4); the highest east coast of Florida count is 1,756 and highest on the west coast is 1,520, both in 2001. It remains unknown what proportions of the total manatee population were counted in these surveys. No statewide surveys were done during the winters of 1992-93 or 1993-94 because of the lack of strong mid-winter cold fronts. These uncorrected counts do not provide a basis for assessing population trends. However, trend analyses of temperature-adjusted aerial survey counts show promise for providing insight to general patterns of population growth in some regions (Garrott *et al*. 1994, 1995; Craig *et al.* 1997; Eberhardt *et al.* 1999).

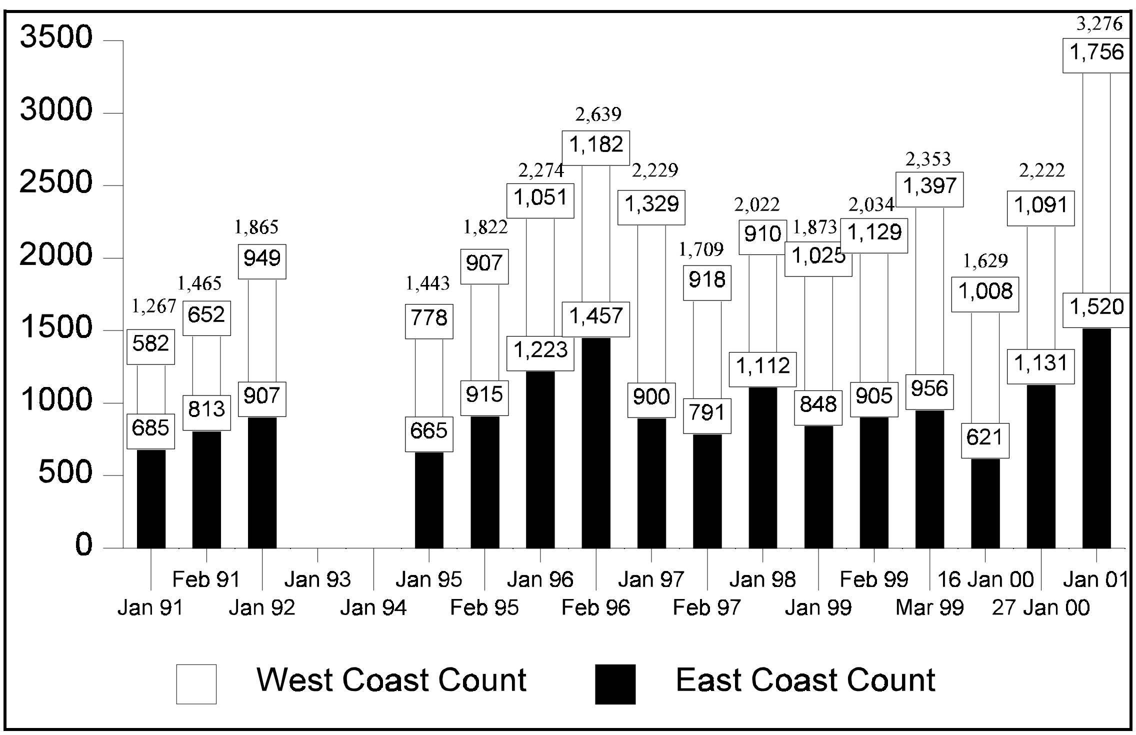


Figure 4. Manatee synoptic survey total, West coast, and East coast counts, 1991-2001 (FWC, unpublished data).

On a more limited basis, it has been possible to monitor the number of manatees using the Blue Spring and Crystal River warm-water refuges. At Blue Spring, with its unique combination of clear water and a confined spring area, it has been possible to count the number of resident animals by identifying individual manatees from scar patterns. The data indicate that this group of animals has increased steadily since the early 1970s when it was first studied. During the 1970s the number of manatees using the spring increased from 11 to 25 (Bengtson 1981). In the mid-1980s about 50 manatees used the spring (Beeler and O'Shea 1988), and in the winter of 1999-2000, the number increased to 147 (Hartley 2001).

On the west coast of Florida, the clear, shallow waters of Kings Bay have made it possible to monitor the number of manatees using the warm-water refuge in Kings Bay at the head of the Crystal River. Large aggregations of manatees apparently did not exist there until recent times (Beeler and O'Shea 1988). The first careful counts were made in the late 1960s. Since then manatee numbers have increased significantly. In 1967 to 1968, Hartman (1979) counted 38 animals in Kings Bay. By 1981 to 1982, the maximum winter count increased to 114 manatees (Powell and Rathbun 1984) and in December 1997, the maximum count was 284 (Buckingham *et al.* 1999). Both births and immigration of animals from other areas have contributed to the increases in manatee numbers at Crystal River and Blue Spring. Three manatee sanctuaries in Kings Bay were established in 1980, an additional three were added in 1994, and a seventh in 1998. The increases in counts at Blue Spring and Crystal River are accompanied by estimates of adult survival and population growth that are higher than those determined for the Atlantic coast (Eberhardt and O'Shea 1995; Langtimm *et al.* 1998; Eberhardt *et al.* 1999).

OPTIMUM SUSTAINABLE POPULATION The MMPA defines the term "optimum sustainable population" (OSP) for any population stock to mean "the number of animals which will result in the maximum productivity of the population or species, keeping in mind the carrying capacity of the habitat and the health of the ecosystem of which they form a constituent element." By regulation (50 CFR 216.3), the OSP is further defined as a range of population sizes between the maximum net productivity level (MNPL) and the carrying capacity (K) of the environment, under conditions of no harvest. The MNPL is defined as the population level producing "the greatest net annual increment in population numbers or biomass resulting from additions to the population due to reproduction and/or growth less losses due to natural mortality."

Pursuant to the MMPA, stocks are to be maintained within their OSP ranges. Just as we are uncertain of the Florida manatee's population size and trend, we are uncertain whether the population is currently below or within its OSP level. Even in the regions where population growth has been documented (Northwest and Upper St. Johns River), we do not know if maximum productivity has yet been achieved.

The MNPL has been estimated only for a few marine mammal species, and is generally treated as a percentage of carrying capacity. Carrying capacity varies over time and space, and is likely to be artificially reduced by a growing human population. Loss of artificial and natural warm-water refuges, for example, could greatly reduce the winter carrying capacity of habitats north of the Sebastian River on the Atlantic coast and the Caloosahatchee River on the Gulf coast. The Recovery Team recognizes the importance of conserving important manatee habitat, and emphasizes the need for sufficient quantity and quality of habitat within each region of the Florida manatee's range to permit sustained manatee population growth from current population levels. Key habitat types include those that are used for the following essential manatee activities: (1) thermoregulation at warm-water refuges; (2) feeding, reproduction and shelter; and (3) travel and migration.

DETERMINATION OF POPULATION STATUS The quality of the long-term database of scarred manatees "captured" by photography (Fig. 5) at winter-aggregation sites, combined with advances in mark-recapture (resighting) statistical models and computer programs, has allowed statistically valid estimates of adult manatee survival rates (Pollock *et al.* 1990; Lebreton *et al.* 1992; Pradel and Lebreton 1993, cited in Langtimm *et al*. 1998; Langtimm *et al.* 1998; White and Burnham 1999). Additional models have been developed that will allow estimation of the proportion of females with calves (Nichols *et al.* 1994). These statistical techniques allow the examination of vital rate variation over time or in association with specific environmental factors. They provide "Goodness-of-Fit" tests of the data to the models to assess bias in the estimates, and provide confidence intervals to assess the precision of the estimates. The application of these techniques to the manatee photo-identification (photo-ID) data provides statistical robustness (Langtimm *et al.* 1998) that has not yet been achieved with trend analyses of aerial survey data (Lefebvre *et al.* 1995; Eberhardt *et al.* 1999) or carcass recovery data (Ackerman *et al.* 1995). Furthermore, population size changes only after there has been a change in survival and/or reproductive rates (or emigration/immigration). Thus, directly monitoring survival and reproduction rates can provide immediate information on probable trends in abundance and gives managers specific information that can help them design realistic plans to achieve species recovery, reclassification, and eventual removal from the List of Endangered and Threatened Wildlife.

The previous recovery plan (FWS 1996) identified the need for a population status working group to assess manatee population size and trends. The first meeting of the Manatee Population Status Working Group (MPSWG), a subcommittee of the Recovery Team, was held in March 1998. The goals of the MPSWG are to: (1) assess the status of the Florida manatee population; (2) advise FWS on population recovery criteria for determining when recovery has been achieved (see Appendix A); (3) provide interpretation of available information on manatee population biology to managers; (4) make recommendations concerning needed research directions and methods; and (5) obtain rigorous external review of manatee population data, conclusions, and research methods by independent researchers with expertise in population biology. The Manatee Population Ecology and Management Workshop, scheduled for April 2002, is a forum that will address these goals and will specifically include a panel of independent experts to review research progress and to make recommendations on how to improve integration of population models with management.

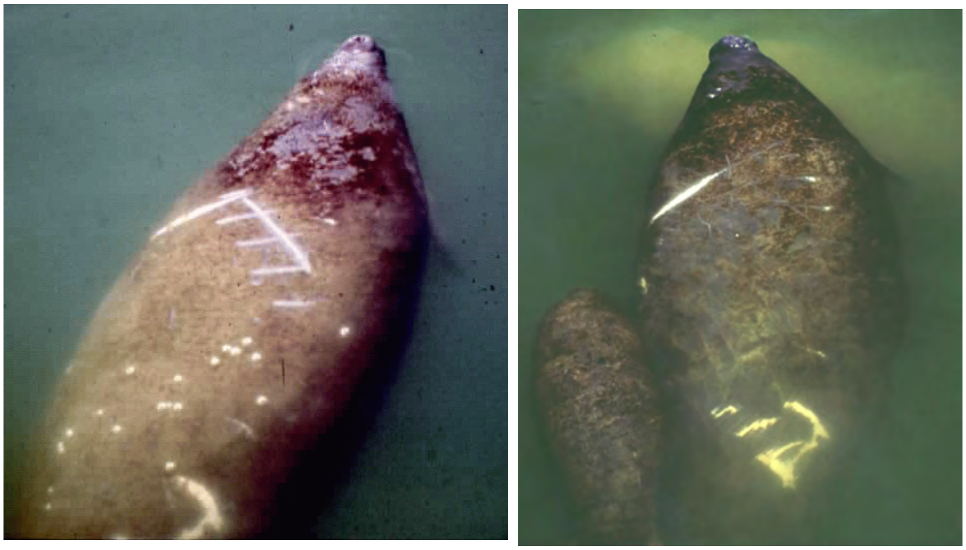


Figure 5. Catalogued female Florida manatee SB 79 was first documented on May 1, 1993 with a large calf (not shown on left). Documented with her third calf (right) on August 15, 1997. These photographs illustrate how injuries/scars appear to change as they heal or as they are altered by new features. This individual uses the Ft. Myers/Charlotte Harbor area during the winter and Sarasota Bay during the warmer months. Estimated to be at least 13 years old, she has given birth to calves in 1992, 1994, 1997, and 2000. (*Photographs by J. Koelsch*)

In order to develop quantitative recovery criteria, the MPSWG reviewed the best available published information on manatee population trends, and determined that analysis of status and trends by region would be appropriate. Based on the highest minimum winter counts for each region between 1996 and 1999 (Fig. 4 and Fig. 6), the number of manatees on the east and west coasts of Florida appears to be approximately equal. Within both the east and west coast segments of the Florida manatee population, documented movements suggest that at least some loosely formed subpopulations exist, which may constitute useful management units. Four subgroups were identified, which tend to return to the same warm-water refuge(s) each winter (Fig. 1) and have similar non-winter distribution patterns. For example, on the east coast, a core group of more than 100 manatees use the Blue Spring warm-water refuge in the upper St. Johns River. Radio-tracking studies (Bengtson 1981) and other information (Beeler and O'Shea 1988; Marine Mammal Commission 1988) suggest that most manatees wintering at Blue Spring tend to remain in the area identified as the **Upper St. Johns River Region** (Fig. 1). The lower St. Johns River, the east coast, and the Florida Keys are considered to represent the **Atlantic Region** (Fig. 1), based on the results of long-term radio tracking and photo-ID studies (Beck and Reid 1995; Reid *et al.* 1995; Deutsch *et al.* 1998).

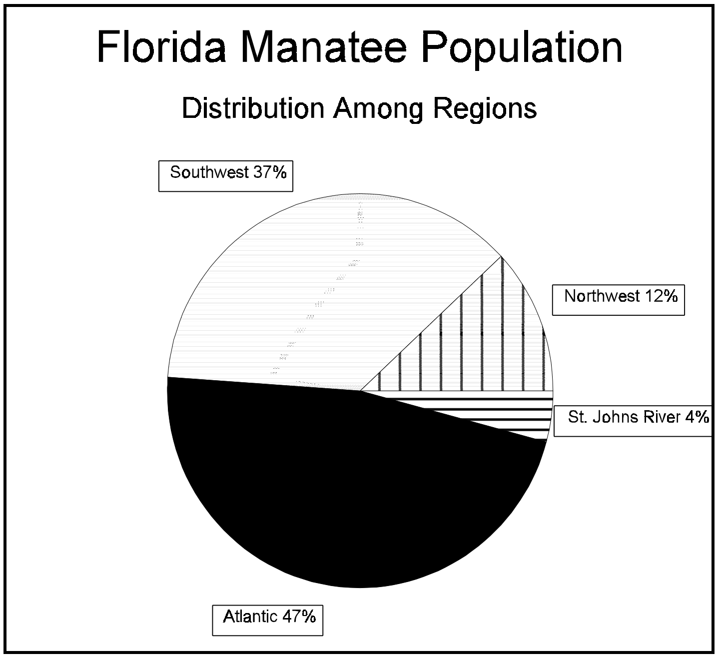


Figure 6. Florida manatee population distribution among regions. Percentage estimates are based upon highest minimum winter counts for each region between 1996 and 2000 (FWC, unpublished data).

On the west coast, Rathbun *et al.* (1995) reported that of 269 recognizable manatees identified at the Kings Bay and Homosassa River warm-water refuges in northwest Florida between 1978 and 1991, 93% of the females and 87% of the males returned to the same refuge each year. Radio-tracking results suggest that many animals wintering at Crystal River disperse north in warm seasons to rivers along the Big Bend coast, particularly the Suwannee River (Rathbun *et al.* 1990). This area is designated as the **Northwest Region** (Fig. 1). The existence of more or less distinct subgroups in the southwestern half of Florida (i.e., from Tampa Bay south) is debatable. It is possible that manatees using warm-water refuges in Tampa Bay, the Caloosahatchee River, and Collier County may be somewhat discrete groups; however, given available data, the Recovery Team chose to identify them as one group, the **Southwest Region** (Fig. 1).

Determination of manatee population status is based upon research described in Objective 2 and Appendix B. Table 2 provides regional status summaries and includes an overview of current status, habitat concerns, carcass recovery and cause of death data, and reproduction, survival, and population growth estimates for each region, if available. Cause of death data are summarized for each region in Appendix C to provide an overview on causes of death for: (1) all age classes; and (2) for adults only. Modeling has shown that manatee population trends are most sensitive to changes in adult survival rates (Eberhardt and O'Shea 1995; Marmontel *et al.* 1997; Langtimm *et al.* 1998).

Table 2. Florida manatee population status summaries by region. Data from the Northwest, Upper St. Johns River and Atlantic Regions were based upon survival rates from Langtimm et al. (1998) and population growth estimates from Eberhardt and O'Shea (1995).

		Northwest Primarily NW peninsular FL	**Southwest** Tampa Bay to Whitewater Bay	**Upper St. Johns** Upstream, South of Palatka	**Atlantic** GA - Miami & lower St. Johns
Photo-identification-based estimates	Adult Survival (% per year)	96.5 (95.1-97.5)	Survival, reproductive and population growth rate estimates based on resightings of known individuals are not currently available.	96.1 (90.0-98.5)	90.7 (88.7-92.6)
	Population Growth Rate (% per year)	7.4		5.7 (3-8)	1.0
	Reproduction: Percent adult females with calf	43% ± 9%		41%	42%
	Percent adult females with 1st year calf	36% ± 6%		30%	39%
	Mean interbirth interval	2.5 ± 0.77		2.6 ± 0.81 winter seasons	2.6 ± 0.64 winter seasons
	Mean calf dependency period	1.2 ± 0.42		1.3 ± 0.48 winter seasons	1.2 ± 0.42 winter seasons
	Mean age females at first reproduction	5.1 ± 1.21 years		5.4 ± 0.98 years	- - -
Causes of death based on carcass recovery	1980 - 1999 Overview	• Total of 153 carcasses • All causes, increasing 5.5% per year • Watercraft-related, increasing 10.8% per year	• Total of 1,358 carcasses • All causes increasing 4.8% per year • Watercraft-related, increasing 7.1% per year	• Total of 79 carcasses • All causes, increasing 2.6% per year • Watercraft-related, increasing 1.6% per year	• Total of 1,659 carcasses • All causes, increasing 6.9% per year • Watercraft-related, increasing 5.5% per year
	1989 - 1999 More recent trends	• Average of 8.9 per year (range = 6-12) • Human related cause of death 30% (adults 40%)	• Average of 85.5 per year (range = 57-134) • 281 in 1996 (including 145 red tide related deaths) • Human related cause of death 30% (adults 48%)	• Average of 4.5 per year (range = 2-7) • Human related cause of death 43% (adults 62%)	• Average of 107 per year (range = 70-135) • 206 in 1990 (46 cold-related) • Human related cause of death 34% (adults 57%)
Habitat Related Concerns		• Spring flow rates • Water quality and SAV • Storm-related salinity fluctuations, resulting in vegetation declines • Storm-related impacts on adult survival • Human disturbance at warm-water springs • Potential conflict between weed control and manatee food supply • Papilloma virus implications unknown	• Manatee dependence on power plants as thermal refuges • Increasing boat traffic • Periodic red tide-related deaths • Moderate level of water control structure deaths • Water quality and SAV • Salinity fluctuations, resulting in vegetation declines • Storm-related impacts on adult survival • Human disturbance	• Spring flow rates • Increasing boat traffic • Water quality and SAV • Low to moderate level of water control structure deaths • Potential conflict between weed control and manatee food supply	• Manatee dependence on power plants as thermal refuges • Increasing boat traffic • ICW shared manatee-human travel corridor • High level of water control structure deaths, especially in SE • Water quality and SAV • Salinity fluctuations, resulting in vegetation declines • Storm-related impacts on adult survival • Human disturbance
Current Status		• Exceeds survival, reproduction, and population growth criteria • Although overall deaths are relatively low, watercraft-related deaths are increasing rapidly	• Estimates of survival and population growth not yet available; reproduction criterion has been exceeded for group that summers in Sarasota Bay • Overall deaths are high, watercraft-related deaths are increasing rapidly	• Meets or exceeds survival, reproduction, and population growth criteria • Overall deaths are moderate, watercraft-related deaths increasing slowly	• Meets reproduction criterion; may meet survival and population growth criteria • Overall deaths are high, watercraft-related deaths increasing moderately

CURRENT STATUS Two goals of the MPSWG are to assess the status of the Florida manatee population and provide interpretation of available information on manatee population biology to managers. The MPSWG developed a status statement (Appendix D) for these purposes, and through Recovery Task 2.1 will update this statement annually.

The **Northwest** and **Upper St. Johns River Regions** have survival and reproduction rates that are adequate to sustain population growth (Eberhardt and O'Shea 1995). The adult survival rates are estimated at 96.5% and 96.1% respectively (Table 2). These two regions represent only 16% of the manatees documented in the last three years (Fig. 6). Collection of comparable life history data for the **Southwest Region** only began in 1995 and was not adequate for these survival estimates. This region represents 37% of the population. The health of the population in the **Atlantic Region**, which represents almost one-half of the entire population, is less certain, and the confidence interval surrounding a 90.7% adult survival rate suggests a cause for concern as it drops below 90.0% (Langtimm *et al*. 1998). These statements about the regions are based on data collected from 1977 to 1993 and thus may not reflect the current status of the population. Additionally, the recent increase in the percentage of watercraft-related deaths as a proportion of the total mortality and the effects this will have on adult survival rates is uncertain. Regional demographic estimates are currently being updated for the Manatee Population Ecology and Management Workshop in April 2002.

The near and long term threats from human-related activities are the reasons for which the Florida manatee currently necessitates protection under the ESA. The focus of recovery is not on how many manatees exist, but instead the focus is on implementing, monitoring and addressing the effectiveness of conservation measures to reduce or remove threats which will lead to a healthy and self-sustaining population. The Florida manatee could be considered for reclassification from endangered to threatened provided that threats can be reduced or removed, and that the population trend is stable or increasing for a sufficient time period.

D. DISTRIBUTION AND HABITAT USE PATTERNS

Based on telemetry, aerial surveys, photo identification sighting records, and other studies over the past 20 years, manatee distribution in the southeastern United States is now well known (Marine Mammal Commission 1984, 1986; Beeler and O'Shea 1988; O'Shea 1988; Lefebvre *et al.* 2001). In general, the data show that manatees exhibit opportunistic, as well as predictable patterns in their distribution and movement. They are able to undertake extensive north-south migrations with seasonal distribution determined by water temperature.

When ambient water temperatures drop below 20° C (68°F) in autumn and winter, manatees aggregate within the confines of natural and artificial warm-water refuges (Fig. 7, Lefebvre *et al.* 2001) or move to the southern tip of Florida (Snow 1991). Most artificial refuges are created by warm-water outfalls from power plants or paper mills. The largest winter aggregations (maximum count of 100 or more animals) are at refuges in Central and Southern Florida (Fig. 7). The northernmost natural warm-water refuge used regularly on the west coast is at Crystal River and at Blue Springs in the St. Johns River on the east coast. Most manatees return to the same warm-water refuges each year; however, some use different refuges in different years and others use two or more refuges in the same winter (Reid and Rathbun 1984, 1986; Rathbun *et al.* 1990; Reid *et al.* 1991; Reid *et al.* 1995). Many lesser known, minor aggregation sites are used as temporary thermal refuges. Most of these refuges are canals or boat basins where warmer water temperatures persist as temperatures in adjacent bays and rivers decline.

During mild winter periods, manatees at thermal refuges move to nearby grassbeds to feed, or even return to a more distant warm season range (Deutsch *et al.* 2000). For example, manatees using the Riviera Power Plant feed in adjacent Lake Worth and in Jupiter and Hobe Sounds, 19 to 24 km (12 to 15 mi) to the north (Packard 1981); animals using the Port Everglades power plant feed in grass beds in Biscayne Bay 24 to 32 km (15 to 20 mi) to the south (Marine Mammal Commission 1988); animals in Kings Bay feed on submerged aquatic vegetation along the mouth of the Crystal River (Rathbun *et al.* 1990); animals at Blue Spring leave the spring run to feed on freshwater aquatic plants along the St. Johns River and associated waters near the spring (Bengtson 1981; Marine Mammal Commission 1986).

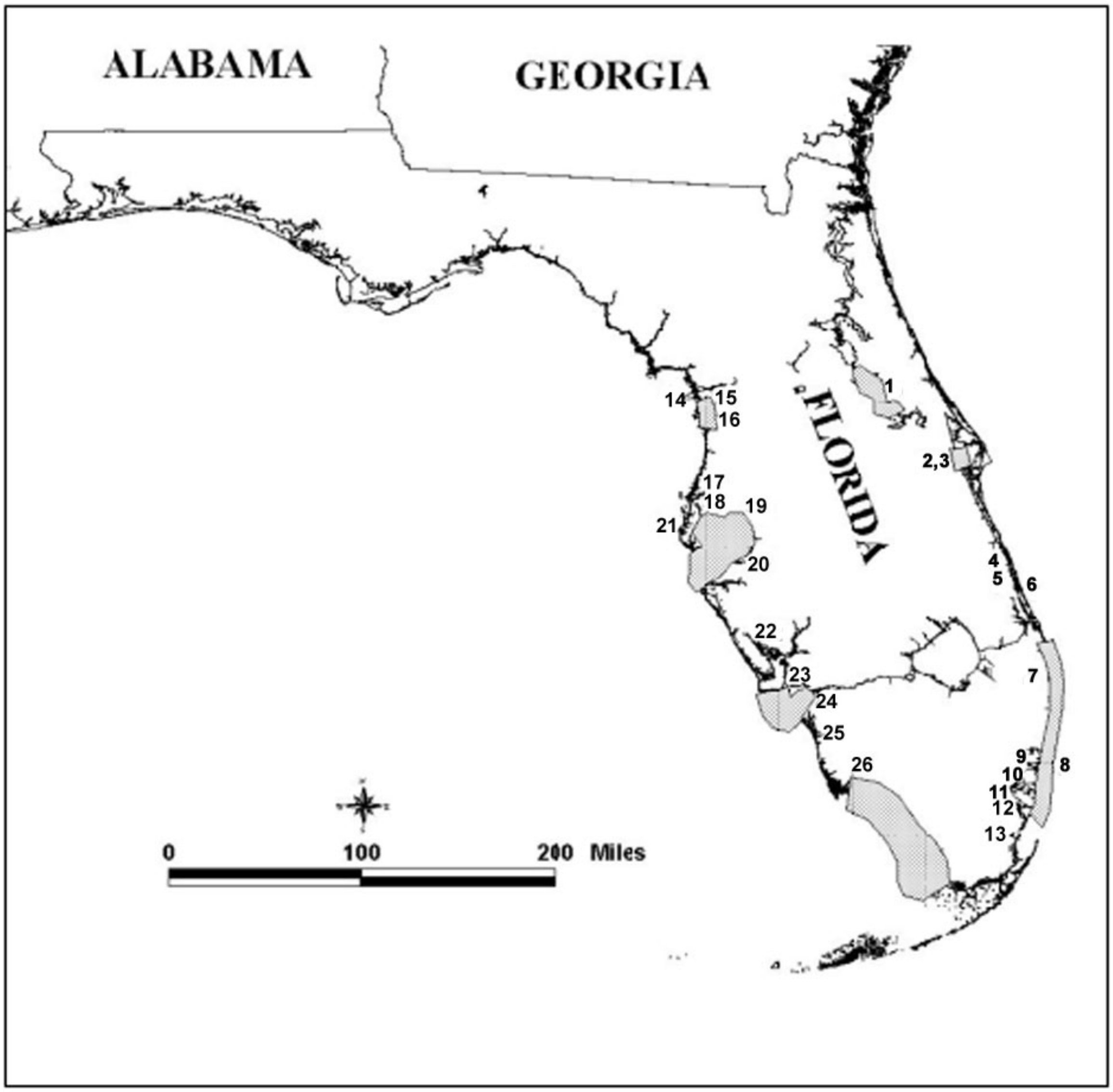


Figure 7. General winter distribution and warm-water manatee aggregation sites in the southeastern United States. Key with name of location and status of refuge is on the following page.

Key to Figure 7. Winter Aggregation Sites (based on Table 1, FWS 1996)

	❶ =	commonly have aggregations of 100 or more manatees
	❷ =	commonly have aggregations of 25 to 100 manatees
	❸ =	aggregations of less than 25 manatees
EAST COAST	(1)	❶Blue Spring (Volusia County, FL)
	(2)	❶Reliant Energy Power Plant (Brevard County, FL)
	(3)	❶FPL Canaveral Power Plant (Brevard County, FL)
	(4)	❷Sebastian River (Brevard County, FL)
	(5)	❷Vero Beach Power Plant (Indian River County, FL)
	(6)	❷Henry D. King Electric Station (St. Lucie County, FL)
	(7)	❶FPL Riviera Beach Power Plant (Palm Beach County, FL)
	(8)	❶FPL Port Everglades Power Plant (Broward County, FL)
	(9)	❶FPL Fort Lauderdale Power Plant (Broward County, FL)
	(10)	❷Little River (Dade County, FL)
	(11)	❷Coral Gables Waterway (Dade County, FL)
	(12)	❷ Palmer Lake (Dade County, FL)
	(13)	❸Black Creek Canal (Dade County, FL)
WEST COAST	(14)	❷FPC Crystal River Power Plant (Citrus County, FL)
	(15)	❶Crystal River (Citrus County, FL)
	(16)	❶Homosassa River (Citrus County, FL)
	(17)	❸Weeki Watchee/Mud/Jenkins Creek Springs (Hernando County, FL)
	(18)	❸FPC Anclote Plant (Pasco County, FL)
	(19)	❷TECO Port Sutton Plant (Hillsborough County, FL)
	(20)	❶TECO Big Bend Power Plant (Hillsborough County, FL)
	(21)	❷FPC Bartow Power Plant (Pinellas County, FL)
	(22)	❷Warm Mineral Springs (Sarasota County, FL)
	(23)	❷Matlacha Isles (Lee County, FL)
	(24)	❶FPL Fort Myers Power Plant (Lee County, FL)
	(25)	❷Ten Mile Canal Borrow Pit (Lee County, FL)
	(26)	❶Port of the Islands (Collier County, FL)
Abbreviations:	FPC	Florida Power Corporation
	FPL	Florida Power & Light Company
	TECO	Tampa Electric Company

As water temperatures rise manatees disperse from winter aggregation areas. While some remain near their winter refuges, others undertake extensive travels along the coast and far up rivers and canals. On the east coast, summer sightings drop off rapidly north of Georgia (Lefebvre *et al.* 2001) and are rare north of Cape Hatteras (Rathbun *et al.* 1982; Schwartz 1995); the northernmost sighting is from Rhode Island (Reid 1996). On the west coast, sightings drop off sharply west of the Suwannee River in Florida (Marine Mammal Commission 1986), although a small number of animals, about 12 to 15 manatees, are seen each summer in the Wakulla River at the base of the Florida Panhandle. Rare sightings also have been made in the Dry Tortugas (Reynolds and Ferguson 1984) and the Bahamas (Lefebvre *et al*. 2001; Odell *et al.* 1978).

In recent years, the most important spring habitat along the east coast of Florida has been the northern Banana River and Indian River Lagoon and their associated waters in Brevard County; more than 300 to 500 manatees have been counted in this area shortly before dispersing in late spring (Provancha and Provancha 1988; FWC, unpublished data). A comparable spring aggregation area does not appear to exist on the west coast, although Charlotte Harbor was visited in the spring by almost half of the 35 manatees radio-tagged at the Fort Myers power plant in Lee County (Lefebvre and Frohlich 1986). During summer, manatees may be commonly found almost anywhere in Florida where water depths and access channels are greater than 1 to 2 m (3.3 to 6.6 ft) (O'Shea 1988). Manatees can be found in very shallow water. Hartman (1979) observed manatees utilizing waters as shallow as 0.4 m with their backs out of the water. In warm seasons they usually occur alone or in pairs, although interacting groups of five to ten animals are not unusual.

Shallow grass beds with ready access to deep channels are preferred feeding areas in coastal and riverine habitats. Manatees often use secluded canals, creeks, embayments, and lagoons, particularly near the mouths of coastal rivers and sloughs, for feeding, resting, cavorting, mating, and calving (Marine Mammal Commission 1986, 1988). In estuarine and brackish areas, natural and artificial fresh water sources are sought by manatees. As in winter, manatees often use the same summer habitats year after year (Reid *et al.* 1991; Koelsch 1997).

E. BEHAVIOR AND PHYSIOLOGY

The first comprehensive study of manatee behavior was conducted in the late 1960s at Crystal River by Hartman (1979). This study attempted, among other things, to develop an ethogram for the species, and despite a number of additional studies that have been done since, Hartman's work stands today as the best source of information on certain aspects of manatee behavior, such as locomotion, breathing, resting, and socializing.

Other aspects of manatee behavioral ecology have been clarified during the last 20 years of manatee research. Migration corridors and responses by individual animals have been elaborated by long-term telemetry studies initiated by scientists at U.S. Geological Survey, Sirenia Lab (USGS-Sirenia) and the Florida Fish and Wildlife Conservation Commission (FWC) Florida Marine Research Institute (FMRI). Scientists have demonstrated site-fidelity in manatees, but have also noted that individual animals adjust their behaviors to take advantage of protected areas or changes in availability of resources. For example, Buckingham *et al.* (1999) confirmed increased manatee use of selected sanctuary areas during times when surrounding disturbance by boats was high. Reynolds and Wilcox (1994) continued to document the extent that manatees seek warm water at power plant discharges in winter (Fig. 8), taking advantage of the tendency by the manatees to aggregate around warm-water refuges in winter. Packard (1981, 1984), Lefebvre and Powell (1990), Rathbun *et al.* (1990) and Zoodsma (1991) described feeding and feeding ecology of manatees aggregated at natural or artificial warm-water refuges in winter, and additional studies further elaborated aspects of feeding behavior and ecological consequences thereof. Studies of foraging ecology were complemented by analyses of gut contents (e.g., Ledder 1986) and assessments of the functional morphology of the gastrointestinal tract (Reynolds and Rommel 1996).

Figure 8. Manatee aggregation at power plant warm-water outfall in Titusville, Florida. (*Photograph by T. O'Shea*)

Descriptions of behaviors have been followed or paralleled by studies that address how and why questions. Perhaps the most obvious questions center around why manatees need to seek warm-water refuges in winter. Gallivan and Best (1980) and Irvine (1983) documented the surprisingly low metabolism of manatees, and scientists suggested that water temperatures below 19° C triggered manatee behavioral changes, such as movements to warm-water sources. Recent research suggests that the temperature eliciting metabolic and behavioral changes in manatees is closer to 17° C, but upper and lower critical temperatures for manatees (the points at which they become metabolically stressed) remain unclear (Worthy *et al.* 1999). It is also unclear, but vital to understand, how manatees would react physiologically and behaviorally to reductions, cessations, or other changes in availability of warm water in winter.

Scientists have noted that manatees seek freshwater sources to drink. Hill and Reynolds (1989) suggested that the structure of the manatee kidney should permit the animals to survive well without regular access to freshwater. In other words, fresh water may be an attractant, without being required for survival, by manatees. Although manatees can tolerate a wide range of salinities (Ortiz *et al.* 1998), they prefer habitats where osmotic stress is minimal or where fresh water is periodically available (O'Shea and Kochman 1990). Ortiz *et al*. (1998) report that "manatees may be susceptible to dehydration after an extended period if freshwater is not available."

A number of research projects have considered manatee sensory capabilities, in part to attempt to comprehend how manatees perceive their environment, including aspects of the environment that are harmful to manatees, such as high-speed watercraft. Behavioral observation studies (e.g., Hartman 1979; Wells *et al*. 1999), and anatomical studies (e.g., Ketten *et al*. 1992) and psychoacoustic research that produced an audiogram for the manatee (Gerstein *et al.* 1999) have all addressed manatee hearing capabilities and the watercraft/manatee issue. These studies have not produced a complete understanding of manatee acoustics.

Other studies that have assessed other sensory capabilities, neuroanatomy, or fine motor coordination include: (1) Cohen *et al.* 1982 (photo receptors and retinal function); (2) Griebel and Schmid 1996 (color vision); (3) Griebel and Schmid 1997 (brightness discrimination); (4) Marshall *et al.*1998a (use of perioral bristles in feeding); (5) Marshall *et al.* 1998b (presence of a muscular hydrostat to facilitate bristle use); (6) Marshall and Reep 1995 (structure of the cerebral cortex); (7) Mass *et al.* 1997 (ganglion layer topography and retinal resolution); (8) O'Shea and Reep 1990 (extent of encephalization); (9) Reep *et al.* 1998 (distribution and innervation of facial bristles and hairs)and (10) Bowles *et al.* 2001(studies of response to novelty). Questions still remain regarding chemosensory ability of manatees, and clarification is needed regarding acoustics and the functional morphology of non-cerebral cortex regions of the brain.

The outcome of research into behavior, general physiology and sensory biology is that these aspects of manatee biology are better understood than is the case for most marine mammals. Due to long-term and diverse research efforts, scientists understand a great deal and continue to learn more about manatee habitat utilization, general behavior patterns, and life history attributes. Science and management would benefit from a carefully structured approach to answering, or providing higher resolution answers to questions associated with thermoregulation and thermal requirements of manatees and aspects of psychoacoustics and perceptual psychology (e.g., what they hear and how they respond to high levels of anthropogenic noise).

A comprehensive description of manatee behavior appears in Wells *et al.* (1999). This chapter provides synopses of the following topics: diving behavior, predation, foraging, thermoregulation and thermally-induced movements, resource aggregations, mating, rearing patterns, communication, and social organization. Sensory and general physiology of manatees are reviewed by Wartzok and Ketten (1999) and Elsner (1999), respectively. Reynolds and Powell (in press) provide a brief overview of manatee biology and conservation, including synopses of behavioral and physiological attributes.

F. FEEDING ECOLOGY

Manatees are herbivores that feed opportunistically on a wide variety of submerged, floating, and emergent vegetation. Because of their broad distribution and migratory patterns, Florida manatees utilize a wider diversity of food items and are possibly less specialized in their feeding strategies than manatees in tropical regions (Lefebvre *et al.* 2000).

Feeding rates and food preferences depend, in part, on the season and available plant species. Bengtson (1981, 1983) reported that the time manatees spent feeding in the upper St. Johns River was greatest (6 to 7 hrs/day) before winter (August to November), least (3 to 4 hrs/day) in spring and summer (April to July), and intermediate (about 5 hrs/day) in winter (January to March). He estimated annual mean consumption rates at 33.2 kg/day/manatee or about 4 to 9% of their body weight per day depending on season (Bengtson 1983). At Crystal River, Etheridge *et al.* (1985) reported cumulative daily winter feeding times from 0 to 6 hrs. 10 min. based on observations of three radio-tagged animals over seven 24-hour periods. The estimated daily consumption rates by adults, juveniles, and calves eating hydrilla (*Hydrilla verticillata*) were 7.1, 9.6, and 15.7% of body weight per day, respectively.

Seagrasses appear to be a staple of the manatee diet in coastal areas (Ledder 1986; Provancha and Hall 1991; Kadel and Patton 1992; Koelsch 1997; Lefebvre *et al.* 2000). Packard (1984) noted two feeding methods in coastal seagrass beds: (1) rooting, where virtually the entire plant is consumed; and (2) grazing, where exposed grass blades are eaten without disturbing the roots or sediment. Manatees may return to specific seagrass beds to graze on new growth (Koelsch 1997; Lefebvre *et al.* 2000).

In the upper Banana River, Provancha and Hall (1991) found spring concentrations of manatees grazing in beds dominated by manatee grass (*Syringodium filiforme*). They also reported an apparent preference for manatee grass and shoalgrass (*Halodule wrightii*) over the macroalga *Caulerpa* spp. Along the Florida-Georgia border, manatees feed in salt marshes on smooth cordgrass (*Spartina alterniflora*) by timing feeding periods with high tide (Baugh *et al*. 1989; Zoodsma 1991).

G. REPRODUCTION

Breeding takes place when one or more males (ranging from 5 to 22) are attracted to an estrous female to form an ephemeral mating herd (Rathbun *et al*. 1995). Mating herds can last up to 4 weeks, with different males joining and leaving the herd daily (Hartman 1979; Bengtson 1981; Rathbun *et al*. 1995. Cited in Rathbun 1999). Permanent bonds between males and females do not form. During peak activity, the males in mating herds compete intensely for access to the female (Fig. 9; Hartman 1979). Successive copulations involving different males have been reported. Some observations suggest that larger, presumably older, males dominate access to females early in the formation of mating herds and are responsible for most pregnancies (Rathbun *et al.* 1995), but males as young as three years old are spermatogenic (Hernandez *et al.* 1995). Although breeding has been reported in all seasons, Hernandez *et al.* (1995) reported that histological studies of reproductive organs from carcasses of males found evidence of sperm production in 94% of adult males recovered from March through November. Only 20% of adult males recovered from December through February showed similar production.

Figure 9. Mating herd in Plummers Cove, St. Johns River, Jacksonville, Florida. (*Photograph by B. Brooks*)

Females appear to reach sexual maturity by about age five but have given birth as early as four (Marmontel 1995; Odell *et al.* 1995; O'Shea and Hartley 1995; Rathbun *et al.* 1995), and males may reach sexual maturity at 3 to 4 years of age (Hernandez *et al.* 1995). Manatees may live in excess of 50 years (Marmontel 1995), and evidence for reproductive senescence is unclear (Marmontel 1995; Rathbun *et al.* 1995). Catalogued Florida manatee CR 28, a wild manatee that overwinters in Crystal River, was last documented with a calf in 1998, at which time she was estimated to be at least 34 years of age (USGS-Sirenia, unpublished data). A captive animal, MSTm-5801, gave birth to a calf in 1990, at which time she was estimated to be 43 to 48 years of age (FWS, unpublished data). The length of the gestation period is uncertain but is thought to be between 11 and 14 months (Odell *et al.* 1995; Rathbun *et al.* 1995; Reid *et al.* 1995). The normal litter size is one, with twins reported rarely (Marmontel 1995; Odell *et al.* 1995; O'Shea and Hartley 1995; Rathbun *et al.* 1995).

Calf dependency usually lasts one to two years after birth (Hartman 1979; O'Shea and Hartley 1995; Rathbun *et al.* 1995; Reid *et al.* 1995). Calving intervals vary greatly among individuals. They are probably often less than 2 to 2.5 years, but may be considerably longer depending on age and perhaps other factors (Marmontel 1995; Odell *et al.* 1995; Rathbun *et al.* 1995; Reid *et al.* 1995). Females that abort or lose a calf due to perinatal death may become pregnant again within a few months (Odell *et al.* 1995), or even weeks (Hartman 1979).

H. THREATS TO THE SPECIES

The most significant problem presently faced by manatees in Florida is death or serious injury from boat strikes. The availability of warm-water refuges for manatees is uncertain if minimum flows and levels are not established for the natural springs on which many manatees depend, and as deregulation of the power industry in Florida occurs. Consequences of an increasing human population and intensive coastal development are long-term threats to the Florida manatee. Their survival will depend on maintaining the integrity of ecosystems and habitat sufficient to support a viable manatee population.

CAUSES OF DEATH (A summary of Cause of Death by region can be found in Appendix C). Data on manatee deaths in the southeastern United States have been collected since 1974 (O'Shea *et al.* 1985; Ackerman *et al.* 1995; FWC, unpublished data). Data since 1976 were used in the following summary (Table 3), as carcass collection efforts were more consistent following that year. They indicate a clear increase in manatee deaths over the last 25 years (Fig. 10, 6.0 % per year exponential regression between 1976 and 2000; Ackerman *et al.* 1995; FWC, unpublished data). Most of the increase can be attributed to increases in watercraft-related and perinatal deaths (Marine Mammal Commission 1993). However, it is unclear whether this represents a proportional increase relative to the overall population of manatees.

Natural causes of death include disease, parasitism, reproductive complications, and other non-human-related injuries, as well as occasional exposure to cold and red tide (O'Shea *et al.* 1985; Ackerman *et al.* 1995). These natural causes of death accounted for 17% of all deaths between 1976 and 2000 (FWC, unpublished data). Perinatal deaths accounted for 21% of all deaths in the same period. Human-related causes of death include watercraft collisions, manatees crushed in water control structures and navigational locks, and a variety of less-common causes. Human-related causes of death accounted for at least 31% of deaths between 1976 and 2000. Cause of death of some carcasses could not be determined, because they were too decomposed, the cause was medically difficult to determine, or the carcass was verified but not recovered. The cause of death for these carcasses was classified as undetermined (30% of deaths between 1976 and 2000).

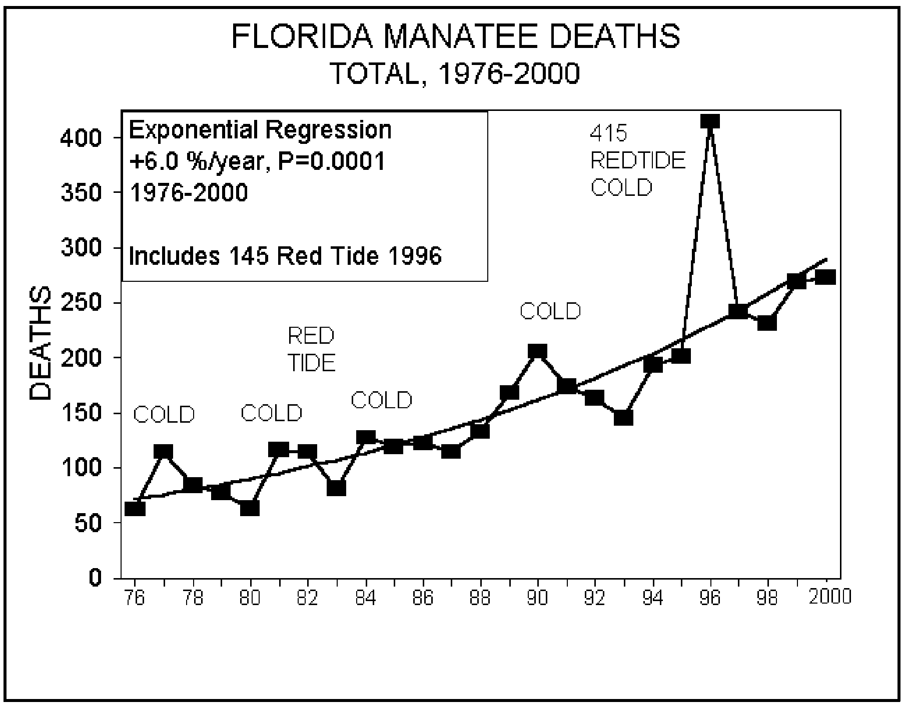


Figure 10. Florida manatee deaths from 1976 to 2000 with an exponential regression of +6.0% per year (FWC, unpublished data).

A prominent natural cause of death in some years is exposure to cold. Following a severe winter cold spell at the end of 1989, at least 46 manatee carcasses were recovered in 1990; cause of death for each was attributed to cold stress. Exposure to cold is believed to have caused many deaths in the winters of 1977, 1981, 1984, 1990, 1996, 2001 and have been documented as early as the 19th century (Ackerman *et al*. 1995; O'Shea *et al.* 1985; FWC, unpublished data).

In 1982, a large number of manatees also died coincidentally with a red tide dinoflagellate (*Gymnodinium breve*) outbreak between February and March in Lee County, Florida (O'Shea *et al.* 1991). At least 37 manatees died, perhaps in part due to incidental ingestion of filter-feeding tunicates that had accumulated the neurotoxin-producing dinoflagellates responsible for causing the red tide. In 1996, from March to May, at least 145 manatees died in a red tide epizootic over a larger area of southwest Florida (Fig. 11; Bossart *et al.* 1998; Landsberg and Steidinger 1998). Although the exact mechanism of manatee exposure to the red tide brevetoxin is unknown in the 1982 and 1996 outbreaks, ingestion, inhalation, or both are suspected (Bossart *et al.* 1998). The critical circumstances contributing to high red tide-related deaths are concentration and distribution of the red tide, timing and scale of manatee aggregations, salinity, and timing and persistence of the bloom (Landsberg and Steidinger 1998). It is difficult to manage for these rare but catastrophic causes of mortality.

Figure 11. Several of the 145 manatees that died during the red tide mortality event, Southwest Florida, 1996. (*Photographs by T. Pitchford*)

Perinatal deaths are carcasses of very small manatees (≤150 cm in length, O'Shea *et al.* 1995). Some are aborted fetuses; others are stillborn or die of natural causes within a few days of birth. Some may die from disease, reproductive complications, and/or congenital abnormalities. The cause of many perinatal deaths is difficult to determine, because these carcasses are generally in an advanced state of decomposition at the time they are retrieved. Most perinatal deaths appear to be due to natural causes; however, watercraft-related injuries or disturbance, or other human-related factors affecting pregnant and nursing mothers also may be responsible for a significant number of perinatal deaths. It has also been suggested that some may die from harassment by adult males (O'Shea and Hartley 1995). Between 1976 and 1999, perinatal deaths increased at an average of 8.8 % per year, increasing from 14% of all deaths between 1976 and 1980 to 22% between 1992 and 2000 (Ackerman *et al.* 1995; FWC, unpublished data).

The largest known cause of manatee deaths is collisions with the hulls and/or propellers of boats and ships. Between 1976 and 2000, watercraft-related deaths accounted for 24% of the total mortality and increased at an average of 7.2% per year: increasing from 21% of all deaths between 1976 and 1980; to 29% between 1986 and 1991; and 24% between 1992 and 2000 (Ackerman *et al.* 1995; FWC, unpublished data). Watercraft-related deaths were much lower in 1992 and 1993, but increased thereafter. From 1996 to 2000, the watercraft-related deaths have been the highest on record.

The next largest human-related cause of manatee deaths is entrapment or crushing in water control structures and navigational locks and accounts for 4% of the total mortality between 1976 and 2000 (Ackerman *et al.* 1995; FWC, unpublished data). These deaths were first recognized in the 1970s (Odell and Reynolds 1979), and steps have been taken to eliminate this source of death. Beginning in the early 1980s gate-opening procedures were modified; annual numbers of deaths initially decreased after this modification. However, the number of deaths subsequently increased, and in 1994, a record 16 deaths were documented. An ad hoc interagency task force was established in the early 1990s and now includes representatives from the South Florida Water Management District (WMD), U.S. Army Corps of Engineers (COE), FWS, Miami-Dade Department of Environmental Research Management (DERM), FWC and Florida Department of Environmental Protection (FDEP). This group meets several times a year to discuss recent manatee deaths and develop measures to protect manatees at water control structures and navigational locks. The overall goal is to eliminate completely structure-related deaths.

Other known causes of human-related manatee deaths include poaching and vandalism, entanglement in shrimp nets, monofilament line (and other fishing gear), entrapment in culverts and pipes, and ingestion of debris. These account for 3% of the total mortality from 1976 to 2000. Together, deaths attributable to these causes have remained constant and have accounted for a low percentage of total known deaths, i.e., about 4% between 1976 and 1980, 3% between 1981 and 1985, 2% between 1986 and 1991, and 2% between 1992 and 2000 (Ackerman *et al*. 1995; FWC, unpublished data). Entrapment in shrimp nets has been the largest component of this catch-all category. Eleven deaths were probably related to shrimping activities from 1976 to 1998 (7 in Florida, 4 in other states; Nill 1998). These deaths have become less common since regulations on inshore shrimping, the 1995 Florida Net Ban regulations, and education efforts about protecting manatees were implemented.

These data on causes of manatee deaths, and particularly the increasing number of watercraft-related deaths, should be viewed in the context of Florida's growing human population, which increased by 130% since 1970, 6.8 to 15.7 million (Florida Office of Economic and Demographic Research, 2001). The rise in manatee deaths during this period is attributable, in part, to the increasing number of people and boats sharing the same waterways. It should be noted that the increasing number of deaths could, in part, also be due to increasing numbers of manatees.

Table 3. Known manatee mortality in the southeastern United States reported through the manatee salvage and necropsy program, 1976 to 2000 (FWC, unpublished data).

Age Class	Adult/Subadult					Perinatal (≤150 cm)				Total
Cause / Year	Water-craft	Lock Gate	Other Human	Natural	Undeter-mined	Water-craft	Lock Gate	Other Human	Natural/ Undeter-mined	
1976	10	3	0	1	32	0	1	0	15	62
1977	13	6	5	1	79	0	0	1	10	115
1978	21	9	1	3	40	0	0	0	10	84
1979	22	8	8	4	24	2	0	1	9	78
1980	15	8	2	6	19	1	0	0	14	65
1981	23	2	4	9	65	1	0	0	13	117
1982	19	3	2	40	37	1	0	0	15	117
1983	15	7	5	6	30	0	0	0	18	81
1984	33	3	1	24	41	1	0	0	27	130
1985	35	3	3	20	39	0	0	0	23	123
1986	31	3	1	13	47	2	0	0	28	125
1987	37	5	3	15	23	2	0	1	31	117
1988	43	7	3	22	25	0	0	1	33	134
1989	50	3	4	32	45	1	0	1	40	176
1990	49	3	4	71	41	0	0	0	46	214
1991	52	9	6	15	39	1	0	0	53	175
1992	38	5	6	21	49	0	0	0	48	167
1993	35	5	7	24	36	1	0	0	39	147
1994	50	16	5	37	40	0	0	0	46	194
1995	43	8	5	35	55	0	0	0	57	203
1996	59	10	1	118	164	1	0	0	63	416
1997	52	8	8	46	67	3	0	1	61	246
1998	66	9	6	23	85	1	0	0	53	243
1999	83	15	7	43	69	0	0	1	56	274
2000	79	8	8	51	75	0	0	0	58	279
Total	973	166	105	680	1,266	18	1	7	866	4,082

THREATS TO HABITAT

WARM WATER One of the greatest threats to the continued existence of the Florida manatee is the stability and longevity of warm-water refuges. Historically, the sub-tropical manatee relied on the warm temperate waters of south Florida and on natural warm-water springs scattered throughout their range as buffers to the lethal effects of cold winter temperatures. With the advent of industrial plants and their associated warm-water discharges, manatees have expanded their winter range to include these sites as refuges from the cold. In the absence of these sources of warm water, manatees are vulnerable to cold temperatures and can die from both hypothermia and prolonged exposure to cold. Based upon recent synoptic survey data, just under two-thirds of the population of Florida manatees rely on industrial sites, which are now made up almost entirely of power plants (FWC unpublished data).

Overall, industrial warm-water refuges have been a benefit to manatees inasmuch as they have: (1) reduced the frequency of cold-related deaths by providing reliable sources of warm water during the winter; (2) reduced the incidence of juvenile, cold-weather related mortality in south Florida; and (3) provided additional winter refuges and foraging sites which supplant heavily-stressed wintering sites in south Florida. While these sites have clearly benefitted the species, they also pose a significant risk. During periods of extreme cold, some plants are unable to provide water warm enough to meet the manatees' physiological needs. Plants are also vulnerable to winter shutdowns due to equipment failures and needed maintenance and, in the long-term, have a limited life span. Older plants are less cost-effective to operate, and market economics will increasingly play a more significant role in the plants' operating schedules (FWS 2000).

In addition, natural wintering sites also have been affected by human activities (FWS 2000). Winter habitat in south Florida has been altered (e.g., shoreline areas have been rip-rapped and bulkheaded, sources of warm water have been diverted and/or capped, foraging and resting sites have been eliminated, etc.). Important springs in the northern area of the species' range have also been altered; demands for water for residential, industrial, and agricultural purposes from the aquifer have diminished spring flows, as have paving and water diversion projects in spring recharge areas. Nutrient loading (e.g., nitrates) from residential and agricultural sources has promoted the growth of alga and clouded water columns, thus reducing available winter forage in these refuges.

Alterations to both natural and industrial warm-water refuges will significantly affect the manatee's ability to tolerate and withstand the cold. In the absence of stable, long term sources of warm water and winter habitat, large numbers of manatees may succumb to the cold. Given the magnitude of the problem, the outright loss of these numbers of animals could significantly affect recovery efforts. The power industry and wildlife managers and researchers are currently working together to secure the manatee's winter habitat.

OTHER HABITAT As discussed earlier in this document, Florida manatees are found in fresh, brackish, and marine environments in the southeastern United States. These areas include many habitat types (including vegetated freshwater bottoms, salt marshes, sea grass meadows, and many others) where manatees ably exploit the many resources found in these areas. As herbivores, manatees feed on the wide range of forage that these habitats provide. In addition, manatees utilize many other resources found in these areas, including: (1) springs and deep water areas for warmth; (2) springs and freshwater runoff sites for drinking water; (3) quiet, secluded tributaries and feeder creeks for resting, calving, and nurturing their young, (4) open waterways and channels as travel corridors, etc.

These habitats are affected by human activities. Dredge and fill activities, polluted runoff, propeller scarring, and other actions have resulted in the loss of vegetated areas and springs. Quiet backwaters have been made more accessible to human activities, and increasing levels of vessel traffic have made manatees increasingly vulnerable to boat collisions in travel corridors. Manatees seem to have adapted to some of these changes. For example, industrial warm-water discharges and deep-dredged areas are now used as wintering sites, stormwater pipes and freshwater discharges in marinas provide manatees with drinking water, and the imported exotic plant, hydrilla (which has replaced native aquatic species), has become an important food source at wintering sites.

While manatees may adapt to some changes, some activities clearly can have an adverse effect on the species. The loss of industrial warm-water discharges can result in the deaths of individuals using these sites. Dozens of manatees die each year due to collisions with watercraft. Other activities may also affect manatees, albeit on a much more subtle level. Harassment by boats and swimmers may drive animals away from preferred sites; the loss of vegetation in certain areas (e.g., as seen in winter foraging areas) requires manatees to travel greater distances to feed. Adequate feeding habitat associated with warm-water refuge sites is important to the overall recovery of the Florida manatee, however, it does not appear that warm season foraging habitat is limiting.

Efforts are in place and are being made to protect, enhance, and restore the manatee’s aquatic environment. There are many existing federal, state, and local government regulations in place to minimize the effect of human activities on manatees and their habitat (e.g., Clean Water Act, Rivers and Harbors Act, ESA, Fish and Wildlife Coordination Act, Coastal Zone Management Act, etc.), and significant efforts are being made to improve this environment and to maintain those resources that are vital to the manatee. Also refer to the discussion in section I, **HABITAT PROTECTION**.

CONTAMINANTS AND POLLUTION EFFECTS The reliance of manatees on inshore habitats and their attraction to industrial and municipal outfalls have the potential to expose them to relatively high levels of contaminants. Despite this relationship, there have been few studies of contaminant levels and their effects on manatees. Available information suggests that direct effects are not significant at a population level. O'Shea *et al.* (1984) investigated levels of pesticides, polychlorinated biphenyls, mercury, lead, cadmium, copper, iron, and selenium in manatee tissues collected in the late 1970s and early 1980s. Of these, only copper levels in the liver were found to be notably high. The highest copper levels (1,200 ppm dry weight) were found in animals from areas of high herbicidal copper usage and exceeded all previously reported concentrations in livers of wild mammals. Despite these findings, there were no field reports of copper poisoning and no evidence of deleterious effects to individual animals. Ames and Van Vleet (1996) analyzed a small number of tissue samples for chlorinated hydrocarbons and petroleum hydrocarbons. None of the latter were found; however, pesticides (o,p-DDT, o,p-DDD, hexachlorobenzene, and lindane) were found in some of the liver, kidney, and blubber samples, but at very low concentrations and at a lower frequency of occurrence than in earlier studies. Contaminants, siltation and modified deliveries of fresh water to the estuary can indirectly impact manatees by causing a decline in submerged aquatic vegetation on which manatees depend.

Manatees ingest various debris incidental to feeding. Beck and Barros (1991) found monofilament fishing line, plastic bags, string, rope, fish hooks, wire, rubber bands, and other debris in the stomachs of 14.4% of 439 manatees recovered between 1978 and 1986. Monofilament line was the most common item found. In most cases, ingested items do not appear to affect animals. However, ingested monofilament line has resulted in death due to blockage of the digestive system (Forrester *et al.* 1975; Buergelt *et al.* 1984). A few deaths were caused by ingesting wire, which perforated the stomach lining, and plastic sheeting, which blocked the digestive tract (Laist 1987). Discarded monofilament line and rope were found wrapped around flippers, sometimes leading to serious injury or death (Beck and Barros 1991). Records of scarred or mutilated flippers on free-ranging manatees known from the photo-ID catalog and rescue events suggest that female manatees are more vulnerable than males to entanglement in fishing gear (Beck and Lefebvre 1995).

I. PAST AND ONGOING CONSERVATION EFFORTS

Under the guidance of previous manatee recovery plans, federal agencies, state agencies, local agencies and private organizations have initiated cooperative actions to address the important conservation needs, which this plan builds upon. Some of the major initiatives are reviewed below.

EFFORTS TO REDUCE WATERCRAFT-RELATED INJURIES AND DEATHS The largest identified cause of manatee death is collisions with watercraft. Many living manatees also bear scars or wounds from vessel strikes. An analysis of injuries to 406 manatees killed by watercraft and recovered between 1979 and 1991 found that 55% were killed by impact, 39% were killed by propeller cuts, 4% had both types of injuries, either of which could have been fatal, and 2% with unidentified specifics (Wright *et al.* 1995). Between 1976 and 2000, the total number of carcasses (i.e., deaths due to all causes) collected has increased at a rate of 6.0 percent per year, while deaths caused by watercraft strikes increased by 7.2 percent per year (Fig. 12). Because watercraft operators cannot reliably detect and avoid hitting manatees, federal and state managers have sought to limit watercraft speed in areas where manatees are most likely to occur to afford both manatees and boaters time to avoid collisions.

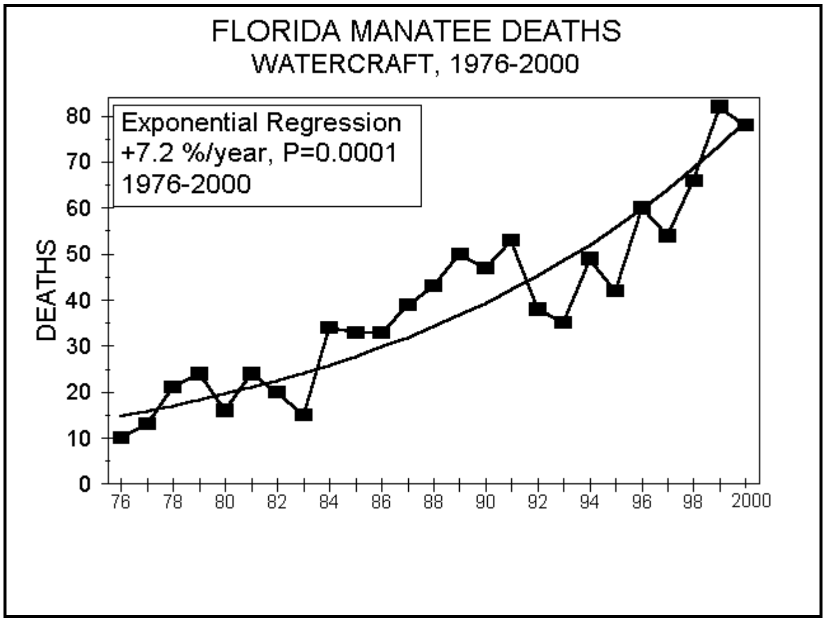


Figure 12. Florida manatee watercraft deaths from 1976 to 2000 with an exponential regression increase of 7.2% per year (FWC, unpublished data).

In 1989, the Florida Governor and Cabinet approved a series of recommendations by the former FDNR to improve protection of manatees in 13 key counties. For the next ten years, state and local governments cooperated in the creation and implementation of four county Manatee Protection Plans and 12 county-wide manatee protection speed zone rules. In 1999, Florida's manatee research and management programs were transferred to the newly created FWC. FWC approved comprehensive manatee protection rules in Lee County, completing the speed zone component of the initiative started in 1989. As the State of Florida's initiative to establish manatee protection zones in the 13 key counties is completed, attention is now focused on the development and approval of key county manatee protection plans.

Two types of manatee protection areas also have been developed by FWS: (1) manatee sanctuaries; and (2) manatee refuges. Manatee sanctuaries are areas in which all waterborne activities are prohibited, and manatee refuges are areas where certain waterborne activities are restricted or prohibited (designation of refuges or sanctuaries, however, will not eliminate waterway property owner access rights). To date, FWS has established seven winter sanctuaries to protect manatees in association with the Crystal River National Wildlife Refuge (NWR). The most recent was a one-quarter-acre sanctuary established in 1997 at Three Sisters Spring run (Fig. 13).

Figure 13. Three Sisters Spring Manatee Sanctuary, Crystal River, Florida. Manatees within the sanctuary and tour boats (left) and snorklers (right) along the outer sanctuary boundary edge. (*Photographs by J. Kleen and C. Shaw*)

FWS and FWC continue to evaluate needs for additional protection areas that may be necessary to achieve recovery. The goal is to consider the needs of the manatee at an ecosystem level and to establish regulations to ensure that adequate protected areas are available throughout Florida to satisfy habitat requirements of the Florida manatee population with a view toward recovery. In addition, through the NWR System Administration Act, access rules for boats have been established by FWS to protect manatees within Merritt Island NWR.

In recent years, both the FWS and FWC have been using targeted enforcement strategies in an attempt to increase boater compliance with speed zones and ultimately reduce manatee injuries and death. FWS strategy has been to allocate significant enforcement manpower to specific areas on designated weekends. These enforcement teams travel to various locations around the state, with particular emphasis given to those zones within counties where there is a history of high watercraft-caused manatee deaths. FWC has increased its emphasis on enforcement and compliance with manatee speed zones by adding new officers, conducting law enforcement task force initiatives, increasing overtime, and increasing the proportion of law enforcement time devoted to manatee conservation.

In addition to manatee protection plans, manatee protection areas, and other efforts, managers, researchers, and the boating industry have investigated the use of various devices to aid in the reduction of watercraft-related manatee deaths. For example, the State of Florida funded an evaluation of propeller guards (Milligan and Tennant 1998). The state's evaluation concluded that these devices would reduce cutting damage associated with propellers when boats were operating at low speeds. However, when boats (including boats equipped with propeller guards) operate at high speeds, guards would be of little benefit because animals would continue to be killed by blunt trauma associated with impacts from boat hulls, lower units, and other gear. The U.S. Coast Guard (USCG) identified additional concerns, stating that propeller guards on small recreational vessels "may create more problems than they solve" and does not support their use on recreational vessels at this time (Carmichael 2001). There are propeller guard applications, however, that appear to work for certain large, commercial vessels; for example, the use of guards on C-tractor tugs has eliminated this specific source of manatee mortality at the Kings Bay Naval Submarine Base in St. Marys, Georgia. To prevent injuries to manatees, propeller guards are used on some rental and sight-seeing boats at Blue Spring and Crystal River.

Researchers have also begun to investigate the manatees' acoustic environment to better evaluate the animal's response to vessel traffic. This line of research needs to be thoroughly assessed for its potential as another management tool to minimize collisions between manatees and boats. Results from Gerstein (1999) indicate that manatees hear in the range from 500 Hz to 38 kHz and that inadequate hearing sensitivity at low frequencies may be a contributing factor to the manatees' ability to effectively detect boat noise to avoid collisions. One technology often discussed is an acoustic deterrence device mounted on a boat. Conceptually, this technological approach may sound like an answer to the manatee/watercraft issue. A number of problems have been defined with the use of acoustic deterrents. No alarm/warning device has yet been demonstrated to adequately protect wildlife or marine mammals. Additionally, concern has also been stated regarding the increase in background noise that these deterrents would add to an already noisy marine environment. It has not been determined what negative impacts this device would have on marine life and what effects it would have on animals that use acoustic cues for a variety of purposes. For these reasons, this technology needs to be thoroughly researched and assessed and managers need to evaluate the MMPA and ESA "take" issues related to implementing such technology.

Current research into the sensory capabilities of manatees is being supported at both the state and federal levels. The FWC contracted Mote Marine Laboratory to further test manatee sensory capabilities. One contract assessed the effects of boat noise in a more controlled environment. This study recorded the physical and acoustic reaction of a manatee to a pre-determined acoustical level. This study design will allow the development of a relationship between acoustic dosage and behavioral responses (vocal and visual displays; movements). Another contract study looked at acoustical propagation over various types of marine topography. In cooperation with Mote Marine Laboratory and the Woods Hole Oceanographic Institution, the FWC is also examining manatee behavioral response to watercraft using new technology, the DTAG, a digital acoustic tag which records acoustic attributes of the environment and detailed manatee movement simultaneously. A FWS contracted study to assess manatee behaviors in the presence of fishing gear and their response to novelty and the potential for reducing gear interactions has an acoustic component. The FWC also received funding to support the development and implementation of technological solutions for reducing the risks that watercraft pose to manatees. They recently issued a Request for Proposals (RFP) to specifically address manatee avoidance technology.

Currently, priority actions in manatee conservation and protection include boater education, enforcement, maintenance of signs and buoys, compliance assessment, and periodic re-evaluation of the effectiveness of the rules. Such work requires close cooperation between FWC Bureau of Protected Species Management (BPSM), FWC's Division of Law Enforcement (DLE), county officials, the Inland Navigation Districts, FWS, USCG, and, of course, boaters.

EFFORTS TO REDUCE FLOOD GATE AND NAVIGATION LOCK DEATHS Entrapment in water-control structures and navigational locks is the second largest cause of human-related manatee deaths. In some cases, manatees appear to have been crushed in closing gates; in others, they may have been drowned after being pinned against narrow gate openings by water currents rushing through openings. Water-control structures implicated in manatee deaths in Dade and Broward counties are operated by the South Florida WMD. From 1976 through 2000, 166 manatees have been killed in water control structures in Dade County alone, accounting for 33% of all manatee deaths in this county.

The COE operates five water-control structures in conjunction with navigational locks along the Okeechobee Waterway and also operates the Port Canaveral Lock, located in Brevard County. FDEP operates locks and water-control structures associated with the Cross Florida Greenway.

In the early 1980s, steps were taken to modify gate-opening procedures to ensure openings were wide enough to allow a manatee to pass through unharmed. Steps were also initiated to fence off openings and cavities in gate structures where manatees might become trapped. Manatee deaths subsequently declined and remained low for much of the 1980s (Table 2). Since the 1996 Recovery Plan, much progress has been made toward identifying, testing, and installing manatee protection devices at water control structures. The COE Section 1135 Study, "Project Modification on Manatee Protection at Select Navigation and Water Control Structures, Part I," has been completed and the technology developed and successfully tested. Consequently, since 1996, pressure sensor devices have been installed at the five water control structures. Three recent deaths at two of the modified South Florida Water Management District water control structures suggests that these type of protective measures will continue to need on-going maintenance, review and refinement. The COE has also installed removable barriers on the upstream side of the Ortona and St. Lucie Lock spillway structures. The large difference in the up and downstream water levels at these structures compromises the effectiveness and use of pressure sensor devices. Such barriers will be considered for other structures where appropriate. A task force, established in 1991, comprised of representatives from the South Florida WMD, COE, FWC, FDEP, DERM, and FWS, continues to monitor, examine and make recommendations to protect manatees at water control structures and navigational locks.

The COE completed the "Section 1135 Project Modification Report on Manatee Protection at Select Navigation and Water Control Structures, Part II," which investigated several alternatives to protect manatees at locks. The COE contracted with the Harbor Branch Oceanographic Institute (HBOI) to develop and install a prototype acoustic array for manatee protection at lock gates. HBOI completed system design, and during 1999 the St. Lucie Lock was equipped with this manatee protection system (Fig. 14). This system consists of a device that is installed on the lock gates and detects the presence of manatees through acoustic signals. When a manatee is detected near the gate during the last 52 inches of closure, an alarm sounds; the gate stops closing and is then re-opened back to 52 inches. An upgraded version of this same type of system also has been installed at Port Canaveral Lock. Future plans are to install protective systems at the following locks: Moore Haven, Ortona, and Port Mayaca.

Figure 14. Water control structure retrofitted with pressure sensitive technology (left). Retrofitting of St. Lucie Lock with acoustic sensors (right) to protect manatees from being crushed as the gates close. (*Photographs by FWS and B. Brooks*)

FDEP currently is designing and preparing to install barriers at the Kirkpatrick Dam (Putnam County), and on the tainter valve culvert pipes at Buckman Lock (Putnam County) and downstream side of Inglis Lock (Levy County); work is anticipated to be completed during 2001. FDEP also has contracted with HBOI to install an acoustic array system at Buckman Lock, similar to arrays installed at the COE's Port Canaveral and St. Lucie Locks. Upon completion of the manatee protection systems at the Rodman Reservoir (Putnam County), FDEP plans to reopen Buckman Lock for operation. Currently the FDEP's Inglis Lock at Lake Rouseau/Withlacoochee River is not operating; long-term plans are to replace Inglis Lock with a smaller one with a manatee protection system installed.

HABITAT PROTECTION Intensive coastal development throughout Florida poses a long-term threat to the Florida manatee. There are three major approaches to address this problem. First, FWS, FWC, Georgia Department of Natural Resources (GDNR), and other recovery partners review and comment on applications for federal and state permits for construction projects in manatee habitat areas and to minimize their impacts. Under section 7 of the ESA, FWS annually reviews hundreds of permit applications to the COE for construction projects in waters and wetlands that include or are adjacent to important manatee habitat. FWC and GDNR provide similar reviews to their respective state's environmental permitting programs.

A second approach is the development of county manatee protection plans. The provisions of these plans are anticipated to be implemented through amendments to local growth management plans under the Florida's Local Government Comprehensive Planning and Land Development Regulation Act of 1985. In addition to boat speed rules, manatee protection plans are to include boat facility siting policies and other measures to protect manatees and their habitat. To date, five counties (Citrus, Collier, Dade, Duval, and Indian River counties) have completed manatee protection plans, which the State of Florida has approved, and other counties' plans are in varying stages of development. Of the five completed plans, FWS has approved only two, those of Citrus and Dade.

A third approach to habitat protection is land acquisition. Both FWS and the State of Florida have taken steps to acquire and add new areas containing important manatee habitat to federal and state protected area systems. The State of Florida has acquired important areas through several programs, most notably the Florida Forever Program (formerly the Conservation and Recreational Lands Program). In Florida, the Governor and Cabinet have included special consideration for purchase of lands that can be of benefit to manatees and their habitat. Over $500 million has been spent to acquire 250,000 acres, whose importance included, but was by no means limited to, protection of manatee habitat. Particularly important purchases have been made along and near the Crystal River, at Rookery Bay, the Sebastian River, and near Blue Spring. FWS has also acquired and now manages thousands of acres of land important to manatees and many other species in the NWR System. In addition to these efforts, FWS's initiative to propose new manatee refuges and sanctuaries factors into habitat protection. Both the State of Florida and FWS are continuing cooperative efforts with a view towards establishing a network of important manatee habitats throughout Florida.

MANATEE RESCUE, REHABILITATION AND RELEASE Thousands of reports of distressed manatees purportedly in need of assistance have been made to the state wildlife enforcement offices and other resource protection agencies by a concerned public. While most of the manatees do not require assistance, dozens of manatees are rescued and treated each year. A network of state and local agencies and private organizations (Fig. 15), coordinated by FWS, has been rescuing and treating these animals for well over twenty years.

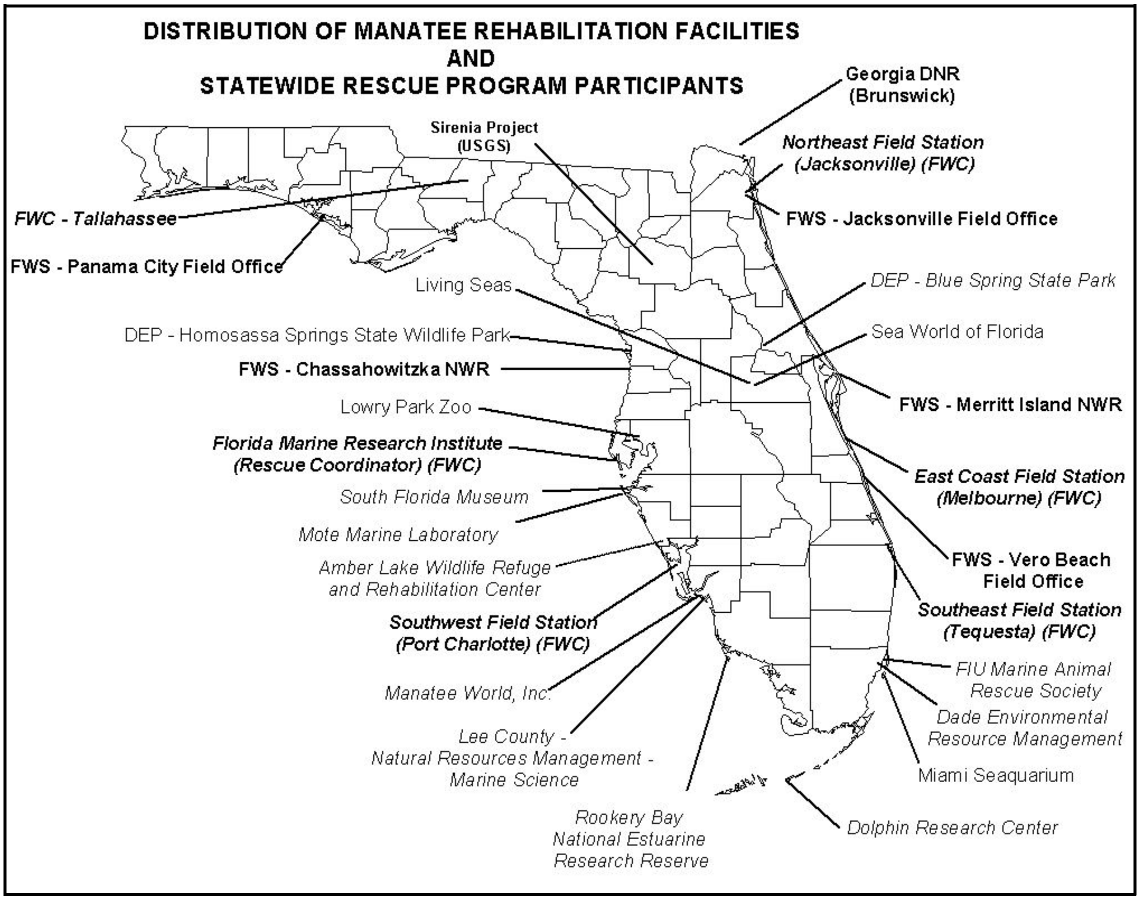


Figure 15. Locations of participants in the manatee rescue, rehabilitation, and release program.

Manatees are brought into captivity when stressed by cold weather, when struck and injured by watercraft, when injured because of entanglements in crab traps and monofilament fishing line, when orphaned, and when compromised by other natural and man-made factors. Program veterinarians and staff have developed treatments and protocols for these animals and have been remarkably successful in their efforts to rehabilitate compromised individuals (Fig. 16). Since 1973, over 180 manatees have been treated and returned to the wild (FWS unpublished data).

Treatments and protocols developed for these distressed animals have provided notable insights into the physiology and behavior of manatees. In certain settings, captive manatees are used in research; captive studies have provided a wealth of information on sensory capacities, digestion, reproduction, etc. Information obtained through treatments and research, in addition to the number of animals released back into the wild each year, contributes significantly to efforts to reduce mortality and further the recovery of the species.

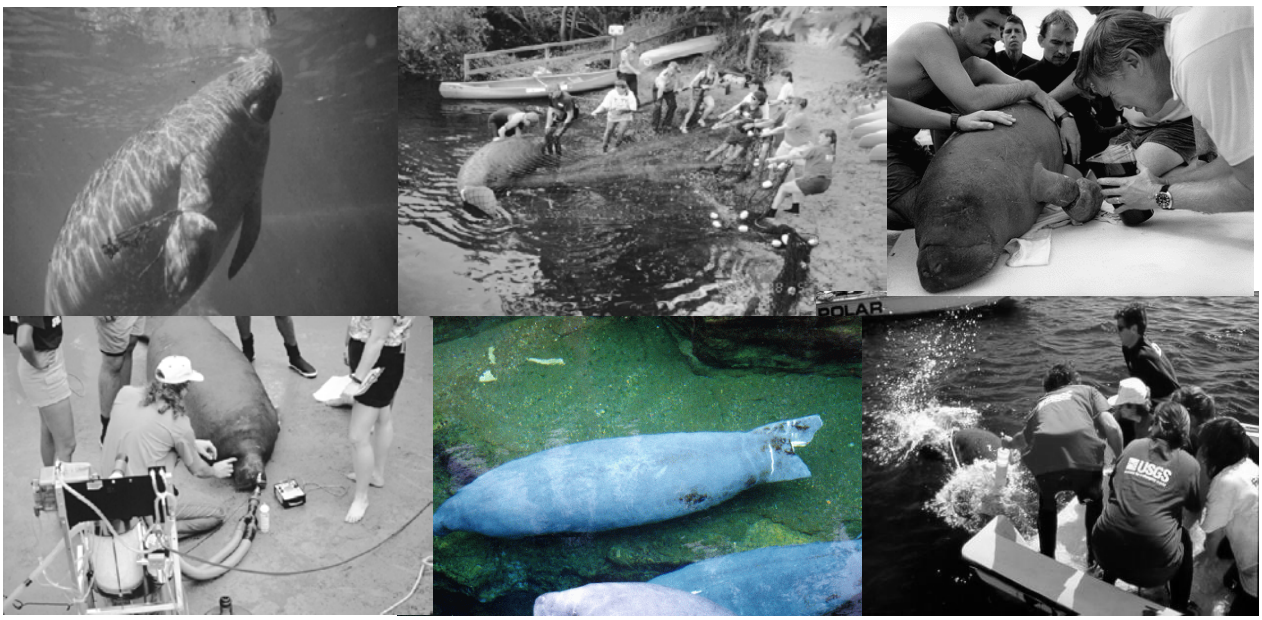


Figure 16. Manatee rescue, rehabilitation, and release program. (*Photographs by G. Rathbun, C. Shaw, J. Reid, Miami Seaquarium, J. Pennington, and J. Reid*)

Media coverage of manatee rescues, treatments, and releases helps to educate millions of people about manatees, the life-threatening problems that they face, and actions that can be taken to minimize the effect of anthropogenic activities on this species. In addition, more than eighteen million visitors a year see manatees at rehabilitation facilities and participate in manatee education programs sponsored by several parks. The publicity and outreach inherent in this program provide significant support to efforts to recover the manatee.

PUBLIC EDUCATION, AWARENESS, AND SUPPORT Government agencies, industries, oceanaria and environmental groups have all contributed to manatee public awareness and education efforts that were initiated in the 1970s. These efforts have expanded in scope and increased in quantity since that time. Some key counties in Florida also have started the education component of their manatee protection plans.

These public awareness and education efforts encourage informed public participation in regulatory and other management decision-making processes and provide constructive avenues for private funding of state manatee recovery programs, research, and land acquisition efforts through programs such as the specialty automobile license tag for manatees. This particular funding source has resulted in substantial savings in federal and state tax revenues and has permitted important work to proceed which likely would not have been possible in their absence.

The public has been made aware of new information on the biology and status of manatees, urgent conservation issues, and the regulations and measures required to assure their protection through the production of brochures, posters, films and videos, press releases, public service announcements and advertisements, and other media-oriented materials. Outdoor signs have been produced that provide general manatee information and highlight the problems associated with feeding manatees.

Manatee viewing opportunities have also been made available to the public. In addition, volunteers from several organizations annually give presentations to schools and other groups and distribute educational materials at festivals and events. Such efforts are essential for obtaining public compliance with conservation measures to protect manatees and their habitats.

Many public awareness materials have been developed specifically focusing on boater education. Public awareness waterway signs are produced and distributed alerting boaters to the presence of manatees. Brochures, boat decals, boater's guides, and other materials with manatee protection tips and boating safety information have been produced and are distributed by law enforcement groups, through marinas, and boating safety classes. Educational kiosks have been designed and installed at marinas, boat ramps, and other waterfront locations. Fishing line collection sites and cleanup efforts are being established. In addition, the Manatee Awareness Coalition of Tampa Bay and Crystal River NWR have initiated programs for on-water manatee public awareness.

Several agencies and organizations provide educator's guides, posters, and coloring and activity books to teachers in Florida and across the United States. In addition, Save The Manatee Club (SMC) and FWC Advisory Council on Environmental Education have produced a video for distribution to schools throughout Florida and the United States. SMC and FWC also provide free manatee education packets to students and staff interviews for students. Agencies and organizations help to educate law enforcement personnel about manatees and inform them about available outreach materials that can be distributed to user groups.

Public interest in manatee conservation also has grown internationally. Manatee education and public awareness materials are distributed in Central and South America and the wider Caribbean, as well as to numerous other countries around the world.

PART II. RECOVERY

The goal of this revised recovery plan is to assure the long-term viability of the Florida manatee in the wild, allowing initially for reclassification from endangered to threatened status (downlisting) and ultimately removal from the List of Endangered and Threatened Wildlife (delisting).

This section of the Recovery Plan presents: (A) details on an upcoming status review; (B) objective and measurable recovery criteria; (C and D) site-specific management actions to monitor and reduce or remove threats to the Florida manatee; and (E) Literature Cited. The steps for reclassification and removal from the list are consistent with provisions specified under sections 4(a)(1), 4(b), 4(c)(2)(B), and 4(f)(1) of the ESA. The FWS must, to the maximum extent practicable, incorporate into each recovery plan objective, measurable recovery criteria which, when met, would result in a determination that the species be removed from the List of Endangered and Threatened Wildlife. In designing these criteria, the FWS has addressed the five statutory listing/recovery factors (section 4(a)(1) of the ESA, (see page 1) to the current extent practicable.

A. STATUS REVIEW

The 1967 Federal Register Notice (32FR406) designating the West Indian manatee and several other species as "endangered" did not provide a detailed explanation for the listing. Since the manatee was designated as an endangered species prior to enactment of the ESA (1973), there was no formal listing package identifying threats to the species, as required by Section 4(a)(1). Under section 4(c)(2) of the ESA, the FWS is charged with periodically reviewing the the status of species included in the List of Endangered and Threatened Wildlife to determine whether any species should change in status from a threatened species to an endangered species, change in status from an endangered species to a threatened species, or be removed from the List.

During the 20 years since approval of the first manatee recovery plan, a tremendous amount of knowledge has been gained about manatee biology and ecology and significant protection programs have been implemented. The knowledge and the results of these protection programs are reflected in this recovery plan. The Manatee Population Ecology and Management Workshop scheduled for April 2002 will update and review the science and population ecology of manatees, including an assessment of the recovery criteria presented in this plan. The FWS has determined that the year following this workshop is an appropriate time to conduct a thorough status review of the Florida manatee and anticipates this review to take place in 2003.

The review will include:

(1) a detailed evaluation of the population status using the most up to date demographic data and other biological indices available (The FWS anticipates that much of this data will come from the April 2002 Manatee Population Ecology and Management Workshop);
(2) an evaluation of the status of manatee habitat as it relates to recovery;
(3) an evaluation of the existing threats to the species and the effectiveness of existing mechanisms to reduce or remove those threats (e.g., adequate protection areas, signage, enforcement, education and compliance have resulted in a reduction or minimization of watercraft deaths) as prescribed in this recovery plan;
(4) recommendations, if any, regarding reclassification of the Florida manatee; and
(5) if necessary, recommendations to update or modify recovery criteria.

B. RECOVERY CRITERIA

RECLASSIFICATION FROM ENDANGERED TO THREATENED (DOWNLISTING)

The near and long term threats from human-related activities are the reasons for which the Florida manatee currently necessitates protection under the ESA. The focus of recovery is not on how many manatees exist, but instead the focus is on implementing, monitoring and addressing the effectiveness of conservation measures to reduce or remove threats which will lead to a healthy and self-sustaining population. The Florida manatee could be considered for reclassification from endangered to threatened status if the following listing/recovery and demographic criteria are met:

LISTING/RECOVERY FACTOR CRITERIA: Tasks listed with each criterion are examples of actions that may reduce or remove the identified threats and were developed from recovery team discussions.

Listing/Recovery Factor A: The Present or Threatened Destruction, Modification, or Curtailment of a Species Habitat or Range (Habitat Working Group and Warm-water Task Force identified in other portions of this plan are tasked to further refine and improve these criteria.) In order to ensure the long-term recovery needs of the manatee and provide adequate assurance of population stability (i.e., achieving the demographic criteria), threats to the manatee's habitat or range must be reduced or removed. This can be accomplished through federal, state or local regulations (identified in Factor D below) to establish minimum spring flows and protect the following areas of important manatee habitat:

a. Minimum flow levels to support manatees at the Crystal River Spring Complex, Homosassa Springs, Blue Springs, Warm Mineral Spring, and other spring systems as appropriate, in terms of quality (including thermal) and quantity have been identified by the WMDs or other organizations.(Task 3.2.4.3)
b. A network of the level 1 and 2 warm-water refuge sites identified in Figure 7 are protected as either manatee sanctuaries, refuges or safe havens. (Task 1.2.3, 1.3, 3.2.2, 3.2.3, 3.2.4, 3.3.1)
c. Feeding habitat sites (extent, quantity and quality) associated with the network of warm-water refuge sites above in (b) have been identified by the HWG for protection. (Task 3.1(3), 3.3.8).
d. A network of migratory corridors, feeding areas, calving and nursing areas are identified by the HWG to be protected as manatee sanctuaries, refuges and/or safe havens in the following Florida counties: Duval (including portions of Clay and St. Johns in the St. Johns River), Volusia, Brevard, Indian River, Martin, Palm Beach, Broward, Dade and Monroe on the Florida Atlantic Coast; Citrus, Pinellas, Hillsborough, Manatee, Sarasota, Charlotte, Lee and Collier on the Florida Gulf Coast; and Glades County on the Okeechobee Waterway. (Task 1.3, 3.3.1)

Listing/Recovery Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes "Take" in the form of harassment, is currently occurring at some of the winter refuge sites and other locations. This "take" is presently not authorized under the MMPA or ESA. However, there are no data at this time to indicate that this issue is limiting the recovery of the Florida manatee. The actions in this plan that address harassment are recommended in order to achieve compliance with the MMPA and ESA and as a conservation benefit to the species. Statutory mechanisms outlined in Factor D to protect and enact protection regulations for important manatee habitats identified in Factor A and enact regulations to address unauthorized "take" identified in Factor E, will also assist to reduce or remove these threats.

Recovery actions and their subtasks specifically addressing this issue are 1.1, 1.11, 4.4 and those tasks identified in Factors A, D and E.

Listing/Recovery Factor C: Disease or Predation At this time, there are no data indicating that this is a limiting factor, thus no reclassification (downlisting) criteria are necessary.

Listing/Recovery Factor D: The Inadequacy of Existing Regulatory Mechanisms The current legal framework outlined below allows federal and state government agencies to take both broad scale and highly protective action for the conservation of the manatee and its habitat. The FWS believes these regulatory mechanisms are adequate for recovery. However, additional specific actions under these laws such as those listed pursuant to Factor A and E must be accomplished (as well as meeting the demographic criteria) before the FWS will consider this species for reclassification.

Factor A (a) Establish Minimum Flows (Task 3.2.4.3)

STATE Florida Water Resources Act of 1972, Chapter 373, F.S. (specifically Minimum Flows and Levels, Sect. 370.42, F.S. and Establishment and Implementation of Minimum Flows and Levels, Sect. 370.421, F.S.)

Factor A (b)(c) and (d) Protect Important Manatee Habitats (Task 1.2, 1.3.1, 1.3.2, 1.4, 3.2.2, 3.2.3, 3.2.4, 3.3.1, 3.3.8)

FEDERAL Endangered Species Act; Marine Mammal Protection Act; Clean Water Act, Sect. 401, 402 and 404; Rivers and Harbors Act, Sect. 10; National Environmental Policy Act; and Coastal Zone Management Act;

STATE Florida Manatee Sanctuary Act, Sect. 370.12(2), F.S.; Florida Water Resources Act of 1972, Chapter 373, F.S.; Florida Air and Water Pollution Control Act, Chapter 403, F.S.; State Lands, Chapter 253, F.S.; and State Parks and Preserves, Chapter 258, F.S.; and

LOCAL Florida Manatee Sanctuary Act, Sect. 370.12(o), F.S. which allows local governments to regulate by ordinance, motorboat speed and operations to protect manatees.

Factor E (a)(b)(c) Reduce or Remove Unauthorized "take" (Task 1.1, 1.2, 1.3.1, 1.3.2, 1.4, 1.6, 1.7, 3.3.1)

FEDERAL Marine Mammal Protection Act; and Endangered Species Act; and

STATE Florida Manatee Sanctuary Act, 370.12(2), F.S.

Listing/Recovery Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence The most predictable and controllable threat to manatee recovery remains human-related mortality. In order to ensure the long-term recovery needs of the manatee and provide adequate assurance of population stability (i.e., achieving the demographic criteria), natural and manmade threats to manatees need to be reduced or removed. This can be accomplished through establishing the following federal, state or local regulations, tasks and guidelines to reduce or remove human caused "take" of manatees:

a. State safe havens and/or federal manatee refuges have been established by regulation and are being adequately enforced to reduce unauthorized watercraft-related "take" in the following Florida counties: Duval (including portions of Clay and St. Johns in the St. Johns River), Volusia, Brevard, Indian River, Martin, Palm Beach, Broward, Dade and Monroe on the Florida Atlantic Coast; Citrus, Pinellas, Hillsborough, Manatee, Sarasota, Charlotte, Lee and Collier on the Florida Gulf Coast; and Glades County on the Okeechobee Waterway. (Task 1.3, 1.4, 1.5, 3.3.1)
b. One half of the water control structures and navigational locks listed as needing devices to prevent mortality have been retrofitted. (Task 1.6)
c. Guidelines have been drafted to reduce or remove threats of injury or mortality from fishery entanglements and entrapment in storm water pipes and structures. (Task 1.7, 1.6.3)

DEMOGRAPHIC CRITERIA: The annual synoptic surveys have too many weaknesses to reliably guage the health of the population (see discussion of Population Size in the Introduction and in Appendix D). Therefore, the FWS has established population related benchmarks for certain aspects of manatee demographics (based upon mark/recapture studies and population modeling) that it will use to help determine the success of manatee conservation efforts. These are derived from the MPSWG's Recommendation for Population Benchmarks To Help Measure Recovery (Appendix A). While these benchmarks are dependent on the amount and statistical reliability of the data available, we believe these "vital signs" are currently the best scientific indicators of the overall health of the manatee population. If future scientific studies indicate that other survival, reproduction, or population growth rates or other population indices are more appropriate for demographic recovery criteria, the FWS will modify these benchmarks.

The current benchmarks are as follows:

a. statistical confidence that the average annual rate of adult manatee survival is 90 % or greater;
b. statistical confidence that the average annual percentage of adult female manatees accompanied by first or second year calves in winter is 40% or greater; and
c. statistical confidence that the average annual rate of population growth is equal to or greater than zero.

These population benchmarks should be achieved with a 95% level of statistical confidence. When they are achieved in each of the four regions for the most recent ten year period of time (approximately one manatee generation), we may conclude that the manatee is not in danger of extinction throughout all or significant portion of its range and reclassify to threatened, provided the listing/recovery factor criteria (outlined above) are also met.

REMOVAL FROM THE LIST OF ENDANGERED AND THREATENED WILDLIFE (DELISTING)
The Florida manatee could be considered for removal from the List of Endangered and Threatened Wildlife if the following listing/recovery and demographic criteria are met:

LISTING/RECOVERY FACTOR CRITERIA: Tasks listed with each criterion are examples of actions that may reduce or remove the identified threats.

Listing/Recovery Factor A: The Present or Threatened Destruction, Modification, or Curtailment of a Species Habitat or Range (The Warm-water Task Force and Habitat Working Group identified in other portions of this plan are tasked to further refine and improve these criteria.) In order to ensure the long-term recovery needs of the manatee and provide adequate assurance of population stability (i.e., achieving the demographic criteria), threats to the manatee's habitat or range must be reduced or removed. This can be accomplished through federal, state or local regulations to establish and maintain minimum spring flows and protect the following areas of important manatee habitat:

a. Minimum flow levels to support manatees at the Crystal River Spring Complex, Homosassa Springs, Blue Springs, Warm Mineral Spring, and other spring systems as appropriate, in terms of quality (including thermal) and quantity have been adopted by regulation and are being maintained.(Task 3.2.4.3)
b. A network of level 1, 2 and 3 warm-water refuge sites identified in Figure 7 have been protected as either manatee sanctuaries, refuges or safe havens. (Task 1.2.3, 1.3, 3.2.2, 3.2.3, 3.2.4, 3.3.1)
c. Adequate feeding habitat sites (extent, quantity and quality) associated with the network warm-water refuge sites identified by the HWG and are protected. (Task 3.1(3), 3.3.8).
d. The network of migratory corridors, feeding areas, calving and nursing areas identified by the HWG are protected as manatee sanctuaries, refuges or safe havens. (Task 1.3, 3.3.1)

Listing/Recovery Factor B: Overutilization for Commercial, Recreational, Scientific, or Educational Purposes "Take" in the form of harassment, is currently occurring at some of the winter refuge sites and other locations. This "take" is presently not authorized under the MMPA or ESA. However, there are no data at this time to indicate that this issue is limiting the recovery of the Florida manatee. The actions in this plan that address harassment are recommended in order to achieve compliance with the MMPA and ESA and as a conservation benefit to the species. Statutory mechanisms outlined in Factor D to protect and enact protection regulations for important manatee habitats identified in Factor A and enact regulations to address unauthorized "take" identified in Factor E, will also assist to reduce or remove these threats.

Recovery actions and their subtasks specifically addressing this issue are 1.1, 1.11, 4.4 and those tasks identified in Factors A, D and E.

Listing/Recovery Factor C: Disease or Predation At this time, there are no data indicating that this is a limiting factor, thus no delisting criteria are necessary.

Listing/Recovery Factor D: The Inadequacy of Existing Regulatory Mechanisms The current legal framework outlined below allows federal and state government agencies to take both broad scale and highly protective action for the conservation of the manatee and its habitat. The FWS believes these regulatory mechanisms are adequate for recovery. However, additional specific actions under these laws such as those listed pursuant to Factor A and E must be accomplished (as well as meeting the demographic criteria) before the FWS will consider this species for removal from the List of Endangered and Threatened Wildlife.

Factor A (a) Establish Minimum Flows (Task 3.2.4.3)

STATE Florida Water Resources Act of 1972, Chapter 373, F.S. (specifically Minimum Flows and Levels, Sect. 370.42, F.S. and Establishment and Implementation of Minimum Flows and Levels, Sect. 370.421, F.S.)

Factor A (b)(c) and (d) Protect Important Manatee Habitats (Task 1.2, 1.3.1, 1.3.2, 1.4, 3.2.2, 3.2.3, 3.2.4, 3.3.1, 3.3.8)

FEDERAL Marine Mammal Protection Act; Clean Water Act, Sect. 401, 402 and 404; Rivers and Harbors Act, Sect. 10; National Environmental Policy Act; and Coastal Zone Management Act;

STATE Florida Manatee Sanctuary Act, Sect. 370.12(2), F.S.; Florida Water Resources Act of 1972, Chapter 373, F.S.; Florida Air and Water Pollution Control Act, Chapter 403, F.S.; State Lands, Chapter 253, F.S.; and State Parks and Preserves, Chapter 258, F.S.; and

LOCAL Florida Manatee Sanctuary Act, Sect. 370.12(o), F.S. which allows local governments to regulate by ordinance, motorboat speed and operations to protect manatees.

Factor E (a)(b)(c) Reduce or Remove Unauthorized "take" (Task 1.1, 1.2, 1.3.1, 1.3.2, 1.4, 1.6, 1.7, 3.3.1)

FEDERAL Marine Mammal Protection Act; and

STATE Florida Manatee Sanctuary Act, 370.12(2), F.S.

Listing/Recovery Factor E: Other Natural or Manmade Factors Affecting Its Continued Existence The most predictable and controllable threat to manatee recovery remains human-related mortality. In order to ensure the long-term recovery needs of the manatee and provide adequate assurance of population stability (i.e., achieving the demographic criteria), natural and manmade threats to manatees need to be removed or removed. This can be accomplished through establishing the following federal, state or local regulations, tasks and guidelines to reduce or remove human caused "take" of manatees:

a. State, federal and local government manatee conservation measures (such as, but not limited to speed zones, refuges, sanctuaries, safe havens, enforcement, education programs, county MPPs etc.) have been adopted and implemented to reduce or remove unauthorized watercraft-related "take" in the following Florida counties: Duval (including portions of Clay and St. Johns in the St. Johns River), Volusia, Brevard, Indian River, Martin, Palm Beach, Broward, Dade and Monroe on the Florida Atlantic Coast; Citrus, Pinellas, Hillsborough, Manatee, Sarasota, Charlotte, Lee and Collier on the Florida Gulf Coast; and Glades County on the Okeechobee Waterway. These measures are not only necessary to achieve recovery, but may ultimately help to comply with the MMPA. (Task 1.3, 1.4, 1.5, 3.3.1).

   Stable or positive population benchmarks as outlined in the demographic criteria provide measurable population parameters that will assist in measuring the stabilization, reduction, or minimization of watercraft related "take." Two other indices (weight of evidence) will assist in measuring success include: (1) watercraft-related deaths as a proportion of the total known mortality; and (2) watercraft-related deaths as a proportion of a corrected estimated population. These and other indices should be monitored.

b. All water control structures and navigational locks listed as needing devices to prevent mortality have been retrofitted. (Task 1.6)
c. Guidelines have been established and are being implemented to reduce or remove threats of injury or mortality from fishery entanglements and entrapment in storm water pipes and structures. (Task 1.7, 1.6.3)

DEMOGRAPHIC CRITERIA: The ESA requires that the FWS, to the maximum extent practicable, incorporate into each recovery plan objective, measurable recovery criteria which, when met, would result in a determination that the species be removed from the List of Endangered and Threatened Wildlife. The MPSWG thus far has not proposed delisting criteria to the FWS "as specific, quantitative habitat criteria have yet to be developed" (Appendix A). In lieu of criteria from the MPSWG, the FWS will use the population benchmarks for reclassification (downlisting) to help determine the long-term success of manatee conservation efforts and recovery. While these benchmarks are dependent on the amount and statistical reliability of the data available, we believe these "vital signs" are currently the best scientific indicators of the overall health of the manatee population. If future scientific studies indicate that other survival, reproduction, or population growth rates or other population indices are more appropriate for demographic recovery criteria, the FWS will modify these benchmarks.

Those benchmarks are as follows:

a. statistical confidence that the average annual rate of adult manatee survival is 90 % or greater;
b. statistical confidence that the average annual percentage of adult female manatees accompanied by first or second year calves in winter is 40% or greater; and
c. statistical confidence that the average annual rate of population growth is equal to or greater than zero.

These benchmarks should be achieved with a 95% level of statistical confidence. When they are achieved in each of the four regions for an additional 10 years after reclassification (an additional manatee generation), we may conclude that the population is healthy and will sustain itself such that the Florida manatee could be removed from the List of Endangered and Threatened Wildlife provided the listing/recovery factor criteria (outlined above) are also met.

C. OUTLINE OF RECOVERY ACTIONS ADDRESSING THREATS

D. NARRATIVE OUTLINE OF RECOVERY ACTIONS

OBJECTIVE 1: Minimize causes of manatee disturbance, harassment, injury, and mortality. Manatees are killed and injured as a result of interactions with boats, water control structures, navigational locks, stormwater pipes, marine debris, and fishing gear. In rare cases, manatees are killed by vandals and poachers. Additional mortalities from natural causes, such as severe cold weather or red tide, may also significantly affect the status of the manatee population. To permit maintenance and/or growth of the manatee population to attain recovery, such causes of mortality, injury, harassment and disturbance must be minimized. This section of the recovery plan identifies activities needed to minimize sources of disturbance, harassment, injury, and mortality.

1.1 Promulgate special regulations for incidental take under the MMPA for specific activities. FWS will evaluate its programs related to watercraft operation and watercraft access facilities and promulgate incidental take regulations under the MMPA for FWS activities (e.g., operation of vessels, managing surface waters and recreation on NWRs, and funding of boat ramps through Federal Aid). The process will lead to appropriate modification to FWS activities to ensure that such activities are minimized to the maximum extent practicable and ensure that these activities will have no more than a negligible impact on the manatee. FWS believes that programs of other federal and state agencies would benefit from a similar review and rule promulgation process.

1.2 Continue state and federal review of permitted activities to minimize impacts to manatees and their habitat. There are three separate processes where state and federal agencies provide biological review in order to minimize impacts to manatees and their habitat. These are: (1) review of permits for development activities (such as marinas, boat ramps, and other boat-related facilities) and dredge and fill activities; (2) review of permits for marine events (boat races and regattas); and (3) review of permits for power plants and other industrial outfalls (authorization to discharge warm water through the NPDES permit). FWS , FWC and GDNR should continue to participate in all of these review processes.

1.2.1 Continue to review coastal construction permits to minimize impacts. Dredge and fill activities and coastal construction of facilities such as marinas or large docks require permits from the COE, environmental resource permits from FDEP or the WMDs, and, in some cases, submerged land leases from Florida's Board of Trustees, and in Georgia from the GDNR Coastal Resources Division. There are several aspects of these development projects that must be considered. First, the construction process itself should be conducted in a way to minimize the direct risk to manatees. Second, the permanent effect of the facility once it is built must be considered. For example, facilities should be designed to minimize shading of submerged aquatic plants. Third, the intended use or indirect effects of the project must also be considered. Marinas, boat ramps, and docking facilities can alter boat traffic patterns and increase boat traffic in specific areas, thus potentially increasing the possibility that manatees will be injured or killed. The effects of that traffic should be considered in the permit evaluation. Finally, the cumulative effect of multiple projects must be taken into account. While the impacts of a small single project may be negligible, multiple small projects may have a cumulative effect as great or greater than single large projects.

FWC will continue to provide assessments and recommendations on permit and submerged land lease applications to FDEP or appropriate WMD. GDNR Wildlife Resources Division will continue to provide assessments and recommendations on permit applications to the Coastal Resources Division. These permitting agencies have specific state statutory obligations to protect listed species and should use the recommendations provided by FWC and GDNR in meeting those obligations. In addition, FWC and GDNR will actively coordinate on an annual basis with the permitting agencies to ensure that the best data are available, that communication remains unimpeded, and that the review process is efficient and effective. FWS will continue to provide consultations, pursuant to section 7 of the ESA and other federal laws to the COE, USCG, and other federal agencies on permit applications where it has been determined that the activity may affect manatees or any other listed species and/or their habitat. This formal review process is a fundamental part of the manatee recovery program and must be continued. (Also refer to Task 3.3.5 regarding regulatory recommendations supporting habitat conservation.)

1.2.2 Minimize the effect of organized marine events on manatees. Marine sport events may also affect manatees, and many of these events require permits from the USCG. Under section 7 of the ESA and other federal laws, the FWS reviews and comments on permit applications where it has been determined that the activity may affect manatees or any other listed species. In order to provide guidance to the USCG regarding the types of events and the locations where manatee conditions are needed, standard draft guidelines were prepared. These are also intended to assist event planners involved in the planning process for boat races, fishing tournaments, water ski events, boat parades, and other organized boating events. The guidelines and standard conditions pertaining to when, where, and under what conditions such events could be held consistent with manatee protection objectives, should be updated and agreed upon by FWS and FWC. These guidelines should be distributed to the USCG groups in Florida. The USCG, in following those guidelines, should consult with FWS on appropriate events. FWC should provide technical expertise and data where needed to assist FWS in the review.

1.2.3 Continue to review NPDES permits to minimize impacts. The NPDES has been approved by the Environmental Protection Agency (EPA) to be implemented by FDEP and GDNR. Power plants and other industries that discharge into state waters are required to obtain a NPDES permit. In Florida, power plants that have the potential to affect manatees because of the attraction of a warm-water discharge are required to have a power plant manatee protection plan (MPP) as part of the permit. FWC works directly with the utilities in the development of the plan. FWC provides a recommendation to FDEP whether to accept, modify, or reject the MPP. FWS also reviews the plan and provides an assessment. This program ensures that issuance of the NPDES permit for discharge of warm water into ambient waters of the State of Florida by powerplants includes FWS- and FWC-approved plans. GDNR Nongame and Endangered Wildlife Program provides an assessment and recommendations to the GDNR Environmental Protection Division on NPDES permits in Georgia. This permit review process should be continued. (Task 3.2.2 provides further discussion of NPDES permits.)

1.2.4 Pursue regulatory changes, if necessary, to address activities that are "exempt," generally authorized, or not covered by state or federal regulations. FWS should look at non-regulated coastal construction projects or projects authorized under general permits to assess their cumulative impact on manatees. FWS should propose changes to existing regulatory programs as appropriate to minimize such impacts.

1.3 Minimize collisions between manatees and watercraft. Significant work is needed to monitor, review, assess needs to update existing protection zones (Task 2.7.2), develop new zones warranted in other areas, and make vessel operators aware of those zones. FWC has the responsibility for developing and amending state waterway speed and access rules to protect manatees. These rules aim to reduce the risk of collisions between manatees and watercraft by considering both manatee use patterns and the needs of the boating public. Further, under the authority of the ESA and MMPA and their implementing regulations at 50 CFR 17, FWS may designate certain waters as manatee protection areas, within which certain waterborne activities will be restricted or prohibited for the purpose of preventing the taking of manatees. Actions to address these needs are discussed below. In addition to these methods, alternative strategies minimizing collisions between manatees and watercraft should be investigated (Tasks 1.5.1, 1.5.2, 2.8.12, and 2.8.16).

1.3.1 **Develop and refine state waterway speed and access rules.** FWC is responsible for developing and amending state waterway speed and access rules to protect manatees under the State of Florida Manatee Sanctuary Act. FWC will monitor and review the effectiveness of existing zones and make appropriate modifications as needed. FWC will establish additional zones, as needed, to protect manatees throughout the state and implement where appropriate.

1.3.2 **Develop and refine federal waterway speed and access rules.** As necessary and appropriate, federal rules should be promulgated and existing rules should be modified in cooperation with the State of Florida and other concerned parties to protect the manatee. Particularly, waterways in or adjacent to NWRs, National Parks, and other federally-managed areas within manatee habitat should be protected as warranted. Under the authority of the ESA and MMPA and their implementing regulations at 50 CFR 17, FWS may establish boating speed and access rules in conjunction with efforts to designate certain waters as manatee sanctuaries (areas where all waterborne activities are prohibited), no entry areas or manatee refuges (areas where certain waterborne activities such as boat speeds may be regulated) (Task 3.3.1).

1.3.3 **Post and maintain regulatory signs.** The effective use of regulatory and informational signs is essential in providing the public with on-site information on manatee protection measures. Sign messages, to the greatest extent possible, should be uniform, understandable, and concise. Sign design and placement should provide for uniformity, rapid identification as a regulatory sign, and should be located at a site where it is readily observable to the target audience. Regulated areas should be posted by the appropriate agency. Of critical need is the continued effort to inspect and repair/replace signs as needed in an expedient manner. A task force, which includes the USCG, FWC, FWS, the navigation districts, and those counties with sign-posting responsibilities needs to be established. This task force should focus on improving the sign-posting and maintenance process and will explore innovative sign designs that would contribute to better compliance and enforcement.

1.4 **Enforce manatee protection regulations.** Enforcement is one the highest priorities for manatee recovery. Compliance with manatee protection regulations will reduce human-caused manatee mortality, particularly that caused by watercraft collisions. Effective enforcement of these regulations is needed to maximize protection efforts and to minimize manatee injuries and deaths.

(Also refer to Task 1.11 and its related tasks regarding enforcement of regulations prohibiting harassment).

1.4.1 Coordinate law enforcement efforts. Enforcement of manatee protection rules is provided by officers of FWS and FWC-DLE, USCG, and local law enforcement agencies, as well as the courts. To ensure compliance with the waterway speed and access rules and with manatee harassment provisions, enforcement capabilities must be expanded and coordinated. Although efforts have increased significantly during the past two years, manatee enforcement operations still must be expanded in both geographic scope and frequency. To meet these needs, federal and state enforcement agencies should take all possible steps to increase funding and heighten agency priority for manatee-related law enforcement activities. Those activities should be maintained at levels commensurate with those of vessel traffic, watercraft-related manatee deaths, and added enforcement responsibilities. To carry out enforcement activities as efficiently and cost-effectively as possible, involved agencies are encouraged to coordinate enforcement efforts. In addition, enforcement agencies should review and assist as possible with the development of new manatee protection statutes and regulations, the posting of manatee regulatory signs, enforcement training seminars, studies to monitor regulatory compliance, and actions by the judiciary to prosecute violations.

1.4.2 Provide law enforcement officer training. Law enforcement officers responsible for enforcing manatee regulations need to receive training in order to acquire knowledge and skills to enhance their abilities. Officers should be given training on manatee regulations during appropriate agency training courses. Refresher training should be conducted annually at appropriate opportunities.

1.4.3 Ensure judicial coordination. Designated personnel will meet periodically with members of the judiciary to ensure their knowledge of present manatee protection regulations or changes thereto, as well as to provide a forum for information exchange.

1.4.4 Evaluate compliance with manatee protection regulations. Compliance with manatee protection regulations is paramount to their subsequent success. FWS, FWC, and local governments should evaluate compliance with manatee protection regulations through research, surveys and other methods to ensure effectiveness and to identify needed improvements (Task 2.7.2.2.).

1.4.5 **Educate boaters about manatees and boater responsibility.** State-wide speed limits, boat operator licenses, and mandatory boater education will enhance efforts to reduce watercraft-related manatee deaths by offering opportunities to educate boaters about rules to protect manatees and to reduce boat speeds in other areas where manatees may occur. New proposals to establish state-wide boating safety measures should be encouraged. Particular efforts should be made to integrate manatee protection concerns into any new boater education programs (Tasks 4.1 through 4.3.). A website should be developed to allow the public and boating community easy access to manatee protection zone information (Task 4.2.2).

1.4.6 **Evaluate effectiveness of enforcement initiatives.** In recent years, both federal and state agencies have been using targeted enforcement strategies in an attempt to increase boater compliance with speed zones and ultimately reduce manatee injuries and death. FWS strategy has been to allocate significant enforcement manpower to specific areas on designated weekends. These enforcement teams travel to various locations around the state, with particular emphasis given to those zones within counties where there is a history of high watercraft-caused manatee deaths. FWC has increased its emphasis on enforcement and compliance with manatee speed zones by adding new officers, conducting law enforcement task force initiatives, increasing overtime, and increasing the proportion of law enforcement time devoted to manatee conservation. FWS and FWC should evaluate the effectiveness of these and other enforcement efforts and make adjustments, as appropriate. The research should evaluate if there are significant changes in boater compliance as a result of additional enforcement, and determine the residual effect of the enforcement efforts, if any.

1.4.7 **Provide updates of enforcement activities to managers.** It is important for managers to have a good understanding of enforcement activities and special initiatives in order to determine if the desired outcomes (reduction of manatee injury/death and enhanced public awareness and compliance) are achieved. In addition, up-to-date information on enforcement activities is needed for outreach and media contacts. As part of a new manatee enforcement initiative, FWC provides updates of manatee-related enforcement every other week to FWC managers. Such data summary and distribution should continue. Other law enforcement agencies also should provide similar updates of their special enforcement details. Information provided in the updates should be standardized across agencies so that a law enforcement database can be developed to provide information on effort, number of citations and/or other contacts, vessel registration, size, type, disposition of the case, and other pertinent information.

1.5 **Assess and minimize mortality caused by large vessels.** Large vessels (e.g., tugs and cargo vessels) and large displacement hull vessels are known to kill manatees. Some animals appear to be pulled into propeller blades by the sheer power of generated water currents, while others are crushed between the bottom and the hull of deep draft ships. When moored, large vessels also can crush manatees between their hulls and adjacent wharves or ships.

1.5.1 **Determine means to minimize large vessel-related manatee deaths.** Studies should be undertaken to: (1) further review mortality data for evidence of deaths attributable to large vessels; (2) examine barge, tug, and other large vessel traffic patterns relative to manatee distribution; (3) assess the feasibility and cost of installing propeller guards or shrouds on large displacement hull vessels or tugs routinely plying waterways used by manatees; (4) evaluate ways to educate harbor pilots about threats large vessels pose to manatees; and (5) identify other possible mitigation measures to minimize these threats. Actions to implement appropriate measures should be taken based on study findings.

1.5.2 **Provide guidance to minimize large vessel-related manatee deaths.** FWS and FWC will promote use of devices such as fenders to maintain minimum stand-off distances of four feet at maximum compression between moored vessels and between vessels and wharves to minimize manatee deaths. If studies support actions to address the threat of large vessel propeller-related incidences to manatees, it is recommended that propellers of large displacement hull vessels, particularly tugs that tend to remain in harbors or rivers, be retrofitted with a propeller guard or shroud to reduce these types of mortalities.

1.6 **Eliminate manatee deaths in water control structures, navigational locks, and drainage structures.** The second largest source of human-related manatee death is due to entrapment in water control structures and navigational locks. These structures are owned and operated by the WMDs, COE, and FDEP and are primarily located in South Florida. They have been responsible for an average of 10 manatee deaths per year since 1995 and a total of 167 deaths since 1976. An ad hoc interagency task force was established in 1991 (current members include South Florida WMD, COE, FWS, DERM, FWC, and FDEP) to examine steps to prevent such deaths. This group meets at least twice a year to discuss recent manatee deaths and measures to protect manatees from structure-related mortality. The overall goal is to eliminate completely structure-related deaths.

In addition to causing crushing deaths, manatees may become trapped in the extensive canal systems of south Florida. Manatees passing through open structures become trapped once the structures close, due to changing water conditions. Manatees trapped in the shallow canal systems are vulnerable to cold stress during the winter. An evaluation and mapping of manatee-accessible canals is needed, and actions should be taken to prevent manatee entry into these areas.

FWS also should assess the need for manatee protection technology and help to update standard operating procedures at the lock systems at Lake Moultrie, South Carolina and Lake Seminole, Florida/Georgia.

Entrapment in drainage structures such as pipes, culverts and ditches also lead to injury and death of manatees. Installation of barriers or guards on such structures can prevent future entrapments.

1.6.1 Install and maintain protection technology at water control structures where manatees are at risk and monitor success. Pressure sensor devices have been installed at the five water control structures in south Florida through a South Florida WMD/COE cooperative project. Although the success of these devices generally has been encouraging, two structures equipped with the device have failed to eliminate all manatee deaths at them. An investigation at S-25B, after two deaths in December 1999, revealed that modifications to the sensitivity were required to provide the needed protection for manatees; after a manatee death at S-27 in January 2000, the South Florida WMD moved the manatee sensor strips in an attempt to get them closer to the actual gate. Thus, while it has been demonstrated that manatees can be successfully protected through the installation of pressure devices at water control structures, it is possible that as more devices are installed and operated, occasional failures will occur until all site-specific maintenance and installation needs are identified and resolved.

Twenty identified water control structures should be equipped with a manatee protection system (MPS) (pressure devices or removable barriers) by the year 2004. Removable barriers should be installed at structures where the pressure sensor devices are not feasible or appropriate. Standard operating procedures to protect manatees also have been developed for periods when the barriers are removed for high flow or cleaning the debris off the barriers. MPSs will be installed at additional water control structures in the Central and South Florida Project on a case-by-case basis as part of the Comprehensive Everglades Restoration Plan (CERP), and standard operating procedures and the need for a MPS should be assessed and installed as needed for other structures in manatee habitat.

The FDEP is designing and preparing to install barriers at the Kirkpatrick Dam, the tainter valve culvert pipes at Buckman Lock, and the downstream side of Inglis Lock. FDEP anticipates to complete this work during the summer of 2001.

1.6.2 **Install and maintain protection technology at navigational locks where manatees are at risk and monitor success.** Manatee protection devices have been installed at the St. Lucie, Port Canaveral, and Taylor Creek Locks. The long-term plan is to continue installing these protective devices on the remaining locks in order of their potential to harm manatees until all such structures are equipped with manatee protection devices. The COE should continue to partner with local sponsors to accomplish this retrofitting as quickly as possible. The COE should prepare an annual report assessing the performance of the manatee protection devices and evaluating the needs for modification and improvement.

FDEP has contracted with HBOI to install an acoustic array system at Buckman Lock similar to arrays installed at the COE's Canaveral and St. Lucie Locks. FDEP plans to reopen Buckman Lock for operation once the manatee protection systems are installed on both the Buckman Lock and Kirkpatrick Dam. It is anticipated that these projects will be completed during the summer of 2001 (the State of Florida has also budgeted $800,000 to begin restoring the Oklawaha River). Currently FDEP's Inglis Lock at Lake Rouseau/Withlacoochee River is not operating; long-term plans are to replace the existing lock with a smaller one which includes manatee protection equipment.

1.6.3 **Minimize injuries and deaths attributable to entrapment in drainage structures.** Sites where manatees have been rescued or died due to entrapment in drainage structures should be identified and, as warranted, steps taken to install barriers or guards which prevent such entrapment at these culverts or drainage structures. Additionally, stormwater outfalls or similar drainage structures in aggregation areas should be retrofitted with appropriate barriers to prevent manatee entrapment. Federal, state, and local permits should require that new drainage structures (greater than 18 but less than 84 inches in diameter) in manatee habitat be grated or otherwise made inaccessible to manatees.

1.6.4 **Assess risk at existing and future water control structures and canals in South Florida.** Using existing data bases and/or field inspections, categorize all structures as to whether manatees could pass through the structure, and what level of risk the structure poses. Similarly, characterize all canals (including minor irrigation ditches and storm water connector canals) as to whether manatees have access. Based on interagency recommendations, some canals may be designated as off-limits to manatees. The South Florida WMD should establish manatee-safe barriers to prevent access to designated areas. The CERP will dramatically alter the water delivery system in south Florida. New canals and water retention areas will be created, and existing canals will be modified or eliminated. It is critical that the COE and South Florida WMD coordinate closely with FWS and FWC and consider impacts to manatees from this long-range restoration project. Only manatee-safe structures should be installed, and manatee access to newly-created areas should be evaluated by the interagency task force.

1.7 Minimize manatee injuries and deaths caused by fisheries and entanglement. Due to the dynamic nature of commercial and recreational fishing and gear, information on interactions with fishing techniques and gear should be kept under review by FWS, GDNR, and FWC, and measures to reduce or avoid such interactions should be taken. This review should also assess the impacts of the mariculture industry and develop recommendations to minimize impacts to manatees and habitat. To minimize adverse entanglement interactions, the following steps are needed. A working group, which was established in 1999 to address fishery and marine debris and to make recommendations to minimize impacts, should continue to meet regularly.

1.7.1 Minimize injuries and deaths attributed to crab pot fishery. With the recent increasing trend of manatee rescues from crab trap buoy lines, information on interactions with buoy lines should be kept under review by FWC and FWS, and steps should be taken to improve reporting and documentation of such incidents. Steps to identify and implement measures which would reduce or avoid such interactions should be taken, including research regarding gear interactions and ways to avoid them, outreach, and promulgation of regulations (e.g., gear modification) if necessary.

1.7.2 Minimize injuries and deaths attributed to commercial and recreational fisheries, gear, and marine debris. Sites where interactions with recreational and/or commercial fishing gear occur should be identified and, as warranted, steps should be taken to assess and implement actions to prevent potentially threatening interactions with fishing gear. Strategies to reduce monofilament entanglements also need to focus on educating the fishing community on properly discarding monofilament and provide an avenue for recycling it. Strategies also should encourage underwater and drift line debris clean-up of monofilament and other debris in popular fishing areas used by manatees (Task 2.7.4).

1.8 **Investigate and prosecute all incidents of malicious vandalism and poaching.** Poaching, shooting, butchering, and other malicious vandalism against manatees are rare occurrences. All reports and evidence regarding such incidents should be turned over to FWS law enforcement agents for investigation and prosecution to the fullest extent of the law.

1.9 **Update and implement catastrophic plan.** FWS and FWC Contingency Plans for Catastrophic Rescue and Mortality Events for the Florida Manatee should be reviewed annually and updated as needed by those who would be involved in the response. Additionally, guidance and notification procedures between FWC and FWS should be developed and updated as needed for events that do not reach unusual or catastrophic levels in order for such events to be documented.

1.10 **Rescue and rehabilitate distressed manatees and release back into the wild.** Thousands of reports have been provided by the public regarding sick, injured, orphaned, entrapped, and wayward manatees that appear to be in need of assistance. While many clearly do not require intervention, 30 to 40 manatees are rescued every year. Some are assisted and immediately released, while others are taken to one of three critical-care facilities for supportive treatment. Animals successfully treated are released, and to the extent possible, their progress is monitored through tagging and tracking studies. Publicity surrounding distressed manatees, their rescues, treatment, and outcome help to educate millions of people every year about manatees and the problems that they face. The number of manatees successfully treated and released back into the wild provides an important safeguard to the wild population of manatees.

1.10.1 **Maintain rescue network.** FWS is responsible for the rescue and rehabilitation network and coordinates this program through an endangered species/marine mammal enhancement permit. Participants are authorized to participate in the program through Letters of Authorization (LOAs) under the permit held by FWS Jacksonville Field Office. Letter holders: (1) verify the status of manatees reportedly in distress; (2) rescue and/or transport rescued manatees; and (3) treat and maintain distressed manatees. The terms and conditions of the LOA describe the letter holders' level of participation and responsibilities in the program, based on their level of experience and resources. FWS must retain a current permit to authorize these activities and must maintain, update, and modify participant LOAs. As needs and circumstances dictate, letter holders may be added or removed from the program.

To ensure prompt, effective responses to distressed manatees, a rescue coordinator is needed to coordinate and mobilize rescue network teams. FWC 's FMRI maintains a network of field stations to conduct manatee research throughout the state. Field station activities are coordinated through the FMRI's Marine Mammal Pathobiology Laboratory's manager, who acts as the rescue coordinator. FMRI's existing network of staff, resources, and contacts with local law enforcement officials (and others likely to receive reports of distressed manatees) provides the necessary infrastructure for the program. Reports of distressed animals are directed to the rescue coordinator and his/her staff, who in turn contact authorized participants to respond. FWS is notified of ongoing rescues and unusual or significant events, as appropriate. GDNR maintains similar capabilities through its Nongame and Endangered Wildlife Program in their Brunswick, Georgia office.

1.10.2 Maintain rehabilitation capabilities. Adequate facilities are needed to place and treat injured animals. Every year, there are approximately 50 manatees in captivity at any given time, including manatees receiving critical and long-term care treatment. In 2000, there were three critical-care and six long-term care facilities treating manatees, including three out-of-state facilities. In order to maintain our ability to treat distressed manatees, critical care space must be available for these animals. While every effort is made to release treated manatees in a timely manner, some animals are not immediately releasable. Manatees that cannot be released quickly may be transferred to long-term care facilities to make room for critical-care cases. When necessary, existing facilities may expand their holding areas, or additional facilities may be authorized to create room for long-term care cases. Critical-care facilities provide the resources needed to conduct these activities; some costs are statutorily defrayed throughout the State of Florida.

1.10.3 Release captive manatees. As manatees complete the rehabilitation process, their medical status is reviewed by respective facility veterinarians in anticipation of their release. Following this review of physical and behavioral parameters, facility veterinarians recommend that the animal is either ready for release or should be retained for further supportive care. If an animal is deemed healthy, FWS (with input from the Interagency Oceanaria Working Group (IOWG)) evaluates the status of the animal in the context of captive release guidelines and determines whether or not the animal should be released. When an animal is deemed releasable, a release site and release date are identified, and appropriate follow-up monitoring plans are selected. The animals are then transported to the selected site and released. Follow-ups are then conducted, relying on either active monitoring (in which the animals are tagged with satellite, very high frequency (VHF), and/or sonic tags and tracked via satellite and in the field) or passive monitoring (which relies on marking the animals with PIT tags and freeze-brands or by their unique, distinctive markings). These animals are then monitored opportunistically in the field during field studies and/or through the carcass salvage program. Methods identified during a 1998 captive release workshop should be implemented to improve survival rates for released captives. Behavioral parameters need to be evaluated to assess their value in the captive release process.

1.10.4 Coordinate program activities. In addition to authorizing network participants, FWS coordinates many of the day-to-day needs of the program. All transfers and releases, research proposals, and follow-up monitoring plans, program concerns, etc., are evaluated and acted upon by FWS. Many of these are discussed and resolved through the IOWG, which meets twice a year to coordinate rescue, rehabilitation, and release activities and to manage captive program activities to meet manatee recovery objectives. Inherent in this are reviews on the status of rescue and rehabilitation activities, record keeping, development and review of rescue, transport, rehabilitation, maintenance, and release methods, informational exchanges, etc. A product of these meetings will include the development of an annual work plan describing projected releases and monitoring activities.

1.10.5 Provide assistance to international sirenian rehabilitators. Manatee rescue and rehabilitation activities in the United States and Puerto Rico are characterized by more than 30 years of experience and expertise. Rescue and transport techniques, medical practices, and release protocols have been successfully developed and are models for similar efforts. These experiences and expertise should be shared with other countries developing manatee and dugong rescue and rehabilitation programs.

1.10.6 Provide rescue report. An annual report summarizing each year's rescue and rehabilitation activities will be prepared consistent with the requirements of FWS's endangered species/marine mammal enhancement permit. In the interim, monthly updates will be made available to program participants through FWS's internet website.

1.11 Implement strategies to eliminate or minimize harassment due to other human activities. In some cases, human activities (e.g., fishing, swimming, snorkeling, scuba diving, manatee observation, and provisioning) may also disturb, alter behavior or harass manatees. Such disturbance could be life-threatening to manatees, for example, if it occurs in warm-water refuges and animals subsequently move into colder waters. Areas of such conflict should be identified and management actions implemented in order to reduce negative impacts on manatees. Harassment of manatees is considered a form of take as defined in both the ESA and MMPA. Any activity that results in a change of natural behavior which could create harm to the animal is considered take. Most waterborne activities, as well as some upland activities, have the potential to disturb and harass manatees. The following efforts are needed to minimize the impact of these activities.

1.11.1 Enforce regulations prohibiting harassment. Where clear and convincing evidence of harassment is occurring, enforcement of regulations controlling such activities is needed.

1.11.2 Improve the definition of "harassment" within the regulations promulgated under the ESA and MMPA. The current definition of harassment is very vague, making it difficult to enforce. Regulatory definitions need to be amended to specify, to the greatest extent practicable, what actions and activities constitute manatee harassment.

OBJECTIVE 2: Determine and monitor the status of manatee populations. The success of efforts to develop and implement measures to minimize manatee injury and mortality depends upon the accuracy and completeness of data on manatee life history and population status. Population data are needed to identify and define problems, make informed judgments on appropriate management alternatives, provide a sound basis for establishing and updating recovery criteria and management plans, and to determine whether or not actions taken are achieving management objectives. The tasks outlined below are essential to a complete understanding of manatee population status and trends. For all tasks, publication of peer-reviewed results is the preferred method of information dissemination. A detailed research plan is presented in Appendix D and includes informative background information and more detail than is presented here in the narratives.

2.1 Continue the MPSWG. The interagency MPSWG was established in March 1998 as a subcommittee of the recovery team. The group's primary tasks are to: (1) assess manatee population trends; (2) advise FWS on population criteria to determine when species recovery has been achieved; and (3) provide managers with interpretation of available information on manatee population biology. The group also has formulated strategies to seek peer review of their activities. The MPSWG should continue to hold regular meetings, refine recovery criteria, annually update regional and statewide manatee status statements, convene a population biology workshop early in 2002, analogous to the one held in 1992, and publish the results of the workshop.

2.2 Conduct status review. After the Population Status Workshop referenced in Task 2.1 is held, FWS will conduct a status review of the Florida manatee. The review will include: (1) a detailed evaluation of the population status using the benchmark data obtained from the 2002 Population Biology Workshop; (2) an evaluation of the status of manatee habitat as it relates to recovery-based information obtained from the HWG; (3) an evaluation of existing threats to the species and the effectiveness of existing mechanisms to control those threats; (4) recommendations, if any, regarding reclassification of the Florida manatee from endangered to threatened; and (5) objective, measurable criteria for delisting.

2.3 **Determine life history parameters, population structure, distribution patterns, and population trends.** Population research and data are needed to determine the status of the Florida manatee population. Data collection should be focused so that information on manatee sightings, movement patterns, site use and fidelity, and reproductive histories all can be utilized for further analyses of manatee survival and reproductive rates. Tools which should be continued as a means of gathering these data include: (1) the Manatee Individual Photo-identification System (MIPS); (2) the carcass salvage program; (3) PIT-tagging; (4) telemetry studies; and (5) aerial survey. It is particularly important to utilize these tools at important wintering sites, areas of high use, and poorly-studied regions.

2.3.1 **Continue and increase efforts to collect and analyze mark/recapture data to determine survivorship, population structure, reproduction, and distribution patterns.** Photographs using standardized protocols for data collection and coding should be collected annually and documented in the field, especially at the winter aggregation sites; these efforts should be expanded, particularly in Southwest Florida. In addition, PIT tags should be inserted under the skin of all manatees that are captured during the course of ongoing research or rescue/rehabilitation. All manatees captured, recaptured, rescued, or salvaged should be checked for PIT tags and other identifying information, because these data provide an additional source of life history information (changes in manatee size, reproductive status, and general condition between time of tagging and recovery). Methods for reliably checking for PIT tags on free-swimming manatees should be developed and tested, and plans should be developed for re-examining the utility of PIT-tagging manatees of certain age classes (juveniles and subadults) or in specific areas where photo-ID is not a feasible way to re-identify individuals.

Analyses using mark-recapture modeling procedures to estimate annual survival rates should be updated annually, utilizing data in MIPS and comparing results to analyses of PIT tag data. To enhance the accuracy and precision of survival estimates, dead manatees previously identified by photographic documentation must be noted in the MIPS database before mark-recapture analyses are undertaken. This research should include estimates of sample sizes required to determine population traits, such as survival and reproductive rates.

Additionally, emphasis should be placed on estimating variance and 95% confidence intervals.

Concurrently with data collection and monitoring, it is important to conduct long-term studies of reproductive traits and life histories of individual females. Such studies would provide information on: (1) age at first reproduction; (2) age-specific birth rates; (3) calving interval; (4) litter size; and (5) success in calf-rearing. The relative success of severely- and lightly-scarred females in bearing and rearing calves also should be determined.

2.3.2 Continue collection and analysis of genetic samples to determine population structure and pedigree. Collection of tissue samples from salvage specimens and from living manatees at winter aggregation sites, captured during research, or rescued for rehabilitation should continue. Continued genetic analysis through collaborations with state and federal genetics laboratories may reveal greater population structure than has been demonstrated thus far (i.e., a significant difference between east and west coasts, but not within coasts). Such research will improve our ability to define regional populations and management units. Stock and individual identity for forensic purposes ultimately will be possible. Analytical techniques recently developed for identifying the structure of other marine stocks should be investigated.

Paternity cannot be established in wild manatees without the ability to determine family pedigrees. This information is needed to determine if successful reproduction is limited to a small proportion of adult males, which has important implications for the genetic diversity of the Florida manatee population. By continuing the development of nuclear DNA markers, pedigree analysis can be applied to the growing collection of manatee tissue samples. Pedigree analysis also would improve greatly our knowledge of matrilineal relationships and female reproductive success. Identification of factors associated with successful breeding by males is important in assessing reproductive potential in the wild and in captivity.

2.3.3 Continue carcass salvage data analysis to determine reproductive status and population structure. Information and tissue samples collected from all carcasses recovered in the salvage program to determine reproductive status should be continued. Resulting estimates of reproductive parameters complement information obtained from long-term data on living manatees and will help to determine trends and possible regional differences in reproductive rates. The salvage program yields important information on the manatee population sex ratio and proportion of age classes (adult, subadult, juvenile, and perinatal) within each cause-of-death category. Annual changes in these proportions may indicate increases or decreases in certain types of mortality, and thus should be considered as part of the weight of evidence that supports (or rejects) a reclassification decision. Ear bone growth-layer-group analysis should be continued to determine more precise ages of dead manatees, particularly those that have a known history through the MIPS database, telemetry studies, or PIT tag data. Although the age structure of the carcass sample is biased toward younger animals, opportunities may occur to document better the natural age structure within specific regions because of age-independent mortality events.

2.3.4 Continue and improve aerial surveys and analyze data to evaluate fecundity data and to determine distribution patterns, population trends, and population size. Aerial surveys provide limited information on the proportion of calves to adults, which may provide insights on reproductive trends when a long time-series of surveys have been conducted by one or relatively few individuals in the same geographic regions. Calf counts from such surveys should be continued and should be compared to those obtained by photo-ID methods.

As appropriate and possible, local and regional aerial surveys should be undertaken or continued to improve information on habitat use patterns and changes in distribution. Documentation of changes in distribution at power plants will be particularly important when changes in warm water availability occur.

Methods to correct for various types of visibility bias in surveys should be developed. Standard procedures for survey teams involved in annual statewide surveys need to be developed and implemented. Where appropriate, strip transect aerial surveys should be used, as it is possible to use this type of survey data to detect regional population trends. Specifically, strip transect surveys should be continued on an annual basis in the Banana River, and their feasibility should be investigated in remote coastal areas of Southwest Florida. To the extent possible, all aerial surveys should be designed to estimate accurately a minimum population number.

2.3.5 Continue collection and analysis of telemetry data to determine movements, distribution, habitat use patterns, and population structure. Multi-year telemetry studies have been completed for the Atlantic coast and Southwest Florida from Tampa Bay through Lee County, and research findings have been summarized in manuscripts currently undergoing peer review. Radio-tracking has provided substantial documentation of seasonal migrations, other long-distance movements, and local movements that reveal patterns of site fidelity and habitat use. Such information is needed from each region, particularly Southwestern Florida and the Everglades and areas where anticipated changes are likely to impact manatees, in order to develop management strategies for all significant subgroups within the regional population, however transitory they may be.

Steps should be undertaken to incorporate geographic positioning system (GPS) technology into telemetry studies to improve the accuracy of manatee location data. Such improvements will be helpful in studying precise habitat-use patterns (e.g., the extent to which manatees use marked boat channels verses waterway margins for travel) and the location of preferred foraging sites, especially around warm-water refuge sites.

2.3.6 Continue to develop, evaluate, and improve population modeling efforts and parameter estimates and variances to determine population trend and link to habitat models and carrying capacity. Uncorrected aerial survey data do not permit statistically valid population estimation or trend analysis. Models to correct for the inherent bias and uncertainty have been developed, and these efforts need to be continued.

It also is important to utilize models such as that developed by Eberhart and O'Shea (1995). The underlying assumptions of a population model, the importance of parameters used in the model, the accuracy and uncertainty of the parameter estimates, the relationships of the parameters, and the appropriateness of the mathematics implemented in the model need to be critically evaluated and updated. Also, comparisons need to be made between predicted outcomes of a model and estimates or indices of population trend from other modeling efforts or other data sets. Steps should be taken to improve and to develop more complex models incorporating additional life history information and which better reflect our understanding of the processes involved in population dynamics.

Where estimates of model parameters need to be developed or improved, other relevant tasks should be modified or strengthened. Because parameters can vary over space and time and such variation affects population growth rates, emphasis should be placed on estimating variance and 95% confidence intervals along with developing best estimates of particular population parameters.

It is important for those developing manatee population models to coordinate their activities and to interact directly with research biologists who have collected manatee life history data or who are very familiar with manatee ecology. Interaction with management also is needed to help focus the questions addressed by present and future modeling efforts. Estimates of the number of manatee deaths that can be sustained per region, while still allowing population stability or growth to be achieved are needed. Coordination is needed to develop better models that meet the needs of manatee biologists, policy makers, and managers. The MPSWG is best positioned to track research developments, link important players, and provide one level of peer review and evaluation. Additional peer review from other internal and external sources also is essential.

As manatee habitat requirements are documented and recovery criteria are identified (based on habitat needs) (Task 3.1.1), it will become possible to link regional population and habitat models and estimate optimum sustainable populations for regions. Integration of population and habitat information is essential to understand the implications of habitat change before negative impacts on manatee population trends can occur. The MPSWG and Geographic Information System (GIS) Working Group should meet jointly on an annual basis to coordinate their activities and progress. Summary reports of these meetings should be distributed to all agencies and interested parties involved in manatee recovery efforts.

2.3.7 **Conduct a PVA to help assess population parameters as related to the ESA and MMPA.** The FWS should conduct a PVA and/or other modeling exercises to: determine minimum viable population(s); model effects of various scenarios of stochastic events; determine consequences of losses of industrial warm-water refuge sites; further test and refine demographic recovery criteria; and assist in determination of negligible impacts under the MMPA.

2.4 **Evaluate and monitor causes of mortality and injury.** The manatee salvage/necropsy program is fundamental to identifying causes of manatee mortality and injury and should be continued. The program is responsible for collecting and examining virtually all manatee carcasses reported in the Southeastern United States, determining the causes of death, monitoring mortality trends, and disseminating mortality information. Program data are used to identify, direct, and support essential management actions (e.g., promulgating watercraft speed rules, establishing sanctuaries, and reviewing permits for construction in manatee habitat).

The current manatee salvage and necropsy program components are: (1) receiving manatee carcass reports from the field; (2) coordinating the retrieval and transport of manatee carcasses and conducting gross and histological examinations to determine cause of death; (3) maintaining accurate mortality records; and (4) carrying out special studies to improve understanding of mortality causes, rates, and trends. The carcass salvage program should continue to: (1) describe functional morphology of manatees; (2) assess certain life history parameters of the population; and (3) collect data on survival of known individuals.

To improve the program, FWC should continue to hold manatee mortality workshops to review critically its salvage and necropsy procedures and methods. These workshops: (1) establish and improve “state-of-the-art” forensic techniques, specimen/data collection, and analyses; (2) identify and create projects focusing on death categories that are unresolved; (3) prepare for and assist with epizootics; (4) generate reference data on manatee health; and (5) generate suggestions for attainment of a “healthy” manatee population.

To implement the salvage and rescue program in Florida, FWC maintains a central necropsy facility called the Marine Mammal Pathobiology Laboratory (MMPL) which is located in St. Petersburg. FWC also has three field stations on the east coast situated in Jacksonville, Melbourne, and Tequesta, and one field station on the west coast at Port Charlotte. The GDNR, South Carolina Department of Natural Resources, Louisiana Department of Wildlife and Fisheries, Texas Marine Mammal Stranding Network, University of North Carolina at Wilmington, and others help to coordinate carcass salvages and rescues in other Atlantic and Gulf coast states. FWS and FWC should provide assistance to these manatee salvage and rescue programs through workshops, providing equipment and assistance when possible. The MMPL will maintain and curate the Southeast U.S. Manatee Mortality Database to facilitate management and enhance communication among state agencies and reinforce timely reporting.

2.4.1 Maintain and improve carcass detection, retrieval, and analysis. To the extent possible, the historic mortality database should be reviewed and updated to reflect the cause of death categories currently in used. To estimate the number of unreported manatee carcasses, studies should be done on carcass detection and reporting rates. Studies focusing on carcass drift, rate of decomposition, and how decomposition affects necropsy results should be conducted. Periodic peer reviews should be conducted of necropsy methods, data recording and analysis, and documentation of tissues collected. Selected representative samples should be archived with appropriate national tissue banks. Workshops such as FWC Manatee Mortality Workshop should continue to be conducted to strengthen collaborative research and information sharing. Partnerships with other agencies and process analysis of carcass retrieval protocols should be ongoing to improve efficiency.

2.4.2 Improve evaluation and understanding of injuries and deaths caused by watercraft. Longitudinal studies should be established to examine the effect of boats and boating activity on population growth and reproductive success. Investigations of the characteristics of lethal compared to non-lethal injuries and causes should be developed using data from carcasses and photo-ID records. Another important data set would be that characterizing healing in rescued injured animals; under-reporting of watercraft mortality may occur as individuals die from complications resulting from injuries sustained by boats. Lethal and non-lethal injuries should be investigated to characterize size of vessels, relative direction of movement of vessel, and propeller vs. blunt trauma statistics. Research on mechanical characteristics of skin and bones should be developed to obtain a better understanding of the effects of watercraft-related impacts. Regional studies are needed to characterize boating intensity, types of boats, boating behavior, and boating hot spots in relation to manatee watercraft-related mortality.

2.4.3 Improve the evaluation and understanding of injuries and deaths caused by other anthropogenic causes. Research is needed to continue to assess manatee behavior leading to vulnerability around the water control structures and navigational locks, as well as operational or structural changes that can prevent serious injury or death of manatees. MMPL should continue to associate forensic observations obtained at necropsy with specific characteristics of the particular structure that caused the death.

Commercial fishing is not a major culprit involved in manatee mortality, unlike the case with most other marine mammals. However, manatees have been killed by shrimp trawls and hoop nets, and in recent years injuries and death from monofilament entanglement, hook and line ingestion, and crab pot/rope entanglement have been more prevalent. There is a need to improve the evaluation and understanding of injuries and deaths of manatees caused by commercial and recreational fisheries. To reduce the increasing numbers of fishing gear entanglements, a multi-agency Manatee Entanglement Task Force has been established and should continue to focus on creating changes in data collection protocols, potential technique/gear modifications, innovative tag designs, entanglement research, gear recovery/clean-up, and education/outreach efforts. Research on rates of entanglement, types of gear, and geographical and temporal changes in rates and types of entanglements should be developed. Studies on behavioral characteristics of manatees contributing to entanglement should be pursued. Research on the amount of marine debris in inshore waters should be conducted, particularly where there are high levels of manatee entanglement. Programs to remove marine debris and recycle monofilament line also should be encouraged and continued (Task 1.7.2).

Although no known death or pathology has been associated with toxicants, some concentrations of contaminants have caused concern. Over time, concentrations of chemicals found in manatees from early studies have changed, possibly as a result of the regulation of chemical use. Such changes highlight the need to monitor tissues for chemical residue and also can provide insight into the presence of different or new compounds in the environment. While a broad range of tests have been conducted, there needs to be a greater focus on endocrine disruptor compounds. These compounds can alter reproductive success and have a dramatic effect on population growth.

2.4.4 Improve the evaluation and understanding of naturally-caused mortality and unusual mortality events. By definition, natural causes of mortality are not directly anthropogenic and thus not easily targeted by management strategies. However, some aspects of natural mortality may be influenced by human activities. These activities include but are not limited to: (1) sources of artificial warm water; (2) nutrient loading; and (3) habitat modification.

Cold stress can be a cause or contributing factor to manatee deaths during the winter. Acute cold-related mortality is related to hypothermia and metabolic changes which occur as a consequence to exposure to cold. Research should continue to focus on critical cold air and water temperatures affecting manatee physiology (particularly as it pertains to acute cold- and cold stress-related mortality). To provide important clues as to how manatees deal with cold temperature, future research should study behavioral adjustments to cold (e.g., directed movement to warm-water refuges, time budget during cold periods, and surface resting intervals during warm spells). Research identifying the manatee's anatomical and physiological mechanisms for heat exchange are an important step to understanding the biological limitation of the species. Ancillary research should include identification of natural warm-water sites, because a growing population of manatees may be seasonally-limited by overcrowding at the larger well-known warm-water refuges.

Research is needed to improve our ability to detect brevetoxin in manatee tissues, stomach contents, urine, and blood. At the same time, environmental detection of red tides, their strengths, and the development of retardants are necessary. More advanced immunological research utilizing manatee cell cultures may result in the development of better treatment of manatees exposed to brevetoxin.

Improved methods are needed to subdivide the perinatal category into categories of: (1) clearly fetal; (2) at or near the time of birth; and (3) clearly born. Once these categories are well-defined, analysis can ascertain the life stage subject to the greatest impact, thus allowing for the future development of appropriate management policies. Field research focusing on factors affecting calf survival should be conducted (e.g., age of mother at reproduction, behavior, characteristics of calving areas, and human disturbance).

The FWS and FWC have created complementary manatee die-off contingency plans (Geraci and Lounsbury 1997; FWS 1998) that have been merged into one comprehensive document (FDEP *et al.* 1998). The document contains information and guidance from the two plans together with advice and provisions outlined in the executive summary from Wilkinson (1996). Research and investigations should follow the protocols and recommendations found in the Contingency Plans. In addition, there should be ongoing collection and storage of tissues and samples from healthy and non-mortality event manatees to establish a baseline and to aid interpretation of test results obtained during a catastrophic event and for retrospective studies. Investigators should contact and work closely with other research projects monitoring and evaluating harmful algal blooms. FWC mortality workshops should continue and help to facilitate and develop cooperative arrangements among investigators and institutions.

2.5 **Define factors that affect health, well-being, physiology, and ecology.** Relatively little attention has been paid to the health and well-being of individual manatees, although factors affecting individuals ultimately influence the overall status of the population. There is a need to determine the relatively constant internal state in which factors such as temperature and chemical conditions remain stable and therefore within a range of values that permit the body to function well, despite changing environmental conditions. Stress is part of existence, and not all stress is bad for an individual. However, a stressor can affect homeostasis and health, and thereby precipitate a chain of events that can compromise the survival of an individual. There also is a need to understand the factors that underlie large-scale trends. For example, individual manatees compromised by severe injury or disease may not be able to reproduce successfully. Similarly, sublethal effects of toxicants and even the effects of nutritional, noise-related, and disturbance-related stresses can impair immune function and potentially reduce the ability of individuals to reproduce. Study plans and protocols should be developed, collaborators identified, and results published.

2.5.1 Develop a better understanding of manatee anatomy, physiology, and health factors. Efforts should be made to develop and publish a synthesis of: (1) current knowledge of manatee serology; (2) ranges of values associated with manatees in various demographic groups; (3) anomalies identified in manatees via serum analyses; and (4) any remaining unanswered questions. Major organs and organ systems have been examined by a variety of scientists over the years. Those systems or organs which have been ignored are important to assessing manatee health and should be studied; these include: (1) the lymphatic system; (2) most parts of the endocrine system; and (3) non-cerebral parts of the brain. In addition, potential changes in reproductive tracts routinely should be assessed as part of ongoing life history assessments. Manatee histology (microscopic anatomy) has been relatively unstudied, compared to gross anatomy. It is of no less importance in understanding normal organ or tissue functions, as well as abnormalities thereof; therefore, responsible agencies should respond to this important deficiency.

Anatomical and experimental studies have indicated that manatees osmoregulate well in either fresh or salt water; however, it is unclear whether or not manatees physiologically require fresh water to drink, and it is unknown what stresses may be created when fresh water is not available. Research should be continued, and managers attempting to protect resources sought by, if not required by, manatees should bear in mind that fresh water is a desirable and possibly necessary resource for healthy manatees.

Body indices research at FMRI has initiated certain measurements documenting the body condition of manatees. Maintenance of this work, and refinements/extensions thereof, should be continued to gain a better understanding of physiology and health of individuals and the population.

Continuous long-term monitoring of individual manatees allows for documentation of an animal's health. Information should be gathered on: (1) the acquisition and severity of new wounds to facilitate research on the length of time required for injuries to heal; and (2) any effects of injuries on behavior or reproduction. Natural factors affecting the health of the population also should be monitored during the course of photo-ID studies on wild individuals (e.g., cold-related skin damage, scars caused by fungal infections, and papilloma lesions).

As discussed earlier, brevetoxin has been implicated or suspected in major and minor mortality events for manatees for decades. Tests now exist to allow pathologists to assess, even retrospectively, manatee tissues for signs of brevetoxicosis. The important questions include: (1) how many manatee deaths can be truly attributed to exposure to brevetoxin over the years; (2) if red tides are a natural occurrence, how can effects of red tides on manatees be reduced or mitigated; (3) would changes in human activities (i.e., creation of warm-water refuges which lead to aggregations of manatees) appreciably change vulnerability of the animals; and (4) have human activities contributed to increased prevalence and virulence of red tides.

Inasmuch as a single epizootic event can cause 2 to 3 times as many manatee deaths as watercraft causes annually, gaining a better understanding of the issue is vital and urgent. Development of cell lines and testing of manatee tissues would represent an extremely useful approach. In particular, preliminary results indicate that exposure to brevetoxin reduces manatee immune system function. Further study of the immune system will define levels of concern and will help to identify when rehabilitated manatees are ready for release into the wild. Other natural toxins have affected marine mammals (e.g., saxitoxin) and may represent another potential problem for manatees. Exposure of cultured cells of manatees to saxitoxin and assessment of the responses of those cells, would be useful.

Toxicant studies demonstrate that a few metals occur in high concentrations in manatee tissues. Testing for toxicants can be extremely expensive, thus a carefully-constructed study plan should be developed first to address the most critical uncertainties and to make the assessments as cost-effective as possible. Sediment chemistry/toxicity testing could be used as an indicator to direct toxicant studies in important habitats known to contain sediments that are contaminated.

A disease involves an illness, sickness, an interruption, cessation, or disorder of body functions, systems, and organs. As noted at the outset of this section, scientists need to learn the boundaries of normal structure and function before they can diagnose what is normal or diseased. This process has occurred to some degree through the necropsy program, but it needs considerable refinement. Over the years, cause of death for about 1/3 of all manatee carcasses has been undetermined; this percentage would doubtless drop considerably with better information about and diagnosis of manatee disease states. Planned workshops by the FMRI will attempt to bring scientists conducting necropsies on manatees together with pathologists and forensic scientists working with humans and other species. This effort should be very useful as a first step in an ongoing process of refinement.

Nutritional characteristics of manatee food plants and the importance of different food sources for different manatee age and sex classes in various regions are needed to help assure that adequate food resources are protected in different areas of the population's range. Ongoing studies should be completed to identify manatee food habits and the nutritional value of different aquatic plants important to manatees. In addition, seasonal patterns of food availability in areas of high manatee use need to be documented. Research should also address manatee foraging behavior, emphasizing ways that manatees are able to locate and utilize optimal food resources.

Since degrees of parasitic infestation may be associated with the changes in the health of manatees, assessments of changes in prevalence of parasites over time should be undertaken. Inasmuch as parasite loads are assessed, at least qualitatively, during necropsies, this should be easy to accomplish, relatively speaking.

2.5.2 Develop a better understanding of thermoregulation. Although work has been ongoing to assess effects of environmental temperatures on metabolism of manatees, the relationship among temperature change, metabolic stress, onset of chronic or acute disease symptoms, and even mortality of manatees is not perfectly understood. As noted above, the relationships among manatee reproductive status, body condition, thermal stress levels, and metabolic responses to such stress remain unclear. Answers are needed as the specter of decreased availability of both natural and artificial warm-water sources looms. The research should focus not only on lower critical temperatures (the cold temperatures where metabolic stress occurs), but also on the upper critical temperature.

2.5.3 Develop a better understanding of sensory systems. Vision in manatees has been well studied and tactile ability and acoustics also have been assessed. Conclusions reached as a result of acoustic studies are somewhat inconsistent and controversial, especially in terms of the extent that manatees may hear approaching watercraft. Since the auditory sense of manatees appears to be vital to their ability to communicate and to avoid injury, further studies are warranted. In addition, although chemoreception has been suggested as a mechanism by which male manatees locate estrous females, chemosensory ability of manatees is virtually unknown and should be studied.

2.5.4 Develop a better understanding of orientation and navigation. It is clear from various lines of evidence that manatees show site fidelity, especially in terms of their seasonal use of warm-water refuges, but also in their use of summer habitat. To some extent, calves learn locations of resources from their mothers. However, the way that manatees perceive their environment, cues they use to navigate, and the hierarchy of factors they use to select a particular spot or travel corridor are all unknown. As humans continue to modify coastal environments (physically, acoustically, visually, and chemically), it would be useful to understand better how such changes may interfere with the manatee's ability to orient and to locate or select optimal habitat.

2.5.5 Develop a better understanding of foraging behavior during winter. Research should address manatee winter foraging behavior, emphasizing ways that manatees are able to locate and utilize optimal food resources. Research should address food availability near winter aggregation areas and determine if they are a limiting resource. Therefore, food resources near winter aggregation sites in each region need to be assessed to ensure that food resources are adequate and protected.

2.5.6 Develop baseline behavior information. Both field studies and controlled experiments at captive facilities are needed to document basic behaviors. This documentation will allow detection and understanding of changes in behavior that occur through changes in allocation of essential resources, such as vegetation and warm water. Telemetry, photo-ID, and aerial videography have been useful tools for behavioral research. New innovative approaches are needed, particularly in habitats where visibility is poor.

2.5.7 Develop a better understanding of disturbance. Stress caused by disturbance will be difficult to document, but if manatees move away from critically important resources (e.g., warm water in winter) to avoid being disturbed, this movement could place the animals in immediate and acute jeopardy. Sources and level of activities eliciting disturbance responses need to be characterized further.

2.5.7.1 Continue to investigate how a vessel's sound affects manatees. In order to understand the nature of watercraft/manatee interactions, the primary reasons for collisions must be identified. Manatees, particularly mothers and calves, communicate vocally. Often, while vessels are still outside of visual range, manatees initiate movements as boats approach, suggesting that they respond on the basis of hearing the boats. Noise from boats or other sources may interfere with communications or provide a source of stress. Hearing capabilities have been examined through studies involving two individuals in captivity (Gerstein 1995, 1999).

There is a need for further research on hearing capabilities and the effects of noise on manatees potentially to provide another management tool to minimize collisions between manatees and boats. In particular, it is important to determine: (1) the sensitivity of manatee hearing to the different kinds of vessels to which they are exposed; (2) the range of frequencies of importance to manatee communication; (3) the abilities of manatees to localize sound sources; and (4) the role that habitat features may play in altering sound characteristics. The levels and characteristics of vessel sounds leading to behavioral changes, including potentially vacating an area, need to be determined. Development of manatee avoidance technology needs to be thoroughly researched and assessed and managers need to evaluate the MMPA and ESA “take” issues related to implementing such technology.

2.5.7.2 **Investigate, determine, monitor, and evaluate how vessel presence, activity, and traffic patterns affect manatee behavior and distribution.** More effective diagnosis of watercraft-related injuries and mortalities is important for describing the extent and nature of the threat posed by watercraft. Mortality workshops are intended to improve our ability to diagnose watercraft-related mortalities more effectively on both fresh and decomposed carcasses. Prevention of such injuries and mortalities is the goal. Research is needed to address the causes of watercraft mortality and the effectiveness of management actions. Importantly, such research also should investigate the effects of sublethal injuries and stress occurring as a result of boating activity. Injuries and stress may: (1) lead to reductions in animal condition and reproductive success; (2) cause animals to abandon habitat important for foraging, reproduction, or thermal regulation; or (3) impair immune system function thereby increasing the vulnerability of animals to disease, pollutants, or toxins. Thus, indirect or secondary effects of boating activity also may impede population recovery in ways that have not yet been assessed.

MML, FWC, and others are investigating reactions of manatees to boats. Preliminary information indicates that manatees perceive boats, but may, under certain circumstances, react in ways that place the animals in the path of, rather than away from, the boats. Additional studies of manatee responses to boats and vessel acoustics are needed (Task 2.5.7.1). Indirect deleterious effects of shallow-draft or jet boats that can disturb manatees and cause them to move to boating channels or interrupt normal behaviors need to be studied. An evaluation of spatial and temporal factors associated with risk to manatees (i.e., proportion of time manatees are exposed to vessels relative to depth, habitat, and manatee activity) should be conducted. Additional factors to be investigated include: (1) types and frequency of approaches; (2) numbers of boats; (3) distance of nearest approach; (4) individual variations in manatee responses to boats; (5) influences on diurnal activity patterns and habitat use; and (6) effects on mothers and young.

2.5.7.3 **Assess boating activity and boater compliance.** Studies that characterize the intensity and types of boating activities should be conducted at selected locations around the state, with emphasis on areas where boat-related mortality of manatees is highest. Studies are underway and should be expanded to additional areas to identify and evaluate adherence to manatee speed zone restrictions through statewide boater compliance studies. The following studies should be continued and assessed: (1) the frequency of boater compliance with posted manatee speed zone restrictions; (2) the degree of boater compliance with posted manatee speed zone restrictions; (3) the levels of compliance among boat classes, seasonally, and temporally; (4) changes in compliance resulting from different enforcement regimes; and (5) changes in compliance resulting from different signage. Underlying sociological factors affecting compliance also should be investigated (Task 1.4.4). New methods for monitoring compliance, such as remote video systems, should be assessed.

2.5.7.4 **Evaluate the impacts of human swimmers and the effectiveness of sanctuaries.** Specific circumstances or characteristics of human swimming, snorkeling, or SCUBA diving that may result in changes in manatee behavior, including vacating an area, remain to be determined. Factors to be investigated include: (1) types and frequency of approaches; (2) numbers of swimmers; (3) distance of nearest acceptable approach; (4) occurrence of contact; (5) individual variations in manatee responses to humans; (6) influences on diurnal activity patterns and habitat use; and (7) effects on mothers and young.

2.5.7.5 **Evaluate the impacts of viewing by the public.** The relative benefits of burgeoning human attention as compared to potential adverse impacts on the animals have not been evaluated properly to determine the desirability of increasing or decreasing control over manatee viewing activities. Studies relating marketing and overall levels of human viewing activities to changes in manatee behavior, including vacating an area, need to be conducted. Conversely, benefits accrued to the manatees from increased viewing by the public also should be evaluated for comparison.

2.5.7.6 Evaluate the impacts of provisioning. In many parts of the species' range, people provide food or water to manatees, in spite of regulations prohibiting such activities. A systematic evaluation should be conducted to determine if these activities potentially adversely affect manatees in terms of changing their behavior, placing them at greater risk from other human activities, or encouraging them to use inappropriate habitat.

OBJECTIVE 3: Protect, identify, evaluate, and monitor manatee habitats. Manatee population recovery and growth depend on maintaining the availability of habitat suitable to support a larger manatee population. Manatee habitat needs include: (1) ample food sources (including submerged, floating, and emergent vegetation); (2) warm-water refuges during cold winter periods; (3) quiet, secluded areas for calving and nursing; (4) mating and resting areas; (5) safe travel corridors connecting such areas; and (6) possibly fresh drinking water. These resources are affected by development in coastal and riverine areas and by human activities in waterways used by manatees. Managers must protect the quality and quantity of essential manatee habitats and provide for human needs.

Many important manatee areas in Florida are protected through the state's Florida Manatee Sanctuary Act, which protects manatees and their habitat through designated manatee protection zones and sanctuaries; manatee areas also are protected under the ESA and MMPA manatee sanctuaries and refuges provisions. These Acts provide a means to minimize the direct and indirect effects of coastal development on manatees. Existing protection areas should be evaluated and properly-managed, and other important unprotected areas should be identified and afforded necessary protection. Resource agencies, through these authorities, are able to address and minimize the effects of development through comments to state and federal permitting agencies. County MPPs are important guidance documents for agencies and developers. Plans should be developed for those counties lacking state- and federally-approved plans. All plans should be reviewed periodically.

In order to protect adequate quantities of essential habitat in the quality necessary to recover the manatee, information is needed to identify habitats, assess their condition, and understand the factors affecting them.

Methods and means should be improved/developed to understand better and monitor the interactions that take place between manatees, manatee habitat, and humans. A HWG should be convened to assess needs and to identify the tools needed to identify, monitor, and evaluate manatee habitats and better define manatee ecology.

3.1 **Convene a Habitat Working Group.** A HWG (established as a subcommittee of the recovery team), that includes resource managers, manatee biologists, and experts familiar with the many features of the manatees' aquatic environment will meet on a regular basis. This group will: (1) assist managers responsible for protecting habitat; (2) help identify information needs; (3) ensure the implementation of tasks needed to identify, monitor, and evaluate habitat; and (4) refine and improve the recovery criteria that address threats to manatee habitat by October 2002.

3.2 **Protect, identify, evaluate, and monitor existing natural and industrial warm-water refuges and investigate alternatives.** One of the greatest threats to the continued existence of the Florida manatee is the stability and longevity of warm-water habitat. Manatees have learned to rely on natural and industrial warm-water refuges during periods of cold weather. This reliance has made it extremely important for managers and researchers to understand the role played by warm-water refuges in overall manatee survival. Protection, enhancement and/or replacement, identification, and characterization of these sites are essential to the continued recovery of the manatee population.

3.2.1 **Continue the Warm-Water Task Force**. A task force consisting of governmental agencies, power industry representatives, and non-government organizations has been convened to develop and implement strategies to ensure safe and dependable warm-water refuges for manatees. In developing these strategies, the task force should: (1) develop a conceptual plan for a long-term network of warm-water refuges; (2) determine the optimal northern extent of industrial warm-water refuges; (3) develop a plan to reduce the potential loss of manatees in the event that a power plant goes off-line, either permanently or for an extended period of time; (4) explore whether new sources of artificial warm water are an avenue that should be considered and, if so, identify potential new sources that could be exploited to produce consistent, dependable, and inexpensive warm water. The task force also should examine the potential effects of deregulation of the Florida power industry.

3.2.2 **Develop and implement an industrial warm-water strategy.** Short- and long-term strategies should be developed for industrial warm-water refuges. Efforts to address short-term concerns currently are accomplished through the state-adopted NPDES permitting program, which includes power plant-specific MPPs. These plans ensure a safe, consistent, and dependable network of warm-water refuges. A long-term plan, addressing concerns identified in Task 3.2.1, should be developed with the creation of an effective network of warm-water refuges as its goal. The development of this plan will require that all industrial sites used by wintering manatees be identified, described, and monitored. These assessments should contain the location and physical description of each plant, expected life span of each plant, and history of manatee use at each plant. Habitat attributes associated with each plant also should be addressed. These attributes should include: (1) availability and location of forage and freshwater; and (2) an assessment of human disturbance levels over the next 5, 10, and 20 years. As more information regarding each plant is collected, BPSM and FWS should recommend modifications to existing power plant-specific MPPs to insure protection of manatees at these facilities.

3.2.2.1 Obtain information necessary to manage industrial warm-water refuges. Research efforts should focus on collating and analyzing existing data related to manatees and industrial warm-water refuges. New research initiatives should focus on filling in data gaps concerning manatees, warm water requirements, and associated behaviors. These research efforts should include: (1) determining the tolerance of manatees to low ambient air and water temperatures; and (2) investigating manatee use of warm-water refuges and nearby habitats in relation to water temperature. Existing research efforts such as aerial monitoring of manatee use at power plants and identifying trends in the abundance of manatees at each plant should be continued. Carrying capacity and factors influencing the number of manatees which can and/or should be using each individual plant should be assessed for each facility. Building partnerships with the industry is imperative in finding resources and answers to a multitude of questions related to this issue.

3.2.2.2 Define manatee response to changes in industrial operations that affect warm-water discharges. Current power plant operations involve activities that affect their respective warm-water discharges. For example, in the absence of demand for electricity, power companies cut back on the amount of electricity produced by certain power plants. These cut-backs may result in temporary or long-term loss of warm water or diminished flows of warm water, thereby reducing their attractiveness to wintering manatees. These operational changes and the effects they have on wintering manatees should be monitored. Understanding the response of manatees to these changes will provide important information for managers seeking to improve short- and long-term management strategies.

3.2.3 Protect, enhance, and investigate other non-industrial warm-water refuges. Non-industrial warm-water refuges include areas such as dredged basins which provide warm water because of their configurations and other features. For example, deep dredged basins with few inputs from adjoining ambient waters may create solar-heated, manatee-accessible systems with water temperatures several degrees above ambient. Dredged areas accessible to manatees also may penetrate sources of groundwater. When tapped into, these warm-water seeps elevate ambient water temperatures and are attractive to manatees in need of refuge from the cold. Due to the uncertainty of some of the power plant discharges being available in the future for manatees, alternatives to these discharges should be identified and developed, if needed. New environmentally-sensitive, non-industry-dependent warm-water refuges should be considered. Sites should be identified and technologies tested while existing refuges remain available.

3.2.4 Protect and enhance natural warm-water refuges. The continued functioning of the natural springs, rivers, and creeks used by manatees is essential to their recovery. Of greatest immediate importance are the spring systems at Blue Spring, Kings Bay, Homosassa Springs, and Warm Mineral Springs. These springs are used as cold season warm-water refuges by at least 20% of the manatee population during winter cold fronts (FWC, unpublished data). Critical to the continued functioning of natural warm-water sites is the maintenance of minimum spring flows and levels, maintenance or improvement of water quality, and protection of adequate foraging habitat within and adjacent to these sites.

3.2.4.1 Develop and maintain a database of warm-water refuge sites. BPSM and FMRI staff should identify and maintain an active database of all natural and non-industrial warm-water refuge sites. When new sites are discovered, these should be added to the database. Manatee use and changes in system function these sites should be monitored over time. Sites should be prioritized based on extent of manatee use and regional importance to cold season populations. FWS and FWC staff also should identify potential natural refuge sites near industrial warm-water facilities used by manatees and assess whether enhancement of these sites should be pursued.

3.2.4.2 **Develop comprehensive plans for the enhancement of natural warm-water sites.** If the strategy for a site includes enhancement, then a comprehensive plan should be developed addressing: (1) agency responsibilities; (2) permitting requirements; (3) funding sources; and (4) physical modifications. Existing and additional needed protection measures for each site should be identified and assessed for effectiveness. To provide for maximum protection of these warm-water sites, protection strategies also should include land acquisition, use of regulatory mechanisms, and outreach.

3.2.4.3 **Establish and maintain minimum spring flows and levels at natural springs.** Water demands from the aquifer for residential and agricultural purposes have diminished spring flows at important manatee wintering areas. Additionally, paving and water diversion projects in spring recharge areas can reduce water levels at springs.

A database of priority springs and flowing systems accessible to manatees should be developed and maintained by FWC staff. The database should include baseline information on water availability and quality so that adverse changes can promptly be identified and impacts mitigated. FWC and FWS should coordinate with the WMDs to prioritize establishing minimum spring flows for high manatee use systems, such as King, Homosassa and Blue Springs. Agency staff should advocate maintaining spring flow rates above the minimum levels necessary to support manatees. FWS and FWC should develop a coordinated review program with FDEP and WMDs' permitting programs on applications requesting ground water withdrawal from applicable spring systems. In addition, FWC and FWS should participate in FDEP and/or WMD springs task force efforts where manatee warm-water refuge protection issues are involved. State legislation protecting spring flow should be sought. Other recovery partners should advocate the establishment of minimum flows and levels as appropriate.

3.2.5 **Assess changes in historical distribution due to habitat alteration.** Summarize what is known about historical distribution in order to clarify how and to what extent artificial warm-water refuge sites and flood control canals have altered distribution and habitat use patterns.

3.3 **Establish, acquire, manage, and monitor regional protected area networks and manatee habitat.** The establishment of manatee sanctuaries, refuges, and protected areas, along with the federal, state, local and private acquisition of coastal areas and essential manatee habitat has created regional networks of protected areas crucial for the long-term survival of the manatee population. Management of these refuges, sanctuaries, reserves, preserves, and parks in Florida offers assurance that habitat (e.g., warm-water springs, grassbeds, and quiet secluded waterways) important to manatees are protected. These efforts need to continue as well as efforts to manage key protected areas in ways that enhance achievement of the recovery objectives.

In addition, work should be undertaken to better understand and monitor the complex interactions among manatees, humans, and manatee habitat. Information from such a program will identify future threats to manatee populations and help to explain observed manatee population trends. Presently, there is no systematic approach to monitoring the condition of important manatee habitats. To provide a means of detecting potential problems in areas supporting manatee populations, essential manatee habitat features should be monitored and evaluated. This information also will assist in determining areas which may need some additional level of protection (i.e., sanctuaries or refuges).

3.3.1 **Establish manatee sanctuaries, refuges, and protected areas.** Under authority of the ESA and its implementing regulations at 50 CFR 17, FWS may designate certain waters as manatee sanctuaries (areas where all waterborne activities are prohibited) or manatee refuges (areas where certain waterborne activities may be regulated). In the 1980s and 1990s, FWS designated six manatee sanctuaries in Kings Bay, Citrus County. In addition, under the NWR System Administration Act, the FWS established a 24-square-km (15-square-mi) zone, in the upper Banana River south of the NASA Causeway, in which motorboats are prohibited. Any such established areas must be posted and enforced.

In 2000, FWS initiated an effort to assess and propose new manatee refuges and sanctuaries throughout peninsular Florida. The goal is to consider the needs of the manatee at an ecosystem level and to use this rule-making provision to ensure that adequately protected areas are available to satisfy the life requisites of the species, with a view toward recovery. The FWS will periodically assess the need for additional or fewer manatee refuges and sanctuaries.

The establishment of No Entry, Limited Entry and No Motorboat zones by state and local regulations function similarly to FWS manatee sanctuaries. These protection areas were established to prevent human disturbance. Examples of these types of zones include: (1) Winter No Entry Zones around power plant warm-water outfalls that attract manatees; (2) Winter No Entry Zone at Blue Spring in Volusia County; (3) Year-round No Entry at Pansy Bayou in Sarasota County; and (4) the Virginia Key and Black Creek Year-round No Entry Zones in Dade County.

3.3.2 Identify and prioritize new land acquisition projects. Manatee-related land acquisition, which helps to expand regional networks of essential manatee habitat, is particularly important. In this regard, identification of priority areas must consider regional manatee habitat requirements and relationships among essential manatee habitats. To promote and guide these efforts, the HWG will establish a subcommittee, to include individuals from FWS, FWC, USGS-Sirenia, and others, to convene an annual meeting regarding acquisition projects. The subcommittee will act as a clearinghouse on the status of manatee acquisition projects and otherwise help coordinate efforts for relevant land acquisition projects by federal and state agencies, The Nature Conservancy, and others. As new information on manatee habitat use patterns and essential habitats become available, new areas for acquisition should be identified as warranted. Recent examples of local, state and federal manatee-related acquisition efforts are at Weeki Wachi Spring, Blue Waters and Three Sisters Spring in Citrus County, Warm Mineral Spring Run in Charlotte County, and Munyon and Little Munyon Islands in Palm Beach County.

3.3.3 Acquire land adjacent to important manatee habitats. Several NWRs managed by FWS contain essential manatee habitat and are adjacent to other essential non-protected manatee habitat areas. Expanding these areas and establishing new refuges would significantly improve protection not only for manatees, but also for many other species. State land acquisition programs administered by the five regional WMDs, FDEP, FWC, and DCA have acquired many areas that will further manatee habitat protection and have many important acquisition projects in varying stages of development. Local and private land acquisition efforts also enhance manatee habitat protection. Particularly important areas utilized as warm-water refuges, such as Three Sisters Spring in Citrus County and Warm Mineral Spring in Sarasota County, should be considered. As possible, FWS and state land acquisition programs cooperatively should pursue expanding publically-owned lands to incorporate manatee habitat.

3.3.4 Establish and evaluate manatee management programs at protected areas. After essential manatee habitats are acquired as identified in Task 3.3.5, the agencies responsible for administering those areas should incorporate manatee protection and public awareness measures into these unit administration programs. Such management measures, depending on local conditions and human activity patterns, may be needed to ensure that activities and development projects within or adjacent to protected areas or affecting state-owned submerged lands do not adversely affect manatees or their habitat. Such measures should be updated as appropriate.

3.3.5 Support and pursue other habitat conservation options. Manatee habitat conservation can be achieved through existing regulatory means (Task 1.2 and its subtasks) and through coordination with private foundations with an interest in environmental protection. Federal and state regulatory programs can provide for additional protection of water quality and aquatic resource protection through establishment of conservation easements and mitigation. Private foundations should be approached to procure sensitive lands around important manatee habitat areas. Purchased lands can be managed with the purpose of maintaining water quality (and quantity in the case of springs) by existing local, state or federal programs or through the foundation itself. It is also possible to foster protection of privately held lands important to manatee habitat protection through government tax incentives and focused outreach efforts.

3.3.6 Assist local governments in development of county MPPs. Local governments in Florida are encouraged to develop comprehensive, multi-faceted MPPs with technical and financial assistance from FWS , FWC, FDEP, COE, special interest groups, and the general public. Each plan should be designed to ensure manatee protection by addressing a variety of recovery elements or components including: (1) regulating boat facility siting; (2) protecting manatee habitat; (3) providing for public outreach and education; and (4) ensuring appropriate levels of law enforcement. Each plan also should reflect manatee protection zones established by state and federal agencies (sanctuaries, refuges, boat speed zones) and consider if other locally-approved zones are needed. These comprehensive plans will assist in planning future development in a manner compatible with manatee protection, and will ensure local government involvement in manatee protection efforts. All efforts should be made to achieve concurrence among state and federal agencies regarding the approval of county plans.

If local governments are not willing or able to develop comprehensive plans, then FWS and FWC will offer assistance in the development of individual components which would aid in manatee recovery and form the basis for future comprehensive planning efforts. For example, such a component might outline local government's public outreach and education efforts and set forth funding needs and sources as well as an implementation schedule. While not as valuable as a comprehensive plan, these individual components would still be helpful in achieving recovery of the manatee.

In the absence of approved MPPs, or components thereof, case-by-case decision-making on permit applications by state and federal regulatory agencies will consider the best available scientific and commercial data in order to render their decisions. It is likely that some permits will be denied or required to undergo significant modifications because of uncertainties resulting in the absence of comprehensive planning. While plans or components do not have official status as state or federal laws, certain elements, such as boat facility-siting, can be adopted as local ordinances, and the implementation of these elements can strongly influence and streamline state and federal permitting systems.

Florida's Governor Jeb Bush convened a special manatee summit in October 2000, to examine improvements which might be made to achieve better manatee protection. A special panel, including representatives from marine-related industries, environmental organizations, local governments, and state and federal agencies, evaluated the elements of a MPP. After discussing boating speed limits, boater education, law enforcement, manatee refuges and sanctuaries, and marina siting, the panel unanimously agreed that improved law enforcement and improved boater education should be a priority. Additionally the panel agreed that speed zones and sanctuaries were both effective means of protecting manatees. Governor Bush envisioned that the results of the summit would be used to develop more detailed budget priorities, legislation, and local plans for the protection and conservation of manatees, while preserving Florida's traditional culture of recreational and commercial boating.

3.3.7 Implement approved MPPs. MPPs approved by FWC and FWS should be implemented with the assistance of the action agencies, as appropriate. Copies of these plans should be provided to federal and state agencies as reference documents for decision-making with regard to permitting, leasing submerged lands, project review, or other agency actions. To affirm federal support for the county MPP process, COE should incorporate county MPPs into their permit review process and consult with FWS regarding the adoption of MPPs for the purpose of permit review.

As new information becomes available on manatees and the effectiveness of measures to protect manatees and manatee habitat, there may be a need to modify MPPs. FWC and FWS shall take the lead in periodically reviewing MPPs and make recommendations regarding the need to modify and/or update them.

3.3.8 Protect existing SAV and promote re-establishment of NSAV. Manatees in most Florida waters depend upon the prolific growth of SAV (e.g., seagrass and freshwater submerged plant communities). Coastal construction activities (e.g., dock development, dredging, shoreline stabilization, and urbanization) have contributed to the destruction of SAV habitat. Water pollution contributing to reduced water transparency has reduced the abundance of SAV in most water bodies around the state. Introduction of exotic plant species has eliminated or threatened diverse assemblages of freshwater NSAV communities, providing manatees with restricted food resources in many accessible rivers, lakes, and springs. Nutrient pollution, through contamination of ground and surface waters at major manatee aggregation areas like Crystal and Homosassa Rivers, has contributed to a reduction of available food plants in these areas. Such pollution has caused dramatic increases in certain blue-green algae species (most notably *Lyngbia spp*.) that covers over SAV and prevents growth of manatee food plants.

All manatee research, resource protection, and conservation agencies/organizations should actively support the establishment of water quality standards that will protect the existing and promote the regeneration of SAV in all Florida waters. In particular, FDEP and WMDs actively should pursue changing water transparency and nutrient pollution standards to reflect the light requirements of seagrass and other NSAV species. Water transparency standards should be based on light regimes needed for native rooted aquatic plant species historically found in affected waters.

3.3.8.1 Develop and implement a NSAV protection strategy. Protection and restoration of NSAV communities can be accomplished by enforcing and augmenting existing regulatory programs. Prior to a permit being issued, an assessment of seagrass resources should be required, involving site sampling. This sampling should occur between May and October to coincide with the seagrass growing season and should be based on a standardized sampling methodology so that the assessments can be compared equitably. For seagrass communities, regulatory agencies should standardize monitoring of seagrass damage and alterations authorized through environmental resource permitting activities. The HWG should develop and implement standardized seagrass mitigation criteria for all projects proposing any activities resulting in damage to seagrass. Freshwater NSAV communities considered for state and federal permitting programs should be afforded the same level of protection as seagrass, because the destruction or alteration of such communities often leads to dominance of exotic species. FWS and FWC should participate actively in regional and local seagrass protection working groups (e.g., National Estuarine Program focus groups) to assist in directing protection efforts in areas important to manatees.

3.3.8.2 Develop and implement a state-wide seagrass monitoring program. FWS, NFS, FWC, and FDEP should develop and implement a regular statewide seagrass monitoring program based on a biennial remote sensing effort. Monitoring efforts should involve trend analysis and comparison to historical distribution of all areas supporting seagrass growth. The FMRI should continue to be the central repository for all collected seagrass monitoring information in Florida. FDEP and FWC should establish a task force to identify total state-wide losses of seagrass due to human activities including, but not limited to, dredge-and-fill projects, dock construction, propeller-scarring, vessel-groundings, freshwater diversion projects, and industrial/municipal pollution changing water transparency. This task force should use the best available scientific data to assess the magnitude of statewide seagrass loss and modify regulatory practices to allow for recovery of seagrass in areas where it has been lost and to protect it in areas where it currently exists.

3.3.8.3 Ensure aquatic plant control programs are properly designed and implemented. Aquatic plant control programs around the state are conducted mostly in freshwater systems and are designed to control the dominance of certain species of exotic or native nuisance plants. Introduced species quickly can displace native plant communities and cause a reduction of diversity, fluctuations in NSAV abundance, and nutritional value of the habitat for manatees. It should be noted, however, that manatees have come to rely on exotic vegetation in some areas. Therefore, while efforts should support NSAV restoration, care must be taken to ensure adequate supplies of winter forage, including both native and exotic species. Such programs are especially important in areas of large manatee aggregations, such as Crystal River, Homosassa River, Warm Mineral Spring, and Blue Spring.

FWC, FWS, FDEP, and COE should continue to coordinate aquatic plant control programs for these systems through established working groups that address the protection of manatee habitat. The focus of these groups should be to: (1) reduce the need for excessive aquatic herbicide use through a policy of maintenance control for nuisance species; (2) focus control efforts during periods of minimal manatee use; (3) remove infestations of new exotic plant species; and (4) maintain a historically diverse NSAV community accessible to manatees as much as possible. New working groups should be established for waterways where aquatic plant control programs may jeopardize the aquatic plant abundance and diversity needed to sustain recognized manatee aggregations. FWC, FDEP, and FWS should continue to coordinate state-wide aquatic plant control policies, such as the exclusion of the use of copper herbicides in manatee habitat and on areas where conflicts between manatees and aquatic herbicide use may develop.

3.3.9 Conduct research to understand manatee ecology. Habitat-oriented research is important in identifying key habitats and the factors that determine what features are important for manatees and their recovery. Research should focus on the interrelationships between humans, manatees and their environment. Researchers should continue to monitor free-ranging manatees throughout their habitat, observe behaviors, document habitat use, and define how these influence the status of the manatee. Such research will help to understand and protect the manatees' environment; therefore, efforts should be made to improve ongoing studies and methods and to develop new ones.

3.3.9.1 Conduct research and improve databases on manatee habitat. Habitat-related research should focus on: (1) evaluating food preferences, nutritional requirements, and freshwater requirements; (2) development of body condition indices as potential indicators of environmental conditions; (3) evaluation of and monitoring the extent and condition of seagrass beds; (4) the effects of manatee grazing on seagrass ecology and recovery; and (5) continuing current studies outside Florida on the relationships between manatee health and reproduction with habitat condition. Results from these studies should provide information useful in the design of monitoring studies, estimation of manatee carrying capacity of seagrass beds in key areas, and a better understanding of the manatee's role in maintaining healthy, diverse seagrass communities.

3.3.9.2 **Continue and improve telemetry and other instrumentation research and methods.** Radio tracking provides an extremely valuable tool to determine and monitor manatee habitat use and behavior associated with environmental and habitat changes. Studies using telemetry should be designed to monitor a large number of manatees for short periods (cross-sectional studies) and individual animals (longitudinal studies) to better understand both population and individual responses to habitat change and habitat use. These studies should be coupled with health and reproductive assessments in order to make comparisons with habitat condition.

The use of conventional VHF and satellite telemetry should continue. Data generated from tracking studies should be entered into GIS databases and analyzed for correlations with habitat preferences and requirements. Verified point data should be provided to management as quickly as possible through technical reports and data transfer. Telemetry results should be published with appropriate analyses in refereed journals as frequently as the data allow.

Emerging technologies such as radio tags utilizing a Global Positioning System (GPS) and data loggersshould be further investigated and incorporated to provide better resolution of manatee movements and habitat use. Tags allowing the compilation and transfer of environmental, acoustical, and physiological data should be developed further and implemented to improve our ability to correlate with environmental and habitat parameters or disturbances.

3.3.9.3 **Determine manatee time and depth pattern budgets.** Time/depth recorders will allow evaluation of risks to manatees from vessel traffic in various habitat types by identifying the position of the animals in the water column. Such information can be related to vessel draft in the area, availability of waters deeper than vessel drafts, and time spent by manatees at specific depths. This information will contribute to a comprehensive risk assessment described in Task 3.3.11.4.

3.3.10 **Define the response to environmental change.** The Florida environment is not static. Future variation and change are anticipated and could impact survival, reproduction, and distribution of animals among regions, which in turn may affect population growth rates. In order to assess recovery, a need to understand how individual manatees, and consequently the population at large, respond to changes in the environment (e.g., changes in minimum flows at natural springs and elimination of industrial warm-water sources) on the redistribution of fresh water through the Everglades. Research to address such response should proceed at two levels: (1) test for correlation of changes in population parameters with known changes in the environment during long-term monitoring studies; and (2) test of hypothesized cause-effect relationships with behavioral and physiological studies and/or manipulative experimental trials.

3.3.10.1 **Define response to changes in fresh water flow patterns in south Florida as a consequence of the Everglades' Restoration.** Restoration of the Everglades to its historic water flow pattern is scheduled for the near future. This restoration will affect not only the distribution of fresh water leaving the Everglades, but also the estuarine ecosystem located off the south Florida coast. Studies should be structured to define how changes in sedimentation, bathymetry, seagrass beds, and fresh water input from restoration affects the distribution, survival, and reproduction of manatees.

3.3.10.2 **Define response to degradation and rehabilitation of feeding areas.** Marine seagrasses and fresh water aquatic vegetation are primary foods for manatees. Regionally, there have been documented declines in seagrass beds and freshwater aquatics resulting from pollution, hurricane-related die-offs, and scarring from boat propellers. Management is making attempts to reverse those declines and has been successful in areas such as Tampa Bay. Studies should be structured to define how changes in the distribution or abundance of feeding areas impact the distribution, survival, and reproduction of manatees.

3.3.11 **Maintain, improve, and develop tools to monitor and evaluate manatee habitat.** Protection of the manatee from human-related threats in part requires the determination of what constitutes optimal manatee habitats. Resource managers need to know what types of habitat are important to the species, including both natural and manmade features. Understanding manatee distribution in relation to the spatial arrangement of their habitat requires: (1) volumes of data; and (2) specialized computer software and appropriate techniques to analyze the data. GIS is used as an important geo-spatial tool and data-management system to store, synthesize, retrieve, and analyze these large volumes of data on manatees and manatee habitat. Site-specific data stored in GIS include: (1) manatee carcass recovery sites; (2) manatee sighting from aerial surveys; (3) ground research; (4) telemetry studies; (5) water depths; (6) vegetation coverage; (7) waterway speed and access zones; (8) shoreline characteristics and development patterns; etc. Computer hardware, software, and databases are used by researchers, resource managers, and conservationists for scientific analyses, permit reviews, developing waterway speed and access rules, and preparing county MPPs. Programs with theoretical and technical expertise need to focus on research and development of geo-spatial techniques to foster proactive manatee conservation strategies.

3.3.11.1 Maintain, improve, and develop tools to monitor and evaluate natural and human-related habitat influences on manatee ecology, abundance, and distribution. Utilize spatial models linked to a GIS to synthesize data and knowledge and to predict the most suitable habitats for manatees in Florida. GIS tools have the potential of evaluating human use impacts on manatees and their habitat. Analyses should be conducted to determine how human activities, such as coastal development and boating, affect manatee habitats and manatee distribution. These analyses will contribute to a comprehensive risk analysis.

3.3.11.2 Maintain, improve, and develop tools to evaluate the relationship between boating activities and watercraft-related mortality. Utilize GIS and manatee carcass information to create density models to spatially explore areas where manatees may be at higher risk. Evaluate the mortality density information in combination with human-use data, such as boating, to contribute to a comprehensive risk assessment.

3.3.11.3 Evaluate impact of changes in boat design and boater behavior. In recent years, changes in boat designs have resulted in changing threats to manatees. For example, the development of shallow draft vessels, such as flats boats and personal watercraft, along with high speed operation of these vessels over seagrass and other shallow water habitats used by manatees have created new threats to manatees in habitats where they were previously free of vessel interactions. The level of risk imposed by changing boating patterns needs to be evaluated. The boating industry, boating community, scientists, and wildlife managers should work to develop predictions of threats resulting from changes in boat designs and market-trend projections.

3.3.11.4 **Conduct a comprehensive risk assessment.** Utilize the results from the above Recovery Tasks and information from other databases to conduct a comprehensive risk assessment for the manatee.

3.4 **Ensure that minimum flows and levels are established for surface waters to protect resources of importance to manatees.** Minimum flows and levels are being established by state WMDs for surface waters throughout the state, including those used by manatees (*e.g.*, Biscayne Bay, Florida Bay and the Caloosahatchee River). Current and future withdrawals from surface waters have the potential to impact aquatic resources (e.g., SAV) important to manatees. Managers and researchers should participate in WMD efforts to set these limits to ensure that resources of importance to manatees are minimally affected.

3.5 **Assess the need to revise critical habitat.** Critical habitat for the Florida manatee was designated in 1976 (50CFR 17.95(a)). Much has been learned about manatee distribution in the decades since manatee critical habitat was originally defined. The FWS should assess the need to revise critical habitat for the Florida manatee.

Objective 4. Facilitate manatee recovery through public awareness and education. Compliance with regulations and management plans depends on broad public support for manatee recovery, which includes both manatee and habitat protection elements. Public support, in turn, depends on an informed public who understands manatee conservation issues and the rationale behind necessary regulatory and management actions. Knowledge of manatees, their habitat requirements, general biology, and protection measures can contribute toward the minimization of manatee disturbance, harassment, injury, and mortality. This information must be clear, consistent, concise, and readily available to the general public and target user groups. Many manatee and habitat education programs and materials are produced and made available to school systems as well as the general public and user groups; however, such efforts need to be continually evaluated and updated.

4.1 **Identify target audiences and key locations for outreach**. The success of a manatee/habitat conservation effort requires identification of target audiences and locations. Target audiences and key locations should be prioritized by need, i.e., areas where manatee mortality and injury are highest, areas where manatee/human interaction occurs frequently, and areas where habitat is most at risk. These areas include, but are not limited to, the thirteen key manatee counties, high watercraft use areas, boat ramps, manatee aggregation sites, manatee observation areas, fishing piers, seagrass areas, and other areas identified as having important habitat features (e.g., fresh water areas and areas used for resting and/or calving).

4.2 Develop, evaluate, and update public education and outreach programs and materials. There are many existing manatee and habitat awareness and education materials. Materials should be developed and updated for the general public, including students. As future stewards of our environment, it is important for students to learn about endangered species and their habitats and how to take positive actions to care for our fragile ecosystems. It is also important that some materials explicitly target specific user groups, such as: (1) boaters in areas of high watercraft mortality; (2) snorkelers/divers in areas where interaction and harassment occur; (3) recreational and/or commercial fishermen in areas where entanglements are prevalent; and (4) commercial/port facilities. Innovative ways to reach the public should be explored.

4.2.1 Develop consistent and up-to-date manatee boater education courses/programs. Boater education is critical to minimizing disturbance, harassment, injury, and mortality to manatees throughout Florida. Both resident and non-resident boat use in Florida continues to increase as water-related activities become more popular throughout the state. With the increasing traffic on our waterways, education becomes crucial for both manatee and public safety. Educating the boating public about the manatee will provide a better understanding of how the manatee lives and create a greater public appreciation toward the species. Efforts should continue to update and implement a consistent manatee education program for use in federal, state, and local boater education and training programs (e.g,. USCG Auxiliary Boating Safety Courses, U.S. Power Squadron Boat Safety Course, FWC On-Line Boating Safety Course).

4.2.2 Publish and post manatee protection zone information. To educate the boating community and public, organizations that produce materials (e.g., boater's guides, waterway guides, and fishing guides) should add or update the manatee protection zone information in forthcoming editions of their documents. A standardized format should be utilized to develop consistency throughout manatee habitat. Further, at all boat ramps, marinas, vessel rental operations and other access areas, efforts should be made to post signs containing information on manatee zones and "you are here" maps. Additionally, a website should be established allowing the public easy access to manatee protection zone information on the internet. This website could contain rules and regulations, detailed maps of the zones, sign locations within individual zones, examples of each type of sign, and definitions and explanations of manatee protection zones.

4.2.3 **Update nautical charts and Coast Pilot to reflect current manatee protection zone information.** FWS should request National Oceanic and Atmospheric Administration (NOAA) to update these documents to include: (1) a chart note referencing manatee protection zones for applicable nautical charts; and (2) information regarding the manatee protection zones for specific water bodies in Coast Pilot 4 and 5.

4.3 **Coordinate development of manatee awareness programs and materials in order to support recovery.** There are overlap and conflicting messages among existing materials produced by various agencies and conservation organizations. A Manatee Education Committee should be convened to review materials and programs with emphasis on reducing redundancy, providing consistent, standardized messages, and coordinating production of materials among participating organizations. All appropriate recovery plan tasks for education and public awareness materials and programs which have not been developed should be identified by the committee, and any unmet needs should be addressed.

4.4 **Develop consistent manatee viewing and approach guidelines.** Harassment is a violation of federal and state laws such as the MMPA, ESA, and Florida Manatee Sanctuary Act. While manatees may occasionally approach people on their own accord, people often chase after and pursue interactions with the animals. Human interference can disturb manatees and disrupt their natural behaviors (e.g., feeding, breeding, parenting, sheltering). Manatees which are harassed may leave preferred habitats or flee into areas with heavy vessel traffic. With increasing popularity of ecotourism, manatee harassment is an issue of growing concern statewide. Consistent viewing guidelines and education programs will be developed to teach responsible manatee viewing and approach practices, while ultimately serving to minimize disturbance. Coordination with agencies responsible for upholding marine mammal protection laws will allow for pooling of resources, thereby increasing the effectiveness of outreach materials and projects. A working group to address manatee harassment has been formed; the objective of this group is to develop easy-to-understand and comprehensive marine mammal and marine wildlife viewing education materials that promote responsible wildlife watching ethics.

4.5 **Develop and implement a coordinated media outreach program.** Public awareness and understanding is crucial to the recovery of the manatee in Florida. Whenever possible, when media opportunities occur, all recovery partners should make an effort to coordinate information prior to release. This coordination would serve to inform the general public with a consistent message on manatee biology, status, laws affecting them, how those laws benefit their quality of life, and why these laws are important to the recovery of the species. Such opportunities include, but are not limited to, annual mortality updates, synoptic survey results, manatee rescues and releases, and annual implementation of seasonal manatee protection zones and sanctuaries.

4.6 Utilize the rescue, rehabilitation, and release program to educate the public. The media heavily publicize rescues and releases and millions of visitors see and learn about manatees at critical- and long-term care facilities every year. Program participants should incorporate accurate, up-to-date information in their news releases, publications, presentations, displays, and other media to accurately portray the status of the manatee.

4.7 Educate state and federal legislators about manatees and manatee issues. Legislators in Tallahassee and Washington, D.C. can enact manatee protection regulations, or conversely, they can enact legislation that could result in harm to the species and/or its habitat. Holders of some legislative seats change as frequently as every two years, making the issue of educating legislators an ongoing one. To the greatest extent possible, at a frequency of at least every to years, recovery team partners should provide legislators with manatee awareness and education materials, as well as available status reports on the species and its management.

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PART III. IMPLEMENTATION SCHEDULE

The Implementation Schedule indicates task priorities, task numbers, task descriptions, duration of tasks, potential or participating parties, and lastly estimated costs (Table 6). These tasks, when accomplished, will bring about the recovery of the Florida manatee as discussed in Part II of this plan.

Parties with authority, responsibility, or expressed interest to implement a specific recovery task are identified in the Implementation Schedule. When more than one party has been identified the proposed lead party is indicated by an asterisk (*). The listing of a party in the Implementation Schedule does not imply a requirement or that prior approval has been given by that party to participate or expend funds. However, parties willing to participate will benefit by being able to show in their own budget submittals that their funding request is for a recovery task which has been identified in an approved recovery plan and is therefore part of the overall coordinated effort to recover the Florida manatee. Also, Section 7(a)(1) of the ESA directs all federal agencies to utilize their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of threatened and endangered species.

Following are definitions to column headings and keys to abbreviations and acronyms used in the Implementation Schedule:

PRIORITY NUMBER

Priority 1 **-** An action that must be taken to prevent extinction or to prevent the species from declining irreversibly in the foreseeable future.

Priority 2 **-** An action that must be taken to prevent a significant decline in species population/habitat quality or some other significant impact short of extinction.

Priority 3 **-** All other actions necessary to provide for full recovery of the species.

TASK NUMBER AND TASK Recovery tasks as numbered in the Narrative Outline.

RESPONSIBLE OR PARTICIPATING PARTY

C Fish Industry	Commercial Fishing Industry
COE	U.S. Army Corps of Engineers
CZS	Chicago Zoological Society
DERM	Miami-Dade Department of Environmental Resources Management
EPA	U.S. Environmental Protection Agency
Ecotour Ind	Ecotourism Industry
FDEP	Florida Department of Environmental Protection
FIND	Florida Inland Navigation District
FPL	Florida Power and Light Company
FWC	Florida Fish and Wildlife Conservation Commission
	Bureau of Protected Species Management
	Florida Marine Research Institute
	Division of Law Enforcement
FWS	U.S. Fish and Wildlife Service
GDNR	Georgia Department of Natural Resources
LE	Law Enforcement
Local Gov'ts	Local Governments
M Industry	Marine Industries
MML	Mote Marine Laboratory
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OC	The Ocean Conservancy (formerly the Center for Marine Conservation)
Oceanaria	Cincinnati Zoo, Columbus Zoo, Homosassa Springs State Wildlife Park, Living Seas, Lowry Park Zoo, Miami Seaquarium, Mote Marine Laboratory, Sea World Florida and California, South Florida Museum
P Industry	Power Industries
Port Auth	Port Authorities
R Fish Industry	Recreational Fishing Industry
Sirenia	U.S. Geologic Survey - Sirenia Project
SMC	Save the Manatee Club
USCG	U.S. Coast Guard
USN	U.S. Navy
WMD's	Water Management Districts

ESTIMATED ANNUAL BUDGETS AND OTHER PROJECTIONS OF RECOVERY PARTNERS

Based upon recovery partners' current or proposed FY2001 budgets, it is estimated that close to $10 million is being spent annually on manatee recovery. This estimate does not include several significant recovery initiatives. Costs for USCG and FWC-DLE's manatee law enforcement efforts are not included in this total, nor are estimates included for COE, FDEP, and WMD regulatory programs which work regularly on manatee issues. Additionally, the COE's and the South Florida WMD's multi-million dollar project to retrofit navigational locks and water control structures with manatee protection technology in South Florida and FDEP's plan to retrofit structures at the Rodman Reservoir are not included in this total. It is possible that these programs may total an additional $4 to 5 million annually.

FWS FY 2001-2002 budget proposal for $1.36 million includes staff salary, recovery implementation projects, and a $1 million congressional add-on for: (1) manatee law enforcement; (2) a new manatee sanctuary and refuges initiative; and (3) a warm-water refuge initiative. In addition, regulatory consultations pertaining to manatee issues cost approximately $350 thousand annually in Florida. There is a need for two additional full time employees to handle the projected increase in consultations at a cost of $150 thousand.

COE, USCG, FDEP, and WMD's regulatory programs work regularly on manatee issues; however it was not possible to project the annual costs of these programs.

COE and South Florida WMD have partnered through the Central and Southern Florida Project, including matching funds, over $6.3 million has been budgeted to retrofit navigational locks and water control structures in South Florida with manatee protection technology during the next five years. In designing and constructing critical projects for the Everglades Restoration Project, water control structures are being designed to be manatee-safe, and cost estimates are not available for these projects.

USCG No estimate regarding the cost of USCG enforcement efforts has been provided. When on patrol, the USCG enforces all applicable federal laws and regulations. Costs of enforcing specific regulations, such as manatee speed zones, are not determinable. However, the USCG spends a significant amount of time patrolling navigable waterways that have speed zone regulations, and enforcement of speed zones is a high priority.

Sirenia FY 2001-2002 projected budget is $683 thousand.

FWC **BPSM** FY July 2000 - June 2001 budget of $1.566 million.

FMRI FY July 2000 - June 2001 budget of $3.325 million. This includes: (1) FMRI's research budget for $1.9 million; (2) $1.1 million administered by FMRI and earmarked for the critical care Oceanaria facilities and to the University of Florida Veterinary School; and (3) an additional $325 thousand in research contracts with MML that are administered by FMRI.

DLE No estimates were made regarding manatee law enforcement efforts, but the effort probably exceeds $1.0 million.

FDEP is budgeting to retrofit the Buchman Lock and Kirkpatrick Dam with manatee protection technology. Costs are anticipated to exceed $600 thousand over the next several years, however, this total is not included in the annual estimate.

GDNR FY 2001 budget of $19 thousand.

SMC FY 2001 proposed budget of $1.535 million.

MML FY 2001 manatee budget is $366 thousand. This includes $325 thousand in research contracts administered by FMRI and $41 thousand from MML and CZS.

Oceanaria estimated costs of $1.5 million for 50 manatees annually at $30 thousand per animal for basic maintenance of captive and rehabilitating animals. The critical care facilities receive $400 thousand from the Florida's Save the Manatee Trust Fund, and these funds are administered through the FWC-FMRI budget.

FPL projects FY 2001 budget that includes $110 thousand for studying warm-water refuge issues and for education.

Implementation Schedule										
Florida Manatee Recovery Plan										**U.S. Fish and Wildlife Service**
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	1.1	Promulgate special regulations for incidental take under the MMPA for specific activities.	5 yrs	**FWS** COE	95	95	95	50	50	
2	1.2	Continue state and federal review of permitted activities to minimize impacts to manatees and their habitat.	Continuous	**FWS** **FWC** COE FDEP **GDNR** M Industry SMC USCG WMDs	500 278 4	500 278 4	500 278 4	500 278 4	500 278 4	
2	1.2.1	Continue to review coastal construction permits to minimize impacts.	Continuous	FWS FWC COE GDNR SMC WMDs						
2	1.2.2	Minimize the effect of organized marine events on manatees.	Continuous	FWS FWC GDNR M Industry SMC USCG						

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	1.2.3	Continue to review NPDES permits to minimize impacts.	Continuous	FWS FWC EPA FDEP GDNR P Industry SMC						
2	1.2.4	Pursue regulatory changes, if necessary, to address activities that are "exempt," generally authorized, or not covered by state or federal regulations.	2 yrs	FWS COE M Industry SMC						
1	1.3	Minimize collisions between manatees and watercraft.	Continuous	**FWS** **FWC** FIND GDNR Local Gov'ts Local LE M Industry OC SMC USCG	25 439	25 439	25 439	25 439	25 439	

Implementation Schedule										
Florida Manatee Recovery Plan										U.S. Fish and Wildlife Service
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
1	1.3.1	Develop and refine state waterway speed and access rules.	5 yrs to Develop Continuous to Refine	FWS FWC Local Gov'ts M Industry OC SMC						
1	1.3.2	Develop and refine federal waterway speed and access rules.	3 yrs to Develop Continuous to Refine	FWS FWC COE Local Gov'ts M Industry NPS OC SMC						
1	1.3.3	Post and maintain regulatory signs.	Continuous	FWS FWC FIND Local Gov'ts NPS USCG						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	1.4	Enforce manatee protection regulations.	Continuous	**FWS** **FWC** Local LE MML NPS USCG	655 9	655 9	655 9	655 9	655 9	
2	1.4.1	Coordinate law enforcement efforts.	Continuous	FWS FWC Local LE NPS USCG						
2	1.4.2	Provide law enforcement officer training.	Continuous	FWS FWC Local LE NPS USCG						
2	1.4.3	Ensure judicial coordination.	Continuous	FWS						
2	1.4.4	Evaluate compliance with manatee protection regulations.	Periodic	FWS FWC MML SMC						

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	1.4.5	Educate boaters about manatees and boater responsibility.	Continuous	FWS FWC Local Gov’ts Local LE M Industry MML OC SMC USCG						
2	1.4.6	Evaluate effectiveness of enforcement initiatives.	Periodic	FWS FWC Local Gov’ts MML						
2	1.4.7	Provide updates of enforcement activities to managers.	Continuous	FWS Local LE USCG						
1	1.5	Assess and minimize mortality caused by large vessels.	1 yr to Assess Continuous to Reduce	**FWS** FWC COE Port Auth. USCG USN	5	5	5	5	5	
2	1.5.1	Determine means to minimize large vessel-related manatee deaths.	2 yrs	FWS						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	1.52	Provide guidance to minimize large vessel-related manatee deaths.	Continuous	FWS FWC COE FDEP USCG						
1	1.6	Eliminate manatee deaths in water control structures, navigational locks, and drainage structures.	Continuous	FWS FWC **COE** DERM FDEP **WMDs**	10 10	10 10	10 10	10 10	10 10	
1	1.6.1	Install and maintain protection technology at water control structures where manatees are at risk and monitor success.	5 yrs to Install Continuous to Maintain & Monitor	FWS FWC COE FDEP WMDs						
1	1.6.2	Install and maintain protection technology at navigational locks where manatees are at risk and monitor success.	5 yrs to Install Continuous to Maintain & Monitor	FWS FWC COE FDEP WMDs						

Implementation Schedule										
Florida Manatee Recovery Plan										**U.S. Fish and Wildlife Service**
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
1	1.6.3	Minimize injuries and deaths attributable to entrapment in drainage structures.	Install or Retrofit as Needed	FWS COE FDEP FWC Local Gov'ts WMDs						
1	1.6.4	Assess risk at existing and future water control structures and canals in South Florida.	2 yrs to Assess Continuous Monitoring	FWS COE FDEP FWC Local Gov'ts WMDs						
2	1.7	Minimize manatee injuries and deaths caused by fisheries and entanglement.	Continuous	**FWS** FWC GDNR SMC C Fish Indus R Fish Indus	10 10 1	10 10 1	10 10 1	10 10 1	10 10 1	
2	1.7.1	Minimize injuries and deaths attributed to crab pot fishery.	Continuous	FWS FWC C Fish Indus R Fish Indus						

Implementation Schedule										
Florida Manatee Recovery Plan									**U.S. Fish and Wildlife Service**	
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	1.7.2	Minimize injuries and deaths attributed to commercial and recreational fisheries, gear, and marine debris.	Continuous	FWS FWC Local Gov't C Fish Indus R Fish Indus OC SMC						
3	1.8	Investigate and prosecute all incidents of malicious vandalism and poaching.	As Needed	**FWS** **FWC** Local LE SMC USCG						
3	1.9	Update and implement catastrophic plan.	As Needed	**FWS** **FWC**	2	2	2	2	2	
2	1.10	Rescue and rehabilitate distressed manatees and release back into the wild.	Continuous	**FWS** Sirenia **FWC** GDNR MML **Oceanaria** SMC	50 1,130 1,000	50 1,130 1,000	50 1,130 1,000	50 1,130 1,000	50 1,130 1,000	
2	1.10.1	Maintain rescue network.	Continuous	FWS FWC MML						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	1.10.2	Maintain rehabilitation capabilities.	Continuous	FWS Oceanaria						
2	1.10.3	Release captive manatees.	Continuous	FWS FWC Oceanaria						
3	1.10.4	Coordinate program activities.	Continuous	FWS						
3	1.10.5	Provide assistance to international Sirenian rehabilitators.	Continuous	FWS FWC Oceanaria SMC						
3	1.10.6	Provide rescue report.	Annually	FWS						
2	1.11	Implement strategies to eliminate or minimize harassment due to other human activities.	Continuous	**FWS** FWC Local Gov't OC SMC	5	5	5	5	5	
2	1.11.1	Enforce regulations prohibiting harassment.	Continuous	FWS FWC USCG						
2	1.11.2	Improve the definition of "harassment" within the regulations promulgated under the ESA and MMPA.	2 yrs	FWS						
		Totals for Objective 1.			4,238	4,238	4,238	4,193	4,193	$21,100

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	2.1	Continue the MPSWG.	Continuous	**FWS** **Sirenia** FWC	5 20 12	5 20 12	5 20 12	5 20 12	5 20 12	
2	2.2	Conduct status review.	1 yr	**FWS**			25			
2	2.3	Determine life history parameters, population structure, distribution patterns, and population trends.	Continuous	FWS **Sirenia** Academia **FWC** GDNR MML	110 342 360 3	110 383 360 3	110 415 360 3	110 430 360 3	110 445 360 3	
2	2.3.1	Continue and increase efforts to collect and analyze mark/recapture data to determine survivorship, population structure, reproduction, and distribution patterns.	Continuous	Sirenia FWC MML SMC						
2	2.3.2	Continue collection and analysis of genetic samples to determine population structure and pedigree.	Continuous	Sirenia FWC MML						
2	2.3.3	Continue carcass salvage data analysis to determine reproductive status and population structure.	Continuous	FWC						

Implementation Schedule

Florida Manatee Recovery Plan — **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	2.3.4	Continue and improve aerial surveys and analyze data to evaluate fecundity data and to determine distribution patterns, population trends, and population size.	Continuous	FWS Sirenia FWC MML						
2	2.3.5	Continue collection and analysis of telemetry data to determine movements, distribution, habitat use patterns, and population structure.	Continuous	Sirenia FWC						
2	2.3.6	Continue to develop, evaluate, and improve population modeling efforts and parameter estimates and variances to determine population trend and link to habitat models and carrying capacity.	Continuous	Sirenia FWC						
2	2.3.7	Conduct a PVA to help assess population parameters as related to the ESA and MMPA	2yrs	FWS						
2	2.4	Evaluate and monitor causes of mortality and injury.	Continuous	**FWS** **Sirenia** **FWC** CZS GDNR MML	15 12 1,102 5	15 12 1,022 5	15 12 1,022 5	15 12 1,022 5	15 12 1,022 5	

Implementation Schedule Florida Manatee Recovery Plan — U.S. Fish and Wildlife Service										
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	2.4.1	Maintain and improve carcass detection, retrieval, and analysis.	Continuous	FWS FWC GDNR						
2	2.4.2	Improve evaluation and understanding of injuries and deaths caused by watercraft.	Continuous	FWS Sirenia FWC M Industry						
2	2.4.3	Improve the evaluation and understanding of injuries and deaths caused by other anthropogenic causes.	Continuous	FWS Sirenia FWC COE FDEP M Industry OC WMDs						
2	2.4.4	Improve the evaluation and understanding of naturally-caused mortality and unusual mortality events.	Continuous	FWS Sirenia Academia FWC MML						

Implementation Schedule Florida Manatee Recovery Plan — U.S. Fish and Wildlife Service										
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	2.5	Define factors that affect health, well-being, physiology, and ecology.	Continuous	FWS **Sirenia** Academia **FWC** MML Oceanaria	10 22 470	10 22 470	10 22 470	10 22 470	10 22 470	
2	2.5.1	Develop a better understanding of manatee anatomy, physiology, and health factors.	Continuous	Sirenia Academia FWC MML Oceanaria						
2	2.5.2	Develop a better understanding of thermoregulation.	Continuous	FWC Academia Oceanaria						
2	2.5.3	Develop a better understanding of sensory systems.	Continuous	FWS Sirenia Academia FWC MML Oceanaria						
2	2.5.4	Develop a better understanding of orientation and navigation.	Continuous	Sirenia Academia FWC Oceanaria						

Implementation Schedule Florida Manatee Recovery Plan — U.S. Fish and Wildlife Service										
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	2.5.5	Develop a better understanding of foraging behaviors during winter.	Continuous	Sirenia FWC Academia Oceanaria						
2	2.5.6	Develop baseline behavior information.	Continuous	FWC Academia Oceanaria						
2	2.5.7	Develop a better understanding of disturbance.	Continuous	FWS Academia CZS FWC MML Oceanaria						
2	2.5.7.1	Continue to investigate how a vessel's sound affects manatees.	Continuous	FWS Academia FWC M Industry MML Oceanaria						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	2.5.7.2	Investigate, determine, monitor, and evaluate how vessel presence, activity, and traffic patterns affect manatee behavior and distribution.	Continuous	FWS Sirenia Academia FWC CZS M Industry MML Oceanaria						
2	2.5.7.3	Assess boating activity and boater compliance.	Periodic Assessment Continuous to Improve Compliance	FWS Sirenia FWC Local Gov'ts M Industry MML SMC						
2	2.5.7.4	Evaluate the impacts of human swimmers and effectiveness of sanctuaries.	2 yrs	FWS FWC						
2	2.5.7.5	Evaluate the impacts of viewing by the public.	2 yrs	FWS FWC						
2	2.5.7.6	Evaluate the impacts of provisioning.	2 yrs	FWS FWC						
		Totals for Objective 2.			2,488	2,449	2,506	2,496	2,511	$12,450

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	3.1	Convene a Habitat Working Group.	Continuous	**FWS** **Sirenia** **FWC** M Industry OC SMC	5 20 80	5 22 80	5 24 80	5 26 80	5 28 80	October 2002, HWG will make recommendations to refine and improve habitat criteria
1	3.2	Protect, identify, evaluate, and monitor existing natural and industrial warm-water refuges and investigate alternatives.	Continuous	**FWS** **Sirenia** **FWC** FPL MML P Industry SMC	10 120 50 80	10 126 50 20	10 132 50	10 160 50	10 160 50	
2	3.2.1	Continue the Warm- Water Task Force.	Continuous	FWS Sirenia FWC FPL P Industry SMC						
1	3.2.2	Develop and implement an industrial warm-water strategy.	2 yrs to Develop Continuous to Implement	FWS Sirenia FWC EPA FDEP P Industry						

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	3.2.2.1	Obtain information necessary to manage industrial warm-water refuges.	3 yrs	FWS FWC FPL P Industry						
2	3.2.2.2	Define manatee response to changes in industrial operations that affect warm-water discharges.	Continuous	FWS Sirenia FWC FPL						
1	3.2.3	Protect, enhance, and investigate other non-industrial warm-water refuges.	Continuous	FWS FWC FDEP SMC WMDs						
1	3.2.4	Protect and enhance natural warm-water refuges.	Continuous	FWS FWC FDEP SMC WMDs						
3	3.2.5	Assess changes in historical distribution due to habitat alteration.	1yr	FWS MMC Sirenia FWC						

Implementation Schedule

Florida Manatee Recovery Plan — U.S. Fish and Wildlife Service

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	3.2.4.1	Develop and maintain a database of warm-water refuge sites.	Continuous	FWS Sirenia FWC						
1	3.2.4.2	Develop comprehensive plans for the enhancement of natural warm-water sites.	Continuous	FWS FWC						
1	3.2.4.3	Establish and maintain minimum spring flows and levels at natural springs.	Continuous	FWS FWC EPA SMC WMDs						
1	3.3	Establish, acquire, manage, and monitor regional protected area networks and manatee habitat.	Continuous	**FWS** **Sirenia** **FWC** FDEP Local Gov'ts SMC WMDs	290 165 547	290 180 547	290 190 547	290 160 547	290 170 547	
1	3.3.1	Establish manatee sanctuaries, refuges, and protected areas.	2 yrs Periodic Update	FWS FWC						

Implementation Schedule Florida Manatee Recovery Plan — U.S. Fish and Wildlife Service										
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
	3.3.2	Identify and prioritize new land acquisition projects.	Annually	FWS Sirenia FWC FDEP FWC SMC WMDs						
2	3.3.3	Acquire land adjacent to important manatee habitats.	Continuous	FWS FDEP Land Trusts Local Gov'ts WMDs						
2	3.3.4	Establish and evaluate manatee management programs at protected areas.	Continuous	FWS FWC						
3	3.3.5	Support and pursue other habitat conservation options.	Continuous	FWS FWC SMC						
1	3.3.6	Assist local governments in development of county MPPs.	Continuous	FWS FWC Local Gov'ts M Industry R Fish Indus OC SMC						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	3.3.7	Implement approved MPPs.	Continuous	FWS FWC Local Gov'ts						
2	3.3.8	Protect existing SAV and promote re-establishment of NSAV.	Continuous	FWS FWC FDEP FWC WMDs Local Gov'ts						
2	3.3.8.1	Develop and implement a NSAV protection strategy.	2 yrs to Develop Continuous to Implement	FWS Sirenia FWC FDEP FWC WMDs Local Gov'ts						
2	3.3.8.2	Develop and implement a state-wide seagrass monitoring program.	Continuous	FWS Sirenia FWC FWC NMFS WMDs Local Gov'ts						

Implementation Schedule										
Florida Manatee Recovery Plan										**U.S. Fish and Wildlife Service**
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
21	3.3.8.3	Ensure aquatic plant control programs are properly designed and implemented.	Continuous	FWS Sirenia FWC COE FDEP FWC						
2	3.3.9	Conduct research to understand and define manatee ecology.	Continuous	Sirenia Academia FWC MML SMC						
2	3.3.9.1	Conduct research and improve databases on manatee habitat.	Continuous	Sirenia FWC						
2	3.3.9.2	Continue and improve telemetry and other instrumentation research and methods.	Continuous	Sirenia FWC						
2	3.3.9.3	Determine manatee time and depth pattern budgets.	Continuous	FWC MML						
2	3.3.10	Define the response to environmental change.	Continuous	FWS Sirenia FWC						

Implementation Schedule										
Florida Manatee Recovery Plan										**U.S. Fish and Wildlife Service**
Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
2	3.3.10.1	Define response to changes in fresh water flow patterns in south Florida as a consequence of the Everglades' Restoration.	Continuous	Sirenia Academia FWC						
2	3.3.10.2	Define response to degradation and rehabilitation of feeding areas.	Continuous	Sirenia FWC						
2	3.3.11	Maintain, improve, and develop tools to monitor and evaluate manatee habitat.	Continuous	FWS Sirenia FWC						
2	3.3.11.1	Maintain, improve, and develop tools to monitor and evaluate natural and human-related habitat influences on manatee ecology, abundance, and distributions.	Continuous	FWS Sirenia FWC						
1	3.3.11.2	Maintain, improve, and develop tools to evaluate the relationship between boating activities and watercraft-related mortality.	Continuous	FWS FWC M Industry MML						
3	3.3.11.3	Evaluate impact of changes in boat design and boater behavior.	Continuous	FWS M Industry MML						
2	3.3.11.4	Conduct a comprehensive risk assessment.	1 yr	FWS						

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
2	3.4	Ensure that minimum flows and levels are established for surface waters to protect resources of importance to manatees.	Continuous	**FWS** FWC SMC WMDs	3	3	3	3	3	
3	3.5	Assess the need to revise critical habitat.	1yr	**FWS**						
		Totals for Objective 3.			1,370	1,333	1,331	1,331	1,343	$6,708
3	4.1	Identify target audiences and key locations for outreach.	3 yrs Periodically Update	FWS FWC GDNR OC SMC	5 5 2	5 5 2	5 5 2	5 5 2	5 5 2	
2	4.2	Develop, evaluate, and update public education and outreach programs and materials.	3 yrs to Develop Periodically Update	FWS FWC FPL GDNR OC SMC	5 205 30 2	5 205 2	5 205 2	5 205 2	5 205 2	
1	4.2.1	Develop consistent and up-to-date manatee boater education courses/programs.	2 yrs to Develop Periodically Update	FWS FWC M Industry OC SMC USCG						

Implementation Schedule

Florida Manatee Recovery Plan **U.S. Fish and Wildlife Service**

Priority	Task Number	Task Description	Task Duration	Participants	Estimated Fiscal Year Costs ($1000s)					Comments
					FY1	FY2	FY3	FY4	FY5	
1	4.2.2	Publish and post manatee protection zone information.	Annually Publish Continuous	FWS FWC COE Local Gov’ts M Industry						
1	4.2.3	Update nautical charts and Coast Pilot to reflect current manatee protection zone information.	1 yr	FWS NOAA						
3	4.3	Coordinate development of manatee awareness programs and materials in order to support recovery.	Continuous	FWS FWC COE FDEP GDNR Local Gov’ts OC SMC USCG WMDs	5 14 2	5 14 2	5 14 2	5 14 2	5 14 2	
2	4.4	Develop consistent manatee viewing and approach guidelines.	2 yrs	**FWS** FWC OC SMC Ecotour Ind	3 1	3 1	3 1	3 1	3 1	

Implementation Schedule

Florida Manatee Recovery Plan | **U.S. Fish and Wildlife Service**

Priority	**Task Number**	**Task Description**	**Task Duration**	**Participants**	**Estimated Fiscal Year Costs ($1000s)**					**Comments**
					FY1	**FY2**	**FY3**	**FY4**	**FY5**	
3	4.5	Develop and implement a coordinated media outreach program.	1 yr to Develop Continuous to Implement	FWS FWC Local Gov’ts OC Oceanaria SMC	5	5	5	5	5	
3	4.6	Utilize the rescue, rehabilitation, and release program to educate the public.	Continuous	**FWS** FWC Oceanaria	3 1	3 1	3 1	3 1	3 1	
3	4.7	Educate state and federal legislators about manatees and manatee issues.	Continuous	FWS FWC M Industry OC P Industry SMC						
		Totals for Objective 4.			288	258	258	258	258	$1,320
		Total for Recovery.			8,384	8,278	8,333	8,278	8,305	$41,578

Manatee Population Status Working Group's (MPSWG) Recommendation of Population Benchmarks To Help Measure Recovery

RECOMMENDED POPULATION BENCHMARKS

The Manatee Population Status Working Group developed the following population benchmarks to assist in evaluating the status of the Florida manatee for reclassification to threatened status. In each of the four regions of the Florida manatee population (Northwest, Southwest, Atlantic, and Upper St. Johns River):

1. the average annual estimated rate of adult survival is at least 94%, with statistical confidence that the rate is not less than 90%;
2. the average annual percentage of adult females with calves during winter is at least 40%; and
3. the average annual rate of population growth is at least 4%, with statistical confidence that the rate is not less than 0 (no growth).

The MPSWG recommended that estimates of the benchmark statistics (survival, reproduction, and population growth rate) be determined over a minimum of a 10-year time period, and that no significant downward trend be detectable in these parameters, before FWS considers reclassification of the Florida manatee from endangered to threatened status. The MPSWG did not propose delisting criteria, as specific, quantitative habitat criteria have yet to be developed.

Table 4. Published population benchmark values for each region.

Region	Percent Survival	Proportion of Females with Calves	Percent Growth
Northwest	96.5 (95.1 - 97.5)[a] (1982 -1993)	.431 (1977 - 1991)	7.4 (1978 - 1991)
Southwest	unknown	unknown	unknown
Upper St. Johns River	96.1 (90.0 - 98.5)[a] (1978 - 1993)	.407 (1979 - 1993)	5.7 (3 - 8) (1978 - 1991)
Atlantic	90.7 (88.7 - 92.6)[a] (1985-1993)	.423 (1979 - 1992)	1.0 (1985 - 1991)

[a] 95% Confidence Interval

Data Sources: **Percent Survival** - Langtimm, O'Shea, Pradel, and Beck 1998. **Proportion of Females with Calves** - Rathbun, Reid, Bonde, and Powell, 1995 (Northwest); O'Shea and Hartley, 1995 (St. Johns River); and Reid, Bonde, and O'Shea, 1995 (Atlantic). **Percent Growth** - Eberhardt and O'Shea, 1995.

METHODS FOR DETERMINING THE POPULATION BENCHMARKS

Criterion A: average annual adult survival estimates, is based upon a mark-recapture approach, using resightings of distinctively marked individual manatees (Langtimm et al. 1998; see p. 11 for further details). Using open population models, adult survival probabilities were estimated for manatees in the Northwest, Upper St. Johns River, and Atlantic regions of Florida. After using goodness-of-fit tests in Program RELEASE to search for violations of the assumptions of mark-recapture analysis, survival and sighting probabilities were modeled with Program SURGE. Statistically robust population models with explicit assumptions will continue to be the basis for estimation of this benchmark.

Criterion B: average annual percentage of adult females with calves, is also based upon resightings of distinctively marked individual manatees. Ongoing development of multi-state models that account for misclassification of breeders and non-breeders will improve the accuracy of regional estimates of productivity. Efforts are also being made to develop a statistically valid method for estimation of a confidence interval for this benchmark.

Criterion C: average annual rate of population growth, is based upon a deterministic population model (Eberhardt and O'Shea 1995). Parameters in the model were primarily derived from life history information obtained through resightings of distinctively marked individual manatees in the Northwest, Upper St. Johns River, and Atlantic regions. It is a simple, 2-stage (calves and adults) model that does not incorporate stochasticity (variability in survival and fecundity rates caused by changes in environmental, demographic, and genetic factors). Future models of population growth rates will undoubtedly incorporate more stages (e.g., juvenile and subadult year classes) and stochasticity. New analyses of life history data (obtained through both carcass salvage data and resightings of known individuals), will undoubtedly improve parameter estimates and reduce uncertainty in modeling results.

BASIS FOR THE POPULATION BENCHMARKS

The benchmarks were based on published estimates of survival, reproduction, and population growth rate (Table 1). Adult survival is the most influential factor determining manatee population dynamics (Eberhardt and O'Shea 1995; Marmontel et al. 1997; Langtimm et al. 1998). Since there is currently no method for determining juvenile survival rates, the MPSWG included a reproduction benchmark. Manatee population growth is less sensitive to changes in reproductive rates than adult survival rates (Marmontel et. al. 1997); however, the average proportion of females with calves over long time spans (at least 10 years) is remarkably consistent across regions (O'Shea and Hartley 1995). The MPSWG concluded that changes in reproductive rates could be a useful indicator of manatee population status, but recognized that a relatively high level of variation in reproductive rates among years requires that a period of at least 10 years be used to estimate this parameter.

Survival rates are estimated from resightings of known individuals in the photo-identification catalog, using adults only (at least 5 years of age), resighted between December and February each year (Langtimm *et al.* 1998). Survival rates for three regions (the Northwest, Upper St. Johns, and Atlantic) were estimated using state-of-the-art statistical methods (Langtimm *et al.* 1998). The target is an adult survival rate of at least 94%, that is, at least 94 of each 100 adult manatees survive from one year to the next. This benchmark is less than the estimated survival rates (96%) in two regions (the Northwest, Upper St. Johns), and higher than the lowest estimated survival rate (91%) in the Atlantic region. The lower bound of the 95% confidence interval should be greater than 0.90 (95% certainty that survival rate is actually greater than 0.90).

Similarly, reproductive rates were estimated from resightings of known individuals in the photo-identification catalog, using adult females only (at least 5 years of age), resighted between December and February of each winter (O'Shea and Hartley 1995, Rathbun *et al.* 1995, Reid *et al.* 1995). The target is 40% of known adult females seen with calves in winter each year (1^{st} or 2^{nd} year calves). The target level has been reached in all three regions (the Northwest, Upper St. Johns, and Atlantic) for which adequate data exist to determine reproductive status of adult females (Table 2). The similarity across regions in the average proportion of adult females observed with calves in winter (43%, 41% and 42%, respectively) suggests that Florida manatees may have achieved a maximum level of reproduction (O'Shea and Hartley 1995).

The population growth rates for each region were calculated using a population model that incorporated estimated survival rates for adults, subadults, and calves, and reproductive rates (Eberhardt and O'Shea 1995). The target is a population growing at 4% per year, which is below the estimated growth rate for the Northwest and Upper St. Johns regions (Table 2). There is a one-to-one correspondence between adult survival above 90% and population growth rate (Eberhardt and O'Shea 1995). Thus, an adult survival rate of 94% corresponds to an annual population growth rate of 4%. In addition, 4% is mid-way between 0 and 8% growth, and 8% is likely to be the maximum manatee population growth rate through internal recruitment. Eberhardt and O'Shea (1995) estimated an annual growth rate of 7.4% for the Crystal River. Without any human-related deaths, this population could almost certainly attain a growth rate of 8%.

The proposed benchmark for population growth (4%) is based upon the results of the Eberhardt and O'Shea (1995) deterministic population model. These authors did not attempt to estimate confidence intervals for two of the three regions for which they estimated population growth rates (Northwest and

Atlantic), and used two different methods to estimate (relatively large) confidence intervals for the growth rate of the Upper St. Johns region. There is clearly uncertainty in their model results. Additionally, they did not attempt to account for the effect of environmental variability over time on population trend. It is essential either to be conservative in selecting a minimum growth rate benchmark, as in selecting 4%, or to require a high degree of statistical confidence that the average growth rate is not lower than 0 in all regions. The latter alternative will require development of new models that include statistically robust methods for estimating confidence intervals.

Research Plan to Determine and Monitor the Status of Manatee Populations

The success of efforts to develop and implement measures to minimize manatee injury and mortality depends upon the accuracy and completeness of data on manatee life history and population status. Population data are needed to identify and define problems, make informed judgments on appropriate management alternatives, provide a sound basis for establishing and updating management actions, and to determine whether or not actions taken are achieving management objectives.

MANATEE POPULATION STATUS WORKING GROUP

The interagency Manatee Population Status Working Group (MPSWG) was established in March 1998. The group's primary tasks are to: (1) assess manatee population trends; (2) advise the U.S. Fish and Wildlife Service (FWS) on population criteria to determine when species recovery has been achieved; and (3) provide managers with interpretation of available information on manatee population biology. The group also has formulated strategies to seek peer review of their activities. The working group should continue to hold regular meetings, refine recovery criteria, annually update regional and statewide manatee status statements, and convene a population biology workshop early in 2002, analogous to the one held in 1992.

STATUS REVIEW

Following the Population Status Workshop in 2002, FWS will conduct a status review of the Florida manatee. The review will include: (1) a detailed evaluation of the population status of the species; (2) an evaluation of existing threats to the species and the effectiveness of existing mechanisms to control those threats, particularly with respect to the five listing factors identified under the Endangered Species Act of 1973, as amended (ESA); and (3) recommendations, if any, regarding reclassification and additional and/or revised recovery objectives, criteria and tasks to deal with remaining threats.

LIFE HISTORY PARAMETERS AND POPULATION TREND

Many manatees have unique features, primarily scars caused by boat strikes. When carefully photographed, these features can provide a means of identifying individuals. **Photographs of distinctively-marked manatees** collected by researchers in the field are compiled in a database begun in 1981 by the U.S. Geological Service Sirenia Project (USGS-Sirenia) with support from the Florida Power and Light Company (FPL). Since its inception, the database has been expanded greatly and improved. It is now a photo CD-based computerized system, known as the Manatee Individual Photo-identification System (MIPS), that utilizes digitized images and PC-based search technologies. The Florida Fish and Wildlife Conservation Commission's (FWC) Marine Research Institute (FMRI) and Mote Marine Lab (MML) now assist in maintaining portions of the database.

It is essential to maintain the photography efforts of the USGS-Sirenia, FMRI, and MML to ensure that vital information on manatee sightings, movement patterns, site use and fidelity, reproductive histories, and related databases remain current for further analyses of survival and reproductive rates. Photos routinely should be collected in the field, especially at the winter aggregation sites, according to standardized protocols for data collection and coding by all cooperators. Annual collection of photographs is essential, as the loss of feature information for individuals in one season could result in an inability to recognize the individual in subsequent years, and potentially compromise the value of the database. Efforts to gather photographic documentation of known females should be continued and expanded to the Southwestern region (Naples through Ten Thousand Islands and the Everglades).

One of the most important parameters for estimating trends in population status is age-specific survival. Photographs documenting sightings of individually-identifiable manatees can be used to estimate minimum ages of manatees in the database and **annual survival rates**. Data on manatees overwintering at specific sites (e.g., Crystal River, Blue Spring, and the warm-water discharges on the Atlantic Coast) are extensive. Analyses using mark-resighting modeling procedures to estimate annual survival rates at these sites have been completed through 1993. Analyses to update these estimates and add additional survival estimates for sites in Southwest Florida (Tampa Bay to the Caloosahatchee River) are underway.

Dead manatees previously identified by photographic documentation must be noted in the database before sight-resighting analyses are undertaken. It is crucial that carcasses continue to be photographically documented and those images distributed to managers of the photo-ID databases, to enhance the accuracy and precision of survival estimates.

Concurrently with photography of individual manatees, information on the **reproductive status of each manatee** (e.g., calf associated with female) should continue to be collected whenever possible. Minimum ages of documented manatees and information such as age at first reproduction, calving interval, and litter size can be determined either during photo-documentation or by timely examination of the database. Long-term studies of reproductive traits and life histories of individual females provide data on age-specific birth rates and success in calf-rearing. The relative success of severely- and lightly-scarred females in bearing and rearing calves should be determined.

Information and tissue samples should continue to be collected from all carcasses recovered in the **salvage program** to determine reproductive status. Resulting estimates of reproductive parameters complement information obtained from long-term data on living manatees and will help to determine trends and possible regional differences in reproductive rates.

Paternity cannot be established in wild manatees without the ability to determine family pedigrees. This information is needed to determine if successful reproduction is limited to a small proportion of adult males, which has important implications for the **genetic diversity** of the Florida manatee population. By continuing the development of nuclear DNA markers, pedigree analysis can be applied to the growing collection of manatee tissue samples. Pedigree analysis also would greatly improve our knowledge of matrilineal relationships and female reproductive success. Identification of factors associated with successful breeding by males is important in assessing reproductive potential in the wild and in captivity.

Aerial surveys provide information on the proportion of calves which may provide insights on reproductive trends when a long time-series of surveys have been conducted by one or relatively few individuals in the same geographic regions. Calf counts from such surveys should be continued (particularly the state-wide surveys conducted by FMRI since 1991, the power plant surveys sponsored by FPL since 1977, and the Crystal/Homosassa River surveys conducted by FWS since 1983). The results should be compared to those obtained by photo-ID methods (particularly for the Crystal/Homosassa River wintering group).

Passive Integrated Transponder (PIT) tags should be inserted under the skin of all manatees captured during the course of ongoing research or rescues. All manatees that are recaptured, rescued, or salvaged should be checked for PIT tags, and identification information should be provided to FMRI. By comparing data on manatee size, reproductive status, and general condition between time of tagging and recovery, one can increase the amount of information obtained on life history parameters. This technique is particularly useful in identifying carcasses, which is very important in obtaining accurate survival estimates. Methods for checking for PIT tags reliably on free-swimming manatees should further be developed and tested. When the latter work shows promise, plans should be developed for re-examining the utility of PIT-tagging manatees of certain age classes (juveniles and subadults) or in specific areas where photo-ID is not a feasible way to re-identify individuals. This research should include estimates of sample sizes required to determine population traits, such as survival and reproductive rates.

POPULATION STRUCTURE

Information on population structure can be obtained through the carcass salvage program, the

MIPS database, and telemetry studies. This information is important for the development of realistic population models.

Collection of tissue samples from salvage specimens and from living manatees at winter aggregation sites, captured during research, or rescued for rehabilitation should continue. Continued genetic analysis through collaborations with state and federal genetics laboratories may reveal greater population structure than has been demonstrated thus far (i.e., a significant difference between east and west coasts, but not within coasts). Such research will improve our ability to define regional populations and management units. Stock and individual identity for forensic purposes ultimately will be possible. Analytical techniques recently developed for identifying the structure of other marine stocks also should be investigated.

To aid in characterizing population structure, life history information (e.g., sex and size class) should continue to be collected concurrent with photographs to augment similar information collected from other sources (e.g., carcasses and telemetry). Long-term patterns of fidelity to winter aggregation sites and summer ranges, as well as movement among sites, also can be documented.

Radio-tracking has provided substantial documentation of seasonal migrations, other long-distance movements, and local movements that reveal patterns of site fidelity and habitat use. In Brevard County, for example, a large group of manatees overwinters in the Indian River, using two power plants for thermal refuge, and another group travels south to Palm Beach and Dade counties, using several power plants for refuge along the way. While these two groups are not entirely mutually exclusive, many individuals consistently display the same pattern each year, in timing and distance of moves as well as destinations. Such information is needed from other regions, particularly Southwest Florida, in order to develop management strategies for all significant subgroups within the regional population, however transitory they may be.

The **salvage program** yields important information on the manatee population sex ratio and proportion of age classes (adult, subadult, juvenile, and perinatal) within each cause-of-death category. Annual changes in these proportions may indicate increases or decreases in certain types of mortality, and thus should be considered as part of the weight of evidence that supports (or rejects) a downlisting decision. Ear bone growth-layer-group analysis should be continued to determine more exact ages of dead manatees, particularly those that have a known history through the photo-ID or telemetry studies, or received PIT tags. Although the age structure of the carcass sample is biased toward younger animals, opportunities may occur to document better the natural age structure within specific regions because of age-independent mortality events.

DISTRIBUTION PATTERNS

Shifts in manatee distribution over time may interfere with our ability to assess accurately regional population trends. Changes may occur in response to human activities, such as modifications of warm-water discharges, enforcement of boat speed regulations, or restoration programs, and because of natural events, such as hurricanes or red tides. Efforts to document manatee distribution through aerial surveys, photo-ID, and telemetry should continue, particularly at important wintering sites, areas of high use, and poorly-studied regions. The validity of the four regional subpopulation designations should be periodically re-evaluated, as they may change over time.

As discussed above, **photographs documenting individual manatees** are important to provide information on life history parameters, population trends, and population structure. Such photographs are also important to provide information on fidelity to winter and summer sites, high-use of and seasonal movements among sites. These photos should continue to be taken at aggregation sites primarily in Florida, but also opportunistically at other sites in the Southeastern United States. Photo-ID efforts recently were initiated in the Ten Thousand Islands region, and should be continued and expanded to other sites in Southwestern Florida.

As appropriate and possible, local and regional **aerial surveys** should be undertaken or continued to improve information on habitat use patterns and changes in distribution. Documentation of changes in distribution at power plants will be particularly important when changes in warm water availability occur.

Telemetry research has proceeded as a series of regional studies with tracking efforts concentrated in different areas in different years. Multi-year studies have been completed for the Atlantic coast and Southwest Florida from Tampa Bay through Lee County, and research findings have been summarized in manuscripts currently undergoing peer review. Verified high quality satellite telemetry location information, with descriptive meta data, will be added to the Marine Resources CD-ROM produced by FMRI. Areas not well-studied, such as the Everglades or where anticipated changes are likely to impact manatees, will be targeted for future research.

POPULATION MODELING

Population models are mathematical representations of the underlying biological processes that control population dynamics. In order to be useful in describing the true behavior of population growth, existing models must be evaluated and improved continually. The underlying assumptions of models, the importance of parameters used in the models, the accuracy and uncertainty of the parameter estimates, the relationships of the parameters, and the appropriateness of the mathematics implemented in the models need to be evaluated critically. Comparisons also need to be made between predicted outcomes from the models and estimates or indices of population trend from other modeling efforts or other data sets.

Eberhardt and O'Shea (1995) developed a deterministic population model using estimates of mortality, reproduction, and survivorship to calculate estimates of population growth rates for three subpopulations of manatees. They considered this a provisional model requiring further development and modification. Steps should be taken to continue to improve this model and to develop more complex models incorporating additional life history information and which reflect better our understanding of the processes involved in population dynamics. Examples of additional population parameters that most likely will be needed in future models are stochastic variation in survival and reproduction rates, genetic population structure, and movement of individuals between regional subpopulations.

To construct valid models, accurate **estimates of population parameters** are required. Where estimates of model parameters need to be developed or improved, other relevant tasks should be modified or strengthened. Because parameters can vary over space and time and such variation affects population growth rates, emphasis should be placed on **estimating variance** and 95% confidence intervals along with developing best estimates of particular population parameters.

It is important for those **developing manatee population models** to coordinate their activities and to interact directly with research biologists who have collected manatee life history data or who are very familiar with manatee ecology. Biologists will understand better how models were derived, and the modelers will obtain feedback on the reasonableness of their assumptions and interpretation of their results. Interaction with management also is needed to help focus the questions addressed by present and future modeling efforts. For example, FWS wants to know if modelers can estimate the number of manatee deaths that can be sustained per region, while still allowing population stability or growth to be achieved. The coordination and interaction of all players will lead to the adaptive development of newer and better models that meet the needs of manatee biologists, policy makers, and managers. The multi-agency MPSWG is best positioned to track research developments, link important players, and provide one level of peer review and evaluation. Peer review from internal and external sources is essential to such evaluations.

Uncorrected aerial survey data do not permit statistically valid population estimation or trend analyses. However, models to correct for some of the inherent bias and uncertainty have been developed, and these efforts should be continued. Methods to correct for various types of visibility bias in surveys should be developed. Standard procedures for survey teams involved in annual statewide surveys need to be developed and implemented. Use of strip transect aerial surveys make it possible to use survey data to detect regional population trends, e.g., in the Banana River and perhaps in Southwest Florida between the Ten Thousand Islands and Whitewater Bay. Strip transect surveys should be continued on an annual basis in the Banana River, and their feasibility should be investigated in remote coastal areas of Southwest Florida. To the extent possible, surveys should be designed to estimate accurately a minimum population number.

As manatee habitat requirements are documented and recovery criteria are identified (based on habitat needs), it will become possible to **link regional population and habitat models and estimate optimum sustainable populations for regions and subregions**. Integration of population and habitat information is essential to understand the implications of habitat change before negative impacts on manatee population trends can occur. The Population Status and Geographic Information System (GIS) working groups should meet jointly on an annual basis to coordinate their activities and progress. Reports of these meetings should be distributed to all agencies and interested parties involved in manatee recovery efforts.

The manatee salvage/necropsy program is fundamental to **identifying causes of manatee mortality and injury**. The program is responsible for collecting and examining virtually all manatee carcasses reported in the Southeastern United States, determining the causes of death, monitoring mortality trends, and disseminating mortality information. Program data help to identify, direct, and support essential management actions (e.g., promulgating watercraft speed rules, establishing sanctuaries, and reviewing permits for construction in manatee habitat). The program was started by FWS and the University of Miami in 1974 and was transferred to the State of Florida in 1985.

The current manatee salvage and necropsy program is administered through FWC 's FMRI. The major program components are: (1) receiving manatee carcass reports from the field; (2) coordinating the retrieval and transport of manatee carcasses and conducting gross and histological examinations to determine cause of death; (3) maintaining accurate mortality records (including out-of-Florida records); and (4) carrying out special studies to improve understanding of mortality causes, rates, and trends. The carcass salvage program also has permitted scientists to: (1) describe functional morphology of manatees; (2) assess certain life history parameters of the population; and (3) collect data on survival of known individuals. Program staff also coordinate rescues of injured or distressed manatees. To implement the salvage program, FWC maintains a central necropsy facility called the Marine Mammal Pathobiology Laboratory (MMPL), located on the Eckerd College campus in St. Petersburg. FWC also has three field stations on the east coast situated in Jacksonville, Melbourne, and Tequesta, and one field station on the west coast at Port Charlotte.

To improve the program, FWC is hosting a series of manatee mortality workshops to review critically its salvage and necropsy procedures and methods. These workshops: (1) establish and improve "state-of-the-art" forensic techniques, specimen/data collection, and analyses; (2) identify and create projects focusing on unresolved death categories; (3) prepare for and assist with epizootics; (4) generate reference data on manatee health; and (5) generate suggestions for attainment of a "healthy" manatee population. In addition, FMRI personnel are urged to move forward with models based on life history and mortality data, and process improvement is being implemented to expedite data dissemination.

Georgia Department of Natural Resources, South Carolina Department of Natural Resources, Louisiana Department of Wildlife and Fisheries, Texas Marine Mammal Stranding Network, University of North Carolina at Wilmington, and others help to coordinate carcass salvages and rescues in other Atlantic and Gulf coast states. Mortality information collected from these efforts needs to be centralized and should be kept in the mortality database maintained by FWC. FWS and FWC should provide assistance to these manatee salvage and rescue programs through workshops, providing equipment and assistance when possible.

While it is believed that most dead manatees are found and reported to the salvage program, an unknown proportion are unreported. Annual manatee carcass totals, therefore, under-represent the actual number of deaths, indicating the need to **improve carcass detection, retrieval, and analysis**. Decomposition, increased in part by delayed carcass retrieval, reduces the ability to assign cause of death in some cases. To estimate the number of unreported manatee carcasses, studies should be done on carcass detection and reporting rates. Studies focusing on carcass drift, rate of decomposition, and how decomposition affects necropsy results should be conducted. Periodic peer reviews should take place on necropsy methods, data recording and analysis, and documentation of tissues collected. Representative samples should be archived with appropriate national tissue banks. Workshops such as the FWC Manatee Mortality Workshop should continue to be conducted to strengthen collaborative research and information sharing. Partnerships with other agencies and process analysis of carcass retrieval protocols should be ongoing in order to improve efficiency.

Collisions between manatees and boats is the largest known cause of manatee mortality, both human and non-human related; in the late 1990s, watercraft-related deaths constituted at least 25% of the total known annual mortality. Therefore, it is essential to **improve the assessment and understanding of manatee injuries and deaths caused by watercraft**. Under-reporting of watercraft mortality may occur because individuals may not die immediately but rather may develop complications resulting from injuries sustained by boats; such deaths are difficult to attribute to watercraft.

Benchmarks have been established for survival, reproduction, and population growth.

Longitudinal studies should be established to examine the effect of boats and boating activity on these parameters. Investigations of the characteristics of lethal compared to non-lethal injuries and causes should be developed using data from carcasses, photo-ID records, and characterizing healing in rescued injured animals. Investigations on lethal and non-lethal injuries also should attempt to characterize size of vessels, relative direction of movement of vessel, and propeller vs. blunt trauma statistics. Research on mechanical characteristics of skin and bones should be developed to obtain a better understanding of the effects of watercraft-related impacts. Regional studies are needed to characterize boating intensity, types of boats, boating behavior, and boating hot spots in relation to manatee watercraft-related mortality.

Increasing numbers of manatees in the Northwest region of Florida may lead to increasing numbers of animals killed by watercraft. However, such population increases would not explain the recent increase in the percent of mortalities related to watercraft. In addition, this explanation cannot be used for areas where the number of manatees is stable or decreasing. The available data suggest that on average in 2000, collisions with watercraft killed a manatee every 4.6 days. However, these data may underestimate the number of manatee mortalities. More effective diagnosis of watercraft-related injuries and mortalities is important for describing the extent and nature of the threat posed by watercraft. Mortality workshops are intended to improve our ability to diagnose watercraft-related mortalities more effectively on both fresh and decomposed carcasses.

Prevention of such injuries and mortalities is the goal. **Research is needed to address the causes of watercraft mortality and the effectiveness of management actions**. Importantly, such research also should investigate the effects of sublethal injuries and stress occurring as a result of boating activity. Injuries and stress may: (1) lead to reductions in animal condition and reproductive success; (2) cause animals to abandon habitat important for foraging, reproduction, or thermal regulation; or (3) impair immune system function thereby increasing the vulnerability of animals to disease, pollutants, or toxins. Thus, indirect or secondary effects of boating activity also may impede population recovery in ways that have not yet been assessed.

Studies are underway to **identify and evaluate adherence to manatee speed zone restrictions through statewide boater compliance studies**. The following should be continued and assessed: (1) the frequency of boater compliance with posted manatee speed zone restrictions; (2) the degree of boater compliance with posted manatee speed zone restrictions; (3) the levels of compliance among boat classes, seasonally, and temporally; (4) changes in compliance resulting from different enforcement regimes; and (5) changes in compliance resulting from different signage. Underlying sociological factors that affect compliance also should be investigated.

MML recently completed a **study that characterizes the intensity and types of boating**

activities in Southwest Florida. Similar studies should be conducted at selected locations around the state, with emphasis on areas where boat-related mortality of manatees is highest.

MML, FWC, and others are **investigating reactions of manatees to boats**. Preliminary information indicates that manatees perceive boats, but may, under certain circumstances, react in ways that place the animals in the path of, rather than away from, the boats. Additional studies of manatee responses to boats and vessel acoustics are needed. Indirect deleterious effects of shallow-draft or jet boats that can disturb manatees and cause them to move to boating channels or interrupt normal behaviors need to be studied. An evaluation of spatial and temporal factors associated with risk to manatees (i.e., proportion of time manatees are exposed to vessels relative to depth, habitat, and manatee activity) should be conducted.

In the 1970s, Odell and Reynolds described the extent to that flood control structures killed manatees in southeastern Florida. In response, the South Florida Water Management District modified the way that the structures operate, to determine if this change would mitigate the problem. The problem, however, continues to exist, and it involves flood control structures and navigational locks located throughout the state. The U.S. Army Corps of Engineers and various flood control agencies (among others) have devoted considerable time and money to possible solutions, but mortality in the structures was the second highest ever in 1999 (15 manatees died, accounting for approximately 5% of the total deaths during this year). **Research is needed to continue to assess manatee behavior leading to vulnerability around these structures**, as well as operational or structural changes that can prevent serious injury or death of manatees.

Presently, pressure-sensitive strips are being installed on vertical lift structures, and acoustic arrays are being installed on navigational locks. Efforts continue to understand better how and why manatees are killed by structures. The MMPL will associate forensic observations obtained at necropsy with specific characteristics of the structure that caused the death. Continued testing and improvement of manatee protection technology is encouraged.

Commercial fishing is not a major culprit involved in manatee mortality, unlike the case with most other marine mammals. Commercial fishing accounts for far fewer manatee deaths than do either collisions with boats or entrapment in water control structures. Nonetheless, manatees are killed by shrimp trawls, hoop nets, monofilament entanglement, hook and line ingestion, and crab pot/rope entanglement, indicating the need to **improve the evaluation and understanding of injuries and deaths of manatees caused by commercial and recreational fishing**.

Since the introduction of Florida's ban on the use of commercial nets in inshore waters in July

1995, manatees have been exposed to fewer opportunities to become entangled in nets. Because of the net ban, however, some former commercial net fishermen switched to crabbing using crab pots. Probably as a result of this increased number of crab pots, rescues of manatees entangled in crab pot lines have more than tripled since 1995. To reduce the increasing numbers of fishing gear entanglements by manatees, a multi-agency Manatee Entanglement Task Force has been established, focusing on creating changes in data collection protocols, potential technique/gear modifications, innovative tag designs, entanglement research, gear recovery/clean-up, and education/outreach efforts. Research on rates of entanglement, types of gear involved, and geographical and temporal changes in rates and types of entanglements should be developed. Studies on behavioral characteristics of manatees contributing to entanglement should be pursued. Hubbs-Sea World Research Institute currently is studying how manatees become entangled. Research on the amount of marine debris in inshore waters should be conducted, particularly where there are high levels of manatee entanglement. Programs to remove marine debris and recycle monofilament line also should be encouraged and continued.

Tests for several types of man-made compounds and elements have been conducted on manatee tissues. Although no known death or pathology has been associated with toxicants, some concentrations of contaminants have caused concern. Over time, concentrations of chemicals found in manatees from early studies have changed, possibly as a result of the regulation of chemical use. Such changes highlight the need to monitor tissues for chemical residues. In addition, survey studies provide insight into the presence of different or new compounds in the environment. While a broad range of tests have been conducted, there needs to be a greater focus on endocrine disruptor compounds. These compounds can alter reproductive success and have a dramatic effect on population growth.

By definition, **natural causes of mortality** are not directly anthropogenic and thus not easily targeted by management strategies. However, some aspects of natural mortality may be influenced by human activities. These activities include but are not limited to: (1) sources of artificial warm water; (2) nutrient loading; and (3) habitat modification.

Cold stress- and cold-related death are both factors contributing to manatee deaths. Acute cold-related mortality is related to hypothermia and metabolic changes which occur as a consequence to exposure to cold. Cold stress is related to the amount of cold exposure, nutritional debt, age and size of the animals, and time; cold stress can last as long as several months before the individual dies. The syndrome was originally described based upon the gross internal appearance of carcasses, combined with age of the animal (e.g., recently-weaned) and time of year (late winter to early spring). More recently, the appearance of skin lesions, not unlike frostbite, have been associated with cold stress, although the presence of these lesions is not considered to be a definitive indicator. Research continues to focus on critical cold air and water temperatures that affect manatee physiology (particularly as it pertains to acute cold- and cold stress-related mortality). To provide important clues as to how manatees deal with cold temperature, future research should study behavioral adjustments to cold (e.g., directed movement to warm-water refuges, time budget during cold periods, and surface resting intervals during warm spells). Research identifying the manatee's anatomical and physiological mechanisms for heat exchange are important to understanding the biological limitation of the species. Ancillary research should include identification of natural warm-water sites, because a growing population of manatees may be seasonally-limited by overcrowding at the larger well-known warm-water refuges.

In Florida, there are many species (approximately 20) of marine alga that can produce harmful **naturally-occurring biotoxins**. These toxins have the potential to cause massive deaths of fish, fish-eating predators (e.g., birds and dolphins), some species of sea turtles, and manatees. Many of the toxins also affect humans after they consume contaminated fish or shell fish (although human deaths are rare). One biotoxin (brevetoxin) has been the suggested cause of deaths of manatees. Brevetoxin is produced by the marine dinoflagellate, *Gymnodinium breve*, and is responsible for the red tides that occur along coastal Florida. The most recent epizootic of manatees in 1996 was attributed to brevetoxin and underscores the catastrophic effect such events can have on the population; in just 8 weeks, 145 manatees died in Southwestern Florida, representing a substantial loss to the population. Research is needed to improve our ability to detect brevetoxin in manatee tissues, stomach contents, urine, and blood. At the same time, environmental detection of red tides, their strengths, and the development of retardants are necessary. More advanced immunological research utilizing manatee cell cultures may result in the development of better treatment of manatees exposed to brevetoxin as well as the development of prophylactic vaccine.

Perinatal mortality has averaged approximately 24% of the total annual mortality for the last ten years; ranging from 11% in 1981 to 30% in 1991. The category termed "perinatal" is based on a size classification and is not a true cause of death; all manatees measuring 150 cm or less are grouped into this category regardless of developmental stage. Since the developmental stage of a young manatee may have important implications in the analysis of overall deaths, the MMPL initiated the generation of a protocol to identify characteristics of specific stages within this category. The protocol includes the documentation of changes in the circulatory system which occur around the time of birth. Improved methods are needed to subdivide the perinatal category into categories of: (1) clearly fetal; (2) at or near the time of birth; and (3) clearly born. Once these categories are well-defined, analysis can ascertain the life stage subject to the greatest impact, thus allowing for the future development of appropriate management policies. Field research focusing on factors affecting calf survival should be conducted (e.g., age of mother at reproduction, behavior, characteristics of calving areas, and human disturbance).

Periodically, **unusual mortality events** occur in which large numbers of manatees die or become moribund. In 1982 and again in 1996, manatees died or became ill from inhalation and ingestion of brevetoxin (see discussion above). Spikes in mortality also occur during periods of extreme or prolonged cold. Such events represent: (1) the potential for disastrous reductions in numbers of manatees occupying certain regions of the state; (2) the opportunity to learn about manatee response to disease agents or about manatee life history; and (3) a logistic ordeal if proper steps for coordination and communication have not been taken ahead of time. Consequently, FWS and FWC have created complementary manatee die-off contingency plans (Geraci and Lounsbury 1997; FWS 1998) that have been merged into one comprehensive document (FDEP *et al*. 1998). The document contains information and guidance from the two plans together with advice and provisions outlined in the executive summary from Wilkinson (1996). Research and investigations should follow the protocols and recommendations found in the Contingency Plans. In addition, there should be ongoing collection and storage of tissues and samples from healthy and non-mortality event manatees to establish a baseline and to aid interpretation of test results obtained during a catastrophic event and for retrospective studies. Investigators should contact and work closely with other research projects monitoring and evaluating harmful algal blooms. FWC mortality workshops should continue to facilitate and develop cooperative arrangements among investigators and institutions.

FACTORS AFFECTING MANATEE HEALTH, WELL-BEING, PHYSIOLOGY AND ECOLOGY

Relatively little attention has been paid to the health and well-being of individual manatees, although factors affecting individuals ultimately influence the overall status of the population. A variety of factors go into the making of a healthy individual, and health is defined by ranges of values rather than specific ones. Scientists discuss these ranges of values in terms of biological limits. Assessment of what is outside the range of normal values is important, and to make such assessments, baseline data are needed. This generally requires multiple samples from individuals representing a range of ages, different sexes, and a variety of reproductive stages.

There is a need to determine the relatively constant internal state in which factors such as temperature and chemical conditions remain stable and therefore within a range of values that permit the body to function well, despite changing environmental conditions. Stress is part of existence, and not all stress is bad for an individual. However, a stressor can affect homeostasis and health, and thereby precipitate a chain of events that can compromise the survival of an individual. There is also a need to understand the factors underlying large-scale trends. For example, individual manatees compromised by severe injury or disease may not be able to reproduce successfully. Similarly, sublethal effects of toxicants and even the effects of nutritional, noise-related, and disturbance-related stresses can impair immune function and potentially reduce the ability of individuals to reproduce. Study plans and protocols should be developed, collaborators identified, and results published.

Blood serum is the watery portion of the blood remaining after cells and fibrin are removed. Analysis of serum permits assessment of electrolyte levels, hormones, antibodies indicative of exposure to certain pathogens, and other factors important to the health of individual manatees. Serum can be banked for retrospective analyses. Efforts should be made to develop and publish a synthesis of: (1) current knowledge of **manatee serology**; (2) ranges of values associated with manatees in various demographic groups; (3) anomalies identified in manatees via serum analyses; and (4) any remaining unanswered questions.

Major organs and organ systems have been examined by a variety of scientists over the years. The compilation of anatomical observations by Bonde *et al*. (1983) reflects the fact that early in the evolution of manatee programs, efforts were made to understand **anatomy of manatees**. Such assessments have assisted scientists performing necropsies of dead manatees to determine morphologies and pathologies. Some systems or organs have been ignored but are important to assessing manatee health; these include: (1) the lymphatic system; (2) most parts of the endocrine system; and (3) non-cerebral parts of the brain. In addition, potential changes in reproductive tracts routinely should be assessed as part of ongoing life history assessments.

Manatee histology (microscopic anatomy) has been relatively unstudied, compared to gross anatomy. However, it is of no less importance in understanding normal organ or tissue functions, as well as abnormalities thereof. Responsible agencies should respond to this important deficiency.

Although work has been ongoing to assess effects of environmental temperatures on metabolism of manatees, the relationship among temperature change, metabolic stress, onset of chronic or acute disease symptoms, and even mortality of manatees is not perfectly understood. As noted above, the relationships among manatee reproductive status, body condition, thermal stress levels, and metabolic responses to such stress remain unclear. Answers to these **thermoregulation** questions are needed urgently as the specter of decreased availability of both natural and artificial warm-water sources looms. The research should focus not only on lower critical temperatures (the cold temperatures where metabolic stress occurs), but also on the upper critical temperature.

It is unclear whether or not manatees physiologically require fresh water to drink, and it is unknown what stresses may be created when fresh water is not available. Anatomical and experimental studies have indicated that manatees **osmoregulate** well in either fresh or salt water. The extent to which manatees seek fresh water suggests that the animals prefer it to drink, and they may be healthiest when they have at least occasional access to fresh water. Managers attempting to protect resources sought by, if not required by, manatees should bear in mind that fresh water is a desirable and possibly necessary resource for healthy manatees.

Stirling *et al*. (1999) provided an important assessment of polar bear **body condition indices** and related those values to changes in the environment and in consequent availability of polar bear food. They also related changes in reproductive performance and survival of offspring with changes in female body condition. This study exemplifies the importance of long-term data regarding animal health (as assessed by body condition), reproduction, and environmental quality. In Florida, where environmental quality varies considerably over time and space, the value of such a study is enormous. Body indices research at FMRI has initiated certain measurements documenting body condition of manatees. Maintenance of this work and refinements/extensions thereof, should be continued to gain a better understanding of physiology and health of individuals and the population.

Continuous long-term monitoring of the **health histories of individual manatees** allows for documentation of an animal's health. Information should be gathered on: (1) the acquisition and severity of new wounds to facilitate research on the length of time required for injuries to heal; and (2) any effects of injuries on behavior or reproduction. Natural factors affecting the health of the population also should be monitored during the course of photo-ID studies on wild individuals (e.g., cold-related skin damage, scars caused by fungal infections, and papilloma lesions).

As discussed earlier, brevetoxin, a **naturally-occurring toxin**, has been implicated or suspected in major and minor mortality events for manatees for decades. Tests now exist to allow pathologists to assess, even retrospectively, manatee tissues for signs of brevetoxicosis. The important questions include: (1) how many manatee deaths can be truly attributed to exposure to brevetoxin over the years; (2) if red tides are a natural occurrence, how can effects of red tides on manatees be reduced or mitigated; (3) would changes in human activities (i.e., creation of warm-water refuges which lead to aggregations of manatees) appreciably change vulnerability of the animals; and (4) have human activities contributed to increased prevalence and virulence of red tides.

Inasmuch as a single epizootic event can cause 2 to3 times as many manatee deaths as watercraft causes annually, gaining a better understanding of the issue is vital and urgent. Development of cell lines and testing of manatee tissues would represent an extremely useful approach. In particular, preliminary results indicate that exposure to brevetoxin reduces manatee immune system function. Further study of the immune system will define levels of concern and will help to identify when rehabilitated manatees are ready for release into the wild.

Other natural toxins have affected marine mammals (e.g., saxitoxin) and may represent another potential problem for manatees. Exposure of cultured cells of manatees to saxitoxin and assessment of the responses of those cells, would be useful.

To date, the only efforts to assess levels of **toxicants** in manatees have involved some organochlorines and a few metals. This situation is typical of toxicological work for marine mammals in general (O'Shea 1999; Marine Mammal Commission 1999). These studies demonstrate that a few metals occur in high concentrations in manatee tissues. Testing for toxicants can be extremely expensive; thus, a carefully-constructed study plan should be developed first to address the most critical uncertainties and to make the assessments as cost-effective as possible. Some important habitats in Dade County (e.g., Miami River and Black Creek) contain sediments contaminated with trace metals and/or synthetic organic chemicals to the extent that the sediments are considered to be toxic. Sediment chemistry/toxicity testing could be used as an indicator to direct toxicant studies in these types of areas.

A **disease** involves an illness, sickness, an interruption, cessation, or disorder of body functions, systems, and organs. In other words, disease represents the antithesis of homeostasis. As previously noted, scientists need to learn the boundaries of normal structure and function before they can diagnose what is normal or diseased. This process has occurred to some degree through the necropsy program, but it needs considerable refinement. Over the years, cause of death for about 1/3 of all manatee carcasses has been undetermined; this percentage probably would drop considerably with better information about and diagnosis of manatee disease states. Planned workshops by FMRI will attempt to bring scientists conducting necropsies on manatees together with pathologists and forensic scientists working with humans and other species. This effort should be very useful as a first step in an ongoing process of refinement.

Nutritional characteristics of manatee food plants and the importance of different food sources for different manatee age and sex classes in various regions are understood poorly. Such information is needed to help assure that adequate food resources are protected in different areas of the population's range. Ongoing studies should be completed to identify manatee food habits and the nutritional value of different aquatic plants important to manatees. In addition, seasonal patterns of food availability in areas of high manatee use need to be documented. Research also should address **manatee foraging behavior**, emphasizing ways that manatees are able to locate and utilize optimal food resources.

Catalogs of **manatee parasites** were prepared two decades ago (Forrester *et al*. 1979). A recent description of parasites for cetaceans (including manatees) in Puerto Rico also was published (Mignucci-Giannoni *et al*. 1998). Since degrees of parasitic infestation may be associated with the changes in the health of manatees, assessments of changes in prevalence of parasites over time should be undertaken. Inasmuch as parasite loads are assessed, at least qualitatively, during necropsies, this should be easy to accomplish, relatively speaking.

Vision in manatees has been well studied relatively. Tactile ability and acoustics also have been assessed. Conclusions reached as a result of acoustic studies are somewhat inconsistent and controversial, especially in terms of the extent that manatees may hear approaching watercraft. Since the auditory sense of manatees appears to be vital to their ability to communicate and to avoid injury, further studies are warranted. In addition, although chemoreception has been suggested as a mechanism by which male manatees locate estrous females, chemosensory ability of manatees is virtually unknown. Studies should continue on these topics to **develop a better understanding of manatee sensory systems**.

It is clear from various lines of evidence that manatees show site fidelity, especially in terms of their seasonal use of warm-water refuges, but also in their use of summer habitat. To some extent, calves learn locations of resources from their mothers. However, the way that manatees perceive their environment, cues they use to navigate, and the hierarchy of factors they use to select a particular spot or travel corridor are all unknown. As humans continue to modify coastal environments (physically, acoustically, visually, and chemically), it would be useful to understand better how such changes may interfere with the manatee's ability to **orient and to locate or select optimal habitat**.

Relatively few studies have been directed at **manatee behavior** since Hartman's work in the late 1970s. Rathbun (1999) summarized existing information on activity and diving, foraging, thermoregulation and movements, resource aggregations, mating, social organization, and communication. He concluded that, although the manatee's herbivorous diet is perhaps the most important factor in understanding their life history and behavior, it is the least studied aspect of manatee behavioral ecology. Both field studies and controlled experiments at captive facilities are needed to document basic behaviors. This documentation will allow detection and understanding of changes in behavior that occur through changes in allocation of essential resources, such as vegetation and warm water. To date, telemetry, photo-ID, and aerial videography have been useful tools for behavioral research. New innovative approaches are needed, particularly in habitats where visibility is poor.

Captive dolphins have developed ulcers and died when subjected to excessive human activity or excessive noise (i.e., from pumps) around their enclosures. Chronic levels of **disturbance** may create stresses to manatees; certainly, manatees change their behavior or actually leave certain areas to avoid disturbance. The stress involved would be difficult to document, but if manatees move away from critically important resources (e.g., warm water in winter) to avoid being disturbed, this movement could place the animals in immediate and acute jeopardy. Buckingham *et al*. (1999) provide an interesting case study for manatees, and data exist to support problems created by disturbance for a variety of marine mammals, including animals sympatric with Florida manatees (i.e., dolphins). Sources and level of activities eliciting disturbance responses need to be characterized further.

Manatees, particularly mothers and calves, communicate vocally. Often, while vessels are still outside of visual range, manatees initiate movements as boats approach, suggesting that they respond on the basis of hearing the boats. Noise from boats or other sources may interfere with communications or provide a source of stress. Hearing capabilities have been examined through studies involving two individuals in captivity (Gerstein 1995, 1999). There is a need for further research on hearing capabilities and the **effects of noise on manatees**. In particular, it is important to determine: (1) the sensitivity of manatee hearing to the different kinds of vessels to which they are exposed; (2) the range of frequencies of importance to manatee communication; (3) the abilities of manatees to localize sound sources; and (4) the role that habitat features may play in altering sound characteristics. The levels and characteristics of vessel sounds leading to behavioral changes, including potentially vacating an area, need to be determined.

Manatee distributions have been found to be **affected by boat traffic** in at least one study, with manatees moving into established sanctuary areas during periods of heavy boat traffic (Buckingham *et al*. 1999). Factors to be investigated include types and frequency of approaches, numbers of boats, distance of nearest approach, individual variations in manatee responses to boats, influences on diurnal activity patterns and habitat use, and effects on mothers and young.

Human swimming (and to a lesser extent diving) with manatees occurs in many parts of the species' range. In a few warm-water refuges, sanctuary areas have been established for manatees to escape from contact with human swimmers, but few data from systematic studies are available to evaluate the potential **impacts of human swimmers** or the effectiveness of the sanctuaries. The specific circumstances or characteristics of human swimming, snorkeling, or SCUBA-diving that may result in changes in manatee behavior, including vacating an area, remain to be determined. Factors to be investigated include types and frequency of approaches, numbers of swimmers, distance of nearest acceptable approach, occurrence of contact, individual variations in manatee responses to humans, influences on diurnal activity patterns and habitat use, and effects on mothers and young.

Public viewing of manatees has become increasingly popular in recent years and now occurs in many parts of the species' range. Commercial operations as well as private individuals are bringing increasing numbers of people to view manatees in areas where the animals can be found predictably. The opportunity for the public to move into close proximity to the animals typically is associated with other potentially disturbing activities such as swimming, diving, boating, or provisioning. The relative benefits of burgeoning human attention as compared to potential adverse impacts on the animals have not been evaluated properly to determine the desirability of increasing or decreasing control over manatee viewing activities. Studies relating marketing and overall levels of human viewing activities to changes in manatee behavior, including vacating an area, need to be conducted. Conversely, benefits accrued to the manatees from increased viewing by the public also should be evaluated for comparison.

In many parts of the species' range, people provide food or water to manatees, in spite of regulations prohibiting such activities. A systematic evaluation should be conducted to determine if these **provisioning** activities potentially adversely affect manatees in terms of changing their behavior, placing them at greater risk from other human activities, or encouraging them to use inappropriate habitat.

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Florida Manatee Cause of Death by Region (1991-2000)
Atlantic, Upper St. Johns River, Northwest and Southwest

Manatee carcasses reported in Florida from 1991 to 2000 (FWC, unpublished data) were assigned to four regions of the state: (1) Atlantic Coast (St. Johns River and tributaries downstream (north) of Palatka); (2) Upper St. Johns River (St. Johns River upstream (south) of Palatka); (3) Northwest (Homosassa/Crystal River and north); and (4) Southwest (Tampa Bay area). The percentage of carcasses by each cause of death was calculated for each region (Tables 5-6 and Figures 17-21).

Two regions contained most of the 2,306 carcasses located state-wide (Atlantic 50%, Upper St. Johns River 2%, Northwest 5%, Southwest 43%); however, the Atlantic and Southwest regions also have the highest numbers of living manatees. Therefore, results should be viewed cautiously because percentages among causes of death can seem contradictory. Large numbers of deaths in one region in one category can make another category seem less important. A mortality event in one region can make all the other causes seem less important (smaller percentages), when actually all of the causes take on even greater importance due to the high number of deaths in a short time period.

Carcasses (n=145) from the 1996 red tide epizootic in southwest Florida were omitted from the following analysis, because this was considered to be a non-typical situation; their inclusion here would make other human-related and natural causes of death seem less important.

Causes of death varied among regions. The percentage of watercraft-related deaths was highest in the St. Johns River region (15 carcasses, 34%) and lowest in the Atlantic (264 carcasses, 24%) region. The highest number of watercraft deaths occurred in the Atlantic and in the Southwest regions (252 carcasses, 27%).

The highest percentage of flood gate and lock deaths occurred in the Atlantic (69 carcasses, 6%) and St. Johns River regions (4 carcasses, 8%), and lowest percentage occurred in the Northwest region (1 carcasses, 1%). The highest number of gate/lock deaths occurred in the Atlantic and Southwest (19 carcasses, 2%) regions. Only a few water control structures and navigational locks are present on the west coast, and percentages were lower there.

All other human-related causes of deaths combined accounted for the highest percentage of deaths in the Atlantic (40 carcasses, 4%) and Northwest regions (4 carcasses, 4%), and accounted for the lowest in the St. Johns River (0 carcasses, 0%). The highest number of other human-related deaths occurred in the Atlantic and Southwest (14 carcasses, 2%) regions.

Perinatal deaths accounted for the highest percentage of deaths in the Northwest region (32 carcasses, 33%). The highest number of perinatal deaths occurred in the Atlantic (296 carcasses, 27%) and Southwest (190 carcasses, 20%) regions.

Cold-related deaths accounted for the highest percentage of deaths in the Atlantic region (29 carcasses, 3%). The only recent large cold mortality event primarily in Brevard County during the winter of 1989-1990. Cold-related deaths were lowest in the two regions with major natural springs, the St. Johns River (0 carcasses, 0%) and Northwest (3 carcasses, 3%) regions.

Other natural causes of death combined accounted for the highest percentage of deaths in the Southwest Region (154 carcasses, 17%), and accounted for the lowest percentage in the St. Johns River (2 carcasses, 5%). The highest number of other-natural deaths occurred in the Southwest and Atlantic (112 carcasses, 10%) regions. The high number of deaths from natural causes in the Southwest region may partly reflect occasional small red tide events.

Undetermined deaths (including verified but not recovered carcasses) accounted for the highest percentage in the Southwest Region (277 carcasses, 30%), and accounted for the lowest percentage in the Northwest (20 carcasses, 20%). The highest number of undetermined deaths occurred in the Southwest and Atlantic (279 carcasses, 26%) regions. The high number of undetermined deaths in the Southwest region may be related to the high levels of carcass decomposition because of the warm temperatures and remoteness of large parts of the region (i.e., few observers to find carcasses and long travel times required to retrieve carcasses). The high percentage of undetermined causes in the Southwest makes all the other categories proportionately smaller in that region.

Deaths of adult-sized animals (276 to 411 cm total length) were summarized separately. Analysis using only deaths of adult-sized animals eliminates all of the perinatal carcasses and most of the cold-related deaths, which are mostly sub-adult manatees. Percentages of deaths, by causes, were similar among the four regions. Regions with high percentages of perinatal and cold-related deaths showed the greatest differences when adults were considered separately.

Statewide, watercraft-related deaths accounted for 39% of adult deaths, and all human-related deaths combined comprised 53% of deaths. All human-related causes combined constituted the highest percentage of deaths in the St. Johns region (14 carcasses, 64%) and in the Atlantic region (181 carcasses, 58%). The Atlantic region has the largest coastal human population of the four regions. The health of a regional population is closely tied to the adult survival rate. Therefore, it is very important that the percentages of human-related deaths be kept as low as possible.

Table 5. Manatee deaths in Florida, 1991-2000, by 4 regions and statewide. **All size classes** (FWC, unpublished data).

CAUSE OF DEATH	ATLANTIC		ST. JOHNS		NORTHWEST		SOUTHWEST		STATEWIDE	
	Number	%	Number	%	Number	%	Number	%	Number	%
Watercraft	264	24.2	15	34.1	26	26.5	252	27.1	557	25.8
Gate/Lock	69	6.3	4	9.1	1	1.0	19	2.0	93	4.3
Other Human	40	3.7	0	0.0	4	4.1	14	1.5	58	2.7
Perinatal	296	27.2	11	25.0	32	32.7	190	20.4	529	24.5
Cold-Related	29	2.7	0	0.0	3	3.1	24	2.6	56	2.6
Other Natural	112	10.3	2	4.5	12	12.2	154*	16.6	280*	12.9
Undetermined	279	25.6	12	27.3	20	20.4	277*	29.8	588*	27.2
TOTAL	1089	100.0	44	100.0	98	100.0	930*	100.0	2161*	100.0

* Omit n=145 Red Tide deaths in Southwest Florida, 1996

Table 6. Manatee deaths in Florida, 1991-2000, by 4 regions and statewide. **Adult-only size class** (>275 cm total length). FWC unpublished data.

CAUSE OF DEATH	ATLANTIC		ST. JOHNS		NORTHWEST		SOUTHWEST		STATEWIDE	
	Number	%	Number	%	Number	%	Number	%	Number	%
Watercraft	122	39.0	11	50.0	8	33.3	103	39.3	244	39.3
Gate/Lock	37	11.8	3	13.6	0	0.0	13	4.9	53	8.5
Other Human	22	7.0	0	0.0	2	8.3	6	2.3	30	4.8
Perinatal	—	—	—	—	—	—	—	—	—	—
Cold-Related	1	0.3	0	0.0	2	8.3	0	00.0	3	0.5
Other Natural	35	11.2	1	4.6	5	20.9	51*	19.5	92*	14.8
Undetermined	96	30.7	7	31.8	7	29.2	89*	34.0	199*	32.1
TOTAL	313	100.0	22	100.0	24	100.0	262*	100.0	621*	100.0

* Omit n=145 Red Tide deaths in Southwest Florida, 1996

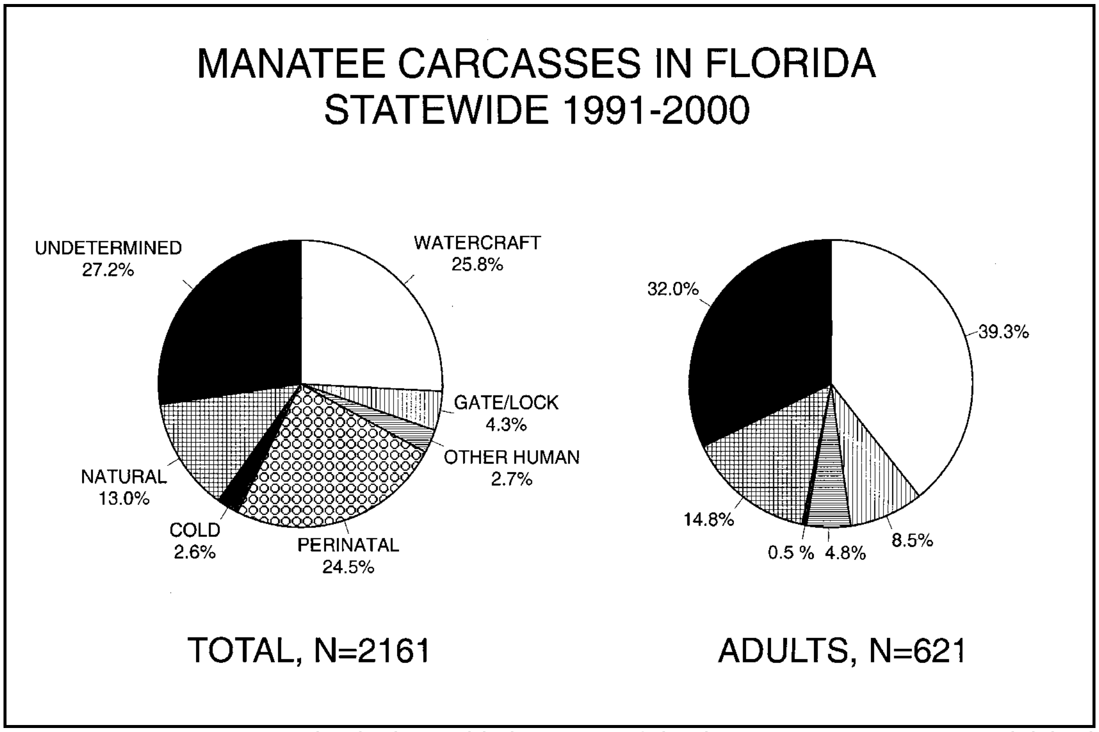

Figure 17. Manatee deaths in Florida by cause of death, 1991-2001. FWC unpublished data.

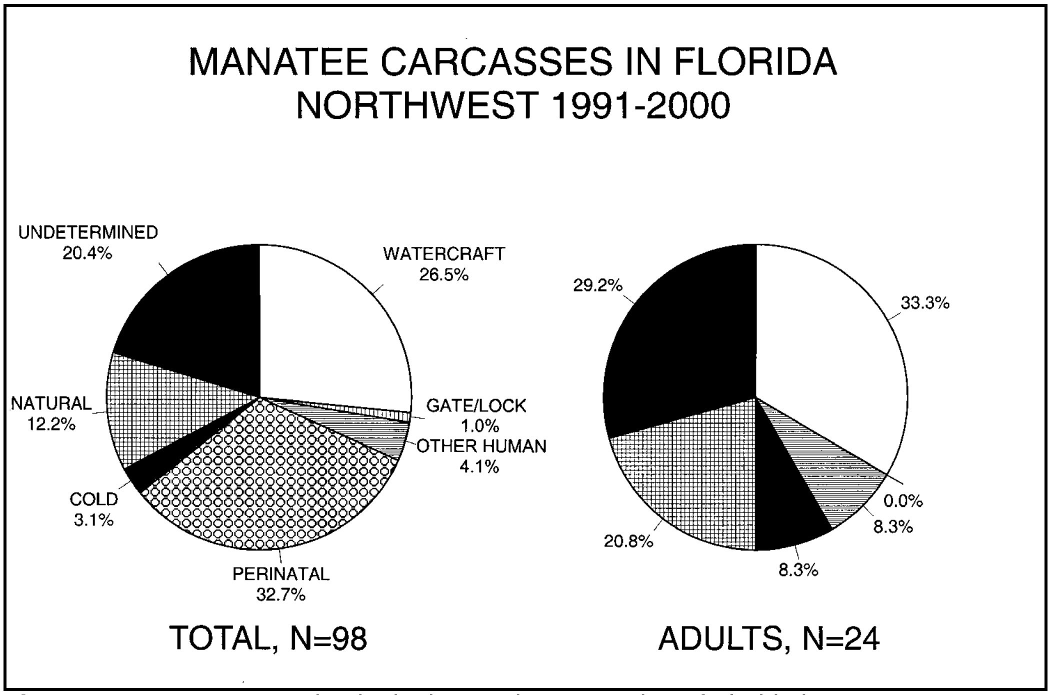

Figure 18. Manatee deaths in the Northwest Region of Florida by cause, 1991-2000. FWC unpublished data.

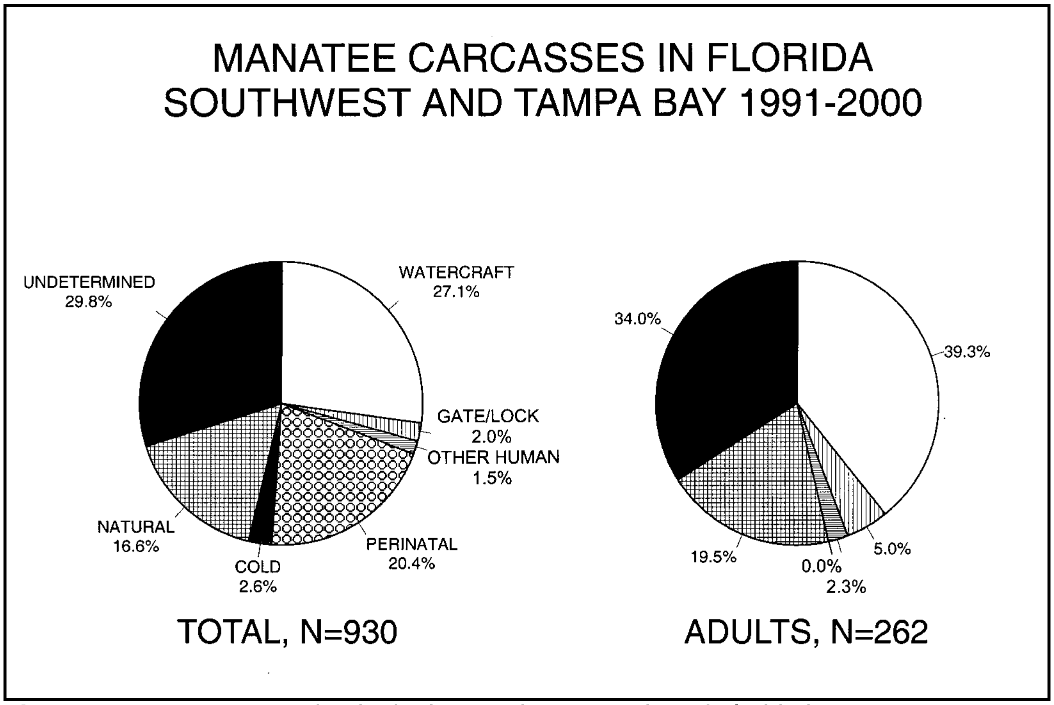

Figure 19. Manatee deaths in the Southwest Region of Florida by cause, 1991-2000. FWC unpublished data.

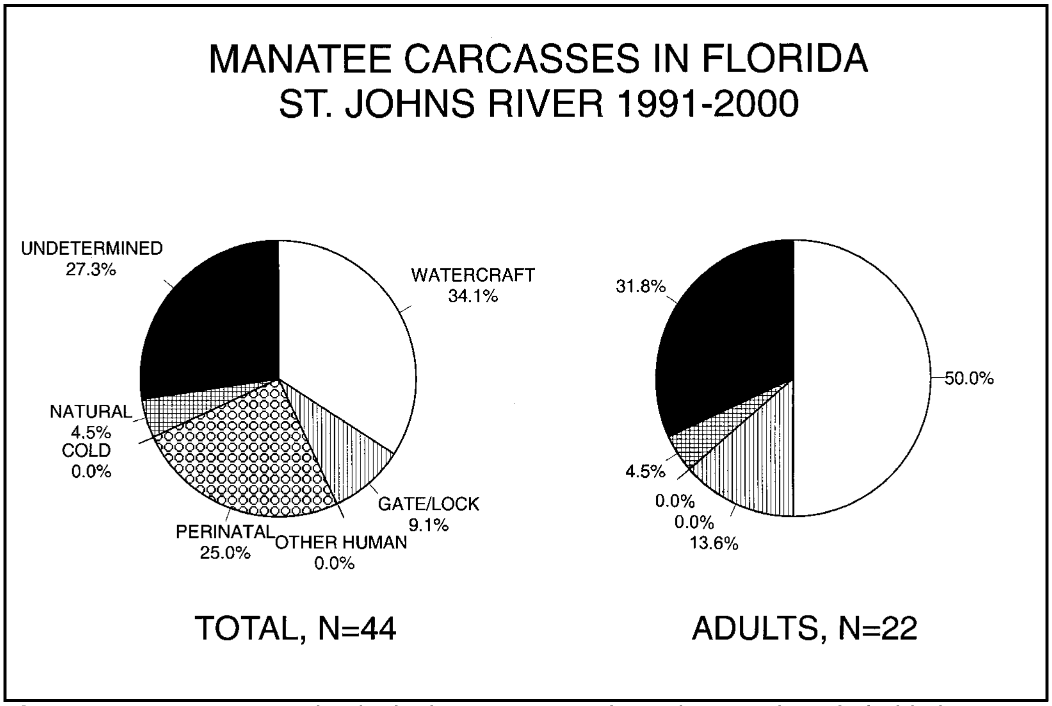

Figure 20. Manatee deaths in the upper St. Johns River Region of Florida by cause, 1991-2000. FWC unpublished data.

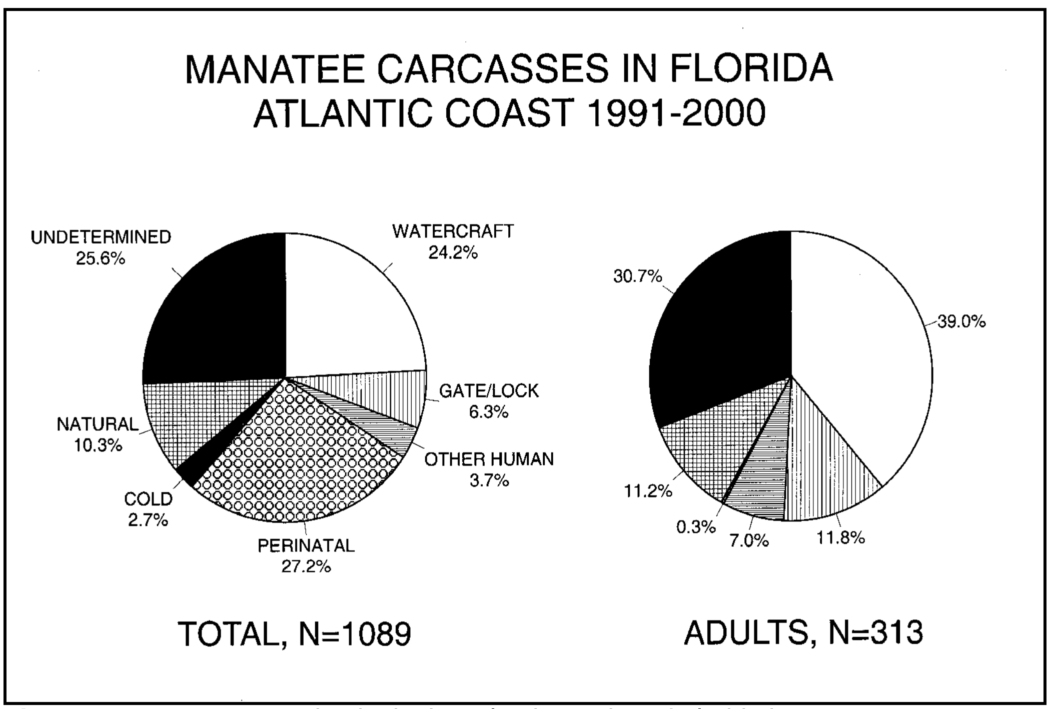

Figure 21. Manatee deaths in the Atlantic Region of Florida by cause, 1991-2000. FWC unpublished data.

FLORIDA MANATEE STATUS STATEMENT

Manatee Population Status Working Group

9 March 2001

Years of scientific study of the Florida manatee have revealed both good news and some cause for concern regarding the status of this endangered aquatic mammal, according to the interagency Manatee Population Status Working Group. The Manatee Population Status Working Group comprises biologists from the U.S. Geological Survey, U.S. Fish and Wildlife Service, Florida Fish and Wildlife Conservation Commission, Chicago Zoological Society, and Wildlife Trust. The group's primary tasks are to assess manatee population trends, to advise the U.S. Fish and Wildlife Service on population criteria to determine when species recovery has been achieved, and to provide managers with interpretation of available information on manatee population biology.

Long-term studies suggest four relatively distinct regional populations of the Florida manatee: Northwest, Southwest, Atlantic (including the St. Johns River north of Palatka), and St. Johns River (south of Palatka). These divisions are based primarily on documented manatee use of wintering sites and from radio-tracking studies of individuals' movements. Although some movement occurs among regional populations, researchers found that analysis of manatee status on a regional level provided insights into important factors related to manatee recovery.

The exact number of manatees in Florida is unknown. Manatees are difficult to count because they are often in areas with poor water clarity, and their behavior, such as resting on the bottom of a deep canal, may make them difficult to see. A coordinated series of aerial surveys and ground counts, known as the statewide synoptic survey, has been conducted in most years since 1991. The synoptic survey in January 2001 resulted in a count of 3,276, the highest count to date. The highest previous count was 2,639 in 1996. Survey results are highly variable, and do not reflect actual population trend. For example, statewide counts on 16 and 27 January 2000 differed by 36% (1,629 and 2,222, respectively). Excellent survey conditions and an unusually cold winter undoubtedly contributed to the high count in 2001.

Evidence indicates that the Northwest and Upper St. Johns River subpopulations have steadily increased over the last 25 years. This population growth is consistent with the lower number of human-related deaths, high estimates of adult survival, and good manatee habitat in these regions. Unfortunately, this good news is tempered by the fact that the manatees in these two regions probably account for less than 20% of the state's manatee population.

The picture is less optimistic for the Atlantic coast subpopulation. Scientists are concerned that the adult survival rate (the percentage of adults that survives from one year to the next) is lower than what is needed for sustained population growth. The population on this coast appears to have been growing slowly in the 1980s but now may have leveled off, or could even be declining. In other words, it's too close to call. This finding is consistent with the high level of human-related and, in some years, cold-related mortality in the region. Since 1978, management efforts to reduce human-related manatee deaths have included strategies focused on reducing manatee collisions with boats, reducing hazards such as entrapment in water control structures and entanglement in fishing gear, and protecting manatee winter aggregation sites to reduce cold-related mortality. Managers are continually challenged to develop innovative protection strategies, given the rapidly growing human population along Florida's coasts.

Estimates of survival and population growth rates are currently underway for the Southwest region. Preliminary estimates of adult survival are similar to those for the Atlantic region, i.e., substantially lower than those for the Northwest and Upper St. Johns River regions. This area has had high levels of watercraft-related deaths and injuries, as well as periodic natural mortality events caused by red tide and severe cold. However, pending further data collection and analysis, scientists are unable to provide an assessment of how manatees are doing in this part of the state.

Over the past ten years, approximately 30% of manatee deaths have been directly attributable to human-related causes, including watercraft collisions, accidental crushing and drowning in water control structures, and entanglements in fishing gear. In 2000, 34% (94 of 273) of manatee deaths were human-related. The continued high level of manatee deaths raises concern about the ability of the overall population to grow or at least remain stable. The Manatee Population Status Working Group is also concerned about the negative impacts of factors that are difficult to quantify, such as habitat loss and chronic effects of severe injuries.

The group agrees that the results of the analyses underscore an important fact: Adult survival is critical to the manatee's recovery. In the regions where adult survival rates are high, the population has grown at a healthy rate. In order to assure high adult survival the group emphasizes the urgent need to make significant headway in reducing the number of human-related manatee deaths.

Appendix D   Conservation Measures

Appendix D-1: Protected Species Construction Conditions

PROTECTED SPECIES CONSTRUCTION CONDITIONS, NOAA FISHERIES SOUTHEAST REGIONAL OFFICE

The action agency and any permittee shall comply with the following construction conditions for protected species under the jurisdiction of NOAA Fisheries Southeast Regional Office (SERO) Protected Resources Division (PRD):[1]

Protected Species Sightings–The action agency and any permittee shall ensure that all personnel associated with the project are instructed about the potential presence of species protected under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). All on-site project personnel are responsible for observing water-related activities for the presence of protected species. All personnel shall be advised that there are civil and criminal penalties for harming, harassing, or killing listed species and all marine mammals. To determine which protected species and critical habitat may be found in the transit area, please review the relevant marine mammal and ESA-listed species at Find A Species (https://www.fisheries.noaa.gov/find-species) and the consultation documents that have been completed for the project.

1. **Equipment**–Turbidity curtains, if used, shall be made of material in which protected species cannot become entangled and be regularly monitored to avoid protected species entrapment. All turbidity curtains and other in-water equipment shall be properly secured with materials that reduce the risk of protected species entanglement and entrapment.

    a. In-water lines (rope, chain, and cable, including the lines to secure turbidity curtains) shall be stiff, taut, and non-looping. Examples of such lines are heavy metal chains or heavy cables that do not readily loop and tangle. Flexible in-water lines, such as nylon rope or any lines that could loop or tangle, shall be enclosed in a plastic or rubber sleeve/tube to add rigidity and prevent the line from looping and tangling. In all instances, no excess line shall be allowed in the water. All anchoring shall be in areas free from hardbottom and seagrass.

    b. Turbidity curtains and other in-water equipment shall be placed in a manner that does not entrap protected species within the project area and minimizes the extent and duration of their exclusion from the project area.

    c. Turbidity barriers shall be positioned in a way that minimizes the extent and duration of protected species exclusion from important habitat (e.g. critical habitat, hardbottom, seagrass) in the project area.

2. **Operations**–For construction work that is generally stationary (e.g., barge-mounted equipment dredging a berth or section of river, or shore-based equipment extending into the water):

    a. Operations of moving equipment shall cease if a protected species is observed within 150 feet of operations.

[1] Manatees are managed under the jurisdiction of the U.S. Fish and Wildlife Service.

   b. Activities shall not resume until the protected species has departed the project area of its own volition (e.g., species was observed departing or 20 minutes have passed since the animal was last seen in the area).

3. **Vessels–**For projects requiring vessels, the action agency, and any permittee shall ensure conditions in the Vessel Strike Avoidance Measures are implemented as part of the project/permit issuance (https://www.fisheries.noaa.gov/southeast/consultations/regulations-policies-and-guidance).

4. **Consultation Reporting Requirements–**Any interaction with a protected species shall be reported immediately to NOAA Fisheries SERO PRD and the local authorized stranding/rescue organization.

   To report to NOAA Fisheries SERO PRD, send an email to takereport.nmfsser@noaa.gov. Please include the species involved, the circumstances of the interaction, the fate and disposition of the species involved, photos (if available), and contact information for the person who can provide additional details if requested. Please include the project's Environmental Consultation Organizer (ECO) number and project title in the subject line of email reports.

   To report the interaction to the local stranding/rescue organization, please see the following website for the most up to date information for reporting sick, injured, or dead protected species:

   Reporting Violations–To report an ESA or MMPA violation, call the NOAA Fisheries Enforcement Hotline. This hotline is available 24 hours a day, 7 days week for anyone in the United States.

   NOAA Fisheries Enforcement Hotline (800) 853-1964

5. **Additional Conditions–**Any special construction conditions, required of your specific project, outside these general conditions, if applicable, will be addressed in the project consultation and must also be complied with.

For additional information, please contact NOAA Fisheries SERO PRD at:
NOAA Fisheries Service
Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701
Tel: (727) 824-5312
Visit us on the web at Protected Marine Life in the Southeast
(https://www.fisheries.noaa.gov/region/southeast#protected-marine-life)

Revised: May 2021

Appendix D-2: Vessel Strike Avoidance Measures

VESSEL STRIKE AVOIDANCE MEASURES, NOAA FISHERIES SOUTHEAST REGIONAL OFFICE

Background
Vessel strikes can injure or kill species protected under the Endangered Species Act (ESA) and the Marine Mammal Protection Act (MMPA). NOAA Fisheries Southeast Regional Office (SERO) Protected Resources Division (PRD) recommends implementing the following identification and avoidance measures to reduce the risk of vessel strikes and disturbance from vessels to protected species under our jurisdiction.[1]

Protected Species Sightings
All vessel operators and crews should be informed about the potential presence of species protected under the ESA and the MMPA and any critical habitat in a vessel transit area. All vessels should have personnel onboard responsible for observing for the presence of protected species. All personnel should be advised that there are civil and criminal penalties for harming, harassing, or killing listed species and all marine mammals. To determine which protected species and critical habitat may be found in the transit area, please review the relevant marine mammal and ESA-listed species at Find A Species (https://www.fisheries.noaa.gov/find-species) and any ESA Section 7 consultation documents if applicable.

Vessel Strike Avoidance
The following measures should be taken when they are consistent with safe navigation to avoid causing injury or death of a protected species:

1. Operate at the minimum safe speed when transiting and maintain a vigilant watch for protected species to avoid striking them. Even with a vigilant watch, most marine protected species are extremely difficult to see from a boat or ship, and you cannot rely on detecting them visually and then taking evasive action. The most effective way to avoid vessel strikes is to travel at a slow, safe speed. Whenever possible, assign a designated individual to observe for protected species and limit vessel operation to only daylight hours.

2. Follow deep-water routes (e.g., marked channels) whenever possible.

3. Operate at "Idle/No Wake" speeds in the following circumstances:
    a. while in any project construction areas
    b. while in water depths where the draft of the vessel provides less than four feet of clearance from the bottom, or
    c. in all depths after a protected species has been observed in and has recently departed the area.

[1] Manatees are managed under the jurisdiction of the U.S. Fish and Wildlife Service.

4. When a protected species is sighted, attempt to maintain a distance of 150 feet or greater between the animal and the vessel. Reduce speed and avoid abrupt changes in direction until the animal(s) has left the area.

5. When dolphins are bow- or wake-riding, maintain course and speed as long as it is safe to do so or until the animal(s) leave the vicinity of the vessel.

6. If a whale is sighted in the vessel's path or within 300 feet from the vessel, reduce speed and shift the engine to neutral. Do not engage the engines until the animals are clear of the area. *Please see below for additional requirements for North Atlantic right whales.*

7. If a whale is sighted farther than 300 feet from the vessel, maintain a distance of 300 feet or greater between the whale and the vessel and reduce speed to 10 knots or less. *Please see below for additional requirements for North Atlantic right whales.*

Injured or Dead Protected Species Reporting

Vessel crews should report sightings of any injured or dead protected species immediately regardless of whether the injury or death is caused by your vessel. Please see How to Report a Stranded or Injured Marine Animal (https://www.fisheries.noaa.gov/report) for the most up to date information for reporting injured or dead protected species.

If the injury or death is caused by your vessel, also report the interaction to NOAA Fisheries SERO PRD at takereport.nmfsser@noaa.gov. Please include the species involved, the circumstances of the interaction, the fate and disposition of the animal involved, photos (if available), and contact information for the person who can provide additional details if requested. Please include the project's Environmental Consultation Organizer (ECO) number and project title in the subject line of email reports if a consultation has been completed.

Reporting Violations

To report any suspected ESA or MMPA violation, call the NOAA Fisheries Enforcement Hotline. This hotline is available 24 hours a day, 7 days week for anyone in the United States.

NOAA Fisheries Enforcement Hotline: (800) 853-1964

Additional Transit and Reporting Requirements for North Atlantic Right Whales

1. Federal regulation prohibits approaching or remaining within 500 yards of a North Atlantic right whale (50 CFR 224.103 (c)). All whales sighted within North Atlantic right whale critical habitat should be assumed to be right whales. Please be aware and follow restrictions for all Seasonal Management Areas along the U.S. east coast. These areas have vessel speed restrictions to reduce vessel strikes risks to migrating or feeding whales. More information can be found at Reducing Vessel Strikes to North Atlantic Right Whales (https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales).

2. Ships greater than 300 gross tons entering the WHALESOUTH reporting area are required to report to a shore-based station. For more information on reporting procedures consult 33 CFR Part 169, the Coast Pilot, or at Reducing Vessel Strikes to North Atlantic

Right Whales (https://www.fisheries.noaa.gov/national/endangered-species-conservation/reducing-vessel-strikes-north-atlantic-right-whales).

3. From November through April, vessels approaching/departing Florida ports of Jacksonville and Fernandina Beach as well as Brunswick Harbor, Georgia are STRONGLY RECOMMENDED to use Two-Way Routes displayed on nautical charts. More information on Compliance with the Right Whale Ship Strike Reduction Rule can be found at (https://media.fisheries.noaa.gov/2021-06/compliance_guide_for_right_whale_ship_strike_reduction.pdf)

4. Mariners shall check with various communication media for general information regarding avoiding vessel strikes and specific information regarding North Atlantic right whale sighting locations. These include NOAA weather radio, U.S. Coast Guard Broadcast to Mariners, Local Notice to Mariners, and NAVTEX. Commercial mariners calling on United States ports should view the most recent version of the NOAA/USCG produced training CD entitled “A Prudent Mariner’s Guide to Right Whale Protection” (contact the NOAA Fisheries SERO, Protected Resources Division for more information regarding the CD).

5. Injured, dead, or entangled right whales should be immediately reported to the U.S. Coast Guard via VHF Channel 16 and the NOAA Fisheries Southeast Marine Mammal Stranding Hotline at (877) WHALE HELP (877-942-5343).

For additional information, please contact NOAA Fisheries SERO PRD at:
NOAA Fisheries Service
Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701
Visit us on the web at Protected Marine Life in the Southeast
(https://www.fisheries.noaa.gov/region/southeast#protected-marine-life)

Revised: May 2021

Appendix D-3: Standard Manatee Conditions for In-Water Activities

STANDARD MANATEE CONDITIONS FOR IN-WATER ACTIVITIES

During in-water work in areas that potentially support manatees all personnel associated with the project should be instructed about the potential presence of manatees, manatee speed zones, and the need to avoid collisions with and injury to manatees. All personnel should be advised that there are civil and criminal penalties for harming, harassing, or killing manatees which are protected under the Marine Mammal Protection Act of 1972 and the Endangered Species Act of 1973. Additionally, personnel should be instructed not to attempt to feed or otherwise interact with the animal, although passively taking pictures or video would be acceptable.

All on-site personnel are responsible for observing water-related activities for the presence of manatee(s). We recommend the following to minimize potential impacts to manatees in areas of their potential presence:

- All work, equipment, and vessel operation should cease if a manatee is spotted within a 50-foot radius (buffer zone) of the active work area. Once the manatee has left the buffer zone on its own accord (manatees must not be herded or harassed into leaving), or after 30 minutes have passed without additional sightings of manatee(s) in the buffer zone, in-water work can resume under careful observation for manatee(s).
- If a manatee(s) is sighted in or near the project area, all vessels associated with the project should operate at “no wake/idle” speeds within the construction area and at all times while in waters where the draft of the vessel provides less than a four-foot clearance from the bottom. Vessels should follow routes of deep water whenever possible.
- If used, siltation or turbidity barriers should be properly secured, made of material in which manatees cannot become entangled, and be monitored to avoid manatee entrapment or impeding their movement.
- Temporary signs concerning manatees should be posted prior to and during all in-water project activities and removed upon completion. Each vessel involved in construction activities should display at the vessel control station or in a prominent location, visible to all employees operating the vessel, a temporary sign at least 8½ " X 11" reading language similar to the following: “CAUTION BOATERS: MANATEE AREA/ IDLE SPEED IS REQUIRED IN CONSTRUCTION AREA AND WHERE THERE IS LESS THAN FOUR FOOT BOTTOM CLEARANCE WHEN MANATEE IS PRESENT”. A second temporary sign measuring 8½ " X 11” should be posted at a location prominently visible to all personnel engaged in water-related activities and should read language similar to the following: “CAUTION: MANATEE AREA/ EQUIPMENT MUST BE SHUTDOWN IMMEDIATELY IF A MANATEE COMES WITHIN 50 FEET OF OPERATION”.
- Collisions with, injury to, or sightings of manatees should be immediately reported to the Service’s Louisiana Ecological Services Office (337/291-3100) and the Louisiana Department of Wildlife and Fisheries, Natural Heritage Program (225/765-2821). Please provide the nature of the call (i.e., report of an incident, manatee sighting, etc.); time of incident/sighting; and the approximate location, including the latitude and longitude coordinates, if possible.

Appendix D-4: Alligator Snapping Turtle Conservation Measures

Fish and Wildlife Service general information and guidance for FEMA projects regarding the proposed alligator snapping turtle

Louisiana Ecological Services Office

Areas and Habitat Conditions likely to host AST

The alligator snapping turtle (AST) has a wide geographic range and occurs in bayous, rivers, streams, swamps, and lakes in Texas, Louisiana, Oklahoma, Arkansas, Missouri, Illinois, Kentucky, Tennessee, Mississippi, Alabama, Georgia, and Florida. They prefer water bodies (small streams [perennial], bayous, canals, swamps, lakes, reservoirs, ponds, and oxbows) with overhang banks and adjacent riparian forest, especially bald cypress bordered banks. Sections of waterways with steep-sloped banks, or those lined with concrete, stone, etc. are likely avoided, especially when there are no trees on the bank. However, relatively short sections of non-preferred bank composition do not necessarily preclude occupation of the entire waterway. They may venture onto the adjacent floodplain during high water events. Although they have been found at the edge of the Gulf of Mexico, coastal marshes and saline water are not their preferred habitat type. They also prefer waterbodies with snags and submerged logs, tree root masses, or other debris in the water. Adults generally stick to deeper water (enough to cover their body to deeper than 20ft), but in areas with deep, loose mud, they have been found in 10 inches of water with a mud layer of several feet. Juveniles can be found in shallow streams less than 1 foot deep. AST are sensitive to water temperature and will change locations as needed to thermoregulate. AST generally stay on the water bottom, but they do move along the bottom, and can travel considerable distances (miles) in just days or weeks. Trapping surveys are generally effective at locating AST, but lack of capture, especially during short-term limited area survey efforts, does not confirm absence.

AST rarely leave the water except for nesting females generally from April to early July (typically April-May in southern parts of the range including Louisiana and May-July in north/western portion of the range). Egg incubation time is generally between 96 and 143 days. Nesting areas may have varying amounts of canopy cover. Nests are generally located between 4 and 656 feet from the water line, and more likely less than 300 feet from the water line.

Potential project effects on the species

<u>Individuals</u>

Adults, juveniles, and hatchlings could be killed, injured, or stressed by instream operation of heavy equipment (e.g., excavator, bucket dredge, hydraulic dredge, shallow water watercraft, etc.)

Nesting females, eggs, and hatchlings could be killed, injured, or stressed by operation of heavy equipment or other disturbance in the riparian zone adjacent to waterbodies during the nesting/hatching season.

<u>Habitat</u>

Removal of snags, submerged logs, and other debris would decrease the value of or eliminate aquatic habitat.

Removal of trees at the bank and adjacent forest could degrade nesting habitat and would likely decrease the use of adjacent aquatic habitat.

Bank hardening and change of bank incline would likely eliminate nesting in the area, and significant use of the adjacent aquatic habitat.

Conservation Recommendations

To minimize effect on AST habitat:

Limit work to deepest part of channels

Limit work to areas previously disturbed or lacking snags, submerged logs or other cover used by AST

Use floating work platform instead of ground-based equipment

Relocate woody debris to streamside instead of removing completely

Minimize removal of trees and brush on bank adjacent to waterbodies

Avoid the use of concrete or other bank hardening methods

To minimize effect on individuals:

Limit work to areas unlikely to be occupied by adult or juvenile AST or live AST nests

Use floating work platform instead of ground-based equipment

If removing snags is necessary, pull up from above water instead of digging out

Avoid work on streamside from the water's edge to 200 meters away during times of the year when nesting/hatching are occurring

Limit work to deepest part of main channels except during the hottest times of the year

Conferencing with Fish and Wildlife Service

Because the AST is proposed, the only requirement for federal agencies is to "confer" (rather than consult) with the Service if any proposed actions are determined by them to be likely to jeopardize the existence of a proposed species or result in destruction or adverse modification of critical habitat. There is currently no critical habitat designated, or proposed, for the AST, so the focus would be mostly on the species itself. Note that regardless of critical habitat, effects on habitat are still considered when analyzing effects on species. (Note: *In certain circumstances, emergency actions in presidentially declared disaster areas can be exempted from the requirements of consultation under sec 7(a)(2) of the Endangered Species Act*.).

Project actions that "may affect" the species do not necessarily make the action, "likely to jeopardize the existence of a proposed species". Actions that kill an individual or even multiple individuals also may not necessarily result in a likely jeopardy determination. The AST has a large multistate range, and the

species is estimated to be comprised of many thousands of individuals. Any effects determination should consider the spatial extent of project effects when analyzing effects on populations and ultimately the species as a whole.

It is the policy of the Service to conduct conferencing if the lead federal agency requests a conference. The Service would require all the same types of information about the project(s) including project timing, specific work, equipment, and expected effects on the species, as when conducting a consultation for a listed species. The Service's practice is to conduct and conclude conferencing in the same manner and time frame as consultations which require variable amounts of time to complete depending on complexity and whether the conference is informal or formal.

Appendix E Species Habitat Analysis

Appendix E-1: Gopher Tortoise Survey

JOHN BEL EDWARDS
GOVERNOR

JACK MONTOUCET
SECRETARY

LOUISIANA DEPARTMENT OF WILDLIFE & FISHERIES

PO BOX 98000 | BATON ROUGE LA | 70898

MEMORANDUM

TO: Amy Dixon, Project Manager, U.S. Army Corps of Engineers- New Orleans District

FROM: Keri Lejeune, State Herpetologist, LA Department of Wildlife and Fisheries

DATE: August 21, 2022

SUBJECT: Gopher Tortoise Survey for the St. Tammany Parish Levee Project (STPFPS)

LA Department of Wildlife and Fisheries staff, along with U.S. Army Corps of Engineers and U.S. Fish and Wildlife Service personnel, conducted gopher tortoise surveys within the project area on 14 June 2022. Right of Entry (ROE) 1, 2 and 3 were assessed from the public roads adjacent to these areas. ROE 1, 2, and 3 appeared to be uninhabitable for gopher tortoises due to the dense forests completely covering these areas. No evidence of gopher tortoises or their burrows were observed.

Permission from landowner(s) was granted for access to ROE 4, 5, and 6. Transects were conducted on all areas with suitable soils that were not heavily forested, which would be appropriate for gopher tortoises. No evidence of gopher tortoises or their burrows were observed. Due to the proximity of ROE 6 to hydric soils and marsh habitat, a minimal amount of this area appeared suitable for gopher tortoises. However, all areas that appeared suitable for gopher tortoises along the levee near ROE 6 were surveyed and no evidence of tortoises or their burrows were observed.

If you need additional information or at any time gopher tortoises or their burrows are encountered within the project area prior to or during development, please contact Keri Lejeune at 337-735-8676 or klejeune@wlf.la.gov.

Appendix E-2: Red-cockaded woodpeckers habitat foraging analysis

Cluster / Habitat Acres	Good	Fair	Fair quality requiring treatment	Poor	Private	Unsuitable	Total
Paquet 3 (cluster #18)	37.53	13.41	0	13.26	0	0	**64.19**
Salmen 1 (cluster #19)	0	46.30	3.97	12.79	8.25	60.76	**132.07**
Salmen 2 (cluster #20)	0	112.79	0	60.20	0	17.63	**190.62**
Salmen 3 (cluster #21)	0	0	0	162.53	0	104.00	**266.53**

Cluster/Habitat in South & West ROW	Fair	Poor	Unsuitable	Private
Paquet 3 (cluster #18)	0	0	0	0
Salmen 1 (cluster #19)	8.314	0	16.429	0.662
Salmen 2 (cluster #20)	5.122	0	0	0
Salmen 3 (cluster #21)	0	4.763	19.084	0

No Habitat	Total Acres
10.678	**10.678**
0	**25.406**
0	**5.122**
0.052	**23.898**

Cluster/Habitat	Good	Fair	Fair quality requiring treatment	Poor	Unsuitable	Total Acres
Paquet 3 (cluster #18)	37.53	13.407	0	13.263	0	**64.195**
Salmen 1 (cluster #19)	0	37.984	3.97	12.789	44.327	**99.074**
Salmen 2 (cluster #20)	0	107.665	0	60.199	17.633	**185.497**
Salmen 3 (cluster #21)	0	0	0	157.769	84.915	**242.684**

Note:
No loss of habitat under post project conditions

DEPARTMENT OF THE ARMY
NEW ORLEANS DISTRICT, CORPS OF ENGINEERS
7400 LEAKE AVENUE
NEW ORLEANS, LOUISIANA 70118

REPLY TO ATTENTION OF

April 27, 2023

Regional Planning and Environment
Division South

Project Name: Supplemental Environmental Impact Statement for the St. Tammany Parish Feasibility Study

Mr. David Bernhart
NMFS - Protected Resources Division
Southeast Regional Office
263 13th Avenue South
St. Petersburg, Florida 33701

Dear Mr. Bernhart,

The U.S. Army Corps of Engineers (USACE), New Orleans District (CEMVN) has prepared this Biological Assessment (BA) to evaluate the potential impacts associated with proposed flood risk reduction project and associated mitigation project in St. Tammany Parish, Louisiana. This BA provides the information required pursuant to the Endangered Species Act (ESA) and implementing regulation (50 CFR 402.13), to comply with the ESA. Additional legal authorities include the National Environmental Policy Act (NEPA) of 1969, 42 U.S.C. section 4321, et seq.; the Fish and Wildlife Conservation Act of 1958 (PL 85-624; 16 U.S.C. 661 et seq.); the Marine Mammal Protection Act of 1972; and the Migratory Bird Treaty Act of 1918.

The proposed project consists of construction of a levee and floodwall system, channelization of a section of Mile Branch, and creation of marsh to offset construction impacts. The levee and floodwall system would be constructed in southeast St. Tammany Parish near Slidell, Louisiana. The Mile Branch channel improvement project is located in St. Tammany Parish, Louisiana within the City of Covington. The marsh creation site (M2) is located along the northeast shore of Lake Pontchartrain near Big Branch Marsh National Wildlife Refuge.

CEMVN has determined that the proposed project “may affect but is not likely to adversely affect” (NLAA) the federally listed Gulf sturgeon and Gulf sturgeon critical habitat. This species could potentially be found in the project area, which also contains its critical habitat; therefore, CEMVN is submitting a request for consultation and requesting concurrence with our determinations pursuant to Section 7 of the ESA of 1973, as amended (16 U.S.C. § 1536), and the consultation procedures at 50 C.F.R. Part 402.

This ESA letter is being submitted to the National Marine Fisheries Service (NMFS) by the CEMVN to initiate informal consultation regarding potential impacts to threatened and endangered species from construction projects related to the St. Tammany Parish Feasibility Study SEIS.

Pursuant to our request for informal consultation, CEMVN is providing, enclosing, or otherwise identifying the following information:

- A description of the action to be considered;
- A description of the action area;
- A description of any listed species or designated critical habitat (DCH) that may be affected by the action; and
- An analysis of the potential routes of effect on any listed species or DCH.

Questions and/or concerns should be directed to Ms. Kristin Gunning; U.S. Army Corps of Engineers; Regional Planning and Environment Division, South; CEMVN PDS-C; Room 139; 7400 Leake Avenue, New Orleans, Louisiana 70118. Ms. Gunning may also be contacted by email at kristin.t.gunning@usace.army.mil or by phone 504-862-1514.

Proposed Action

<u>Description of Proposed Action</u>

Construction Elements

The proposed action consists of the construction of a levee and floodwall system along an alignment in South and West Slidell, Louisiana, channelization of a portion of the Mile Branch in Covington, Louisiana, and the creation of new habitat mitigation areas to offset losses within the project's construction footprint areas. See Appendix for details of the project features.

Channel improvements would occur on the lower 2.15 miles (11,341 ft channel) of Mile Branch in Covington, Louisiana (Figure 1). The proposed work would consist of approximately 20 acres of channel that would be cleared and grubbed prior to mechanical dredging. The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and end at the intersection of Mile Branch and the Tchefuncte River. Assumptions for channel improvements included a 65-ft from the centerline of each side of the channel for ROW as a general guideline (total width of 130 ft).

The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel would be widened as well as deepened. The channel bottom would be lowered by 5 ft. All work would be performed from the bank. The trees located close to the bank would be removed. The banks would be stabilized and seeded and fertilized to have a grass cover. Work would be done by excavators or small skid steers. Material removed may include sediment, trees, debris, or other obstructions within the waterway. Up to 130,000 cubic yards of material would be removed by truck or sidecast along the bank. Sidecast material would temporarily increase water turbidity and decrease water quality, and naturally revegetate or move through the water channel to be deposited downstream. Removed material would be trucked off-site and disposed at a facility licensed to handle the material. Table 1 lists the Mile Branch attributes of the TSP for the 50-year period of analysis.

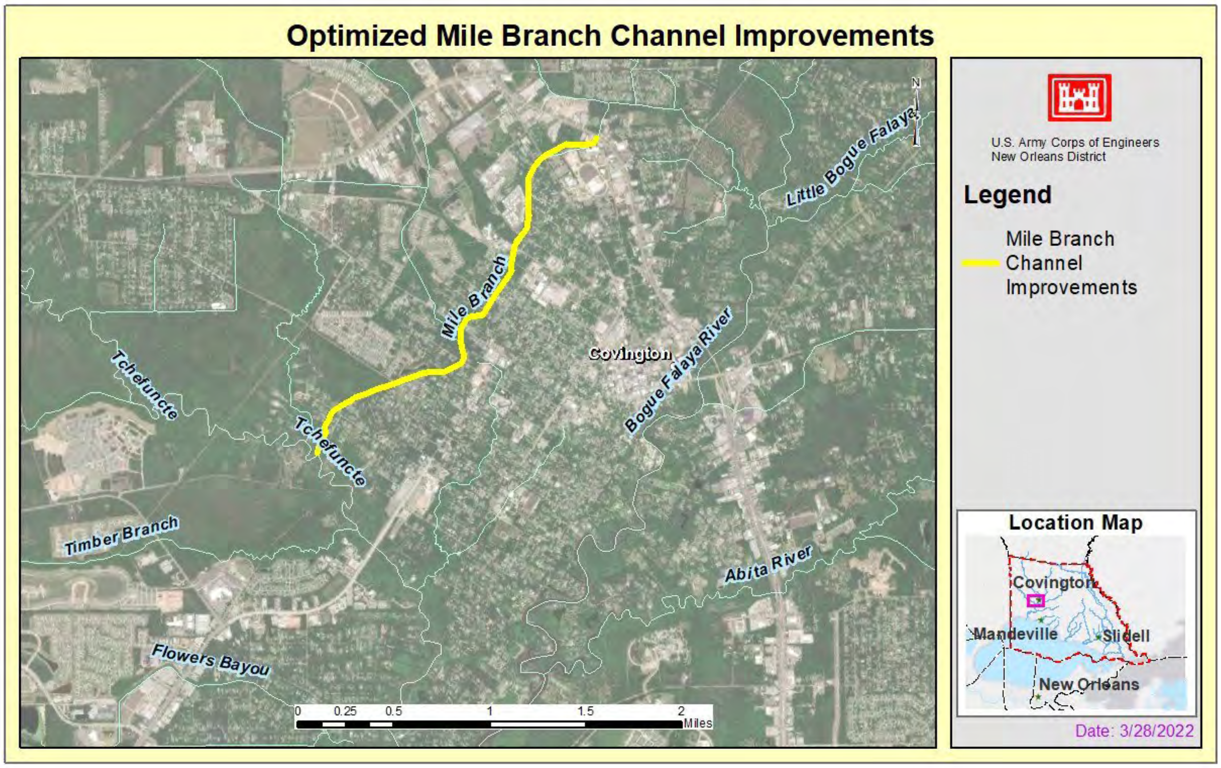

Figure 1. Mile Branch Channel Improvements

Table 1. Summary Table of TSP for Mile Branch

Attribute	Mile Branch Channel Improvements
Total Length of improvements	2.15 miles (11,341 feet)
Material to be Mechanically Dredged	130,000 cubic yards
Access Roads for both clearing and for bridge replacement?	0 acres
Number of staging areas for clearing and grubbing and mechanical dredging and for culvert/bridge replacement	19 (7 for culvert/bridge replacements, 11 for clear and grubbing and mechanical dredging and one that becomes a backwater area)
Number of Bridge Replacements of Culverts	7
Temporary ROW	7.3 acres (2.2 acres for culvert/bridge replacements and 5.1 acres for clear and grubbing and mechanical dredging)
Permanent ROW	38.5 acres

	(34 acres for clear and grubbing and mechanical dredging and 4.5 acres for one staging area that becomes a backwater area)

The levee and floodwall system would consist of a total of approximately 18.4 miles (96,950 feet) of earthen levee and floodwall which includes approximately 15 miles (79,100 feet) of levees constructed in separate (non-continuous) segments, and 3.4 miles (17,850 feet) of separate (non-continuous) segments of a floodwall (Figure 2). Construction of the levee alignment would impact approximately 520.7 acres of permanent ROW and it would require approximately 7,069,000 cubic yards of fill, including fill material required for future levee lifts (estimates include a 30 percent contingency). Table 2 provides a summary of the attributes of the South and West Slidell Levee and Floodwall System.

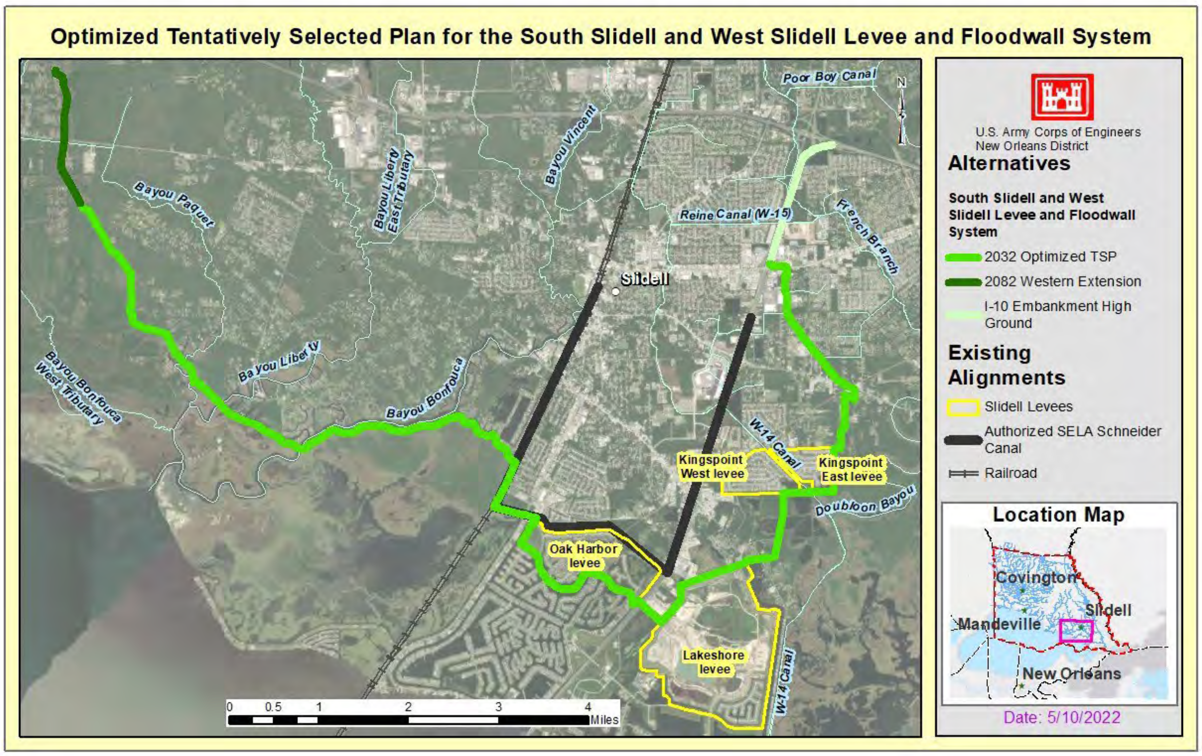

Figure 2. South and West Slidell Levee and Floodwall alignment in St. Tammany Parish, Louisiana

Table 2. Summary Table of South Slidell and West Slidell Levee and Floodwall System

Attribute	South Slidell and West Slidell Levee and Floodwall System
Total Length of alignment	18.4 miles (96,950 feet)
Length of Floodwall	3.4 miles (17,850 feet)
Length of earthen Levee	15 miles (79,100 feet)
Temporary Acres of Construction for Levee and Floodwall system	109 acres
Permanent Acres for Levee and Floodwall system	521 acres
Hydraulic Design Elevation Range (Dependent on location)	13.5 to 16 (year 2032) 17.5 to 20 (year 2082)
Pump Stations	8
Sluice Gates/Lift Gates	13
Number of Vehicular Floodgates	16
Number of Pedestrian Floodgates	1
Number of Railroad Gates	1
Number of Road Ramps	11
Fill (Borrow Material) Required	7,069,000 cubic yards

Proposed mitigation for marsh consists of 200 acres of marsh creation on the north shore of Lake Pontchartrain, east of the Causeway Bridge near Lacombe (Figure 3). The assumed existing elevation is -1.65' NAVD88. Initial target elevation for dredge fill would be to approximate elevation +2.5 NAVD88, to ultimately hit a target marsh elevation of +1.0 NAVD88. At this 35% design level, total perimeter retention would be required to retain dredge material and allow for vertical accretion. Approximately 14,718 linear ft of new retention dike would be required along the limit of the project footprint. The dike would be built with borrow from within the footprint. The dike would be built with a 5 ft crown width to elevation +4.8' NAVD88, to provide one ft of freeboard during pumping operation and allow for settlement. This dike would be degraded in year 1, upon settlement and dewatering of the created marsh platform. The degraded material can be disposed of in the original borrow canal if settlement allows or cast into the open water immediately outside of the project footprint. Spill boxes or weirs would be constructed at pre-determined locations within the retention dike to allow for effluent water release from within the marsh creation area. If deemed necessary by the construction contractor, low level interior weir or baffle dikes can be constructed to assist in vertical stacking of dredged material.

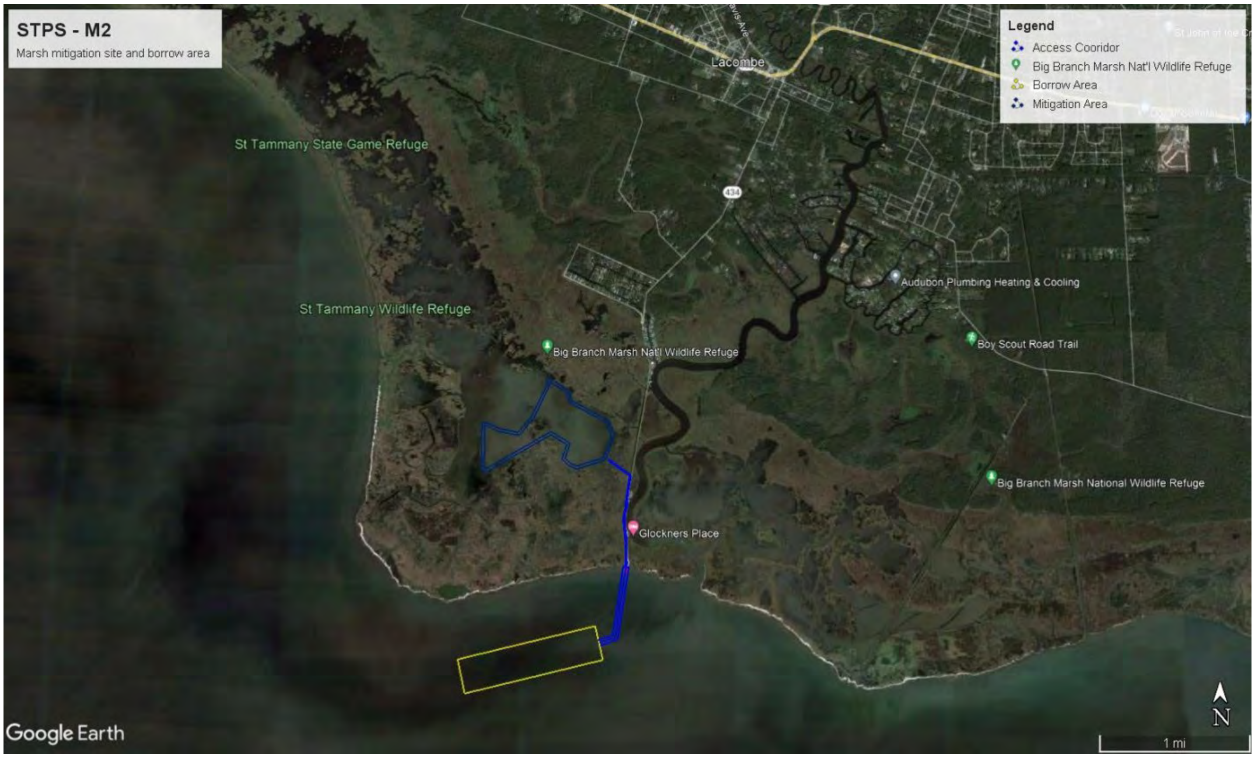

Figure 3. Marsh mitigation site and borrow area.

Borrow Excavation Component

Marsh creation would require borrow of approximately 2,200,000 cubic yards of material. A borrow site of 134 acres would accommodate this requirement. The borrow plan is to obtain material from Lake Pontchartrain, requiring a buffer of 2000 ft between the existing shoreline and the borrow area limit. Borrow would not be allowed greater than 10 ft below the existing lake bottom, except that a tolerance of 1-ft below this target elevation would be provided the contractor to account for inaccuracies in the dredging process. To assure adequate borrow, the fill quantity was doubled account for unsuitable materials, unknown utilities, unidentified anomalies, and/or unsighted cultural finds. An access corridor of approximately 7,340 linear feet would be allowed from the lake to the proposed marsh creation site. The access corridor can be used to establish a pipeline corridor, offload equipment as necessary, and transport personnel to and from the worksite. The contractor would be instructed to minimize usage and damage within the access corridor, by using existing waterways for daily transportation of supplies and personnel where possible.

Construction Access and Staging Components

Site access to Mile Branch would be via public roads and public rights of way. Staging areas are assumed to be dry. Any trees would be removed and hauled away to an approved facility. If necessary, crushed stone would be placed in the staging area prior to construction. After construction, the crushed stone would be removed and the disturbed areas would be fertilized and seeded. For the culvert and bridge replacement work, all staging areas were assumed to be located within the individual structure construction areas. Staging areas are to be tree and vegetation free and covered with crushed stone.

Levee and floodwall construction sites would be accessed via existing public roads to the maximum extent as possible. In locations where access cannot be achieved via existing roadways, a new road would be constructed. Construction of new roads would require permanent ROW. New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for VFZ on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

For the construction of the levee on the refuge land (from Bayou Bonfouca to the railroad tracks), the ingress and egress would be at the Norfolk Southern railroad tracks on the east side of Bayou Bonfouca and existing roads on the west side. A one-way flow of traffic would be maintained. The USACE would need to obtain permission from the railroad owner (Norfolk Southern Railway Corp.) prior to construction. An access road would be constructed on the protected side of the ROW between the proposed crown of the levee and Bayou Bonfouca. The access road would be a temporary road. Once construction is complete, the area would be cleared of vegetation within the right of way and graded to drain away from the levee. Access during future inspections would be done by driving on the crown of the levee.

There would be one 2-acre staging area on the reach on the refuge land that would be considered a temporary easement. The staging area would be located off the refuge and would be used to process the material prior to building the levee. Staging areas would be required to be continuously accessible. Any trees would be removed and hauled away to an approved facility. The area would be restored to pre-construction elevation that existed prior to impacting the site due to construction activities.

Table 3 provides a summary of the necessary staging areas and permanent ROW required for construction of the levee and floodwall segments for the 50-yr period of analysis. The staging areas required during initial construction of the levee alignment would be the same staging areas required for construction of future levee lifts. Staging areas are assumed to be dry. Any trees would be removed and hauled away to an approved facility. If necessary, crushed stone would be placed in the staging area prior to construction. After construction, the crushed stone would be removed and the disturbed areas would be fertilized and seeded.

Table 3. Summary of Staging Areas and Permanent ROW

SUMMARY of STAGING AREAS AND PERMANENT ROW		
Levees	**Staging Areas (Acres)**	**Permanent ROW (Acres)**
Western High Ground Tie In	2	30
West Slidell	8	270
South Slidell (includes 23 acres for I-10)	29	120
Sub-Total for Levees	**39**	**420**
Floodwall Segments		
Western High Ground Tie In	NA	NA
West Slidell	0	3.7
South Slidell	0	22.7
Sub-Total for Floodwall Segments	**0 ***	**26.4**
Floodgates and Pump Stations		

Western High Ground Tie In	1.5	2.5
West Slidell	11	21
South Slidell	3.75	6.25
Sub-Total for Floodgates and Pump Stations	**16.25**	**29.75**
Vehicular, Pedestrian, and Railroad Gates		
Western High Ground Tie In	1.5	1.25
West Slidell	1.25	0
South Slidell	9	0
Sub-Total for Vehicular, Pedestrian, and Railroad Gates	**11.75**	**1.25**
Road Ramps		
Western High Ground Tie In	0.5	0
West Slidell	0	0
South Slidell	5	0
Sub-Total for Road Ramps	**5.5**	**0**
Access Roads - New		
Western High Ground Tie In	0.1	0.1
West Slidell	0.45	0.45
South Slidell	2.75	2.75
Access Roads - Existing		
Western High Ground Tie In	0	0
West Slidell	15.8	0
South Slidell	9.9	0
Sub-Total for Access Roads	**29**	**3.3**
Mile Branch Channel Improvements	7.3	38.5
Sub-Total for Mile Branch Channel Improvements	**7.3**	**38.5**
Total Acres for 50-year Period of Analysis	**109**	**520**

*for floodwall segments, staging areas would be included in the 80 ft wide permanent ROW.

Operation and Maintenance Elements

During the operation and maintenance (O&M) phase of the project, prior to transfer of monitoring responsibilities to the non-Federal sponsor (NFS), the site would be monitored and surveyed to ensure the marsh creation area has met the initial success criteria. At a minimum, these actions would include periodic eradication of invasive/nuisance plants in the mitigation feature and mitigation monitoring and reporting. Approximately one year after the construction of the marsh platform is complete, once dewatering and settlement of the marsh platform has occurred, the retention dikes would be degraded to the target marsh elevation. The degraded material can be disposed of in the original borrow canal if settlement allows or cast into the open water immediately outside of the project footprint. The marsh feature is not expected to require planting, since it is assumed that native marsh plants would colonize the marsh naturally. If marsh species do not colonize the site on their own, marsh plant species would be planted.

Description of Project Purpose

The proposed action consists of the construction of a levee and floodwall system along an alignment in South and West Slidell, Louisiana, channelization of a portion of the Mile Branch in Covington, Louisiana (Figure 1), and the creation of 200-acres of new marsh habitat to mitigate losses within the project's construction footprint areas.

Conservation Measures and BMPs

To reduce impacts to Gulf sturgeon critical habitat, a cutterhead dredge would be utilized to remove borrow material from the designated borrow area. This equipment is slower moving and has not been identified as equipment that would impact Gulf sturgeon. CEMVN would also adhere to the Protected Species Construction Conditions[1].

Description of the Action Area

Pursuant to 50 C.F.R. § 402.02, the term *action area* is defined as "all areas to be affected directly or indirectly by the federal action and not merely the immediate area involved in the action." Accordingly, the action area typically includes the affected jurisdictional waters and other areas affected by the authorized work or structures within a reasonable distance. The ESA regulations recognize that, in some circumstances, the action area may extend beyond the limits of the Corps' regulatory jurisdiction.

For the purposes of this consultation, CEMVN has defined the action area to include the following:

Mile Branch

This measure consists of channel improvements on the lower 2.15 miles (11,341 ft channel) of Mile Branch in Covington, Louisiana. The proposed work would consist of approximately 20 acres of channel that would be cleared and grubbed prior to mechanical dredging (Figure 1). The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and end at the intersection of Mile Branch and the Tchefuncte River.

Levee and Floodwall System

The levee and floodwall system would consist of construction of approximately 18.4 miles of earthen levee and floodwall in St. Tammany Parish, Louisiana. Construction of the levee alignment would impact approximately 520.7 acres of permanent ROW and it would require approximately 7,069,000 cubic yards of fill, including fill material required for future levee lifts. Figure 2 provide illustrations of the proposed levee and floodwall alignment.

PSR-01 Mitigation Site

Impacts to Big Branch Marsh National Wildlife Refuge would be mitigated by managing approximately 70 acres of pine savanna habitat (PSR-01) within the refuge via controlled burns.

M2 Mitigation Site

Proposed mitigation for marsh consists of 200 acres of marsh creation on the north shore of Lake Pontchartrain, east of the Causeway Bridge near Lacombe. Borrow would be obtained from a 134-acre site within Lake Pontchartrain. Figure 3 provides an illustration of the M2 mitigation site.

Physical and Biological Attributes of the Action Area

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[1]NMFS. 2021. Protected Species Construction Conditions. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service, Southeast Regional Office, Saint Petersburg, FL.

The Louisiana Department of Wildlife and Fisheries, Wildlife Diversity Program, identified 22 habitat types occurring within St. Tammany Parish. Of the 22 vegetative habitat types identified, 15 are classified as wetlands, of which all are in a state of decline. Habitat to be impacted within the Action Area that may impact Gulf sturgeon and Gulf sturgeon critical habitat include freshwater marsh, intermediate marsh, and open water.

Freshwater marsh is found surrounding bodies of open water and is located along the shoreline of Lake Pontchartrain. It forms in accreting, sediment rich, high-energy environments typical for this region and is dominated by rush and reed plant species like cattails and arrowhead. These marshes can form detached mats of vegetation, known as flotant, which encourage colonization by other plant species. Fresh marshes provide nursery habitat for estuarine-dependent species important to recreational and commercial fisheries such as blue crab, white shrimp, Gulf menhaden, Atlantic croaker, red drum, southern flounder, bay anchovy, striped mullet, and others. Fresh marshes also provide habitat for largemouth bass, warmouth, black crappie, blue catfish, bowfin, and gar.

Intermediate marsh is a unique type of wetland marsh found in the Action Area whose vegetative community reflects the shifts in salinity associated with proximity to marine environments. This type of marsh is the middle part of the gradient found in vegetative communities shifting from fresh to saline waters, and the marsh species that are found in this type like saltmeadow grass are capable of withstanding spikes of salinity that are associated with tropical storm surge events. It is commonly a narrow band of vegetation when compared with other marsh types due to the large differences between freshwater and brackish salinities. Wildlife found within an intermediate marsh is less diverse than found in freshwater marshes, but more individuals may be present.

Open water habitats within Lake Pontchartrain are characterized by sandy bottoms and relatively shallow depths extending to 15 feet (NOAA Chart 11639). Desktop review of National Oceanic and Atmospheric Administration Bathymetric Data of Lake Pontchartrain (ESD-PHB-21, W00561) indicate water depth between approximately 3 ft to 11 ft in the vicinity of the M2 borrow site.

Potentially Affected NMFS ESA-Listed Species and Critical Habitat

Within St. Tammany Parish there are ten documented animal and one plant species under the jurisdiction of the ESA. Of the listed animal and plant species occurring in St. Tammany Parish, only the Gulf sturgeon is expected to potentially be found in the proposed borrow area in Lake Pontchartrain. Additionally, it would be highly unlikely that Gulf sturgeon would be found in the M2 mitigation site due to very shallow water. Gulf sturgeon are typically found in deeper water where they are able to maneuver and forage effectively. Project activities have the potential to affect listed species as shown in Table 4 below, and their DCH.

Table 4: DCH in the action area

Species	DCH in the Action Area	DCH Rule/Date	USACE Effect Determination (DCH)
Gulf sturgeon	Unit 8. Lake Pontchartrain, Lake St. Catherine, The Rigolets, Little Lake, Lake Borgne, and Mississippi Sound in Jefferson, Orleans, St. Tammany, and St. Bernard Parish, Louisiana, Hancock, Jackson, and Harrison Counties in Mississippi, and in Mobile County, Alabama	68 FR 13369/ March 19, 2003	Not likely to adversely affect

<u>Gulf Sturgeon</u>

The Gulf sturgeon was federally listed as threatened throughout its range on September 30, 1991. The Gulf sturgeon is an anadromous fish that migrates from salt water into coastal rivers to spawn and spend the warm summer months. Subadults and adults typically spend the three to four coolest months of the year in estuaries or Gulf of Mexico waters foraging before migrating into the rivers. This migration typically occurs from mid-February through April. Most adults arrive in the rivers when temperatures reach 70 degrees Fahrenheit and spend 8 to 9 months each year in the rivers before returning to estuaries or the Gulf of Mexico by the beginning of October.

Prior to the listing of the species, Davis et al. (1970) reported the collection of Gulf sturgeon from Lake Pontchartrain during a Louisiana Department of Wildlife and Fisheries (LDWF) anadromous fish survey from 1966 to 1969. From 1988 to 1999, LDWF, through various means and studies, captured and recorded at least 60 Gulf sturgeon throughout Lake Pontchartrain, Lake Catherine, the Rigolets and Lake Borgne. A LDWF trammel net study conducted by Inland Fisheries Division in the spring of 2001 resulted in the capture of three young of the year juvenile sturgeon at the intersection of the East Pearl River and Little Lake. In 2002, LDWF Seafood Division reported the capture of a Gulf sturgeon in one of their gill nets while sampling in a cove west of Alligator Point, Lake Borgne. By-catch of Gulf sturgeon has been reported by several recreational and commercial fishermen within these waters. A total of 177 Gulf sturgeon, measuring up to 7.2 feet in length and weighing from 2 to 152 lbs, were captured in these lakes and in the Rigolets from October 1991 to September 1992 (Rogillio, 1993). Reynolds (1993) reported that sturgeon measuring up to 7.2 feet in length and weighing up to 258 lbs were incidentally caught by shrimp trawlers, netters, and recreational anglers from 1889 to 1993 in Lake Pontchartrain.

<u>Gulf Sturgeon Critical Habitat</u>

Critical habitat identifies specific areas that have been designated as essential to the conservation of a listed species. The project area is located within the boundary of critical habitat Unit 8. In 2003, Unit 8 was designated as critical habitat for Gulf sturgeon. Unit 8 encompasses Lake Pontchartrain east of the Lake Pontchartrain Causeway, all of Little Lake, the Rigolets, Lake St. Catherine, Lake Borgne, including Heron Bay, and the Mississippi Sound in Jefferson, Orleans, St. Tammany, and St. Bernard Parish, Louisiana, Hancock, Jackson, and Harrison Counties in Mississippi, and in Mobile County, Alabama.

Unit 8 includes approximately 1377 square miles of critical habitat with 277 square miles in Lake Borgne, 3 in Little Lake, 295 in Lake Pontchartrain, 10 in Lake St. Catherine, 5 in the Rigolets, 725 in Mississippi Sound, and 62 along the Mississippi near shore Gulf (68 FR 13369-13495). Critical habitat follows the shorelines around the perimeters of each included lake. The Mississippi Sound includes adjacent open bays, including Pascagoula Bay, Point aux Chenes

Bay, Grand Bay, Sandy Bay, and barrier island passes, including Ship Island Pass, Dog Keys Pass, Horn Island Pass, and Petit Bois Pass. Critical habitat excludes St. Louis Bay, north of the railroad bridge across its mouth; Biloxi Bay, north of the U.S. Highway 90 bridge; and Back Bay of Biloxi.

Critical habitat for the Gulf sturgeon has been designated within the project area, specifically the borrow area in Lake Pontchartrain (Figure 3) which is part of Unit 8 so the species may be present. USGS surveys of Lake Pontchartrain found that the majority of Lake Pontchartrain bottoms near the center of the lake were defined as having sandy composition which is prime habitat for sturgeon. As part of the design for this project those borrow locations closer to the Lake Pontchartrain center were avoided to minimize impacts to Gulf Sturgeon foraging habitat. The borrow site is approximately 2000 ft from the shoreline and likely receives fine sediment from wave induced shoreline erosion. However, the proposed borrow site is within the designated critical habitat but given that prime habitat is available nearby, any Gulf Sturgeon that may be present would likely congregate in the ample nearby prime habitat, especially during construction.

Route(s) of Effect to Gulf Sturgeon:
Gulf sturgeon may be physically injured if struck by construction equipment, vessels, or materials during dredging. This effect is discountable due to the ability of the species to move away from the project site if disturbed. Gulf sturgeon are mobile and are able to avoid construction noise, moving equipment, and placement or removal of materials during construction. NMFS has previously determined in dredging Biological Opinions (e.g., (NMFS 2007)) that, while ocean-going hopper-type dredges may lethally entrain sturgeon, non-hopper type dredging methods, such as the cutterhead dredging method used in this project, are slower and extremely unlikely to adversely affect Gulf sturgeon.

The construction activities and related construction noise may prevent or deter Gulf sturgeon from entering the project area. However, the effect to sturgeon from temporary avoidance of the project area due to construction activities, including related noise, would likely be insignificant. The size of the area from which animals would avoid is relatively small in comparison to the available similar habitat nearby, which would be accessible to sturgeon during construction. Disturbances and loss of habitat access would be temporary and limited to days of in-water construction. After the project is completed, Gulf sturgeon would be able to return to the project area.

Indirect impacts to Gulf Sturgeon could occur due to turbidity from construction which would be minimized by utilizing dikes to contain the dredged material. In addition, any runoff from construction activities on land would be controlled through the use of best management practices and adherence to regulations governing stormwater runoff at construction sites and staging areas. No permanent indirect impact to gulf sturgeon are expected to occur from construction of the propose project.

Hypoxic and anoxic conditions can occur in deep borrow pits that have a tendency to accumulate organic material. This accumulation would be reduced for the M2 borrow pit within Lake Pontchartrain by limiting the depth of the pit to 10 feet. Therefore, effects to Gulf sturgeon from hypoxic or anoxic conditions are discountable.

We believe the effect to Gulf sturgeon from the potential loss of foraging habitat due to dredging would be insignificant. Gulf sturgeon are opportunistic feeders that forage over large areas and would be able to locate prey beyond the small dredging footprint (approximately 134 acres).

Also, impacts to foraging resources from dredging are temporary since benthic invertebrate populations in dredged areas have been observed to recover in 3-24 months after dredging (Culter and Mahadevan 1982; Saloman et al. 1982; Wilber et al. 2007).

Route(s) of Effect to Gulf Sturgeon Critical Habitat
The project is located in critical habitat unit 8. The essential features/primary constituent elements (PCEs) are present in Unit 8 and are those habitat components that support feeding, resting, sheltering, migration, and physical features necessary for maintaining the natural processes that support those habitat components. The following are the primary constituent elements for Gulf sturgeon critical habitat that are present and CEMVN's response on how the proposed action for the M2 borrow site in critical habitat would affect these elements. Only three of the four PCEs are likely to be affected. The CEMVN has determined the proposed action is "Not Likely to Adversely Affect" Gulf sturgeon critical habitat based on these responses for the three PCEs.

(1) Abundant prey items, such as amphipods, lancelets, polychaetes, gastropods, ghost shrimp, isopods, molluscs and/or crustaceans, within estuarine and marine habitats and substrates for subadult and adult life stages.

Adult and subadult Gulf sturgeon feed on amphipods, lancelets, polychaetes, gastropods, molluscs and/or crustaceans within estuarine and marine habitats. Dredging may remove substrates containing sturgeon prey items. However, overall impacts to sturgeon prey are expected to be insignificant since the estimated impact area is relatively small compared to the surrounding area available (approximately 134 acres). Effects to sturgeon prey are also expected to be temporary and short-term in nature, consisting of a temporary loss of benthic invertebrate populations in the dredged areas. Observed rates of benthic community recovery after dredging range from 3-24 months (Culter and Mahadevan 1982; Saloman et al. 1982; Wilber et al. 2007). The relatively species-poor benthic assemblages associated with low salinity estuarine sediments can recover in periods of time ranging from a few months to approximately one year, while the more diverse communities of high salinity estuarine sediments may require a year or longer.

(2) Water quality including temperature, salinity, pH, hardness, turbidity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages.

Localized and temporary reductions in water quality through increased turbidity may result from dredging. Effects to water quality from localized and temporary increased turbidity are expected to be insignificant because the Action Area is also in a high wave/current area where construction-induced turbidity is not expected to remain and where turbidity curtains are not practical to use. Effects to temperature, salinity, pH, hardness, oxygen content, and other chemical characteristics of water quality are also not expected to result from dredging activities.

(3) Sediment quality including texture and other chemical characteristics necessary for normal behavior, growth, and viability of all life stages.

Effects to sediment quality from dredging would be insignificant. During prior consultations (BAs for SER-2010-4236 and SER-2014-14728, hereby incorporated by reference), surveys were conducted by USGS and NOAA that used remote imagery to determine bottom substrates within Lake Pontchartrain. The majority of Lake Pontchartrain bottoms were defined as having sandy composition and thus prime habitat for sturgeon.

The borrow site is approximately 2000 ft from the shoreline and likely receives fine sediment from wave induced shoreline erosion. The sandier composition areas, which are located further into the lake center, would be avoided and thus minimizing impacts to sturgeon foraging. Given that prime habitat is available nearby, any Gulf Sturgeon that may be present would likely congregate in the ample nearby prime habitat, especially during construction. No permanent alteration of habitat composition is expected to occur within the action area.

Based on currently available historical and catch data; a review of current literature and studies; and with the employment of avoidance measures recommended through guidelines set up during coordination with NMFS; the CEMVN has determined that the proposed action is “Not Likely to Adversely Affect” the Gulf sturgeon species or Gulf sturgeon critical habitat.

Conclusion

CEMVN has reviewed the proposed project for its impacts to federally listed species and their DCH. Based on currently available historical and catch data; a review of current literature and studies; and with the employment of avoidance measures recommended through guidelines set up during coordination with NMFS; including protected species construction conditions; CEMVN has concluded the project may affect but is not likely to adversely affect Gulf sturgeon and DCH listed in Table 4. This analysis was prepared based on the best scientific and commercial data available.

CEMVN is requesting NMFS’s written concurrence with these determinations. CEMVN appreciates your cooperation in completing this informal section 7 consultation by concurring with CEMVN’s effect determination(s) a timely manner. If NMFS disagrees with the CEMVN effect determination(s) and requests formal Section 7 consultation, please contact Ms. Kristin Gunning (kristin.t.gunning@usace.army.mil) to discuss suggested modifications to the action to avoid potential adverse effects and NMFS’ additional information needs. CEMVN would continue to coordinate with NMFS office via email to provide the requested information and, if warranted, a revised effects determination.

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Appendix: Project Description for the Optimized Tentatively Selected Plan
St. Tammany Parish Louisiana Feasibility Study

SUMMARY

PROJECT DESCRIPTION
for the
Optimized Tentatively Selected Plan
St Tammany Parish Louisiana Feasibility Study

1.0 INTRODUCTION

Subsequent to the release of the June 2021 Draft Integrated Feasibility Report and Draft Environmental Impact Statement (DIFR and DEIS), the Project Delivery Team (PDT) conducted additional engineering, economic, and environmental investigations on the individual features of the Optimized Tentatively Selected Plan (TSP) which is comprised of a structural plan and a non-structural plan. Information gathered by the PDT through these additional investigations, together with the consideration of comments received from the public, stakeholders, the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service assisted the PDT in further refining the design of the Draft TSP. This document is a summary project description of the proposed Optimized TSP. Refer to Appendix F and H for the full description of the non-structural plan and Appendix D for full description of the structural plan.

1.1 SCOPE OF WORK

The Optimized TSP includes a non-structural plan and a structural plan. For planning purposes, the 50-yr period of analysis for the study was estimated to be from the year 2032 to 2082. Project authorization would occur in the year 2024 and kick-off planning, engineering, and design (PED). PED was originally estimated to be complete by the year 2027. Initial construction of the project would begin 2027 and conclude by the year 2032 (base year). These original assumptions will be revised once the construction schedule is prepared by the Cost team in MVN Engineering. Figure 1-1 illustrates the optimized TSP including a non-structural and a structural plan.

<u>Non-Structural Plan</u>:

Insert summary of the non-structural plan from Economics.

<u>Structural Plan</u>:

The structural plan consists of construction of a levee and floodwall system along an alignment in South and West Slidell and channelization of a portion of the Mile Branch in Covington.

1.2 **Mile Branch Channel Improvement:** This measure consists of channel improvements on the lower 2.15 miles (11,341 ft channel) of Mile Branch in Covington, Louisiana. The proposed work would consist of approximately 20 acres of channel that would be cleared and grubbed prior to mechanical dredging.

The mechanical dredging would consist of a maximum of 130,000 cubic yards of fill dredged from the channel. There are no surveys available for this area for this study, and no surveys will be conducted during the study phase. The existing elevations used for the hydraulic analysis and design of the Optimized TSP were obtained from the LIDAR raster dataset. Designs are based on existing information gathered from reports provided by the non-Federal sponsors as shown on Table 1.2 in the main report.

Design refinements would occur during PED based on field data collections. Based on data collected, the design would be refined to minimize impacts to aquatic and riparian habitat and real estate. Riparian Zone bioengineering techniques and nature-based-solutions (NBS) would be incorporated as appropriate during PED in coordination with the NFS and resource agencies. A backwater area has been incorporated in the design of Mile Branch.

Table 1.1 lists the Mile Branch attributes of the TSP for the 50-year period of analysis.

Table 1.1 Summary Table of TSP for Mile Branch

Attribute	**Mile Branch Channel Improvements**
Total Length of improvements	2.15 miles (11,341 feet)
Material to be Mechanically Dredged	130,000 cubic yards
Access Roads for both clearing and for bridge replacement?	0 acres
Number of staging areas for clearing and grubbing and mechanical dredging and for culvert/bridge replacement	19 (7 for culvert/bridge replacements, 11 for clear and grubbing and mechanical dredging and one that becomes a backwater area)
Number of Bridge Replacements of Culverts	7
Temporary ROW	7.3 acres (2.2 acres for culvert/bridge replacements and 5.1 acres for clear and grubbing and mechanical dredging)
Permanent ROW	38.5 acres (34 acres for clear and grubbing and mechanical dredging and 4.5 acres for one staging area that becomes a backwater area)

The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and end at the intersection of Mile Branch and the Tchefuncte River. Assumptions for channel improvements included a 65-ft from the centerline of each side of the channel for ROW as a general guideline (total width of 130 ft).

The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel would be widened as well as deepened. The channel bottom would be lowered by 5 ft. All work would be performed from the bank. The trees located close to the bank would be removed. The banks would be stabilized and seeded and fertilized to have a grass cover. Work would be done by excavators or small skid steers.

Material removed may include sediment, trees, debris, or other obstructions within the waterway. Removed material would be trucked off-site and disposed at a facility licensed to handle the material. Site access to Mile Branch would be via public roads and public rights of way.

For the channel improvements, approximately 34 acres of permanent ROW would be needed. This area would include 25 ft on each side of the Mile Branch channel. Within the 34 acres, approximately 21 acres of channel would be cleared and grubbed prior to mechanical dredging. An assumed maximum of 130,000 cubic yards of material may be mechanically dredged from the channel.

Mile Branch improvements may include bridge replacements or culverts. Approximately 2.2 acres would be required for staging along the various areas of the bridge/culvert replacements.

1.3 South and West Slidell Levee and Floodwall Alignment: The levee and floodwall system would consist of a total of approximately 18.4 miles (96,950 feet) of earthen levee and floodwall which includes approximately 15 miles (79,100 feet) of levees constructed in separate (non-continuous) segments, and 3.4 miles (17,850 feet) of separate (non-continuous) segments of a floodwall. Construction of the levee alignment would impact approximately 520.7 acres of permanent ROW and it would require approximately 7,069,000 cubic yards of fill, including fill material required for future levee lifts (estimates include a 30 percent contingency). Table 1.2 provides a summary of the attributes of the South and West Slidell Levee and Floodwall System. Table 1.3 is a summary of the levee quantities required for the initial construction.

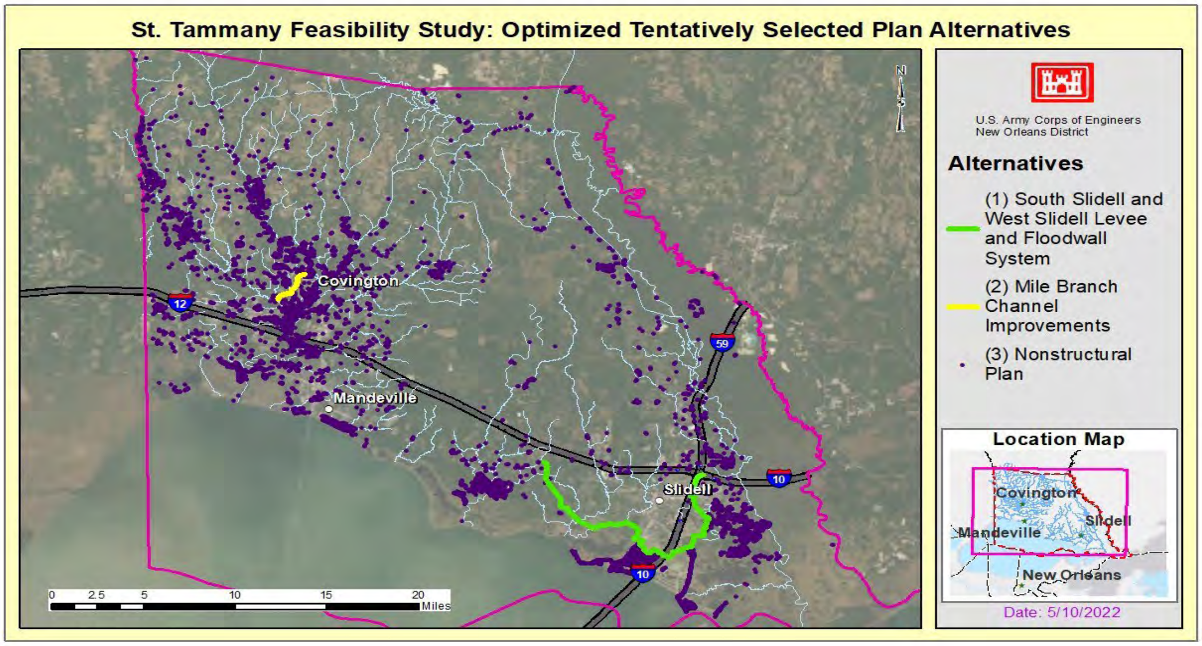

Figure 1-1. Optimized Tentatively Selected Plan

Table 1.2 Summary Table of South Slidell and West Slidell Levee and Floodwall System

Attribute	**South Slidell and West Slidell Levee and Floodwall System**
Total Length of alignment	18.4 miles (96,950 feet)
Length of Floodwall	3.4 miles (17,850 feet)
Length of earthen Levee	15 miles (79,100 feet)
Temporary Acres of Construction for Levee and Floodwall system	109 acres
Permanent Acres for Levee and Floodwall system	521 acres
Hydraulic Design Elevation Range (Dependent on location)	13.5 to 16 (year 2032) 17.5 to 20 (year 2082)
Pump Stations	8
Sluice Gates/Lift Gates	13
Number of Vehicular Floodgates	16
Number of Pedestrian Floodgates	1
Number of Railroad Gates	1
Number of Road Ramps	11
Fill (Borrow Material) Required	7,069,000 cubic yards

The existing elevations utilized were obtained from the LIDAR raster dataset. No survey data was obtained at this stage of the study; therefore, a 30% contingency was

used for the calculation of the borrow quantities for the South Slidell and West Slidell levee alignment.

Table 1.3 Summary Table: TSP Levee Quantities for Initial Construction

Levee Alignment ROW and Levee Quantities Initial Construction (Year 2032)	
WEST SLIDELL	
Permanent ROW	240 acres
Fill Material (includes 30% contingency)	2,007,000 cubic yards
SOUTH SLIDELL	
Permanent ROW	120 acres
Fill Material (includes 30 %contingency)	825,000 cubic yards**
TOTAL	
Permanent ROW	360 acres
Fill Material (includes 30 % contingency)	2,832,000 cubic yards

**includes quantities for I-10 portion of the alignment.

Levee lifts would be required over the 50-yr period of analysis. The levee lift schedule would follow the hydraulic design elevation requirements and thus were divided into 3 geotechnical reaches: Oak Harbor South; I-10 Crossing and Slidell East/Northeast as illustrated in Table 1-4. The fourth lift (final lift for the 50-year period of analysis), projected to occur in year 2076 would elevate the levee to a construction elevation of 19 ft. It is during the scheduled 4th lift that construction of the Western High Ground Tie-in would be necessary for year 2082. The fill quantities listed for the 4th lift, include quantities for the construction of the Western High Ground Tie-In.

Table 1.4. Future Levee Lifts

	Construction Lift (year)	Construction Elevation (feet)	Permanent ROW (acres)	Fill Material (+30% contingency; cubic yards)
WEST SLIDELL				
First lift	2033	16	N/A	771,000
Second lift	2038	17.5	N/A	901,000
Third lift	2051	19	N/A	685,000
Fourth lift	2076	19	30 *	709,000 *
SOUTH SLIDELL				
Oak Harbor South				
First Lift	2035	17	N/A	106,000
Second Lift	2048	18	N/A	120,000
Third Lift	2064	19	N/A	115,000
I-10 Crossing **				
Slidell East / Northeast				

First Lift	2034	19	N/A	271,000
Second Lift	2047	20.5	N/A	295,000
Third Lift	2064	21.5	N/A	264,000
Total For Future Lifts				
			30	4,237,000
Total for Life of the Project (initial construction + lifts)				
			390	**7,069,000**

***** Includes the levee quantities (192,000 cubic yards) for the Western High Ground Tie-in for Year 2082.

** I-10 Crossing features would be constructed to the 2082 elevation and therefore would not require additional lifts.

2 LEVEE AND FLOODWALL SYSTEM DESCRIPTION

The levee and floodwall system consists of a combination of portions of the West Slidell levee alignment and the South Slidell levee alignment. The two alignments would be connected by a new railroad gate across the existing Norfolk Southern Railway Corp. railroad tracks. The alignment is shown in lime green in Figure 1-2.

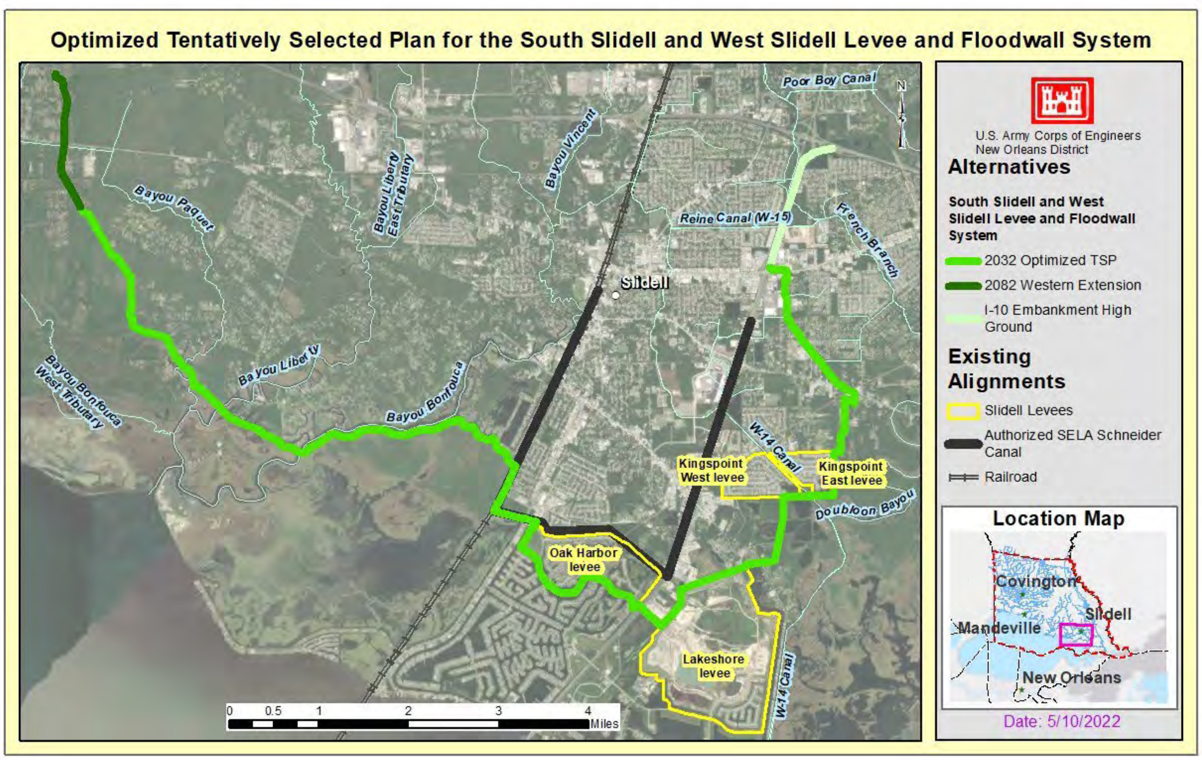

Figure 2-2. Optimized TSP for the West Slidell and the South Slidell Levee and Floodwall System

2.2 LEVEE AND FLOODWALL ALIGNMENT AND STRUCTURES

This section describes the alignment starting on the northwest end and continuing east. For floodwall segments refer to table 2.4, for pump stations refer to Table 2.9, for sluice, lift and sector gates refer to table 2.7, and for vehicular, pedestrian, and railroad floodgates refer to Table 2.8. All structural components would be constructed during initial construction.

2.2.1 WESTERN EXTENTION

Western Terminus: The intermediate scenario of relative sea level change between years 2032 and 2082 was used to develop the 2082 hydraulic design elevations. Based on that analysis, the levee was extended to the west to maintain a 1% risk reduction. The Western High Ground Tie-in for Year 2082 is shown in dark green in Figures 1-3 and 1-4. Based on modeling, the western extension would not be necessary until the year 2076 when the risk reduction would be needed. It is anticipated that this levee segment would be constructed during the fourth levee lift of the West Slidell alignment.

The alignment would commence north of US Highway 190 in the neighborhood near the intersection of North Tranquility Road and Shannon Drive between two properties. The alignment would be a berm with hydraulic design elevation of 17.5 ft for year 2082. The alignment would switch to levee (hydraulic design elevation of 17.5 ft (Year 2082)) and would continue south on the edge of the properties and cross US Highway 190, the Tammany Trace Bike Trail and South Tranquility Road on the eastern side of Pineridge Road. The alignment would run south southeast an additional 890 feet past the intersection with South Tranquility Road and tie with the existing year 2032 alignment for West Slidell.

2.2.2 WEST SLIDELL ALIGNMENT

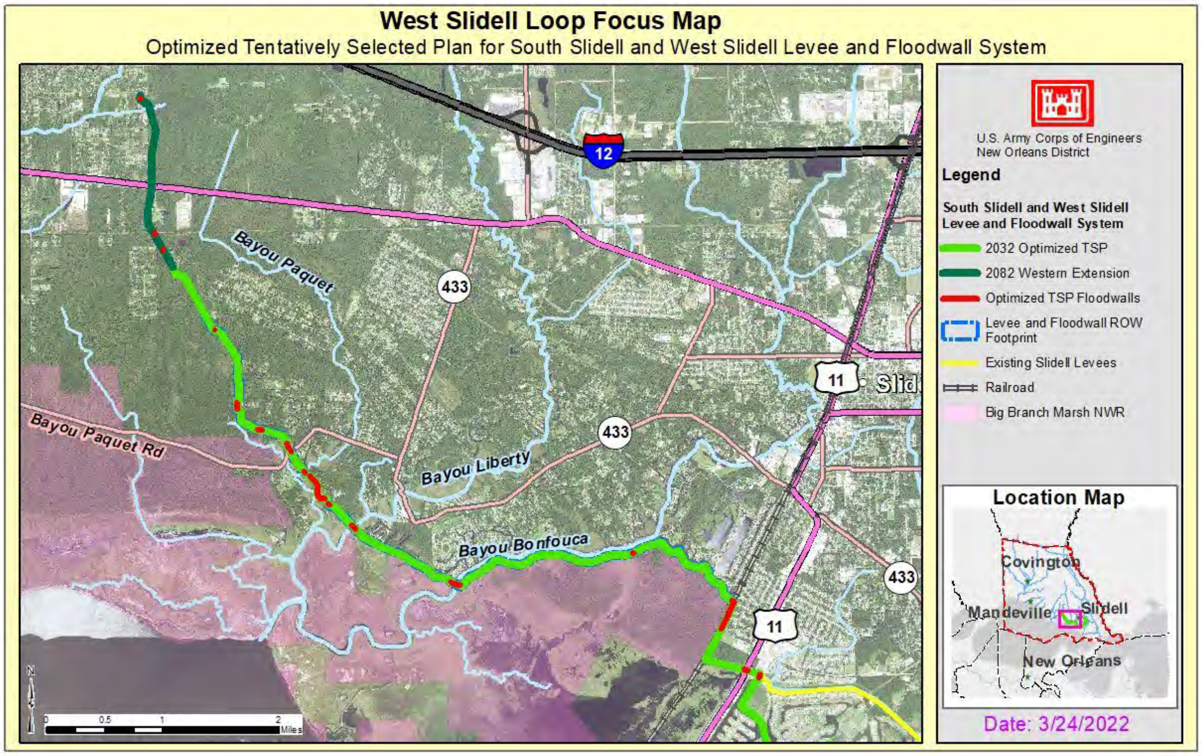

Figure 1-3. West Slidell Levee and Floodwall System- Optimized Tentatively Selected Plan Focus with Floodwall Segments

<u>West Slidell Levee Segment</u>: Levee construction would commence on the south side of US Highway 190 and South Tranquility Road, and on the eastern side of Pineridge Road. For the West Slidell portion of the alignment, the levee segments would have a hydraulic design elevation of 13.5 ft (Year 2032).

The alignment would run southward and would run on the west side of Tranquility Road (CC Road) and then it would turn in the southeast direction crossing Bayou Paquet Road and would stay on the east side of Bayou Paquet Channel to avoid impact to the Big Branch Marsh National Wildlife Refuge (NWR). The alignment would cross Bayou Paquet and Bayou Liberty and would continue eastward on the northside of the Big Branch Marsh NWR. The alignment would cross Bayou Bonfouca and would continue on the south bank of the bayou (northern side of the refuge) until reaching the Norfolk Southern Railway Corp. railroad tracks west of US Highway 11 in the vicinity of Dellwood Pump Station in Slidell.

2.2.3 SOUTH SLIDELL ALIGNMENT

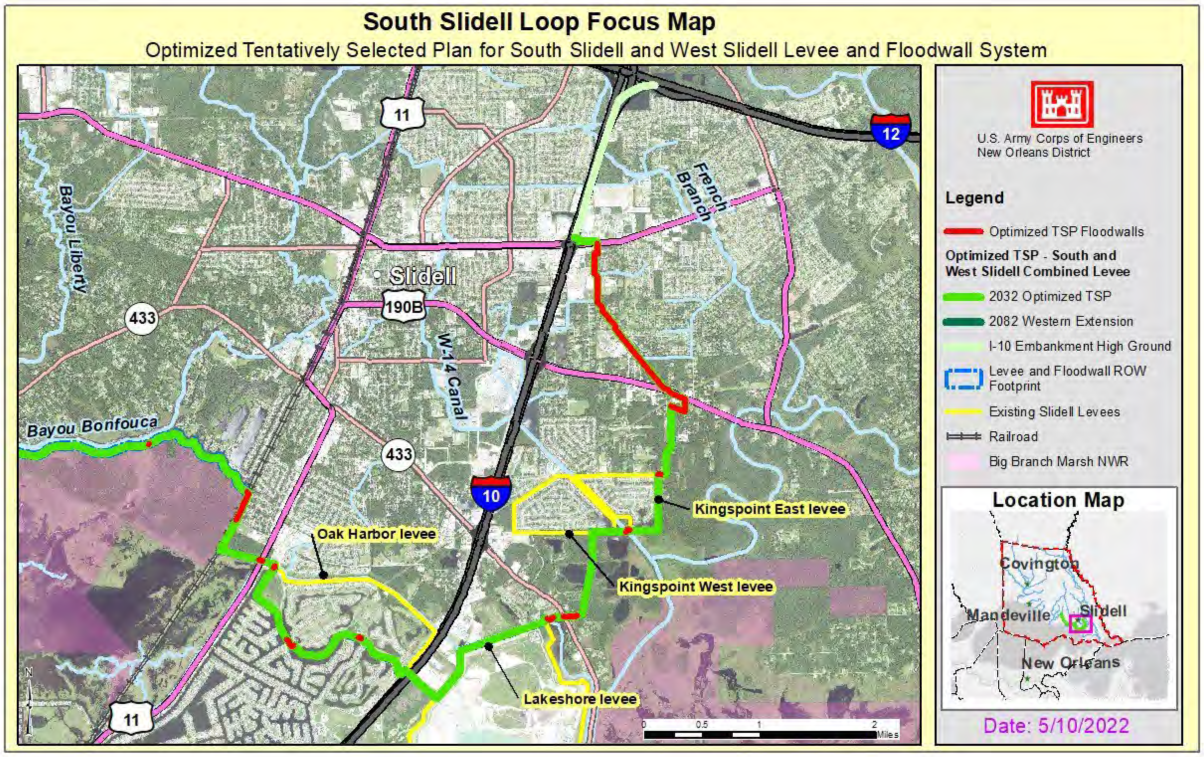

Figure 1-4. South Slidell Levee and Floodwall System- Optimized Tentatively Selected Plan Focus

South Slidell Levee Segment: The levee and floodwall system alignment from West Slidell would continue to South Slidell. From the railroad gate connecting West Slidell with South Slidell, the alignment would transition to a floodwall running parallel along the east side of the railroad tracks. The floodwall by the railroad tracks would have a hydraulic design elevation of 16.5 ft for year 2082.

The alignment would transition to levee when it turned east toward Highway 11. The alignment would cross Highway 11 and would turn south in the vicinity of the existing Schneider Canal Pump Station and then turn east (on a portion of the existing Oak Harbor ring levee). The alignment would run on the south side of Oak Harbor Boulevard and would cross to the north side immediately past Mariners Cove Boulevard. The levee along the south side of the Oak Harbor would have a hydraulic design elevation of 14 ft for year 2032.

The alignment would run on a portion of the existing Oak Harbor ring levee. The alignment would turn north and then east in the vicinity of the I-10. The I-10 would be raised to ramp over the new levee section (hydraulic design elevation of 18.5 ft for year 2082).

The alignment would continue southeast and would tie to an existing portion of the Lakeshore Estates ring levee. The alignment then would turn north and then east and cross Old Spanish Trail/Highway 433. The alignment would continue north and tie to a portion of the existing King's Point west levee. The section of levee would have a hydraulic design elevation of 16 ft for year 2032.

The alignment would cross the W-14 Canal and would tie to a portion of the existing King's Point east levee and would turn north. The levee would have a hydraulic design elevation of 16 ft for year 2032. The levee would turn east and then north. Immediately south of Highway 190 Business the alignment would turn from levee to floodwall to provide risk reduction to the existing Hardin Road power substation. The floodwall would have a hydraulic design elevation of 18.5 ft for year 2082.

The alignment would cross Highway 190 Business and continue northwest on the west side of the existing CLECO Corporate Holdings, LLC utility corridor. The alignment would cross South Holiday Drive and continue north. The alignment would turn east on Manzella Drive and turn north in the middle of the block between Yaupon Drive and Malbrough Drive.

The alignment would cross Gause Boulevard as a ramp crossing and would turn west and tie to high ground (hydraulic design elevation of 18.5 ft for year 2082) in the vicinity of the I-10. There would be additional road ramps for businesses on the north side of Gause Boulevard, the I-10 Service Road and the I-10 on-ramp for the I-10 eastbound at Gause Boulevard.

The existing highway embankment would serve as the means of risk reduction in order for the project to form a continuous system up to the elevation required in 2082. Refer to light green portion of the alignment in Figure 1-5.

CLECO Corporate Holdings, LLC has right-of-way use requirements pertaining to USACE work around their existing utility lines on the northeast corner of the floodwall alignment that would have to be met to provide clearance for construction activities (i.e., pile driving).

INTERSTATE 10 ELEVATION

The I-10 road surface would be raised to construction elevation 21.5 ft to ramp over the new levee section to stay above the hydraulic design elevation for year 2082, to ensure the entire pavement section remains above the hydraulic design elevation across the interstate. The hydraulic design elevation at this location for year 2082 is 18.5 ft. The pavement section was assumed to have a thickness of 2.5 ft.

The existing elevation of the I-10 at the proposed location is approximately 12.8 feet as per LIDAR raster dataset. This proposed location is the highest elevation of the I-10 in the vicinity of the proposed alignment. The I-10 elevation is lower (approximately 10 feet) on the adjacent areas.

The levee and the Interstate 10 would be lifted during initial construction in year 2032 to construction elevation of 21.5 ft to avoid future disruptions to the traffic on the interstate.

2.3 TYPICAL SECTION AND ELEVATIONS

2.3.1 WEST SLIDELL LEVEE DIMENSIONS AND QUANTITIES

The dimensions for the new West Slidell levee may be found in Table 2.1 and Figure 1-5.

Geotextile would be placed for West Slidell during initial construction under the levee. Geotextile would be placed 70 ft from the centerline of the levee on the floodside and 40 ft from the centerline of the levee on the land side for a total of 110 ft.

Table 2.1. West Slidell Levee

West Slidell Levee **Initial Construction**	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Floodside Berm Slope	1V:42H
Landside Berm Slope	1V:33H
Construction Elevation	14.5 ft
Geotextile	13,200 lbs/ft

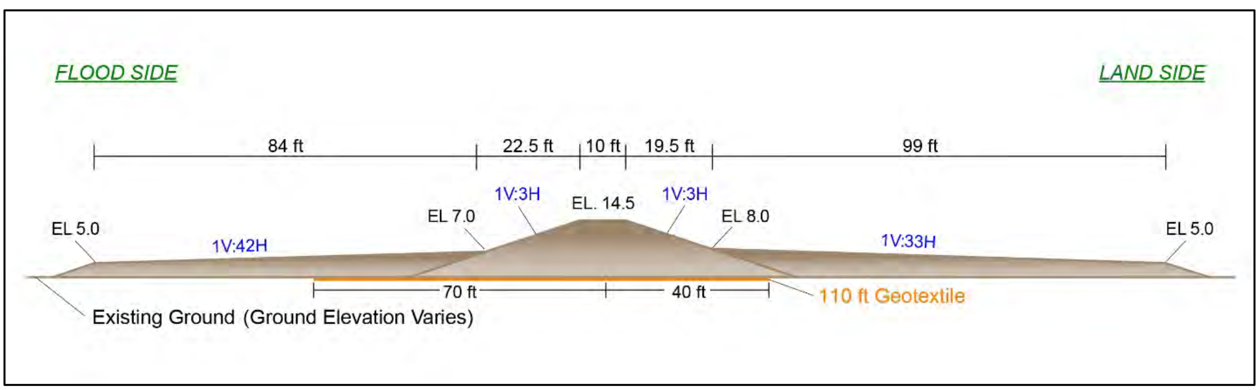

Figure 1-5. Typical Cross-Section with Berms for West Slidell

The hydraulic design elevations of the new West Slidell levee would be 13.5 feet (year 2032) and the 17.5 ft (year 2082). Right of way for the levee was assumed to be 300 ft wide.

2.3.2 SOUTH SLIDELL DIMENSIONS QUANTITIES

The dimensions for the new South Slidell levee may be found in Table 2.2 and Figure 1-6. The construction elevation for the first lift would vary depending on location. This portion of the alignment would not have berms or geotextile.

Table 2.2. South Slidell Levee

South Slidell Levee Initial Construction	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Construction Elevation	Varies

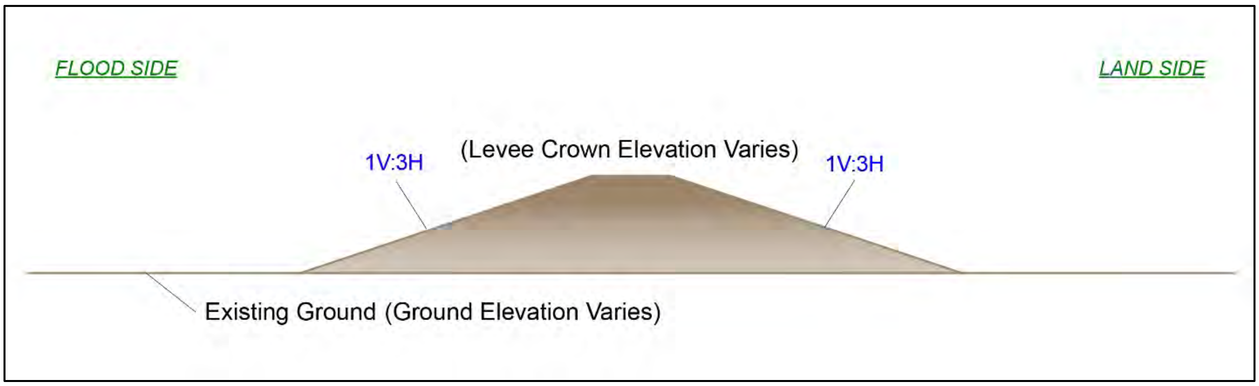

Figure 1-6. Typical Cross-section for South Slidell

The hydraulic design elevation of the new South Slidell levee would vary between 14 ft and 16 ft (year 2032) depending on the location.

2.4 FUTURE LEVEE LIFTS

To maintain the levee crown at or above the base year (2032) and future year (2082) design elevations while accounting for levee settlement and relative sea level rise, levees would be constructed in multiple lifts over the period of analysis. Both the design elevations and constructed "top of levee" elevations vary by location. Design elevations vary by levee location because of surge and wave differences due to storm path, wind speeds and direction, etc.

Levee portions of the Optimized TSP would require future lifts to bring the levees to hydraulic design elevations for year 2082.

For West Slidell, four future levee lifts are projected to be needed. The assumed cross-section for these lifts would have a 10 ft wide levee crown and side slopes of 1V:3H.

Existing berm sections from initial construction would be in place on both sides of the levee.

For the first lift (Year 2033) and the second lift (Year 2038), it was assumed that in addition to elevating the levee, the berm previously built during initial construction would settle 25 percent. Additional material would be placed on the berms during these two lifts.

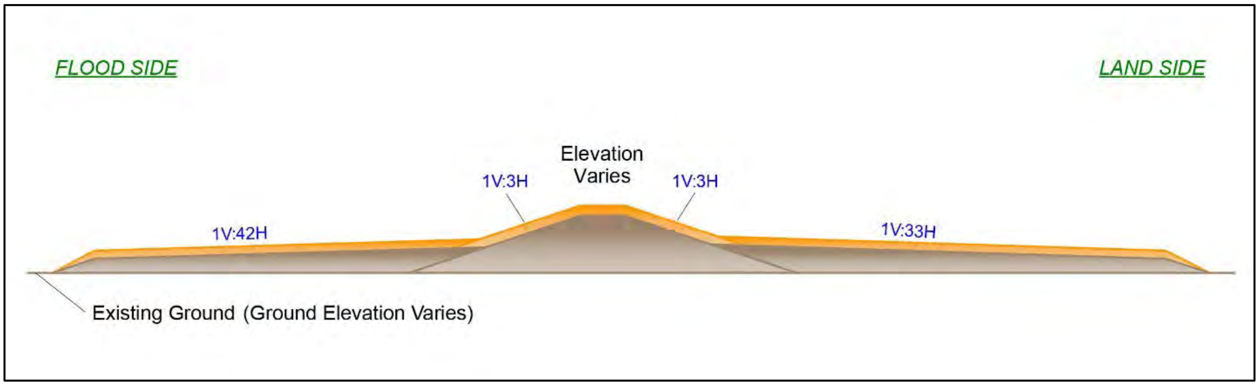

Figure 1-7. Typical Cross-section with berms for First and Second Lifts for West Slidell

For the third lift (Year 2051) and the fourth lift (Year 2076), it was assumed that no additional material would be placed on the berms.

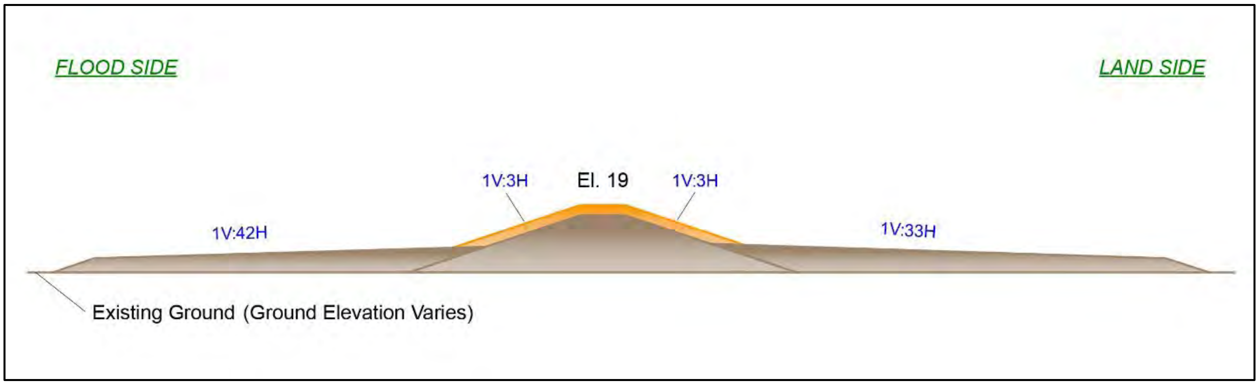

Figure 1-8. Typical Cross-section with berms for Third and Fourth Lifts for West Slidell

2.4.1 WESTERN HIGH GROUND TIE-IN LEVEE CONSTRUCTION

The construction of the Western High Ground Tie-In would be performed during the fourth lift for West Slidell which is projected for year 2076.   The dimensions for the Western High Ground Tie-In may be found in Table 2.3 and Figure 1-9. This portion of the alignment would not have berms or geotextile.

Table 2.3. Western High Ground Tie-In *Levee*

Western High Ground Tie-In	
Levee Crown Width	10 ft
Side Slopes of Levee	1V:3H
Construction Elevation	19 ft

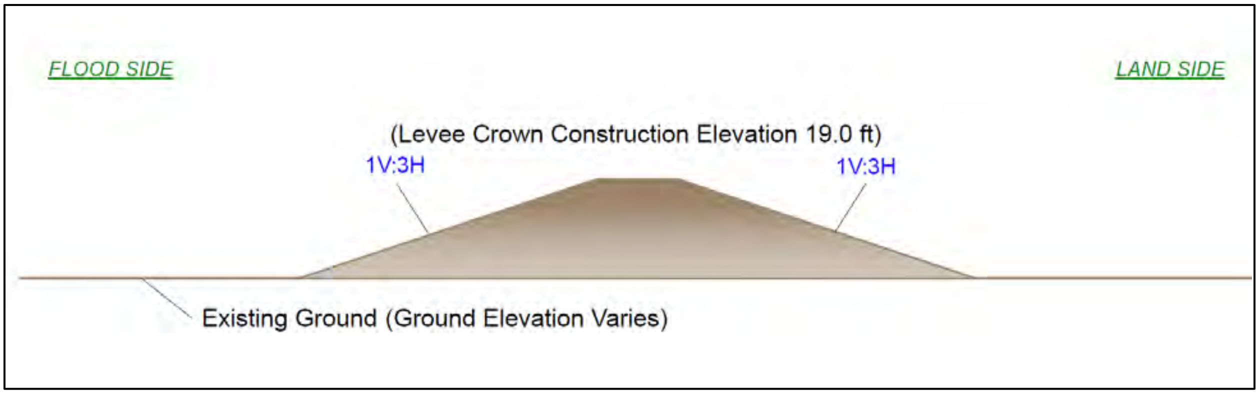

Figure 1-9. Typical Cross-section for the Western High Ground Tie-in for Year 2082

The lift schedules for West Slidell consisted of one geotechnical reach as shown in Figure 1-9. The hydraulic design elevation is 13.5 ft for year 2032 and 17.5 ft for year 2082 are shown in the design line in blue. The red lines represent the projected lifts.

2.4.2 SOUTH SLIDELL LEVEE TYPICAL CROSS SECTION FOR FUTURE LIFTS

The future lifts for South Slidell levee would have a 10 feet wide levee crown and side slopes of 1V:3H.

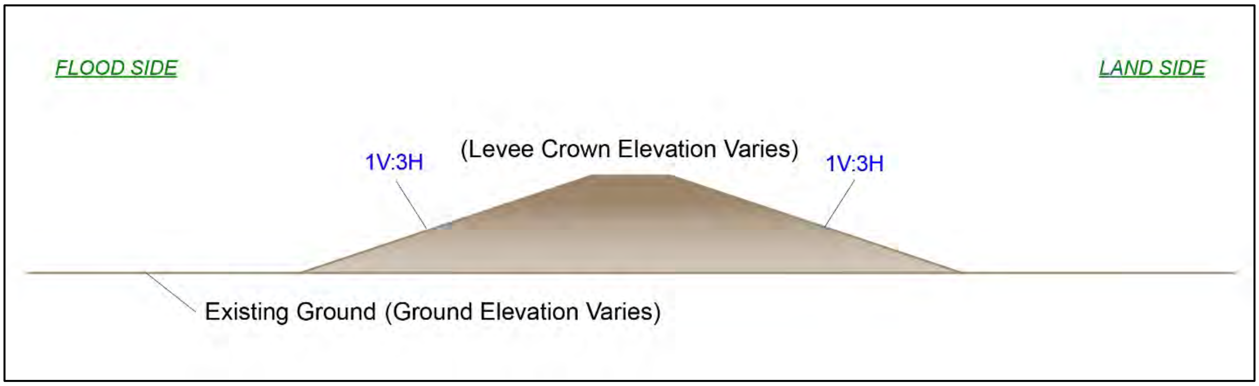

Figure 1-10. Typical Cross-section for South Slidell for Future Lifts

2.5 Typical Floodwall Section and Elevations

The T-wall sections would vary based on location. Table 2.4 lists the floodwall segment and the various dimensions for each floodwall segment.

Table 2.4. Floodwall Segment dimensions

Description of Floodwall Segment	Length of Floodwall Segment (ft)	Base of Slab BOS (ft)	Base of Wall BOW (ft)	Top of Wall TOW (ft)	Stem Height (ft)	Wall Thick (ft)	Slab Width (ft)	Number of piles per row
Western High Ground Tie-in for Year 2082								
N/A								
West Slidell								
Properties at the end of West Doucette	350	1.5	4.5	17.5	**13**	2	15	3
North Side Bayou Paquet Dr.	250	-1.5	1.5	16.5	**15**	2.5	20	4
Bayou Paquet/Mayer Dr.	1400	-1.5	1.5	16	**14.5**	2.5	20	4
South Slidell								
Front Street/ Railroad	1375	-0.5	2.5	16.5	**14**	2.5	20	4
Old Spanish Trail	300	-2.5	0.5	18.5	**18**	2.5	20	4
Esprit du Lac Street	450	1	4	18.5	**14.5**	2.5	20	4
Substation Floodwall	1950	4.5	7.5	18.5	**11**	2	15	3
Highway 190 Business	430	5	8	18.5	**10.5**	2	15	3
Utility Corridor	3530	5	8	18.5	**10.5**	2	15	3
Hollywood Dr. to Yaupon	3700	9	12	18.5	**6.5**	1.5	10	2
Manzella Dr. to Gause	650	10.5	13.5	18.5	5	1.5	10	2

2.6 CONCRETE AND PILE QUANTITIES FOR FLOODWALL SEGMENTS

The floodwall segments would require the following concrete quantities during initial construction as shown on Table 2.5.

Table 2.5: Concrete Quantities for Floodwall Segments

CONCRETE FLOODWALL SEGMENTS	
Total Concrete Quantities	36,200 cubic yards
Total Sheetpile Quantities	451,400 square feet
Total Length of Piles	887,000 linear feet

Total Slope Paving for floodwall/levees tie-ins	7,000 square feet

Table 2.6: Pile Quantities for Floodwall Segments

PILES FOR FLOODWALL SEGMENTS	
Type of pile	18-inch pipe
Configuration	1H:2V battered
Length of each pile	101 feet
Total Length of Piles	26,300 linear feet

2.7 FLOODGATES DESIGN INFORMATION

The Optimized TSP would include a total of 13 gates. Three (3) gates would be lift gates and one gate would be a sector gate. These gates would allow navigation of recreational vessels. There are nine (9) sluice gates which would be control structures (non-navigable).

During construction of the gated structures, temporary bypass channels would be constructed for recreational vessels in Bayous Paquet, Bonfouca, and Liberty.

Table 2.7: Floodgate Dimensions

Description of the Floodgate	Type of Gate	Width of Opening of the Gate (ft)	Ground/ Sill Elevation (ft)	Structural Height of Drainage Gate (ft)
Western High Ground Tie-in for Year 2082				
Sluice gate near Shannon Drive	Sluice	4	15.5	2.0
Tammany Trace Sluice Gate	Sluice	15	12	5.5
West Slidell				
Sluice Gate # 7 (Near CC Road)	Sluice	25	8.6	8.9
Sluice Gate # 6 (Bayou Paquet North Tributary)	Sluice	75	0.8	15.2
Bayou Paquet Gate Nav. Gate	Lift	90	-0.5	16.5
Bayou Liberty Nav. Gate	Lift	80	-6.8	22.8
Bayou Bonfouca Nav. Gate	Lift	110	-9	25.0
Sluice Gate # 2 (Bayou Bonfouca Sluice Gate)	Sluice	50	0.4	15.6
South Slidell				
W-14 Canal Nav. Gate	Sector	90	0.1	18.4
Sluice Gate # 8 (Kings Point East)	Sluice	90	4.4	14.1

Sluice Gate # 10 (Near Eastern Terminus)	Sluice	20	10.5	8.0
Reine Canal	Sluice	30	7.5	11.0
French Branch at I-10	Sluice	25	8.3	10.2

The floodgate locations and minimum sizes above are an estimate. A detailed interior drainage design would be provided during PED.

Limited information and estimates of channel depths and widths has been considered in estimates of the minimum gated opening dimensions. An increase in the size of the gated openings would likely benefit environmental conditions and would provide additional flood flow conveyance. Any channel constriction such as a gate has the potential to locally increase velocities, which could erode natural channels.

It is assumed that most of these floodgate locations would need to retain some flood conveyance capacity during construction. During PED, bypass channels would be considered as part of the design.

Temporary Bypass Channel

Temporary bypass channels would be constructed at locations where a pump station or floodgate is proposed within the limits of a channel. The temporary bypass channel would route water around the structure in order for the construction to be done in dewatered conditions.

In order to maintain pre-construction flow conditions and minimize environmental impacts during construction, the temporary bypass channels would be similarly sized to the channels being impacted. After construction, the bypass channel is assumed to be included in the footprint of the structure site and the channel flow would be rerouted through the new structure feature. Navigation of common local vessels would be considered for the bypass channels, and design features of a navigable bypass channel would be developed during PED.

Temporary Retaining Structures (TRS)

Temporary Retaining Structures (cofferdams) are temporary features that facilitate the construction of major structures. Cofferdams allow water or other materials to be removed inside the TRS in order to work in an excavated and/or dewatered condition.

Cofferdams would be required during the construction of the pump stations and floodgates. Qualified designers employed or sub-contracted by the construction contractors would design the TRS for this project.

2.8 TYPES OF FLOODGATES

2.8.1 FISH-FRIENDLY LIFT GATE

For Bayou Paquet, Bayou Bonfouca and Bayou Liberty, the proposed navigable gates would be designed to have a small amount of restriction and a gradual slope so that fish and larvae may traverse the structures. The navigable gates would consist of a lift gate which would be raised during open mode to let water and recreational vessels traverse. This design would include smaller sluice gates on both sides of the lift gate to simulate the natural opening of the bayous.

During PED, the PDT would consider additional fish-friendly studies and input provided by the NFS, USFWS and National Marine Fisheries Service criteria, including the rock arch and rock ramp designs.

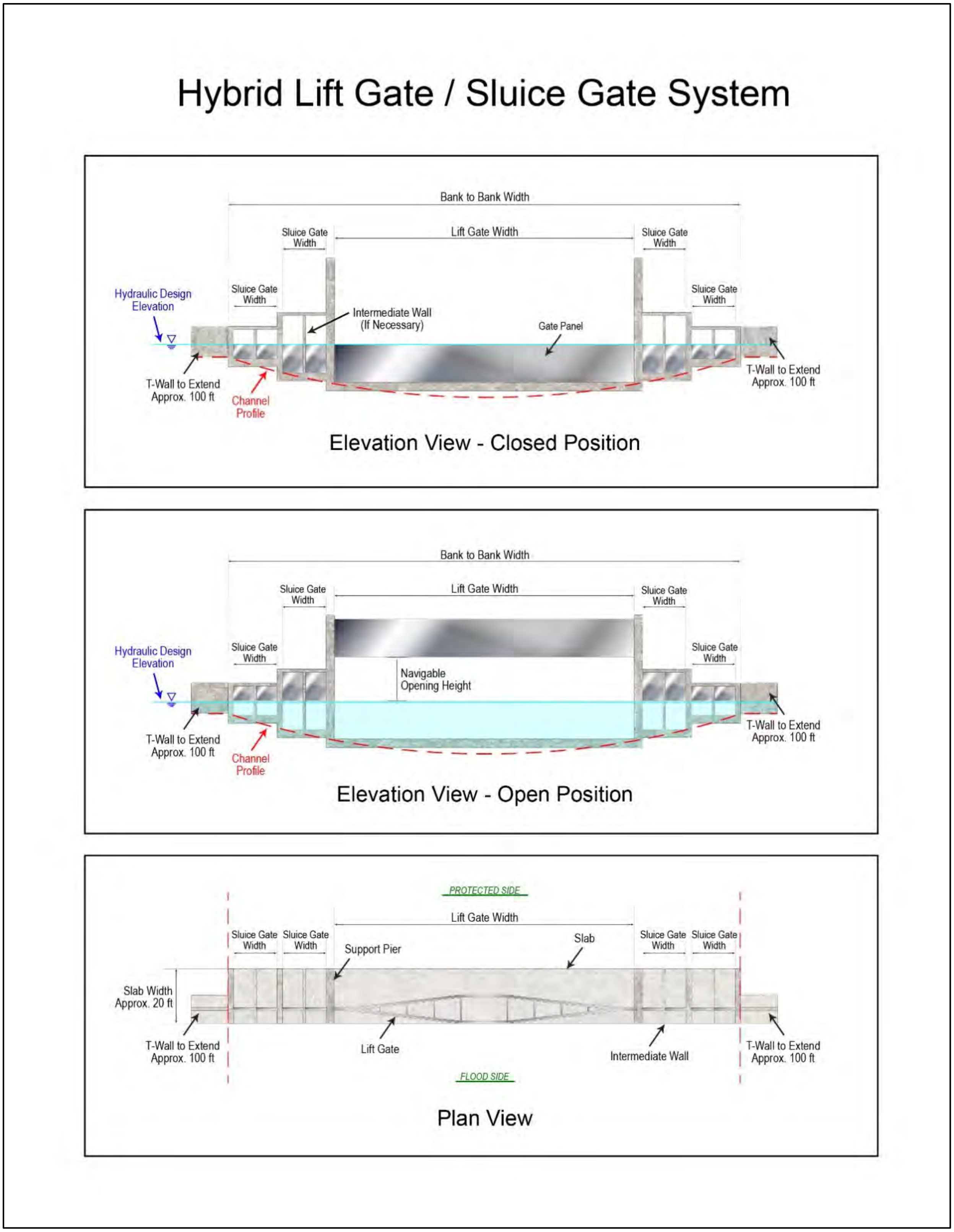

Figure 1.11. Typical Fish-Friendly Gate - Elevation and Plan Views

2.8.2 SLUICE GATE

A sluice gate is a structure that contains a movable gate or series of movable gates that, when lifted, allow material and water to flow under it. Generally, sluice gates are not navigable as they do not raise high enough, or they have fixed components that do not allow vessels to pass through."

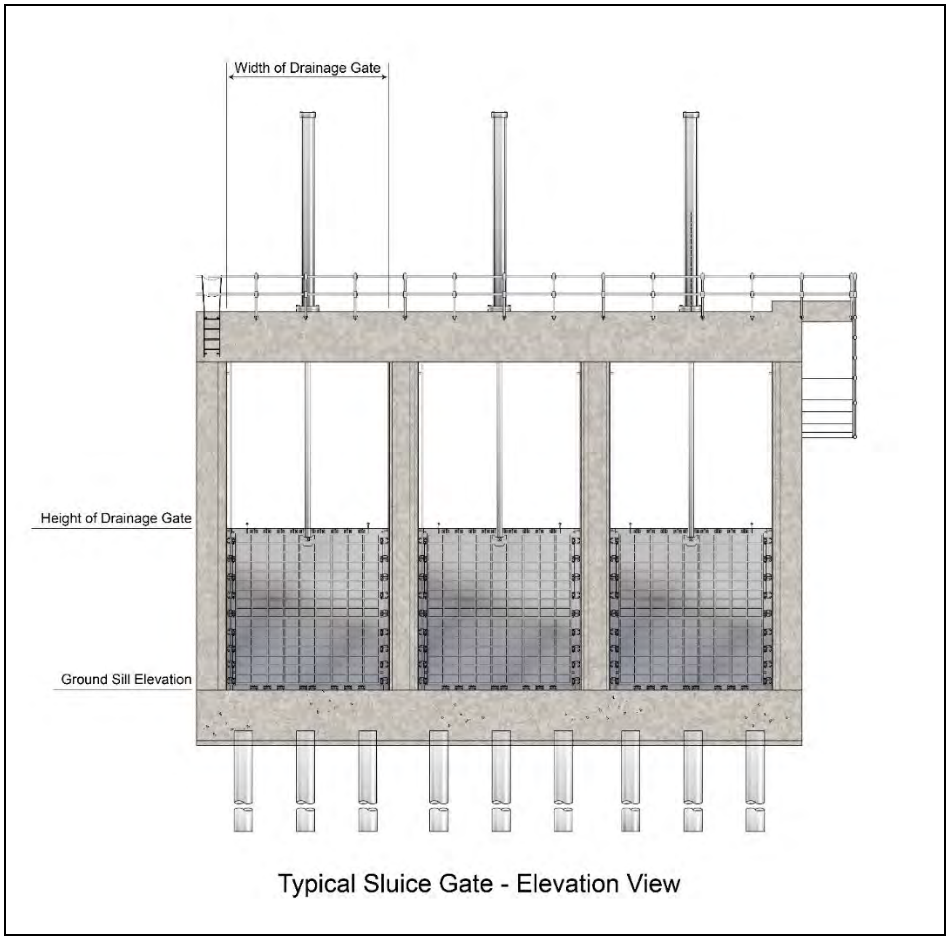

Figure 1-12. Sluice Gate - Elevation View

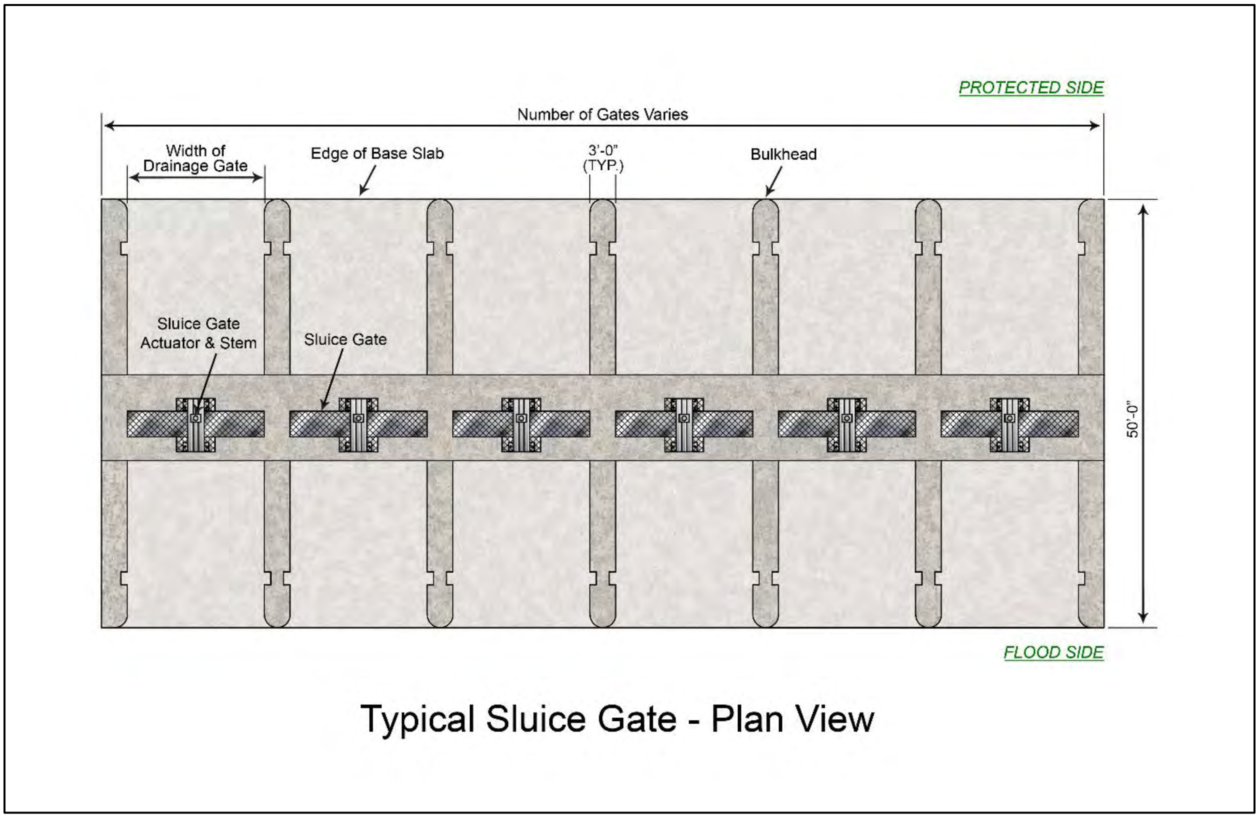

Figure 1-13. Sluice Gate - Plan View

2.8.3 SECTOR GATE

A sector gate is a pie-slice structure that allows navigation to get through when in the open position.

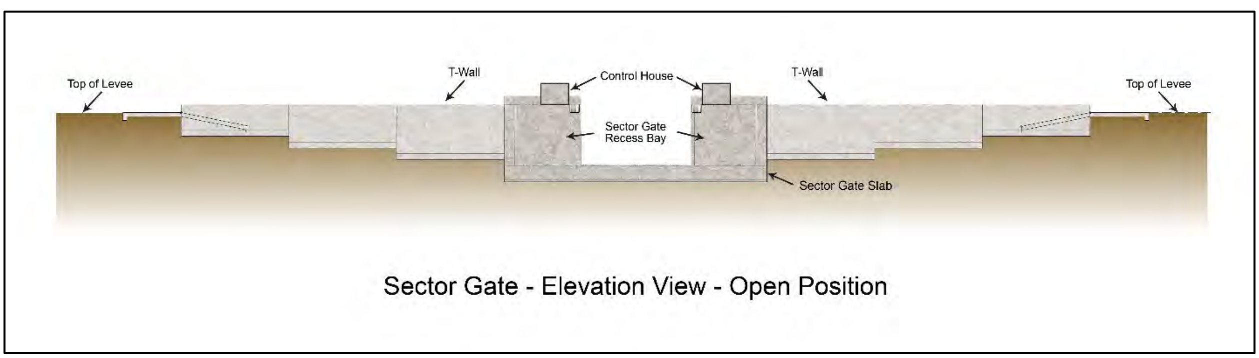

Figure 1-14. Sector Gate - Elevation View with Gates in Open Position

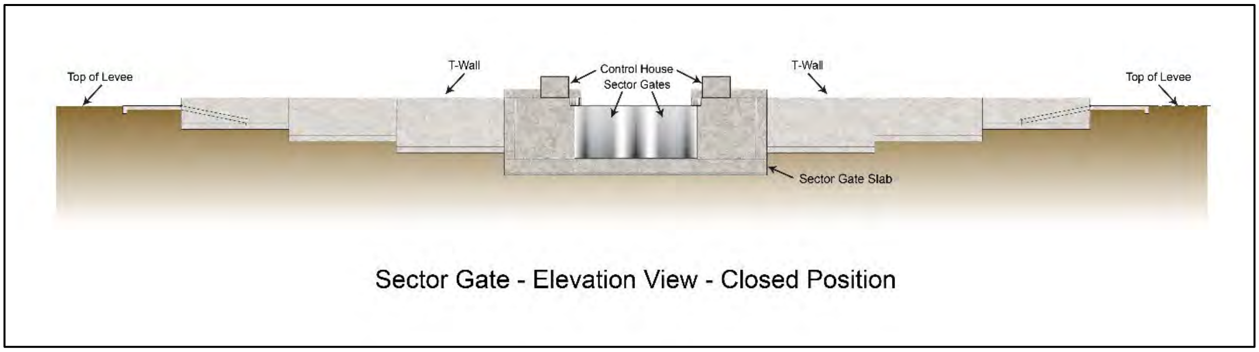

Figure 1-15. Sector Gate - Elevation View with Gates in Closed Position

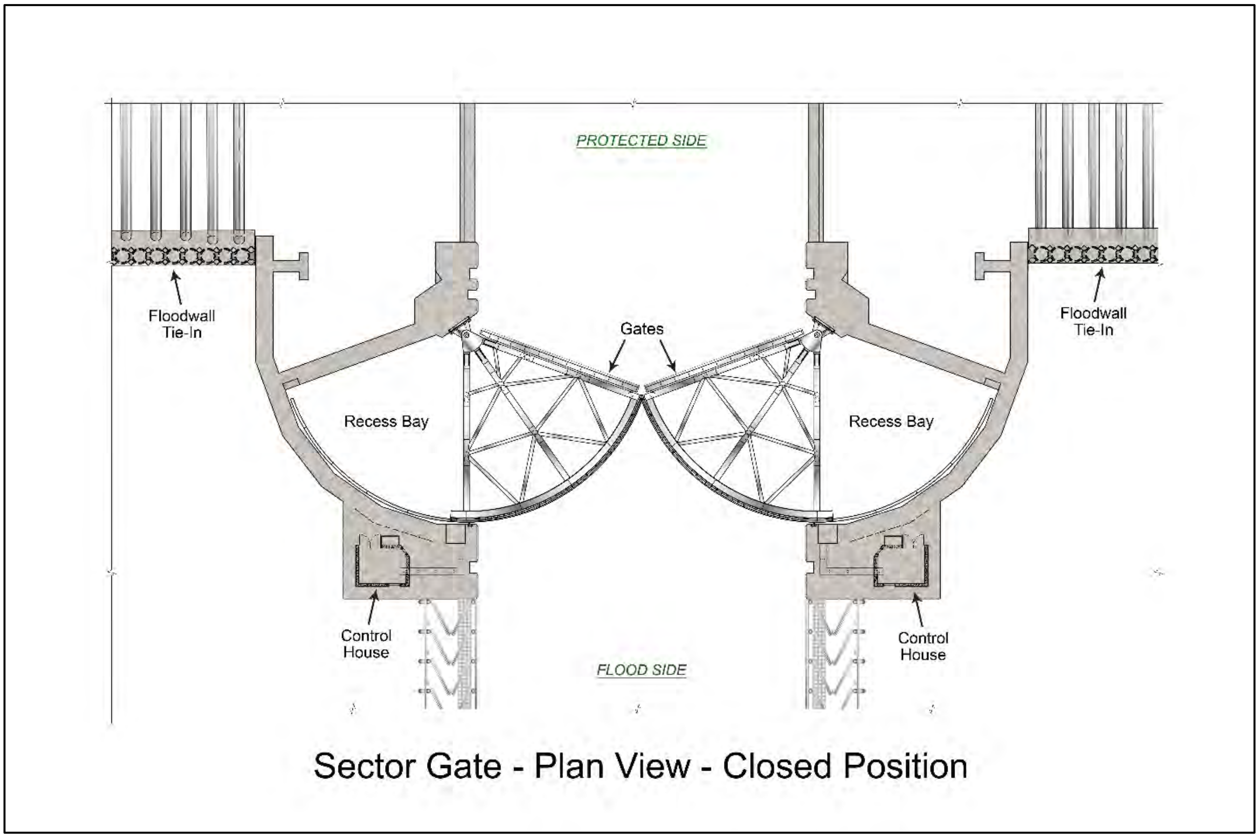

Figure 1-16. Sector Gate - Plan View

2.8.4 ROLLER GATE

A roller gate is a structure that uses rollers for the gate to open and close. The operating motion of the gate is typically parallel to the skin plate face of the gate.

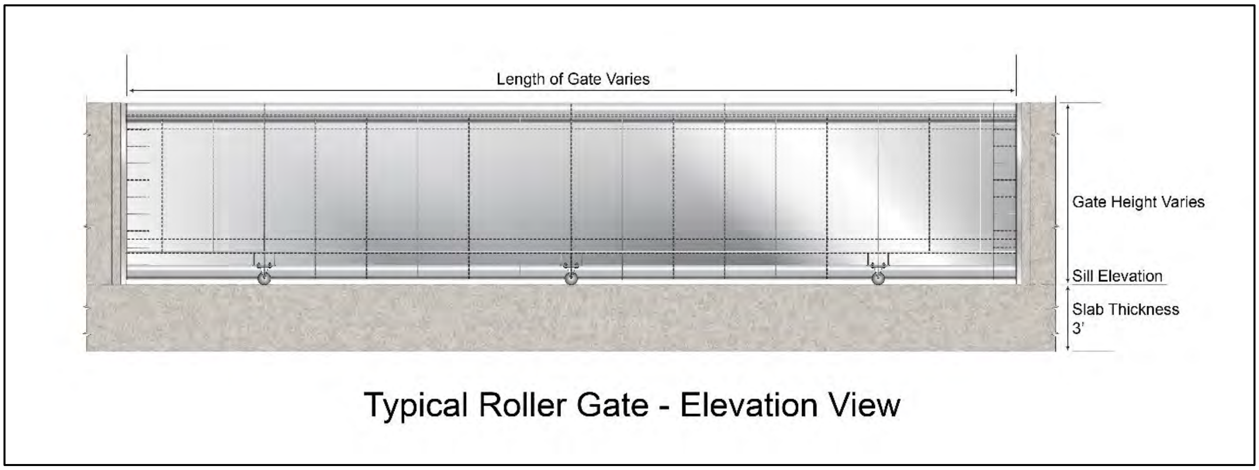

Figure 1-17. Roller Gate - Elevation View

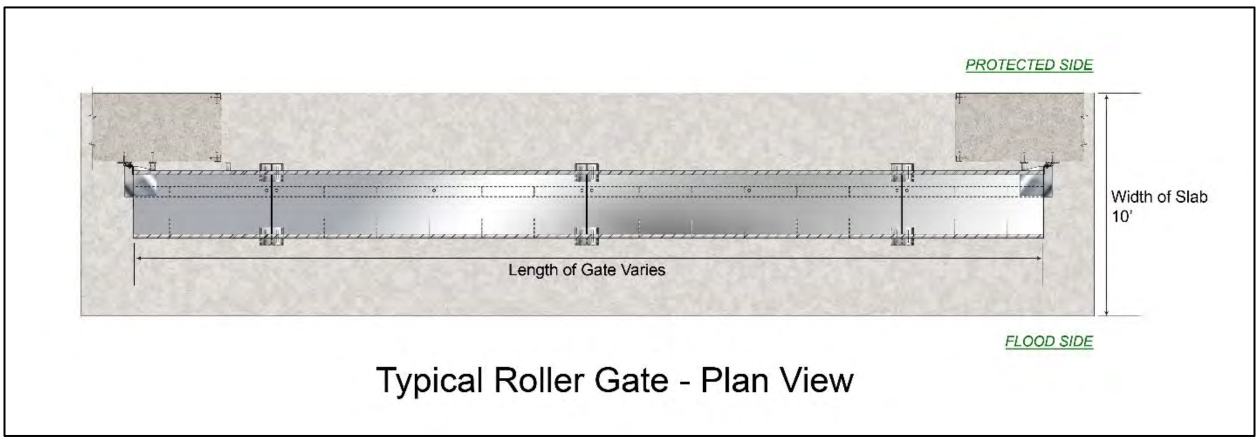

Figure 1-18. Roller Gate - Plan View

2.8.5 SWING GATE

A swing gate is a structure that uses a hinge system to open horizontally. The gate can be actuated through automated mechanical means such as hydraulic arm or manually.

It was assumed that a swing gate would be constructed where the alignment crosses the Southern Railway Corp. railroad tracks. (The analysis for this gate was based on Mississippi River Levee (MRL) Carrollton Railroad Gate.)

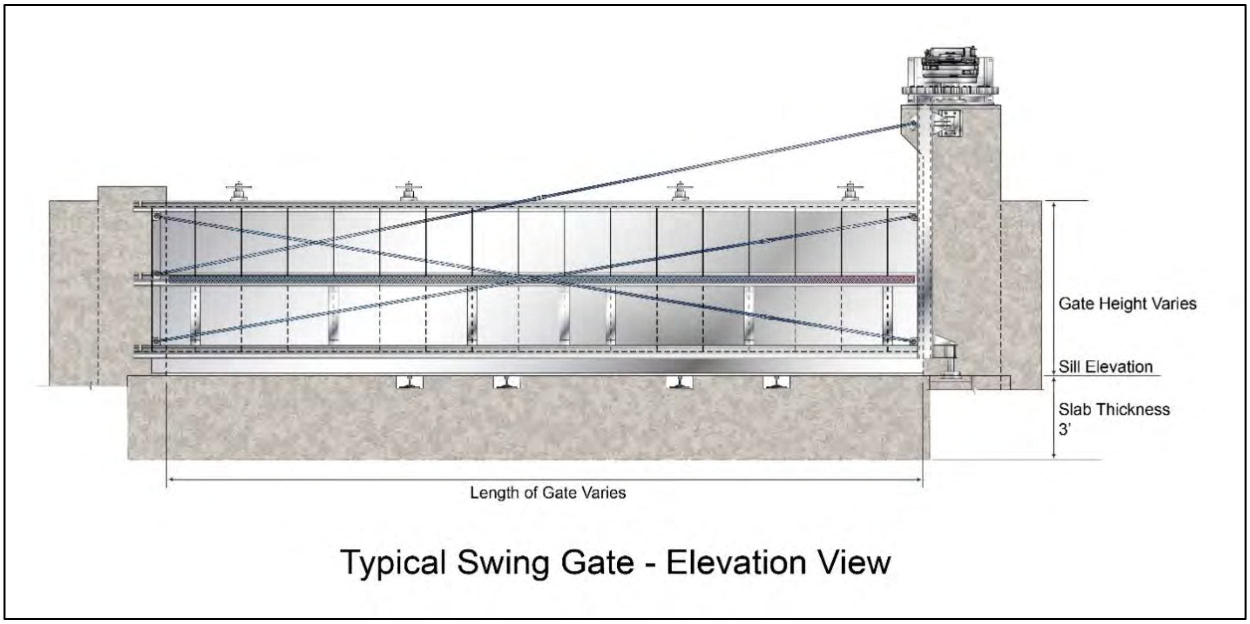

Figure 1-19. Swing Gate - Elevation View

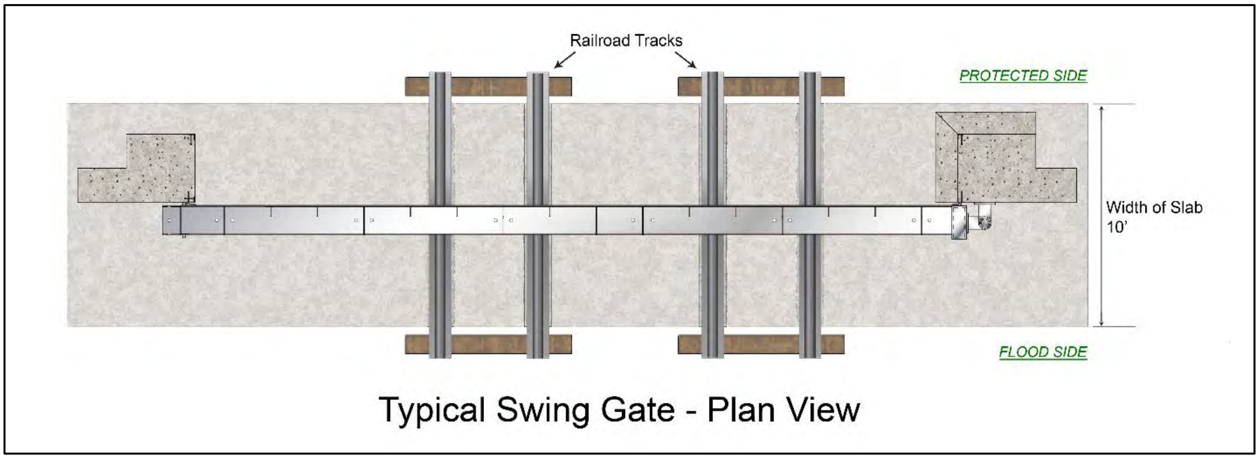

Figure 1-20. Typical Swing Gate - Plan View

2.9 VEHICULAR, PEDESTRIAN AND RAILROAD GATES DESIGN INFORMATION

Table 2.8 contains the design information for the vehicular, pedestrian and railroad gates for the Optimized TSP.

Table 2.8: Vehicular, Pedestrian and Railroad Gates

Name	Description	Type	Mode	Width	Ground/ Sill Elevation (ft)	Design Height (ft)	Height of Gate (ft)
Western High Ground Tie-in for 2082							
Tammany Trace Pedestrian Gate and Culvert	10-ft Pedestrian Gate at Tammany Trace with Lift Gate for Culvert on south side	Swing	Pedestrian	10	13	17.5	3.5
Tranquility Road Vehicular Gate	20-ft Vehicular Gate at Tranquility Road	Roller	Vehicle	20	12	17.5	4.5
West Slidell							
Bayou Paquet Road Floodgate # 2	60-ft Floodgate at Bayou Paquet Road	Roller	Vehicle	60	3	16	13
Mayer Drive Vehicular Gate	20-ft Vehicular Gate at Mayer Road	Roller	Vehicle	20	2.5	16	13.5
Railroad Floodgate	60-foot floodgate for Railroad	Swing	Railroad	60	0.5	16.5	16
South Slidell							
Hwy 11 Vehicular Gate	75-ft Roller Gate at Hwy 11 (Pontchartrain Drive)	Roller	Vehicle	75	4	16.5	12.5
Mariners Cove Floodwall and Vehicular Gate	500 Linear feet of floodwall for narrow section of Oak Harbor levee at Mariners Cove Blvd	Roller	Vehicle	50	10.5	16.5	6
Oak Harbor Vehicular Gate	Floodwall and 20-foot Vehicular Gate for Oak Harbor	Roller	Vehicle	20	11.5	16.5	5
Oak Harbor Country Club Vehicular Gate	Floodwall and 20-foot Vehicular Gate for access to Oak Harbor Country Club	Roller	Vehicle	20	11.5	16.5	
Old Spanish Trail Floodgate (Hwy 433)	30-foot roller gate at Hwy 433 east crossing (Old Spanish Trail)	Roller	Vehicle	30	3.5	18.5	15

Hardin Rd Substation Gate	20-foot roller gate for access from Hardin Road to power substation	Roller	Vehicle	20	8	18.5	10.5
Hwy 190-B Floodgate (East Floodwall)	50-foot roller gate at Hwy 190-B east crossing (Fremaux Road)	Roller	Vehicle	50	9	18.5	9.5
South Holiday Drive Vehicular Gate	20-foot roller gate at South Holiday Drive	Roller	Vehicle	20	14	18.5	4.5
Jaguar Drive Vehicular Gate	20-foot roller gate at Jaguar Avenue	Roller	Vehicle	20	12	18.5	6.5
Natchez Drive Vehicular Gate	20-foot roller gate at Natchez Avenue	Roller	Vehicle	20	12	18.5	6.5
Kisatchie Drive Vehicular Gate	20-foot roller gate at Kisatchie Avenue	Roller	Vehicle	20	14	18.5	4.5
Manzella Drive Vehicular Gate	20-foot roller gate at Manzella Drive (Added to extend floodwall to 18.5 ft ground elevation south of Hwy 190)	Roller	Vehicle	20	15	18.5	3.5

2.10 PUMP STATIONS DESIGN INFORMATION

The Optimized TSP would include a total of eight (8) pump stations. These pump stations are divided into large pumping capacity and small pumping capacity.

In West Slidell there would be two (2) pump stations with large pumping capacity and two (2) pump stations with small pumping capacity. In South Slidell there would be four (4) pump stations with small pumping capacity.

Table 2.9: Pump Stations

Pump Station Location	Pump Station Capacity
Western High Ground Tie-in for 2082	
N/A	
West Slidell	
Bayou Liberty	1,800 cfs

Bayou Bonfouca	2,000 cfs
Bayou Paquet North Tributary	300 cfs
Bayou Paquet	500 cfs
South Slidell	
W-14 Canal	1,000 cfs
Kings Point	200 cfs
Reine Canal	200 cfs
French Branch at the I-10	450 cfs

The Optimized TSP would include two (2) pump stations with large pumping capacity at Bayou Liberty (1,800 cfs) and Bayou Bonfouca (2,000 cfs). These pump stations were assumed to have similar components and configuration as the USACE West Shore Lake Pontchartrain Reserve Relief Canal Pump Station (WSLP Pump Station). The structural quantities from the Reserve Relief Canal Pump Station were scaled accordingly to reflect the size of the pump stations for this study.

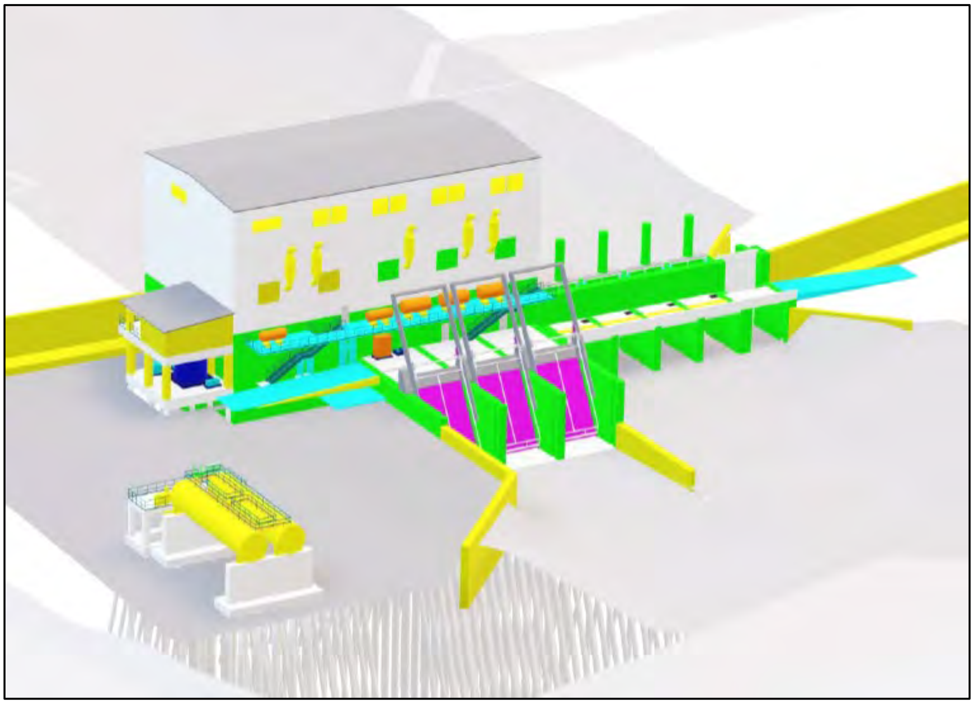

Figure 1-21. Typical Site Plan of a Pump Station with Large Pumping Capacity

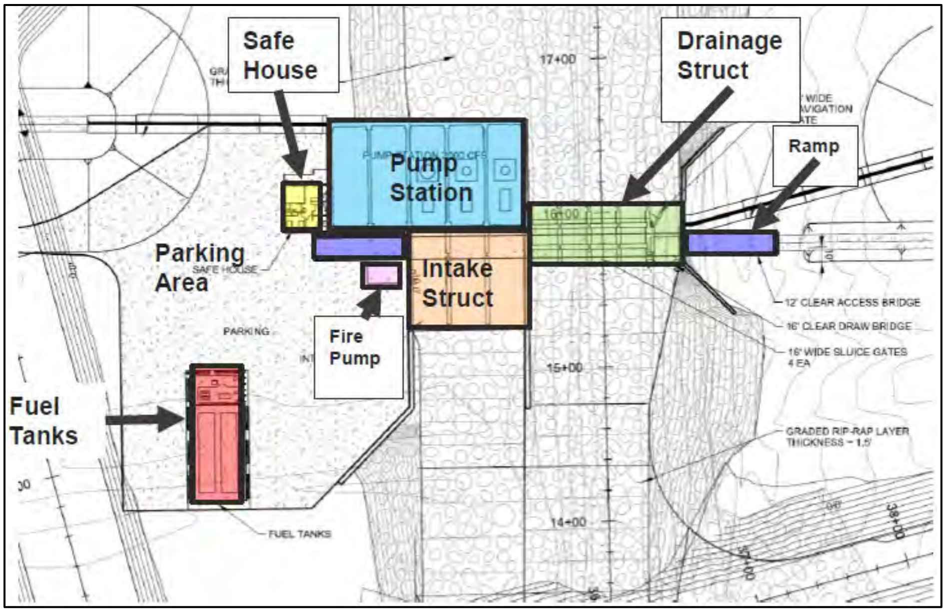

Figure 1-22. Typical Layout of a Pump Station with Large Pumping Capacity

The TSP would include six (6) pump stations with small pumping capacity at sluice gate #6 on the Bayou Paquet North Tributary (300 cfs), Bayou Paquet lift gate (500 cfs), W-14 Canal (1,000 cfs), sluice gate # 8 at Kings Point (200 cfs), Reine Canal (200 cfs) and at French Branch at the I-10 (450 cfs).

These pump stations would have similar pumping capacities to the Prescott Road Pump Station for the Lake Pontchartrain Lakeshore study. The structural quantities from the Prescott Road Pump Station were scaled accordingly to reflect the size of the pump stations for this study.

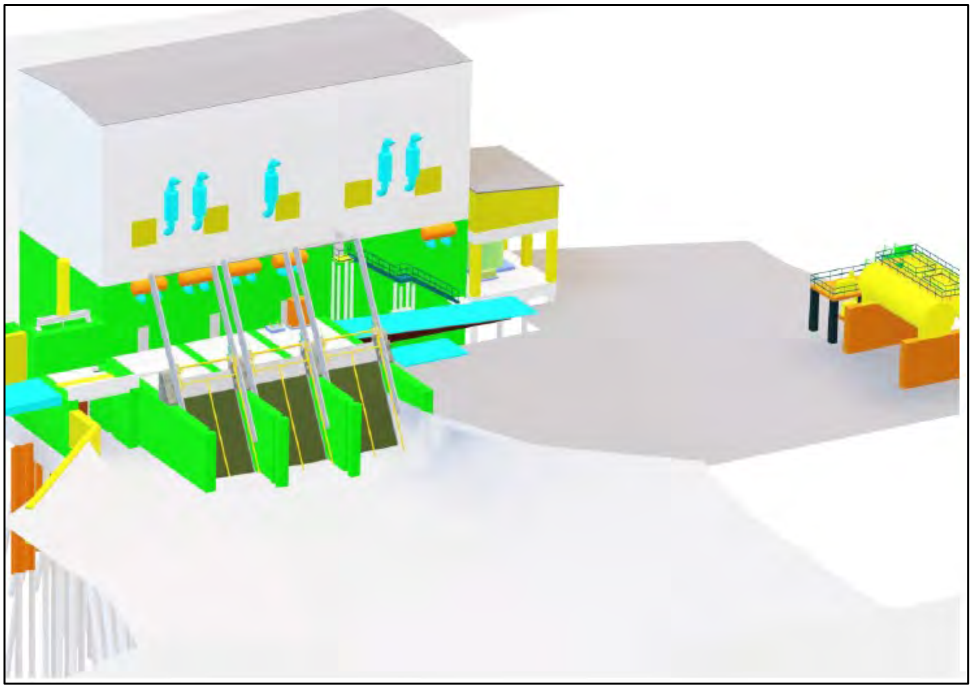

Figure 1-23. Typical Site Plan of a Pump Station with Small Pumping Capacity

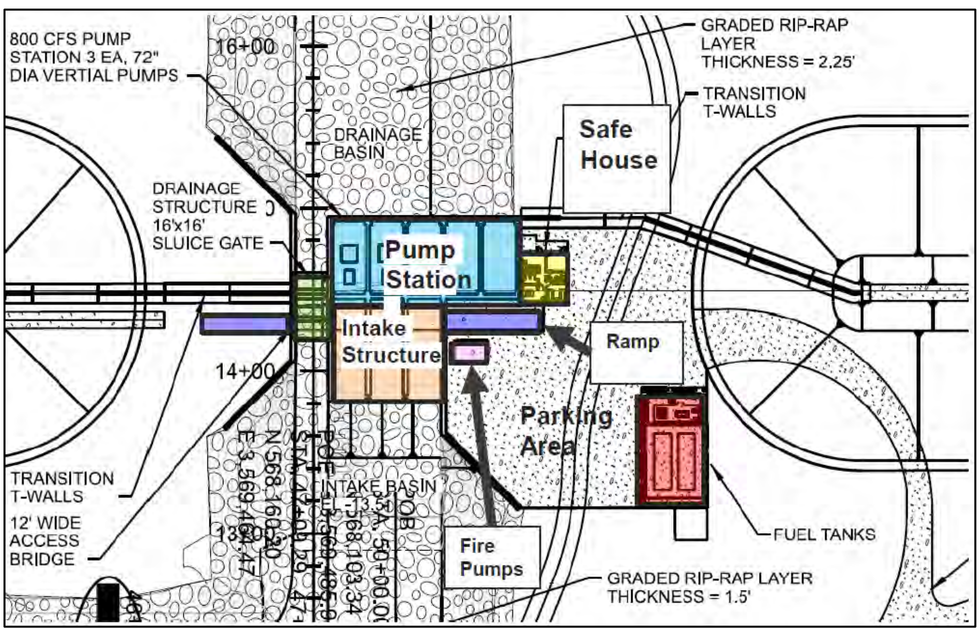

Figure 1-24. Typical Layout of a Pump Station with Small Pumping Capacity

Note: the schematics on this section were obtained from a presentation prepared by Stantec.

3 ACCESS ROUTES AND STAGING AREAS REQUIRED

Table 3.1 provides a summary of the necessary staging areas and permanent ROW required for construction of the levee and floodwall segments for the 50-yr period of analysis. The staging areas required during initial construction of the levee alignment would be the same staging areas required for construction of future levee lifts.

Table 3.1 Summary of Staging Areas and Permanent ROW

SUMMARY of STAGING AREAS AND PERMANENT ROW		
Levees	**Staging Areas (Acres)**	**Permanent ROW (Acres)**
Western High Ground Tie In	2	30
West Slidell	8	270
South Slidell (includes 23 acres for I-10)	29	120
Sub-Total for Levees	**39**	**420**
Floodwall Segments		
Western High Ground Tie In	NA	NA
West Slidell	0	3.7
South Slidell	0	22.7
Sub-Total for Floodwall Segments	**0 ***	**26.4**
Floodgates and Pump Stations		
Western High Ground Tie In	1.5	2.5
West Slidell	11	21
South Slidell	3.75	6.25
Sub-Total for Floodgates and Pump Stations	**16.25**	**29.75**
Vehicular, Pedestrian, and Railroad Gates		
Western High Ground Tie In	1.5	1.25
West Slidell	1.25	0
South Slidell	9	0
Sub-Total for Vehicular, Pedestrian, and Railroad Gates	**11.75**	**1.25**
Road Ramps		
Western High Ground Tie In	0.5	0
West Slidell	0	0
South Slidell	5	0
Sub-Total for Road Ramps	**5.5**	**0**
Access Roads - New		
Western High Ground Tie In	0.1	0.1
West Slidell	0.45	0.45
South Slidell	2.75	2.75
Access Roads - Existing		
Western High Ground Tie In	0	0
West Slidell	15.8	0
South Slidell	9.9	0
Sub-Total for Access Roads	**29**	**3.3**
Mile Branch Channel Improvements	7.3	38.5

Sub-Total for Mile Branch Channel Improvements	**7.3**	**38.5**
Total Acres for 50-year Period of Analysis	**109**	**520**

*for floodwall segments, staging areas would be included in the 80 ft wide permanent ROW.

Table 3-2 lists the ROW width required per levee or floodwall segment. The width includes a 15 ft of vegetation free zone (VFZ) on each side of the levee/floodwall segment.

Table 3.2 Typical Widths of Permanent ROW for Levee and Floodwalls Segments

Levee and Floodwall Segments	Width of Permanent ROW (ft)*
Western High Ground Tie-in	160
West Slidell	300
South Slidell	160
Floodwall Segments	80
Access Roads	NA

***(Includes 15-ft VFZ on both sides)**

3.1 ACCESS ROUTES AND STAGING FOR MILE BRANCH

Site access to Mile Branch would be via public roads and public rights of way.

Staging areas are assumed to be dry. Any trees would be removed and hauled away to an approved facility. If necessary, crushed stone would be placed in the staging area prior to construction. After construction, the crushed stone would be removed and the disturbed areas would be fertilized and seeded.

For the culvert and bridge replacement work, all staging areas were assumed to be located within the individual structure construction areas. Staging areas are to be tree and vegetation free and covered with crushed stone.

3.1 ACCESS ROUTES AND STAGING FOR LEVEE CONSTRUCTION

There are locations where an existing road would be used for access. In other locations, a new road would be built.

New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for VFZ on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

LEVEE CONSTRUCTION EXCEPT REFUGE AREA

For staging areas for levee construction, crushed stone would be placed (assuming crushed stone for vehicle parking/staging and for path from road to area).

Any trees would be removed and hauled away to an approved facility. Contractor would use the area to process material prior to levee construction.

LEVEE CONSTRUCTION ON REFUGE AREA

For the construction of the levee on the refuge land (from Bayou Bonfouca to the railroad tracks), the ingress and egress would be at the Norfolk Southern railroad tracks on the east side of Bayou Bonfouca and existing roads on the west side. A one-way flow of traffic would be maintained. The USACE would need to obtain permission from the railroad owner (Norfolk Southern Railway Corp.) prior to construction. An access road would be constructed on the protected side of the ROW between the proposed crown of the levee and Bayou Bonfouca. The access road would be a temporary road. Once construction is complete, the area would be cleared of vegetation within the right of way and graded to drain away from the levee. Access during future inspections would be done by driving on the crown of the levee.

There would be one 2-acre staging area on the reach on the refuge land that would be considered a temporary easement. The staging area would be located off the refuge and would be used to process the material prior to building the levee. Staging areas would be required to be continuously accessible. Any trees would be removed and hauled away to an approved facility. The area would be restored to pre-construction elevation that existed prior to impacting the site due to construction activities.

3.2 ACCESS ROUTES AND STAGING AREAS FOR STRUCTURES

Existing public roads would be utilized for access to the maximum extent as possible. In locations where access cannot be achieved via existing roadways, a new road would be constructed. Construction of new roads would require permanent ROW.

New access roads would be a 40-ft wide footprint (consisting of a 25 ft right-of-way for the access road itself and a 7.5-ft width for VFZ on both sides of the road. Access roads would be constructed using crushed stone for the road surface.

For the floodwall segments, the temporary ROW (during construction) and the permanent ROW would be as shown in Table 3.3 below.

Table 3.3: ROW for Floodwall Segments

Floodwall Segments		**Staging Area (Acres)**	**Permanent Access (Acres)**
Western High Ground Tie-in for 2082			
N/A			
West Slidell			
Properties west of Doucette Road		0.4	0.4
North Side Bayou Paquet Drive		0.3	0.3

Bayou Paquet/Mayer Drive		1.6	1.6
South Slidell			
Front Street/Railroad		1.6	1.6
Mariners Cove Boulevard		0.6	0.6
Oak Harbor Country Club		0.2	0.2
Old Spanish Trail		0.3	0.3
Esprit du Lac Street		0.5	0.5
Substation Floodwall		2.2	2.2
Highway 190 Business		0.5	0.5
Utility Corridor		4.1	4.1
Hollywood Drive to Yaupon		4.2	4.2
Manzella Drive to Gause Boulevard		0.7	0.7
Total		**18**	**18**

For the floodgates and pump stations, the temporary ROW (staging area during construction) and the permanent ROW would be as shown in Table 3.4.

Table 3.4: ROW for Floodgates and Pump Stations

Floodgates and Pump Stations	Pump Station	Pumping Capacity (cfs)	Staging Area (Acres)	Permanent Area (Acres)
Western High Ground Tie-in for 2082				
Sluice gate near Shannon Drive	No		0.75	1.25
Sluice gate at Tammany Trace	No		0.75	1.25
West Slidell				
Sluice Gate # 7 (Near CC Road)	No		0.75	1.25
Sluice Gate # 6 (Bayou Paquet North Tributary)	Yes	300	0.75	1.25
Bayou Paquet Navigable Gate and Pump Station	Yes	500	0.75	1.25
Bayou Liberty Navigable Gate and Pump Station	Yes	1800	4	8
Bayou Bonfouca Navigation Gate and Pump Station	Yes	2000	4	8
Sluice Gate # 2 (Bayou Bonfouca Sluice Gate)	No		0.75	1.25
South Slidell				
W-14 Canal Navigable Gate and Pump Station	Yes	1000	0.75	1.25
Sluice Gate # 8 (Kings Point East) and Pump Station	Yes	200	0.75	1.25

Sluice Gate # 10 (Near East Terminus)	No		0.75	1.25
Reine Canal and Pump Station	Yes	200	0.75	1.25
French Branch at I-10 and Pump Station	Yes	450	0.75	1.25
Total for Floodgates and Pump Stations			**16.25**	**29.75**

3.3 ACCESS ROUTES AND STAGING AREAS FOR VEHICULAR, PEDESTRIAN AND RAILROAD GATES INITIAL CONSTRUCTION

For the vehicular, pedestrian and railroad gates, the temporary ROW (staging area during construction) and the permanent ROW would be as shown in Table 3.5:

Table 3.5: ROW for Vehicular, Pedestrian and Railroad Gates

Name	Staging Area (Acres)	Permanent ROW (Acres)
Western High Ground Tie-in for 2082		
Tammany Trace Pedestrian Gate	0.75	1.25
Tranquility Road Vehicular Gate	0.75	0
West Slidell		
Bayou Paquet Road Floodgate # 2	0.75	0
Mayer Drive Vehicular Gate	0.75	0
Railroad Floodgate	0.75	0
South Slidell		
Hwy 11 Vehicular Gate	0.75	0
Mariners Cove Floodwall and Vehicular Gate	0.75	0
Oak Harbor Vehicular Gate	0.75	0
Oak Harbor Country Club Vehicular Gate	0.75	0
Old Spanish Trail Floodgate (Hwy 433)	0.75	0
Hardin Road Substation Gate	0.75	0
Hwy 190-B Floodgate (East Floodwall)	0.75	0
South Holiday Drive Vehicular Gate	0.75	0
Jaguar Drive Vehicular Gate	0.75	0
Natchez Drive Vehicular Gate	0.75	0
Kisatchie Drive Vehicular Gate	0.75	0
Manzella Drive Vehicular Gate	0.75	0

3.4 STAGING AREAS AND ACCESS MATERIALS

LEVEE

For staging areas and access roads for levee construction, not including area for material processing during levee construction, a 7-inch depth of stone, and 115 lbs/cubic feet stone weight was assumed.

MILE BRANCH AND STRUCTURES

For the construction in Mile Branch and for the construction of structures, the staging areas and access roads, were assumed to have a 7-inch depth of crushed stone.

4 MILE BRANCH CHANNEL IMPROVEMENTS

The proposed work at Mile Branch would be located in a heavily populated area. There are properties in close proximity of the Mile Branch. There are no surveys available for this area.

Figure 4-1 provides the location of this work.

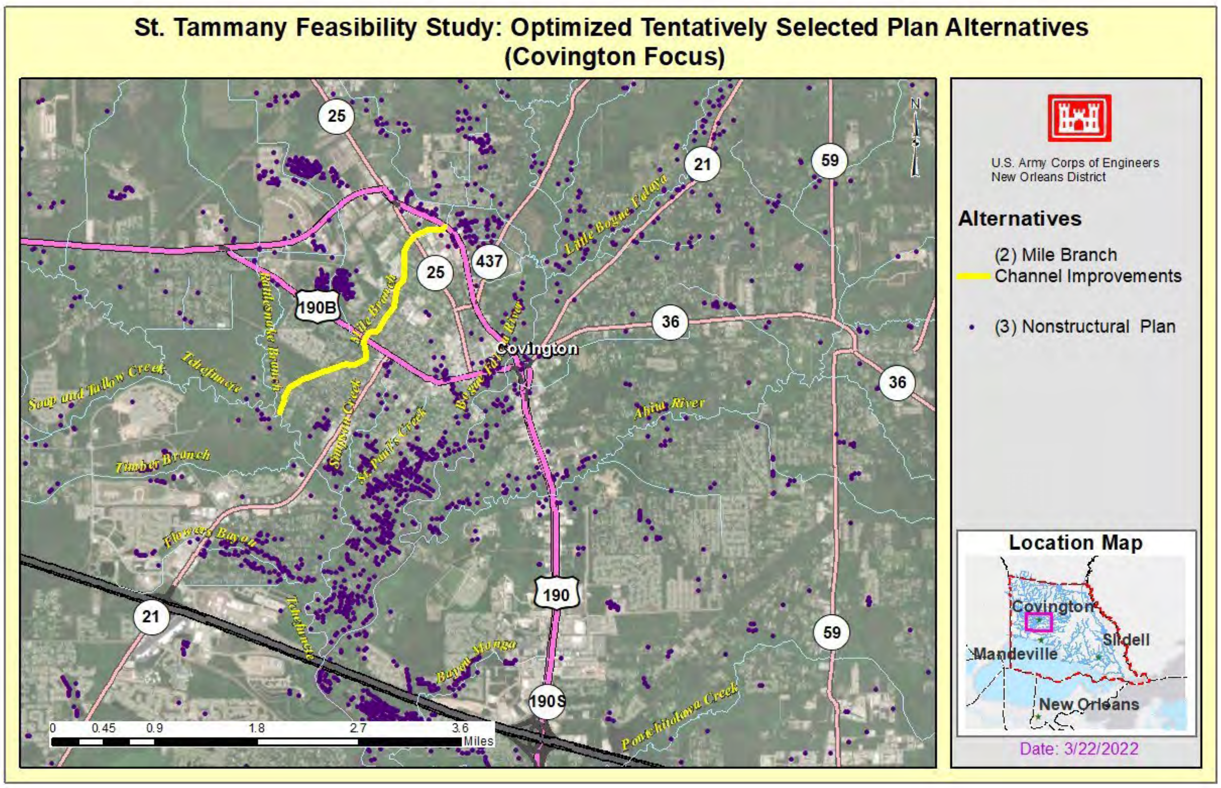

Figure 4-1. Optimized Tentatively Selected Plan Alternatives- Covington Focus

The Mile Branch channel improvements would start at the intersection of Mile Branch and Highway 190, crossing Highway 190 Business, and ending at the intersection of Mile Branch and the Tchefuncte River. Refer to Figure 4-2.

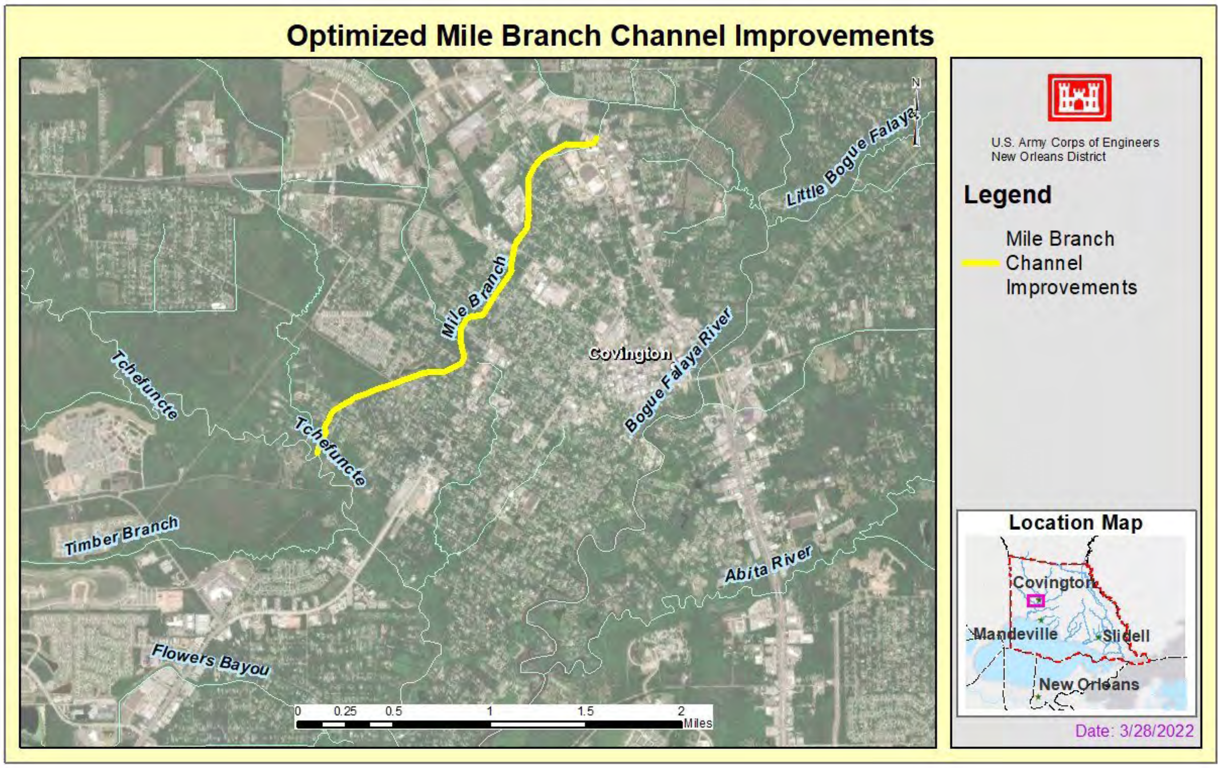

Figure 4-2. Optimized Mile Branch Channel Improvements

The preliminary design assumes an existing bank elevation of 1 ft, a 10-ft bottom width at elevation (-) 5 ft. The bank is at 1V:3H slope. The improvements would include clearing and grubbing and mechanical dredging of the channel. The channel bottom would be lowered by 5 ft. Refer to Figure 4-3 for typical cross-section.

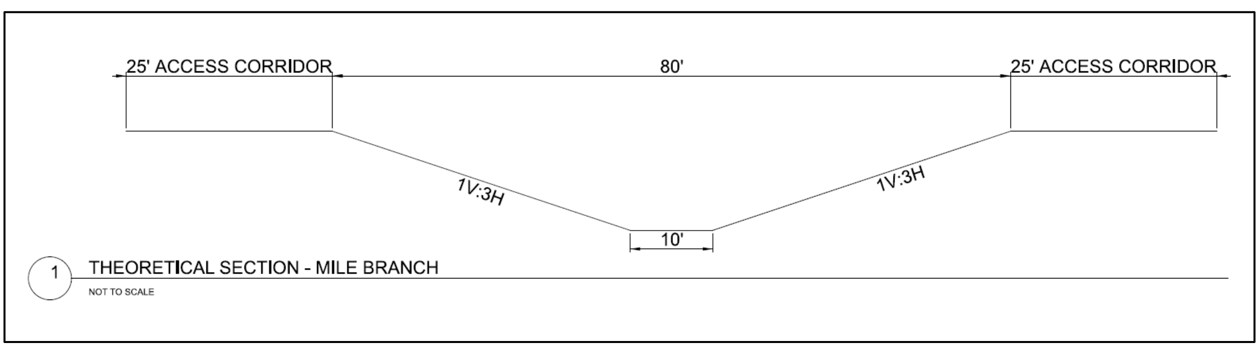

Figure 4-3. Mile Branch Improvements- Typical Cross-Section

Approximately 20 acres of channel would be cleared and grubbed prior to mechanical dredging. An assumed maximum of 130,000 cubic yards of material may be mechanically dredged from the channel. Material removed may include sediment, trees, debris, or other

obstructions within the waterway. For the channel improvements, approximately 34 acres of ROW would be needed for a temporary easement.

Riparian Zone bioengineering techniques and nature-based-solutions (NBS) would be considered as appropriate for Mile Branch FRM during PED in coordination with the NFS and resource agencies. A backwater area was included in the study phase.

4.1 STRUCTURAL IMPROVEMENTS

The Mile Branch channel improvements may include bridge replacements or new culverts (starting from north to south) at 29th, 28th, 25th, 23rd, 21st, 19th, and 18th Avenues. No work is anticipated at the 15th and 11th Avenue channel crossings as those bridges have been replaced prior to this study (and the new bridges were designed to safely pass higher flows on Mile Branch).

Assumptions for channel improvements included a 65 ft from the centerline of each side of the channel for ROW as a general guideline (total width of 130 ft); which includes space for equipment access. All work would be within the project footprint. Temporary work easement would be within ROW. The material to be disposed of would be trucked away from the site. Assumption is that all access would be through public lands.

Additional refinements would occur during PED. Future surveys would determine final channel section and bridge replacements or new culverts. Impacts to habitat and real estate would also be minimized. Opportunities to include natural features would be considered in future designs.

4.2 ACCESS ROUTES AND ROW CRITERIA FOR MILE BRANCH

Figure 4-4 provides the locations of the Mile Branch channel improvements including the structural improvements.

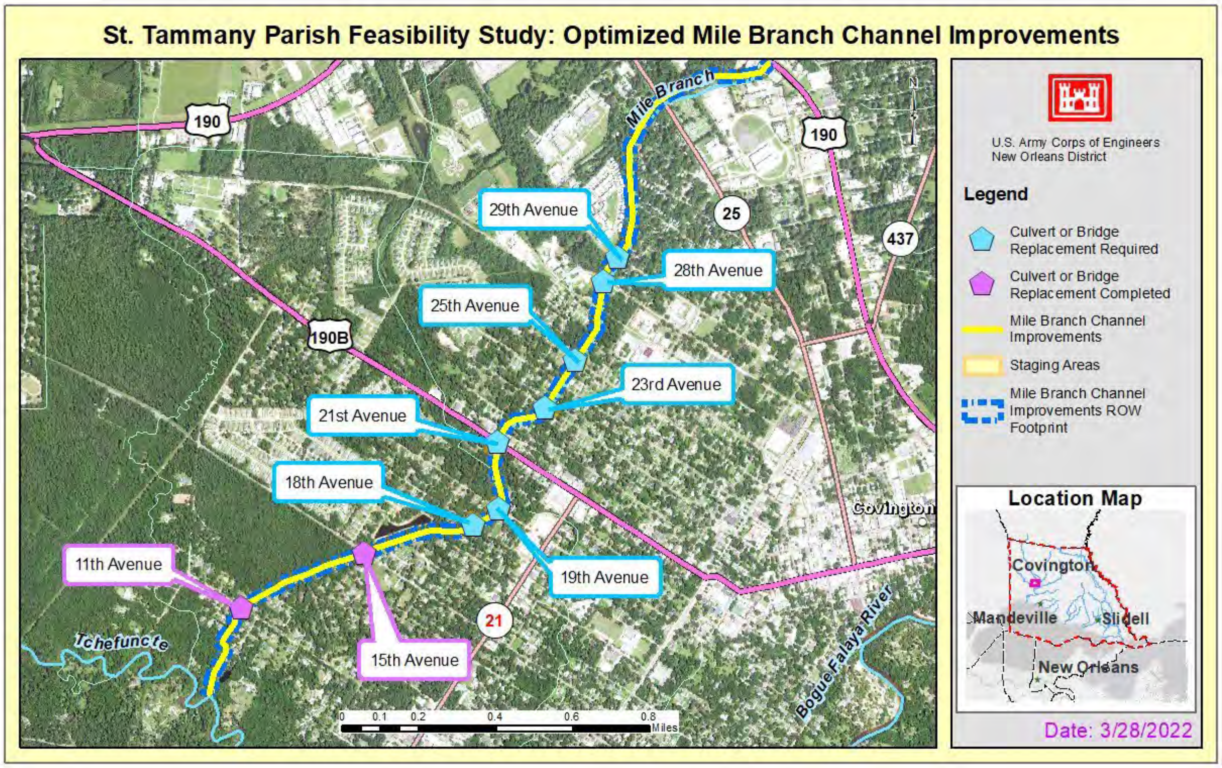

Figure 4.4. Optimized Mile Branch Improvements- Structural Improvements

Reference Table 3.1 for a listing of the staging areas and acres required for the structural improvements for Mile Branch. Table 4-1 below lists the staging area locations required for the bridge/culvert replacements and the necessary acres.

Table 4.1: Staging areas for the bridge/culvert replacements

Location	Temporary ROW Staging Area (Acres)
29th Avenue	0.37
28th Avenue	0.35
25th Avenue	0.20
23rd Avenue	0.21
21st Avenue	0.36
19th Avenue	0.36
18th Avenue	0.38
TOTAL	**2.23**