Mississippi Valley Division,
Regional Planning and Environment Division South

St. Tammany Parish, Louisiana Feasibility Study

Appendix C – Annex M - Modeling

July 2023

Mississippi Valley Division,
Regional Planning and Environment Division South

Annex M Modeling

HEP Assumptions

Revised Draft Integrated Feasibility Report
and Environmental Impact Statement

Environmental Appendix July 2023

Pine Savannah HSIs For Project Impacts

Since WVAs have not been developed for pine savannah habitats, the Habitat Suitability Index (HSI) modeling approach was selected to assess project impacts. The RCW HSI was selected for this project to quantify impacts to pine savannah habitats. HSI models are species specific models that evaluate habitat quality and identify and quantify the relationship between key environmental variables and habitat suitability on a scale from 0 to 1. The HSI value of 0.0 represents totally unsuitable habitat and a value of 1.0 represents optimum habitat. Each model contains multiple environmental variables important to the associated species and HSI scores are calculated independently for each of these variables. A weighting scheme is then used to combine the SI for individual variables to determine an overall SI score.

Described below are the assumptions used to determine pine savannah baseline conditions and FWOP and FWP projections for the proposed project area for direct and indirect impacts.

General Assumptions

The period of analysis expands from 2031 (TY0) to 2082 (TY50), with TY0 representing baseline conditions. In determining future with-project conditions, all project-related direct (construction) impacts were assumed to occur in Target Year 1.

Both direct and indirect impacts to pine savannah habitat, as a result of project construction, are anticipated and were evaluated and quantified. Direct temporary impact (staging) areas are not proposed within pine savannah habitat. A summary of the number of model runs associated with the type of impact anticipated is provided in Table 1.

Low quality pine savannah habitat currently dominates lands to be impacted by the proposed project that are located off of Big Branch Marsh National Wildlife Refuge. Due to the lack of pine savannah management on these lands a dense hardwood midstory/understory is present. Future pine savannah management (i.e., prescribed burns, thinnings, herbicide treatment, etc.) is not expected to occur on these areas in the future.

All currently managed (or soon to be managed) impacted pine savannah habitat within the project area currently occurs on Big Branch Marsh National Wildlife Refuge (Figure 1); therefore, under the FWOP scenario, it is assumed that all future pine savannah habitation management would be conducted by that refuge. Because construction of the proposed levee and associated structures are not compatible with the refuge's Congressionally mandated wildlife conservation goals the USACE would be required to conduct a land swap for the lands that are impacted on the refuge. In other words, the USACE would purchase land and donate those properties to the refuge to replace the land lost due to construction of the proposed project. The USACE would then own the direct project impact areas. Since the land swap only compensates the refuge for lands taken, USACE would still be required to mitigate for the loss of pine savannah habitat present within the impact area.

Target Years (TYs) for pine savannah impacts under both FWP and FWOP scenarios include TY0, TY1, TY18, TY35 and TY50.

Land Loss/ Sea Level Rise Effects

An inherent assumption used to determine future impacts to pine savannah with Relative Sea Level Rise (RSLR) is that persistent flooding of pine sites will cause the pine to convert to another habitat type resulting in loss of pine savannah acres in the lower elevation persistently flooded zones.

In accordance with the USACE EC-1165-2-212, RSLR was determined using USACE's Sea-Level Calculator (SLC) at the Lake Pontchartrain at Mandeville gauge (Aug 1957 to July 2002, gauge number 85575). The low, intermediate, and high SLR curve (gauge 85575) were used as appropriate for all SLR estimates. Based on the USACE's SLC, an estimated subsidence rate of 4.9 mm/yr from the Lake Pontchartrain at Mandeville (gauge 85575) was used for RSLR estimates. The eustatic sea level rise was assumed to be 1.7 mm/yr.

LIDAR data was obtained for the pine savannah direct and indirect sites to determine the average annual baseline elevation, which was assumed to be equivalent to the forest floor. The LIDAR data in combination with the RSLR was used to determine future pine savannah acres. A reduction in pine savannah acres assumes some acres are lost to persistent flooding and have likely converted to open water or marsh.

RCW HSI – Pine Savannah

Tirpak, J.M., D.T. Jones-Farrand, F.R. Thompson, III, D.J. Twedt, and W.B. Uihlein, III. 2009. Multiscale Habitat Suitability Index Models for Priority Landbirds in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions. U.S. Department of Agriculture, Forest Service Northern Research Station General Technical Report NRS-49, Washington, D.C., USA. 201pp.

Because the pine savannah habitat on Big Branch Marsh NWR is known to be inhabited by the endangered RCW, this species was selected to quantify habitat impacts. 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. 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 HSI model for the RCW includes eight variables: landform, landcover, successional age class, forest patch size, pine basal area, hardwood basal area, connectivity, and large pine (> 35 cm dbh) density (Tirpak et al 2009).

<u>Direct Permanent Impacts - BBMNWR</u>

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

		Successional age class				
Landform	Landcover Type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

Landcover Type Definitions:

Floodplain Valley – land adjacent to a river which stretches from the banks of its channel to the base of the enclosing valley walls, and which experiences flooding during periods of high discharge

Terrace Mesic – infrequently flooded (flooding for only a very short period). This ecological system is found in limited upland areas, including ravines and side slopes, of the Gulf Coastal Plain west of the Mississippi River. These areas are topographically isolated from historically fire-prone, pine-dominated uplands in eastern Texas, western Louisiana, and southern Arkansas.

Xeric-Ridge – excessively drained, sandy uplands in gentle terrain. Historically, this type has had frequent fires. The overstory is rather open, and ericaceous shrubs commonly form the understory.

Successional Age Class Definitions:

Young Timber – 5-8.99 inches dbh
Saw Timber – ≥9.0 inches dbh
https://www.fs.usda.gov/srsfia/php/tpo_2009/tpo_docs/DEFINITIONS.htm

FWP

While current conditions (2021) consist of degraded pine savannah stands with a dense hardwood midstory/understory component a goal of the refuge is to manage and protect threatened and endangered species. Big Branch Marsh is within the Gulf Coast Prairies and Marshes Ecoregion of the Red-cockaded Woodpecker (RCW) Recovery Plan, second revision (U.S. Fish and Wildlife Service 2003). The refuge population is the only one existing in this ecoregion and while it is not considered a recovery unit, it is designated as a significant support population for the recovery of the species. The refuge's role is to maintain the RCW's intrinsic value, conserve genetic resources, represent variations in habitats occupied by the species, and serve as immigrants for core, recoverable populations. Because of the importance of pine savannah habitat to the RCW and the refuge's commitment to manage for this species, thinnings, burns, herbicide treatments, etc. are anticipated throughout the project life. With implementation of these management techniques the quality of pine savannah habitat is expected to increase. By TY1 (2032) we assume that all or a combination of these management techniques have been initiated.

TY0:

Floodplain Valley
Mixed
Saw Timber

0.4 SI

TY1-TY50: All forested habitat will be removed for levee construction. Grasses will dominate the levee once construction is complete.

0 SI

FWOP

TY0:

Floodplain Valley
Mixed
Saw Timber

0.4 SI

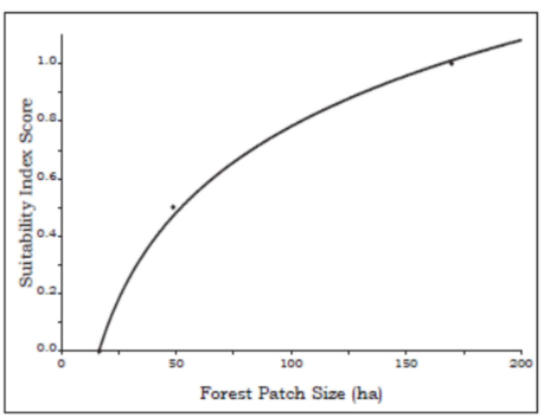
TY1-TY50:

Floodplain Valley
Evergreen
Saw Timber

0.8 SI

Variable V2: Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



FWP

Acreage of pine savannah habitat within the levee footprint is removed at TY1 due to the permanent loss of this habitat.

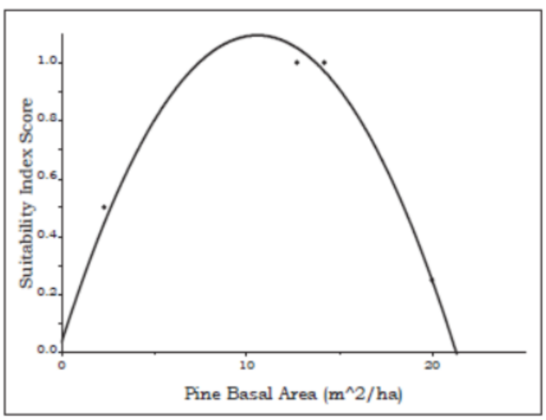
TY0: 248.2 ha
TY1: 239.9 ha
TY18: 210.9 ha
TY35: 155.3 ha
TY50: 65.3 ha

FWOP

TY0: 248.2 ha
TY1: 248.2 ha
TY18: 216.8 ha
TY35: 158.7 ha
TY50: 65.9 ha

<u>Variable V3:</u> Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees from plots. This spreadsheet projects individual tree dbh and project site basal area over time. It is important to note that while there is currently a hardwood component in each of our sample plots, only the pine tree field measurements were entered into the ingrowth spreadsheet because this variable strictly relates to the pine basal area component of the stand.

FWP

Permanent loss of habitat would occur at TY1

TY0: 34.3 m^2/ha

TY1: 0 m^2/ha
TY18: 0 m^2/ha
TY35: 0 m^2/ha
TY50: 0 m^2/ha

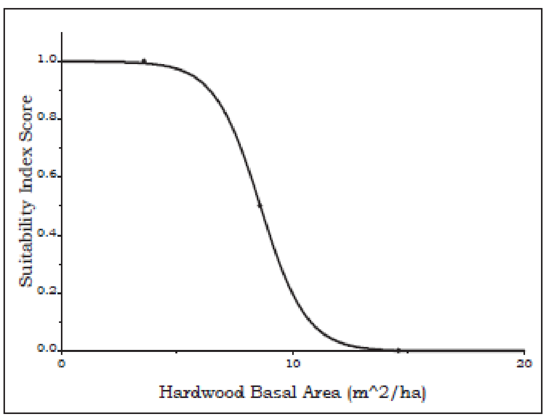
FWOP

Because normal forestry practices on Big Branch Marsh include possible thinnings every 10 years, we are assuming a thinning operation at TY1 (2032). The refuge typically thins pine stands in these lower elevations to approximately 80 ft^2/acre BA. Pines in these areas are slower growing then pines in more upland sites and reducing the BA below 80 ft^2/acre would increase the risk of windthrow.

TY0: 34.3 m^2/ha
TY1: 18.4 m^2/ha
TY18: 18.4 m^2/ha
TY35: 18.4 m^2/ha
TY50: 18.4 m^2/ha

Variable V4: Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees from plots. This spreadsheet projects individual tree dbh and project site basal area over time. It is important to note that only the hardwood tree field measurements were entered into this ingrowth spreadsheet because this variable strictly relates to the hardwood basal area component of the stands. The pine basal area component of the stands was assessed under V3.

FWP

Permanent loss of habitat would occur at TY1

TY0: 19.8 m^2/ha

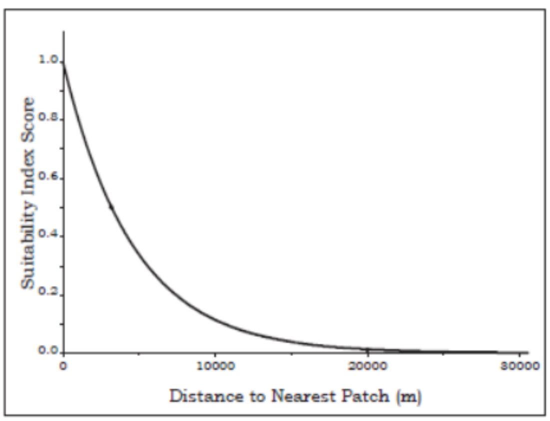
TY1: 0 m^2/ha
TY18: 0 m^2/ha
TY35: 0 m^2/ha
TY50: 0 m^2/ha

FWOP

Pine savannah management practices (e.g., thinnings, burns, herbicide treatments, etc.) would reduce the density of overstory and midstory hardwoods to an approximate basal area of 5 ft^2/acre. This is comparable to other stands on the refuge that are actively being managed for RCWs.

TY0: 19.8 m^2/ha
TY1: 1.1 m^2/ha
TY18: 1.1 m^2/ha
TY35: 1.1 m^2/ha
TY50: 1.1 m^2/ha

Variable V5: Relationship between distance to nearest habitat patch and SI



The project footprint is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP

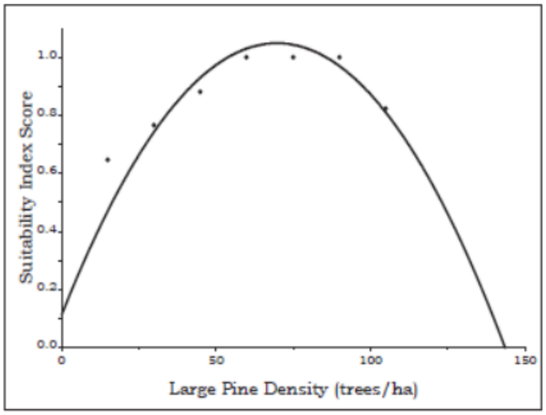
TY0-TY50: 0m

FWOP

TY0-TY50: 0m

Variable V6: Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Permanent loss of habitat would occur at TY1

TY0: 21.4 (trees/ha)
TY1: 0 (trees/ha)
TY18: 0 (trees/ha)
TY35: 0 (trees/ha)
TY50: 0 (trees/ha)

FWOP

TY0: 21.4 (trees/ha)
TY1: 22.2 (trees/ha)
TY18: 24.7 (trees/ha)
TY35: 53.5 (trees/ha)
TY50: 25.5 (trees/ha)

Direct Permanent Impacts – Private Land

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

FWP

TY0:

Floodplain Valley
Mixed
Saw Timber

0.4 SI

TY1-TY50: All forested habitat will be removed for levee construction. Grasses will dominate the levee once construction is complete.

0 SI

FWOP

TY0:

Floodplain Valley
Mixed
Saw Timber

0.4 SI

Due to past and ongoing fire suppression, it is assumed that pine savannah habitat management will not be conducted in the future on private lands; therefore, mixed pine/hardwood stands are expected.

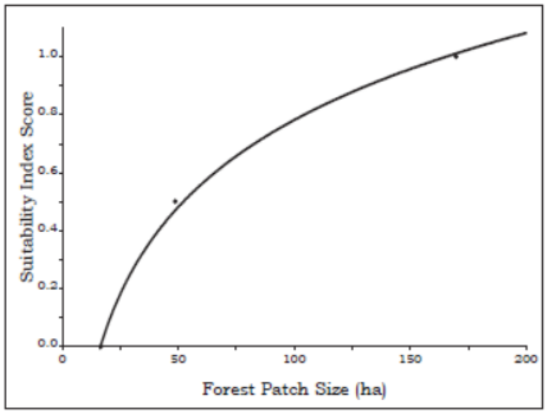
TY1-TY50:

Floodplain Valley
Mixed
Saw Timber

0.4 SI

Variable V2: Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



FWP

Acreage of pine savannah habitat within the levee footprint is removed at TY1 due to the permanent loss of this habitat.

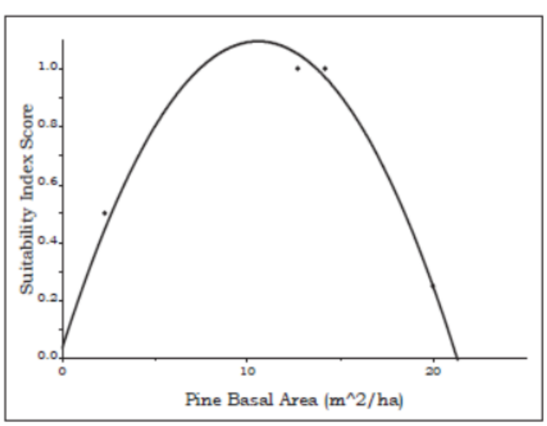
TY0: 3761.3 ha
TY1: 3713.1 ha
TY18: 3713.1 ha
TY35: 3708.6 ha
TY50: 3670.2 ha

FWOP

TY0: 3761.3 ha
TY1: 3761.3 ha
TY18: 3761.3 ha
TY35: 3753.2 ha
TY50: 3717.4 ha

__**Variable V3:**__ Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees from plots. This spreadsheet projects individual tree dbh and project site basal area over time.

FWP

Permanent loss of habitat would occur at TY1

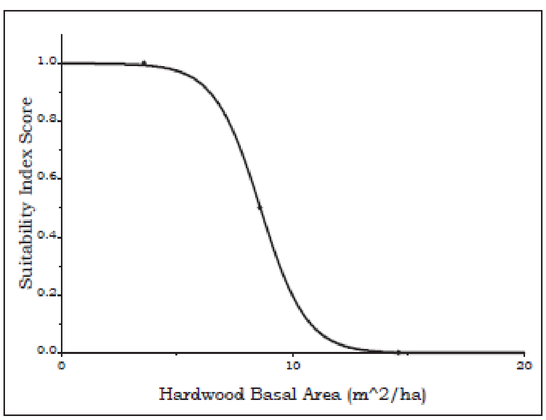
TY0:   50.7 m^2/ha
TY1:   0 m^2/ha
TY18: 0 m^2/ha
TY35: 0 m^2/ha
TY50: 0 m^2/ha

FWOP

TY0:   50.7 m^2/ha
TY1:   51.7 m^2/ha
TY18: 69.2 m^2/ha
TY35: 91.1m^2/ha
TY50: 83.3 m^2/ha

Variable V4: Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees from plots. This spreadsheet projects individual tree dbh and project site basal area over time.

FWP

Permanent loss of habitat would occur at TY1

TY0:   16.3 m^2/ha

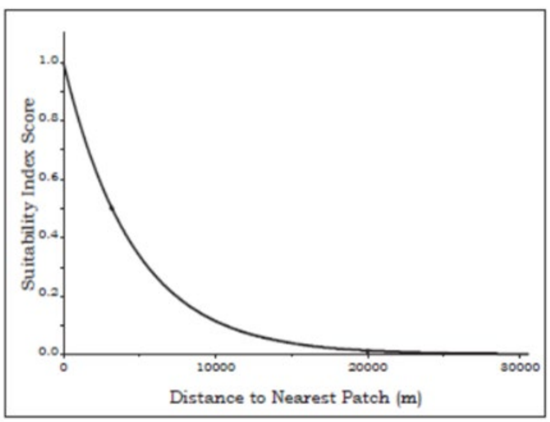
TY1: 0 m^2/ha
TY18: 0 m^2/ha
TY35: 0 m^2/ha
TY50: 0 m^2/ha

FWOP

Lack of pine savannah management practices (e.g., thinnings, burns, herbicide treatments, etc.) would increase the density of overstory and midstory hardwoods over time.

TY0: 16.3 m^2/ha
TY1: 17.8 m^2/ha
TY18: 56.2 m^2/ha
TY35: 74.2 m^2/ha
TY50: 93.0 m^2/ha

Variable V5: Relationship between distance to nearest habitat patch and SI



The project footprint is adjacent to pine savannah habitat, albeit low quality habitat, under both the FWP and FWOP scenarios.

FWP

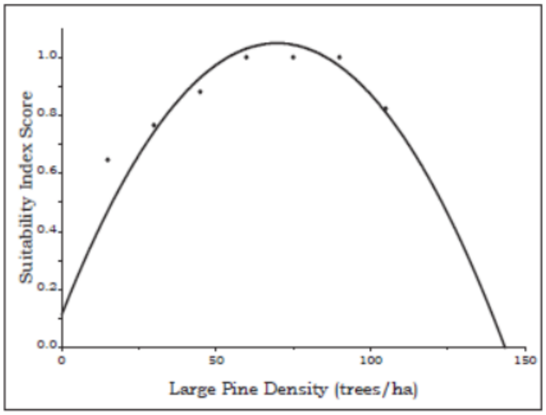
TY0-TY50: 0m

FWOP

TY0-TY50: 0m

Variable V6: Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Permanent loss of habitat would occur at TY1

TY0: 11.7 (trees/ha)
TY1: 0 (trees/ha)
TY18: 0 (trees/ha)
TY35: 0 (trees/ha)
TY50: 0 (trees/ha)

FWOP

TY0: 11.7 (trees/ha)
TY1: 13.6 (trees/ha)
TY18: 65.4 (trees/ha)
TY35: 59.9 (trees/ha)
TY50: 31.5 (trees/ha)

Indirect Impacts - BBMNWR Flood/Unprotected Side

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

FWP and FWOP

Under both the FWP and FWOP scenarios the indirect impact area will be managed for RCWs over the project life.

TY0:
Floodplain Valley
Mixed
Saw Timber

0.4 SI

TY1-TY50:
Floodplain Valley
Evergreen
Saw Timber

0.8 SI

Variable V2: Relationship between forest patch size and SI

Under the FWP scenario the impact area would be subjected to longer periods of inundation resulting in the loss of pine savannah habitat over time.

FWP

TY0: 248.2 ha
TY1: 239.9 ha
TY18: 210.9 ha
TY35: 155.3 ha
TY50: 65.3 ha

FWOP

TY0: 248.2 ha
TY1: 248.2 ha
TY18: 216.8 ha
TY35: 158.7 ha
TY50: 65.9 ha

Variable V3: Relationship between basal area of pines and SI

A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees from plots. This spreadsheet projects individual tree dbh and project site basal area over time. When the spreadsheet showed that basal area would fall below 80 ft^2/acre (i.e., the current management practice) at a specific TY, that basal area was input into the model to account for loss of pines as a result of increased inundation.

FWP

TY0: 33.8 m^2/ha
TY1: 18.4 m^2/ha
TY18: 18.4 m^2/ha
TY35: 18.4 m^2/ha
TY50: 11.3 m^2/ha

FWOP

TY0: 33.8 m^2/ha
TY1: 18.4 m^2/ha
TY18: 18.4 m^2/ha
TY35: 18.4 m^2/ha
TY50: 15.5 m^2/ha

Variable V4: Relationship between basal area of hardwoods (m^2/ha) and SI

FWP and FWOP

Under both the FWP and FWOP scenarios pine savannah management practices (e.g., thinnings, burns, herbicide treatments, etc.) would reduce the density of overstory and midstory hardwoods to an approximate basal area of 5 ft^2/acre.

TY0: 17.7 m^2/ha
TY1: 1.2 m^2/ha
TY18: 1.2 m^2/ha
TY35: 1.2 m^2/ha
TY50: 1.2 m^2/ha

Variable V5: Relationship between distance to nearest habitat patch and SI

The indirect impact area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP and FWOP

TY0-TY50: 0m

Variable V6: Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

TY0: 20.6 (trees/ha)
TY1: 18.9 (trees/ha)
TY18: 23.01 (trees/ha)
TY35: 23.9 (trees/ha)
TY50: 10.7 (trees/ha)

FWOP

TY0: 20.6 (trees/ha)
TY1: 21.4 (trees/ha)
TY18: 24.7 (trees/ha)
TY35: 29.7 (trees/ha)
TY50: 23.9 (trees/ha)

Indirect Impacts - Private Lands Flood/Unprotected Side

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

FWP and FWOP

Under both the FWP and FWOP scenarios habitat conditions will continue to be mixed pine/hardwood saw timber stands. Due to the lack of fire suppression on private lands, a dense hardwood midstory/understory would be present in this area over the project life.

TY0-TY50:
Floodplain Valley
Mixed
Saw Timber

0.4 SI

Variable V2: Relationship between forest patch size and SI

Under the FWP scenario the impact area would be subjected to longer periods of inundation resulting in the loss of pine savannah habitat over time.

FWP

TY0: 3713.1 ha
TY1: 3713.1ha
TY18: 3713.1 ha
TY35: 3708.6 ha
TY50: 3670.2 ha

FWOP

TY0: 3761.3 ha
TY1: 3761.3 ha
TY18: 3759.5 ha
TY35: 3738.5 ha
TY50: 3687.2 ha

Variable V3: Relationship between basal area of pines and SI

A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees from plots. This spreadsheet projects individual tree dbh and project site basal area over time.

FWP

TY0: 50.7 m^2/ha
TY1: 52.2 m^2/ha
TY18: 81.4 m^2/ha
TY35: 86.6 m^2/ha
TY50: 64.9 m^2/ha

FWOP

TY0: 50.7 m^2/ha
TY1: 52.8 m^2/ha
TY18: 81.7 m^2/ha
TY35: 87.7 m^2/ha
TY50: 65.9 m^2/ha

Variable V4: Relationship between basal area of hardwoods (m^2/ha) and SI

A bottomland hardwood ingrowth spreadsheet was developed and used to predict tree growth for individual trees from plots. Fire suppression on private lands is assumed to continue over the life of the project; therefore, a reduction of bottomland hardwoods is not anticipated over time.

FWP

TY0: 16.3 m^2/ha
TY1: 17.8 m^2/ha
TY18: 55.2 m^2/ha
TY35: 71.7 m^2/ha
TY50: 88.1 m^2/ha

FWOP

TY0: 16.3m^2/ha
TY1: 17.8 m^2/ha
TY18: 55.7 m^2/ha
TY35: 74.8 m^2/ha
TY50: 95.9 m^2/ha

Variable V5: Relationship between distance to nearest habitat patch and SI

The indirect impact area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP and FWOP

TY0-TY50: 0m

Variable V6: Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

TY0: 11.7 (trees/ha)
TY1: 13.6 (trees/ha)
TY18: 63.0 (trees/ha)
TY35: 59.9 (trees/ha)
TY50: 32.1 (trees/ha)

FWOP

TY0: 11.7 (trees/ha)
TY1: 13.6 (trees/ha)
TY18: 65.5 (trees/ha)
TY35: 59.9 (trees/ha)
TY50: 32.1 (trees/ha)

Indirect Impacts - Private Lands Protected Side

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

FWP and FWOP

Under both the FWP and FWOP scenarios habitat conditions will continue to be mixed pine/hardwood saw timber stands. Due to fire suppression on private lands, a dense hardwood midstory/understory would be present in this area over the project life.

TY0-TY50:

Floodplain Valley
Mixed
Saw Timber

0.4 SI

Variable V2: Relationship between forest patch size and SI

Under the FWP scenario the impact area would be subjected to longer periods of inundation resulting in the loss of pine savannah habitat over time.

FWP

TY0: 3713.1 ha
TY1: 3713.1ha
TY18: 3713.1 ha
TY35: 3708.6 ha
TY50: 3670.2 ha

FWOP

TY0: 3761.3 ha
TY1: 3761.3 ha
TY18: 3759.5 ha
TY35: 3738.5 ha
TY50: 3687.2 ha

Variable V3: Relationship between basal area of pines and SI

A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees from plots. This spreadsheet projects individual tree dbh and project site basal area over time.

FWP

TY0: 50.7 m^2/ha
TY1: 52.8 m^2/ha
TY18: 81.8 m^2/ha
TY35: 87.7 m^2/ha
TY50: 65.8 m^2/ha

FWOP

TY0: 50.7 m^2/ha
TY1: 52.8 m^2/ha
TY18: 82.0 m^2/ha

TY35: 88.1 m^2/ha
TY50: 66.2 m^2/ha

Variable V4: Relationship between basal area of hardwoods (m^2/ha) and SI

A bottomland hardwood ingrowth spreadsheet was developed and used to predict tree growth for individual trees from plots. Fire suppression on private lands is assumed to continue over the life of the project; therefore, a reduction of bottomland hardwoods is not anticipated.

FWP

TY0: 16.3 m^2/ha
TY1: 17.8 m^2/ha
TY18: 55.9 m^2/ha
TY35: 74.6 m^2/ha
TY50: 95.1 m^2/ha

FWOP

TY0: 16.3 m^2/ha
TY1: 17.8 m^2/ha
TY18: 56.3 m^2/ha
TY35: 76.1 m^2/ha
TY50: 97.9 m^2/ha

Variable V5: Relationship between distance to nearest habitat patch and SI

The indirect impact area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP and FWOP

TY0-TY50: 0m

Variable V6: Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

TY0: 11.7 (trees/ha)
TY1: 13.6 (trees/ha)
TY18: 65.5 (trees/ha)
TY35: 59.9 (trees/ha)
TY50: 32.1 (trees/ha)

FWOP

TY0: 11.7 (trees/ha)
TY1: 13.6 (trees/ha)
TY18: 66.7 (trees/ha)
TY35: 59.9 (trees/ha)
TY50: 32.1 (trees/ha)

Pine Warbler HSI – Pine Savannah

Schroeder, R. L. 1982. Habitat suitability index models: pine warbler. U.S. Dept. Int., Fish Wildl. Serv. FWS/OBS-82/10.28. 8 pp.

Pine warblers are found mainly in pine forests. They are year-round residents throughout the Southeast and are breeding residents in the northcentral and northeastern States. The pine warbler is one of the few breeding species that are generally restricted to pines.

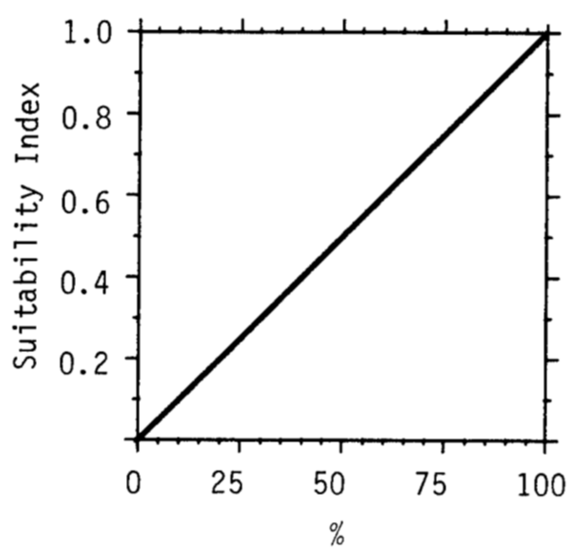
Optimal cover and reproductive (nesting) habitat for the pine warbler is provided by pure, dense, mature stands of pine (excluding white, pond, and sand pine) lacking a tall deciduous understory. A forest comprised totally of deciduous trees or white, pond, or sand pine is considered unsuitable for the pine warbler.

The HSI model for the pine warbler includes three variables: Percent tree canopy closure of overstory pines, successional stage of stand, and percent of dominant canopy pines with deciduous understory in the upper 1/3 layer.

Direct Permanent Impacts - BBMNWR

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

Permanent loss of habitat would occur at TY1

TY0: 41.7 %
TY1: 0%
TY18: 0%
TY35: 0%
TY50: 0%

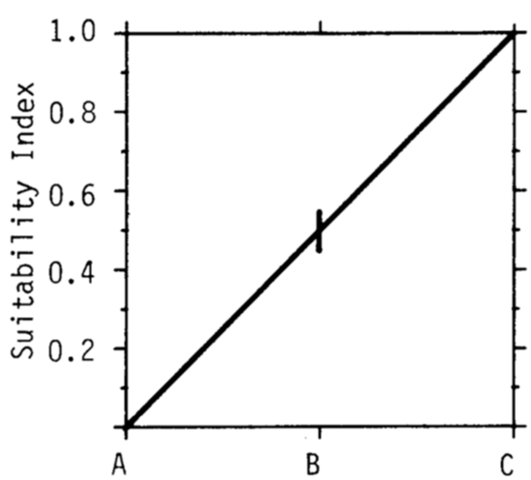
FWOP

It is assumed that thinning and burning to reduce vegetative density (to increase habitat quality for RCWs) of the pine savannah habitat present at TY0 would result in a decrease of pine canopy closure.

TY0: 41.7 %
TY1: 25%
TY18: 25%
TY35: 25%
TY50: 25%

Variable V2: Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.



A = pole or sapling
B = young
C = mature or old growth

FWP

Permanent loss of habitat would occur at TY1

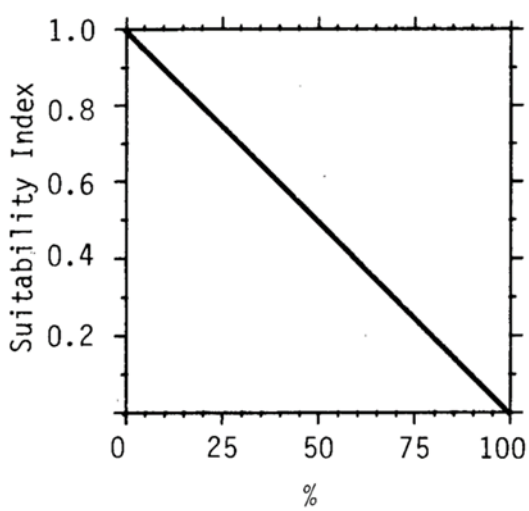
TY0: 1 SI
TY1: 0 SI
TY18: 0 SI
TY35: 0 SI
TY50: 0 SI

FWOP

TY0: 1 SI
TY1: 1 SI
TY18: 1 SI
TY35: 1 SI
TY50: 1 SI

Variable V3: Percent of dominant canopy pines with deciduous understory in the upper 1/3 layer

Pine forests with a deciduous understory reaching into the top 1/3 layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

Permanent loss of habitat would occur at TY1

TY0: 53.3 %
TY1: 0%
TY18: 0%
TY35: 0%
TY50: 0%

FWOP

It is assumed that pine savannah management practices (e.g., thinnings, burns, herbicide treatments, etc.) would reduce the density of overstory and midstory hardwoods, thereby reducing the percent of dominant canopy pines with deciduous understory in the upper 1/3 layer.

TY0: 53.3 %
TY1: 5%
TY18: 5%
TY35: 5%
TY50: 5%

Direct Permanent Impacts – Private Land

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.

FWP

Permanent loss of habitat would occur at TY1

TY0: 71.3%
TY1: 0%
TY18: 0%
TY35: 0%
TY50: 0%

FWOP

Due to fire suppression on private lands, it is assumed that vegetative density of overstory pines would decrease over time as hardwoods encroach the canopy.

TY0: 71.3%
TY1: 71.3%
TY18: 61.3%

TY35: 61.3 %
TY50: 56.3 %

Variable V2: Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

FWP

Permanent loss of habitat would occur at TY1

TY0: 1 SI
TY1: 0 SI
TY18: 0 SI
TY35: 0 SI
TY50: 0 SI

FWOP

TY0: 1 SI
TY1: 1 SI
TY18: 1 SI
TY35: 1 SI
TY50: 1 SI

Variable V3: Percent of dominant canopy pines with deciduous understory in the upper 1/3 layer

Pine forests with a deciduous understory reaching into the top 1/3 layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.

FWP

Permanent loss of habitat would occur at TY1

TY0: 30.0%
TY1: 0%
TY18: 0%
TY35: 0%
TY50: 0%

FWOP

It is assumed that in the absence of pine savannah management the percent of hardwood midstory and understory would increase over time, thereby increasing the percent of dominant canopy pines with deciduous understory in the upper 1/3 layer.

TY0: 30.0%
TY1: 30.0%
TY18: 41.3%
TY35: 46.3%
TY50: 50.0%

Indirect Impacts – BBMNWR Flood/Unprotected Side

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.

Under both FWP and FWOP scenarios, it is assumed that thinning and burning to reduce vegetative density (to increase habitat quality for RCWs) of the pine savannah habitat present at TY0 would result in a decrease of pine canopy closure. An approximate 25% canopy closure would be maintained within the impact area over the project life.

FWP

It is assumed that with increased inundation pine savannah habitats would transition to bottomland hardwoods over time. The pine savannah habitat remaining, however, over the life of the project would be managed for RCWs.

TY0: 41.7%
TY1: 25%
TY18: 25%
TY35: 25%
TY50: 25%

FWOP

TY0: 41.7%
TY1: 25%
TY18: 25%
TY35: 25%
TY50: 25%

Variable V2: Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

FWP

A mature stand is expected to be maintained under both the FWP and FWOP scenarios.

TY0: 1 SI
TY1: 1 SI
TY18: 1 SI
TY35: 1 SI
TY50: 1 SI

FWOP

TY0: 1 SI
TY1: 1 SI
TY18: 1 SI
TY35: 1 SI
TY50: 1 SI

Variable V3: Percent of dominant canopy pines with deciduous understory in the upper 1/3 layer

Under both the FWP and FWOP scenarios it is assumed that pine savannah management practices (e.g., thinnings, burns, herbicide treatments, etc.) would reduce the density of overstory and midstory hardwoods, thereby reducing the percent of dominant canopy pines with deciduous understory in the upper 1/3 layer.

FWP

It is assumed that with increased inundation pine savannah habitats would transition to bottomland hardwoods over time. The pine savannah habitat remaining, however, over the life of the project would be managed for RCWs.

TY0: 53.3%
TY1: 5%
TY18: 5%
TY35: 5%
TY50: 5%

FWOP

TY0: 53.3 %

TY1: 5%
TY18: 5%
TY35: 5%
TY50: 5%

Indirect Impacts – Private Land Flood/Unprotected Side

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.

FWP

Due to fire suppression on private lands, it is assumed that vegetative density of overstory pines would decrease over time as hardwoods encroach the canopy. It is assumed that there would be an accelerated rate of decrease under the FWP scenario as compared to the FWOP scenario due to increased inundation.

TY0: 71.3%
TY1: 71.3%
TY18: 61.3%
TY35: 51.3%
TY50: 41.3%

FWOP

Due to fire suppression on private lands, it is assumed that vegetative density of overstory pines would decrease over time as hardwoods encroach the canopy.

TY0: 71.3%
TY1: 71.3%
TY18: 66.3%
TY35: 63.5 %
TY50: 56.3 %

Variable V2: Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

FWP

A mature stand is expected to be maintained under both the FWP and FWOP scenarios.

TY0: 1 SI
TY1: 1 SI
TY18: 1 SI
TY35: 1 SI
TY50: 1 SI

FWOP

TY0: 1 SI
TY1: 1 SI
TY18: 1 SI
TY35: 1 SI
TY50: 1 SI

Variable V3: Percent of dominant canopy pines with deciduous understory in the upper 1/3 Layer

Due to fire suppression on private lands, it is assumed that the density of hardwoods in the canopy would increase over time.

FWP

It is also assumed that there would be an accelerated rate of increase under the FWP scenario as compared to the FWOP scenario due to lack of pine savannah management (e.g., thinnings, burnings, herbicide treatments, etc.).

TY0: 30.0%
TY1: 30.0%
TY18: 40.0%
TY35: 48.8%
TY50: 57.5%

FWOP

TY0: 30.0%
TY1: 30.0%
TY18: 35.0%
TY35: 40.0%
TY50: 45.0%

Indirect Impacts – Private Land Protected Side

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.

FWP

Due to fire suppression on private lands, it is assumed that vegetative density of overstory pines would decrease over time as hardwoods encroach the canopy. It is assumed that there would be an accelerated rate of decrease under the FWP scenario as compared to the FWOP scenario due to increased inundation.

TY0: 71.3%
TY1: 71.3%
TY18: 61.3%
TY35: 51.3%
TY50: 41.3%

FWOP

Due to fire suppression on private lands, it is assumed that vegetative density of overstory pines would decrease over time as hardwoods encroach the canopy.

TY0: 71.3%
TY1: 71.3%
TY18: 66.3%
TY35: 63.5 %
TY50: 56.3 %

Variable V2: Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

FWP

A mature stand is expected to be maintained under both the FWP and FWOP scenarios.

TY0: 1 SI
TY1: 1 SI
TY18: 1 SI
TY35: 1 SI
TY50: 1 SI

FWOP

TY0: 1 SI
TY1: 1 SI

TY18: 1 SI
TY35: 1 SI
TY50: 1 SI

Variable V3: Percent of dominant canopy pines with deciduous understory in the upper 1/3 Layer

Due to fire suppression on private lands, it is assumed that the density of hardwoods in the canopy would increase over time.

FWP

It is assumed that there would be an accelerated rate of increase under the FWP scenario as compared to the FWOP scenario due to lack of pine savannah management (e.g., thinnings, burnings, herbicide treatments, etc.).

TY0: 30.0%
TY1: 30.0%
TY18: 40.0%
TY35: 48.8%
TY50: 57.5%

FWOP

TY0: 30.0%
TY1: 30.0%
TY18: 35.0%
TY35: 40.0%
TY50: 45.0%

Pine Savannah
HSI Results

See below for a summary of resulting Annual Average Habitat Unit (AAHUs) at the end of the period of analysis (year 50) for the pine savannah intermediate RSLR scenarios.

Pine Savannah - BBMNWR	Intermediate SLR		
Impact Type	**Species**	**Net Acres**	**AAHUS**
BBMNWR Direct		-1.19	
	RCW		-9.74
		-1.19	
	Pine Warbler		-2.53
BBMNWR Indirect - Protected Side		N/A	
	RCW		N/A
		N/A	
	Pine Warbler		N/A
BBMNWR Indirect - Unprotected Side		-0.25	
	RCW		-6.62
		-0.25	
	Pine Warbler		-1.71
Cumulative		**-1.44**	**-20.60**

Pine Savannah - Private Lands	Intermediate SLR		
Impact Type	**Species**	**Net Acres**	**AAHUS**
Private Land Direct		-145.31	
	RCW		0.00
		-145.31	
	Pine Warbler		-42.45
Private Land Indirect - Protected Side		-3.09	
	RCW		0.00
		-3.09	
	Pine Warbler		-10.52
Private Land Indirect - Unprotected Side		0.00	
	RCW		0.00
		0.00	
	Pine Warbler		-1.55
Cumulative		**-148.40**	**-54.52**

TOTAL		**-149.84**	**-75.12**

Pine Savannah HSIs For Mitigation Sites

Mitigation Site – BBMNWR PS-1 RCW

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

		Successional age class				
Landform	Landcover Type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

FWP

TY0: Baseline Conditions

Floodplain Valley
Mixed
Saw Timber

0.4 SI

TY1-TY50: Mitigation construction will be completed by TY1, therefore, we assume that hardwood midstory and overstory removal has occurred by this time resulting in an evergreen stand.

Floodplain Valley
Evergreen
Saw Timber

0.8 SI

FWOP

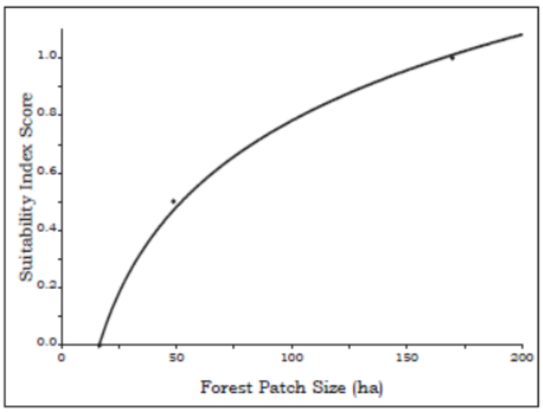
TY0-TY50: Without the proposed mitigation activities we assume that the subject site will remain a degraded pine savannah with dense hardwoods in the midstory and overstory.

Floodplain Valley
Mixed
Saw Timber

0.4 SI

<u>Variable V2:</u> Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



Due to time restrictions, we were not able to re-run the relative sea level rise calculations for the mitigation HSI acreage calculations. Instead, the forest patch size calculations that were developed in this area for the HSI impact analysis were used. While the TY0, TY1 and TY50 acreages would be the same between the impact and mitigation analyses, the mitigation HSI uses TY20 as a target year unlike the impact assessment which uses TY18. Assumed that insignificant acreage would be lost between TY18 and TY20 and used the TY18 acreages calculated for the impact analysis for TY20 acreages in the mitigation analysis.

FWP

Acreage of pine savannah habitat within the levee footprint is removed at TY1 due to the permanent loss of this habitat.

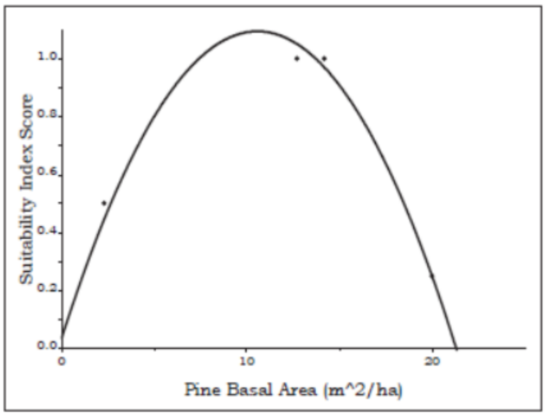
TY0: 248.2 ha
TY1: 239.9 ha
TY20: 210.9 ha
TY50: 65.3 ha

FWOP

TY0: 248.2 ha
TY1: 248.2 ha
TY20: 216.8 ha
TY50: 65.9 ha

Variable V3: Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees from plots. This spreadsheet projects individual tree dbh and project site basal area over time. It is important to note that while there is currently a hardwood component in each of our sample plots, only the pine tree field measurements were entered into the ingrowth spreadsheet because this variable strictly relates to the pine basal area component of the stand.

Because of the limited amount of time given to the Service to complete the mitigation WVAs, field data collection site visits to obtain site specific habitat conditions were not possible. This mitigation site is, however, in proximity to sites where data was collected on the refuge for the impact assessments. In addition, based on aerial imagery, habitat conditions appear to be similar across these locations. We, therefore, assumed that habitat conditions at this mitigation site on BBMNWR are similar to those sites where data was collected on the refuge for the impact assessments.

FWP

We are assuming that mitigation construction will be completed by TY1. Pine stands within the refuge are typically thinned to approximately 80 ft^2/acre BA. Pines in these areas are slower growing then pines in more upland sites and reducing the BA below 80 ft^2/acre would increase the risk of windthrow.

TY0: 34.3 m^2/ha
TY1: 18.4 m^2/ha
TY18: 18.4 m^2/ha
TY35: 18.4 m^2/ha
TY50: 18.4 m^2/ha

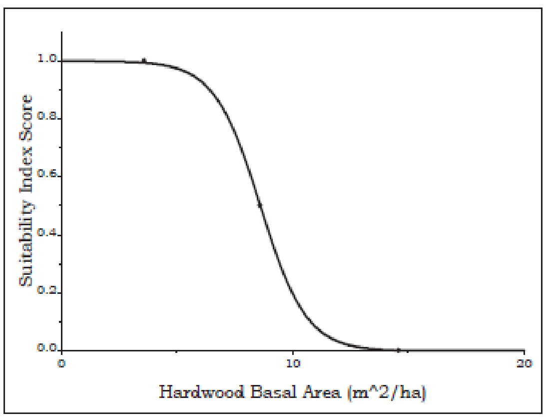
FWOP

We are assuming that without the proposed mitigation activities, the site would not be managed in the future as pine savannah habitat.

TY0: 34 m^2/ha
TY1: 35 m^2/ha
TY20: 56 m^2/ha
TY50: 36 m^2/ha

<u>Variable V4:</u> Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees from plots. This spreadsheet projects individual tree dbh and project site basal area over time. It is important to note that only the hardwood tree field measurements were entered into this ingrowth spreadsheet because this variable strictly relates to the hardwood basal area component of the stands. The pine basal area component of the stands was assessed under V3.

FWP

Pine savannah management practices (e.g., thinnings, burns, herbicide treatments, etc.) would reduce the density of overstory and midstory hardwoods to an approximate basal area of 5 ft^2/acre. This is comparable to other stands on the refuge that are actively being managed for RCWs.

TY0: 19.8 m^2/ha
TY1: 1.2 m^2/ha
TY20: 1.2 m^2/ha
TY50: 1.2 m^2/ha

FWOP

We are assuming that without the proposed mitigation activities, the site would not be managed in the future as pine savannah habitat.

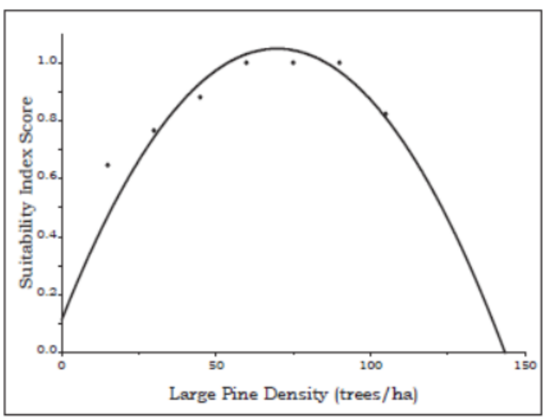
TY0: 19.8 m^2/ha
TY1: 20.8 m^2/ha
TY20: 56.2 m^2/ha
TY50: 57.0 m^2/ha

<u>Variable V5:</u> Relationship between distance to nearest habitat patch and SI

The indirect impact area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

<u>Variable V6:</u> Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

TY0: 21.4 (trees/ha)
TY1: 22.2 (trees/ha)
TY20: 27.2 (trees/ha)

TY50: 49.4 (trees/ha)

FWOP

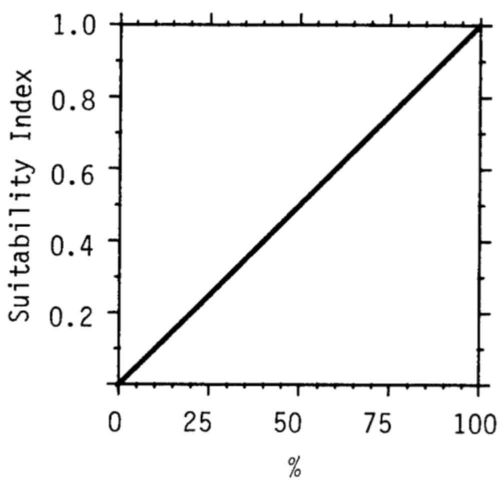
Assumed habitat would not be managed in the future for RCWs.

TY0: 21.4 (trees/ha)
TY1: 22.2 (trees/ha)
TY20: 27.2 (trees/ha)
TY50: 25.5 (trees/ha)

Mitigation Site – BBMNWR PS-1 Pine Warbler

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

It is assumed that thinning and burning to reduce vegetative density (to increase habitat quality for RCWs) of the pine savannah habitat present at TY0 would result in a decrease of pine canopy closure.

TY0: 42 %
TY1: 25%
TY20: 25%
TY50: 25%

FWOP

Assumed that without the proposed mitigation activities, the site would not be managed as pine savannah habitat into the future and would consist of mixed pine/hardwood. Without thinnings and prescribed burns, assumed a dense canopy would exist over the life of the project. While hardwoods comprise a portion of the canopy only pines are considered under this variable.

It is assumed that a slight increase of pine canopy closure would occur over time as pines in midstory reach canopy height.

TY0: 42 %
TY1: 42%
TY20: 50%
TY50 50%

<u>Variable V2:</u> Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

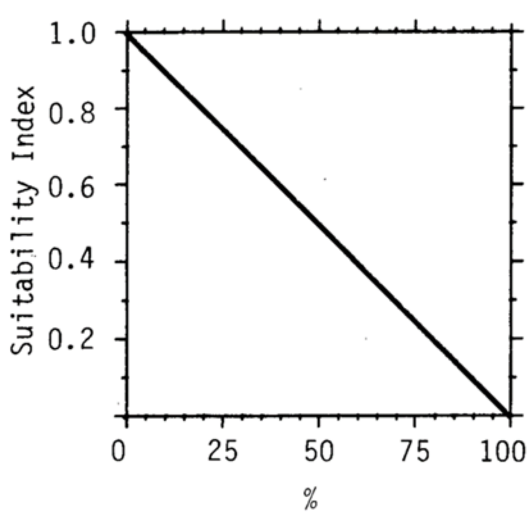
FWP and FWOP

A mature stand is expected to be maintained under both the FWP and FWOP scenarios.

TY0-TY50: 1 SI

<u>Variable V3:</u> Percent of dominant canopy pines with deciduous understory in the upper 1/3 layer

Pine forests with a deciduous understory reaching into the top 1/3 layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

It is assumed that pine savannah management practices (e.g., thinnings, burns, herbicide treatments, etc.) would reduce the density of overstory and midstory hardwoods, thereby reducing the percent of dominant canopy pines with deciduous understory in the upper 1/3 layer.

TY0: 53%
TY1: 5%
TY20: 5%
TY50: 5%

FWOP

It is assumed that there would be an increase under the FWOP scenario as compared to the FWP scenario due to lack of pine savannah management (e.g., thinnings, burnings, herbicide treatments, etc.).

TY0: 53%
TY1: 53%
TY20: 75%
TY50: 90%

<u>Mitigation Site – Camp Whispering Pines PS-25 (Forested) RCW</u>

<u>Variable V1:</u> Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

		Successional age class				
Landform	Landcover Type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

Until recently, Camp Whispering Pines was owned and managed by the Girl Scouts of America as longleaf pine savannah habitat. The property was recently sold to a private entity who has expressed an interest in logging the pines on the site.

FWP

Assumed that logging would not take place and the Camp Whispering Pines mitigation area would continue to be maintained as pine savannah habitat.

TY0-TY50:

Floodplain Valley
Evergreen
Saw Timber

0.8 SI

FWOP

TY0: Baseline Conditions

Floodplain Valley
Evergreen
Saw Timber

0.8 SI

TY1: Assumed that without the proposed mitigation activities the subject site will be logged and all pine removed by TY1. Since prescribed burns are often suppressed on private lands, assumed that burns would not take place under the FWOP scenario resulting in a regenerated mixed pine/hardwood stand.

Floodplain Valley
Mixed
Seedlings

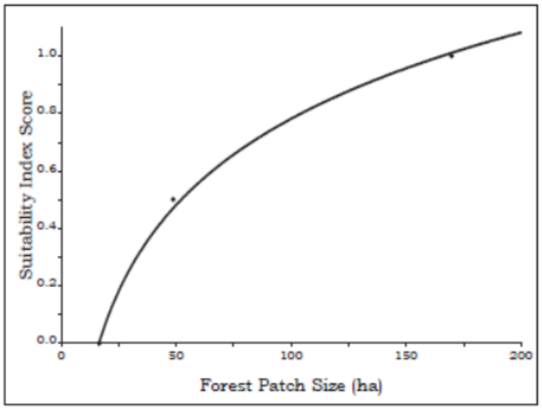
0.0 SI

TY20: Assumed that regenerated trees post harvest have reached pole size timber size by TY20 and saw size by TY50.

TY20: 0.4 SI
TY50: 0.4 SI

Variable V2: Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



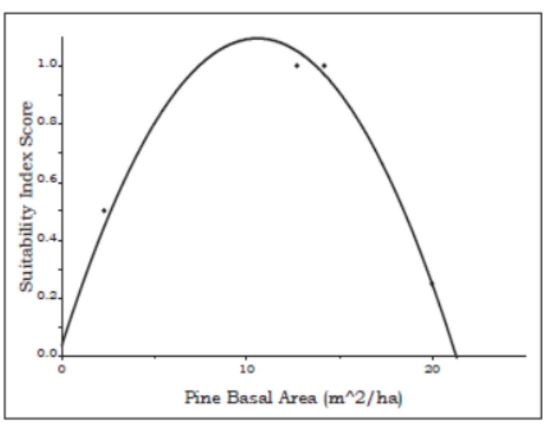
FWP and FWOP

Given the interior location of this mitigation site (north of I-12), RSLR impacts are not expected to extend to this area; therefore, assumed no change to size of contiguous forest under both FWP and FWOP scenarios.

TY0-TY50: 1458.08 ha

Variable V3: Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees.

FWP

Assumed that initial mitigation construction will be completed by TY1. The site is currently managed as pine savannah; accordingly, we assumed that high quality habitat currently exists starting at TY0 and continuing over the life of the project.

TY0-TY50: 11.48 m^2/ha

FWOP

Assumed that without the proposed mitigation activities, the site would be logged and would not be managed as pine savannah habitat into the future.

TY0: Baseline Condition

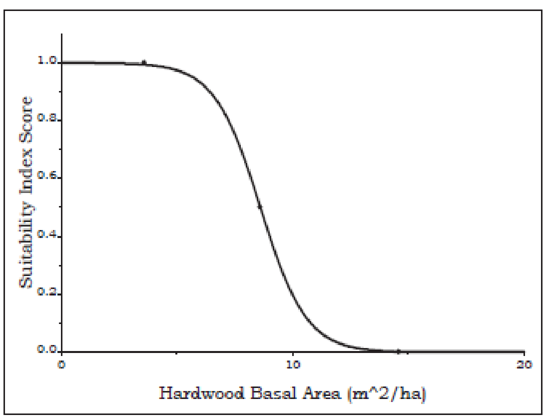
11.48 m^2/ha

TY1-TY50: Assumed as the site regenerates post logging the basal area of pines will increase over time. Used the pine in-growth spreadsheet to determine BAs at given TYs.

TY1: 0.2 m^2/ha
TY20: 20.6 m^2/ha
TY50: 48.5 m^2/ha

<u>Variable V4:</u> Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees.

FWP

Assumed that initial mitigation construction will be completed by TY1. Given that the site is currently managed as pine savannah habitat, we assumed that hardwood midstory and understory control would continue over the life of the project.

TY0-TY50: 1.15 m^2/ha

FWOP

The proposed project was sold to a private entity who has expressed intention to log the site. Assumed that without the proposed mitigation activities the site would be logged and would not be managed as pine savannah habitat into the future.

TY0: Baseline Condition
1.15 m^2/ha

TY1-TY50: Assumed that the proposed site would not be managed as pine savannah habitat into the future. Also assumed that as the sites regenerates the basal area of hardwoods would increase over time.

TY1: 0.16 m^2/ha
TY20: 7.58 m^2/ha
TY50: 28.21 m^2/ha

<u>Variable V5:</u> Relationship between distance to nearest habitat patch and SI

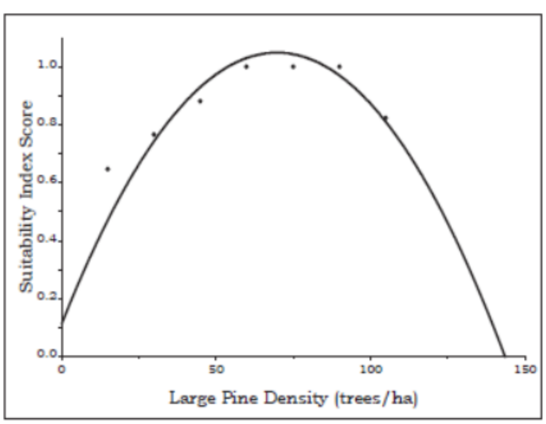
The proposed mitigation area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP and FWOP

TY0-50: 0 m

<u>Variable V6:</u> Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Assumed that initial mitigation construction will be completed by TY1. The site is currently managed as pine savannah habitat with mature trees present. Assumed that any thinnings necessary would be conducted by TY1 and high quality pine savannah habitat would be maintained over the life of the project.

TY0-TY50: 74 (trees/ha)

FWOP

The proposed project was sold to a private entity who has expressed intention to log the site. Assumed that without the proposed mitigation activities the site would be logged and would not be managed as pine savannah habitat into the future.

TY0: Baseline Conditions
74 (trees/ha)

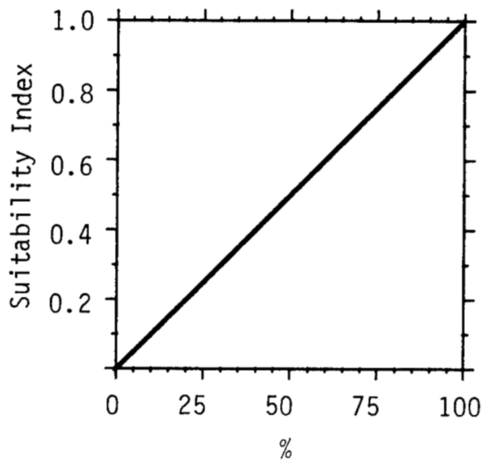
TY1-TY50: Assumed that pine trees that have regenerated after harvest will not have reached 35 cm or greater until TY50.

TY0: 0 (trees/ha)
TY1: 0 (trees/ha)
TY20: 0 (trees/ha)
TY50: 32 (trees/ha)

Mitigation Site – Camp Whispering Pines PS-25 (Forested) Pine Warbler

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

Assumed that logging would not take place and the Camp Whispering Pines mitigation area would continue to be maintained as high quality pine savannah habitat.

TY0: 25%
TY1: 25%
TY20: 25%
TY50: 25%

FWOP

Assumed that without the proposed mitigation activities, the site would be logged and would not be managed as pine savannah habitat into the future.

TY0: Baseline Conditions
25%

TY1: Assumed that without the proposed mitigation activities the subject site will be logged and all pine removed. Assumed at TY1 regenerated trees would be 1 year old and would not have reached canopy height.

TY1: 0%

TY20-TY50: Assumed that without pine savannah management practices a dense pine/hardwood stand would regenerate post harvest; therefore, estimated an increasing pine canopy closure over time.

TY20: 40%
TY50: 50%

<u>**Variable V2:**</u> Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

FWP

A mature stand is expected to be maintained under the FWP scenario.

TY0-TY50: 1 SI

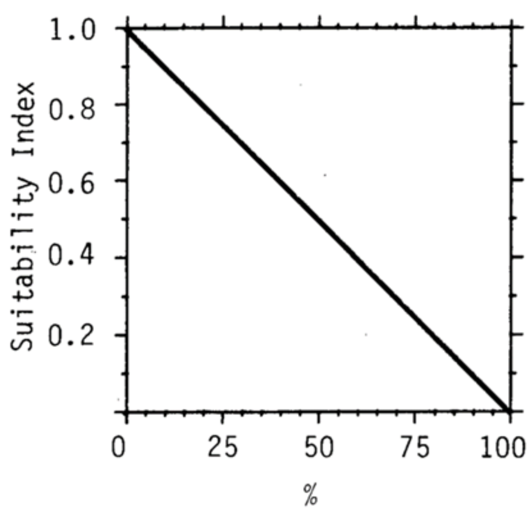
FWOP

Assumed that logging would take place by TY1 and site would regenerate naturally.

TY0: Baseline Conditions
1 SI
TY1: 0 SI
TY20: 0.5 SI
TY50: 1.0 SI

<u>Variable V3:</u> Percent of dominant canopy pines with deciduous understory in the upper 1/3 layer

Pine forests with a deciduous understory reaching into the top 1/3 layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

Assumed that logging would not take place and the Camp Whispering Pines mitigation area would continue to be maintained as pine savannah habitat with low percentage of hardwoods in the upper $^{1}/_{3}$ layer.

TY0-TY50: 5%

FWOP

Assumed that site would be logged by TY1. In the absence of pine savannah management, the percent of hardwood midstory and understory would be a significant portion of the canopy, resulting in a large percentage of overstory pines with deciduous understory in the upper $^{1}/_{3}$ layer.

TY0: Baseline Conditions
5%

TY1: Sapling trees present post harvest
0%

TY20: 75%
TY50: 90%

Mitigation Site – Camp Whispering Pines PS-25 (Cleared) RCW

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

Landform	Landcover Type	Successional age class				
		Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

Until recently, Camp Whispering Pines was owned by the Girl Scouts of America with a majority of the property managed as longleaf pine savannah habitat. There are cleared areas, however, within the Camp Whispering Pine tract that could be restored and managed as pine savannah habitat into the future.

FWP

Assumed that the currently cleared areas are dominated by grasses/forbes.

TY0: Baseline Conditions

Floodplain Valley
Low Density Residential
Grass/Forb

0.0 SI

Assumed that longleaf pine plantings would take place and the site managed as pine savannah over the project life.

TY1: Assumed recent plantings, therefore, seedlings at TY1

Floodplain Valley
Evergreen
Seedling

0.0 SI

Assumed that planted longleaf have reached pole size timber by TY20 and saw size by TY50.

TY20:

Floodplain Valley
Evergreen
Pole

0.6 SI

TY50:

Floodplain Valley
Evergreen
Saw

0.8 SI

FWOP

TY0: Baseline Conditions

Floodplain Valley
Low Density Residential
Grass/Forb

0.0 SI

TY1: Assumed that without the proposed mitigation activities the currently cleared sites would naturally regenerate as a mixed pine/hardwood stand.

Floodplain Valley
Mixed
Seedling

0.0 SI

TY20-50: Assumed that the stand is comprised of timber size by TY20 and saw size by TY50. Since prescribed burns are often suppressed on private lands, assumed that burns would not take place under the FWOP scenario resulting in a regenerated mixed pine/hardwood stand.

TY20:

Floodplain Valley
Mixed
Pole

0.4 SI

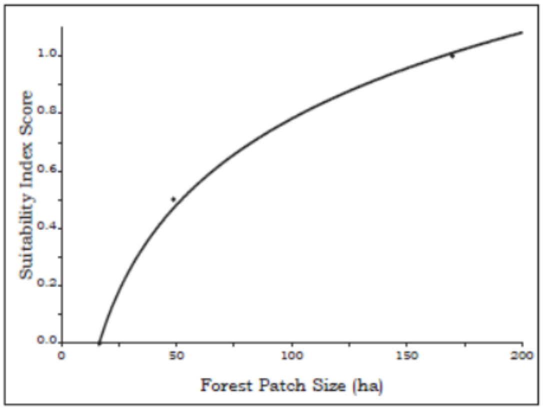
TY50:

Floodplain Valley
Mixed
Saw

0.4 SI

<u>Variable V2:</u> Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



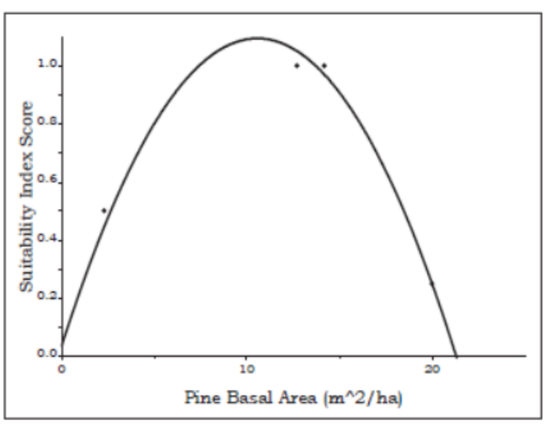
FWP and FWOP

Given the interior location of this mitigation site (north of I-12), RSLR impacts are not expected to extend to this area; therefore, assumed no change to size of contiguous forest under both FWP and FWOP scenarios.

TY0-TY50: 1458.08 ha

<u>Variable V3:</u> Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees.

FWP

Assumed that longleaf pine plantings will be completed by TY1 and pine basal area would increase over time.

TY0: Baseline Condition
0 m^2/ha

TY1-TY50: Assumed as the pines mature on-site the basal area will increase.

TY1: 0.2 m^2/ha
TY20: 20.6 m^2/ha

TY50: Assumed that at TY50 the sight would have been thinned to maintain high quality pine savannah habitat.
11.5 m^2/ha

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand.

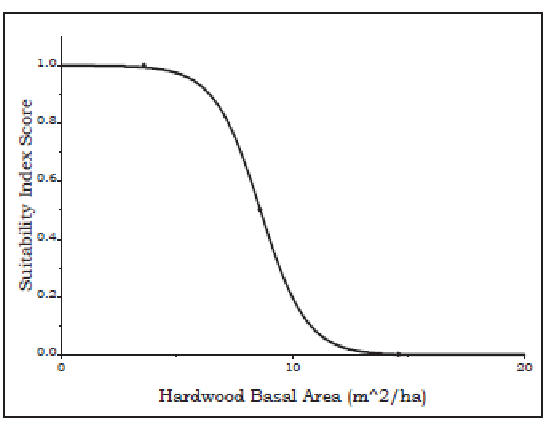
TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed that cleared areas are no longer maintained and regeneration begins. Assumed as the site regenerates the basal area of pines will increase over time.

TY1: 0.2 m^2/ha
TY20: 20.6 m^2/ha
TY50: 48.5 m^2/ha

__Variable V4:__ Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees.

FWP

Assumed that initial mitigation construction will be completed by TY1. Given that the site would be managed as pine savannah habitat, we assumed that management (i.e., prescribed burns, herbicide treatments, etc.) would result in low hardwood basal areas over the project life.

TY0: Baseline Conditions:
0 m^2/ha

TY1: Assumed that cleared areas are planted with longleaf pine at TY1.
0.2 m^2/ha

TY20-TY50: Assumed hardwood midstory control.
1.15 m^2/ha

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand.

TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed that the proposed site would not be managed as pine savannah habitat into the future. Also assumed that as the sites regenerates the basal area of hardwoods would increase

TY1: 0.16 m^2/ha
TY20: 7.58 m^2/ha
TY50: 28.21 m^2/ha

Variable V5: Relationship between distance to nearest habitat patch and SI

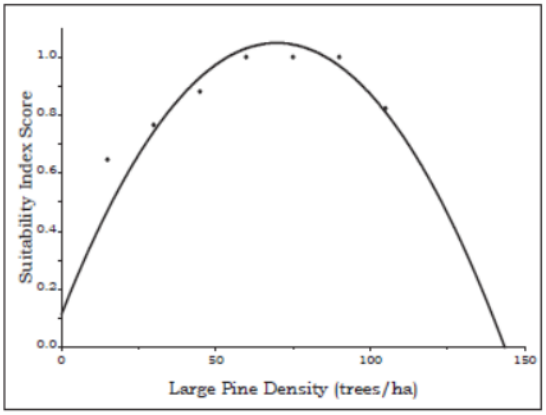
The proposed mitigation area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP and FWOP

TY0-50: 0 m

Variable V6: Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Assumed that longleaf pine trees will be planted and would reach >35 cm dbh by TY50.

TY0-TY20: 0 (trees/ha)
TY50: 74 (trees/ha)

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand. Assume natural regeneration begins at TY1.

TY0: Baseline Conditions
0 (trees/ha)

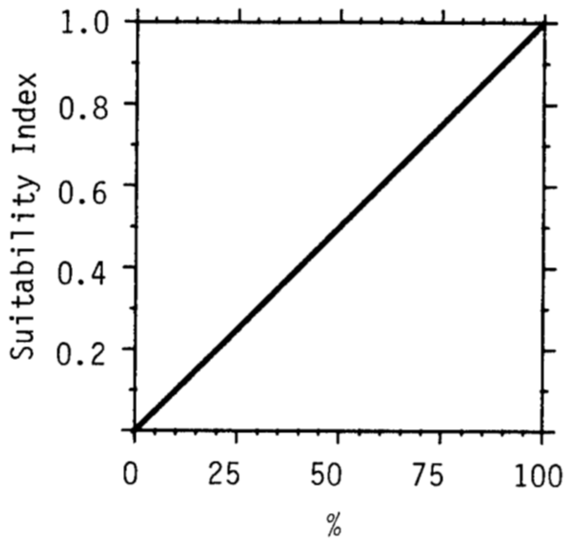
TY1-TY50: Assumed that pine trees that have regenerated after harvest will not have reached 35 cm or greater until TY50. Under this scenario have hardwoods in the midstory and overstory limiting the number of large pines as compared to the FWP scenario.

TY0-TY20: 0 (trees/ha)
TY50: 32 (trees/ha)

Mitigation Site – Camp Whispering Pines PS-25 (Cleared) Pine Warbler

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

Assumed longleaf pine plantings will be completed by TY1.

TY0: Baseline Conditions
0%

TY1: Planted longleaf have not reached canopy height
0%

TY20: Assumed first thinnings have been conducted and as pines mature the percent canopy closure would increase.
30%

TY50: Assumed that thinning and burning to reduce vegetative density (to increase habitat quality for RCWs) of the pine savannah habitat present would result in a decrease of pine canopy closure.
25%

FWOP

Assumed that without the proposed mitigation activities, the site would not be managed as pine savannah habitat into the future and would regenerate as a pine/hardwood stand.

TY0-TY1: Assumed at TY1 regenerated trees would be 1 year old and would not have reached canopy height.

0%

TY20-TY50: Assumed that without pine savannah management practices a dense pine/hardwood stand would regenerate post harvest; therefore, estimated an increasing pine canopy closure over time.

TY20: 40%
TY50: 50%

<u>Variable V2:</u> Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

FWP and FWOP

TY0-TY1: Assumed saplings dominate area

0 SI

TY20: Assumed young stand

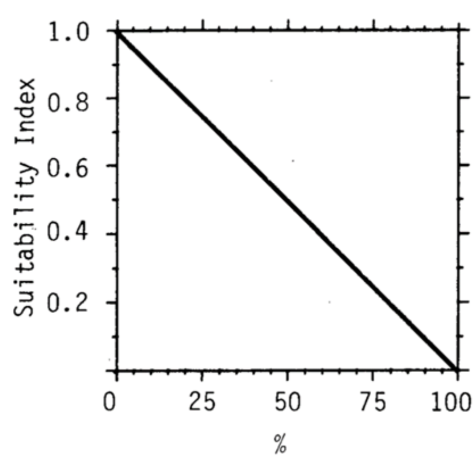
.5 SI

TY50: Assumed mature stand

1.0 SI

<u>Variable V3:</u> Percent of dominant canopy pines with deciduous understory in the upper 1/3 layer

Pine forests with a deciduous understory reaching into the top 1/3 layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

Assumed that pine savannah management techniques would limit the percentage of hardwoods in the upper $^{1}/_{3}$ layer.

TY0-TY1: Assumed saplings present, no trees in the canopy
0%

TY20-TY50: Assumed low density of hardwoods due to pine savannah management.
5%

FWOP

Assumed that in the absence of pine savannah management, the percent of hardwood midstory and understory would be a significant portion of the canopy, resulting in a large percentage of overstory pines with deciduous understory in the upper $^{1}/_{3}$ layer.

TY0-TY1: No canopy trees present
0%
TY20: 75%
TY50: 90%

Mitigation Site –PS-7 (Forested) RCW

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

		Successional age class				
Landform	Landcover Type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

FWP

TY0: Baseline Conditions

Floodplain Valley
Mixed
Saw Timber

0.4

TY1-TY50: Assumed thinnings and hardwood control in existing forested area would be complete by TY1, resulting in an evergreen stand.

Floodplain Valley
Evergreen
Saw Timber

0.8 SI

FWOP

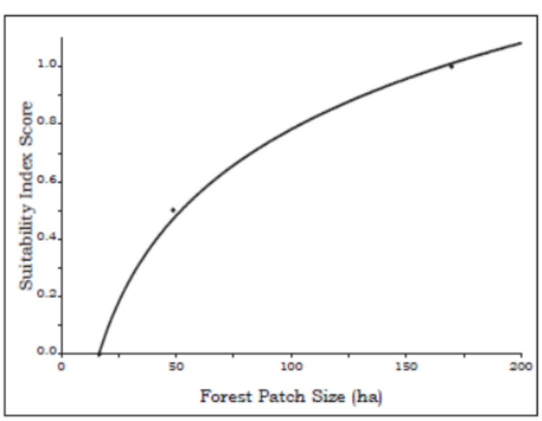
TY0-TY50: Since prescribed burns are often suppressed on private lands, assumed that without the proposed mitigation activities the subject site would consist of a mixed pine/hardwood stand into the future.

Floodplain Valley
Mixed
Saw Timber

0.4 SI

__Variable V2:__ Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



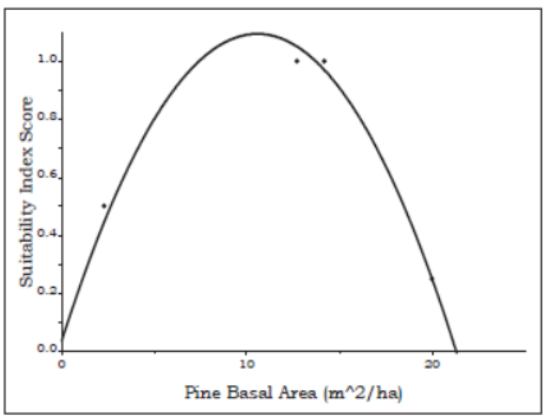
FWP and FWOP

Given the interior location of this mitigation site (north of I-12), RSLR impacts are not expected to extend to this area; therefore, assumed no change to size of contiguous forest under both FWP and FWOP scenarios.

TY0-TY50: 1078.45 ha

__Variable V3:__ Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions - Assumed that forested portions of mitigation site were comprised of a mixed pine/hardwood with an average age of 30 years. Used the pine in-growth spreadsheet to estimate BAs.

32.2 m^2/ha

TY1-TY50: Assuming that the site is currently dominated by mature pine trees in the overstory, any necessary thinning and burning would result in pine savannah habitat starting at TY1 and continuing over the life of the project.

11.48 m^2/ha

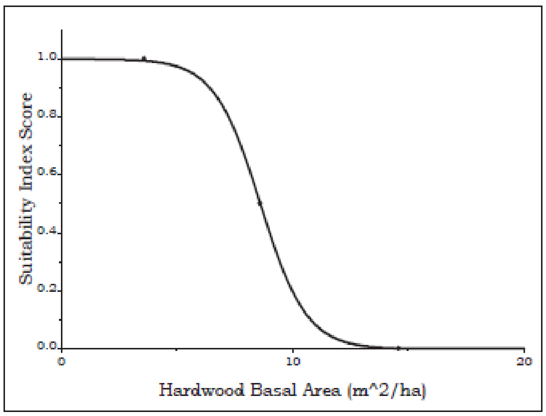
FWOP

Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Assumed site consists of 30 year old pines at TY0 and used the pine in-growth spreadsheet to estimate BA over time.

TY0: 32.2 m^2/ha
TY1: 33.5 m^2/ha
TY20: 48.5 m^2/ha
TY50: 42.7 m^2/ha

Variable V4: Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions - Assumed that forested portions of mitigation site were comprised of a mixed pine/hardwood with an average age of 30 years. Used the hardwood in-growth spreadsheet to estimate BAs.

14.2 m^2/ha

Assumed that mitigation construction will be completed by TY1. Given that the site would be managed as pine savannah habitat, we assumed that hardwood midstory and understory control would be conducted over the life of the project.

TY1-TY50: 1.15 m^2/ha

FWOP

Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Used hardwood in-growth spreadsheet to estimate BA starting with a 30-year-old stand.

TY0: 14.2 m^2/ha
TY1: 14.9 m^2/ha
TY20: 28.2 m^2/ha
TY50: 43.7 m^2/ha

<u>Variable V5:</u> Relationship between distance to nearest habitat patch and SI

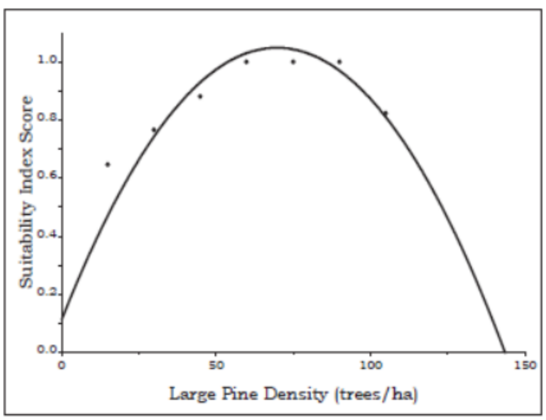
The proposed mitigation area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP and FWOP

TY0-50: 0 m

<u>Variable V6:</u> Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Used pine in-growth spreadsheet to estimate the number of large pines starting with a 30-year-old stand. Assumed that any thinnings necessary would be conducted by TY1 and high quality pine savannah habitat would be maintained over the life of the project. With more open canopy, assumed pine regeneration and trees reaching >35cm by TY20.

TY0: 0 (trees/ha)
TY1: 0 (trees/ha)
TY20: 74 (trees/ha)

TY50: 74 (trees/ha)

FWOP

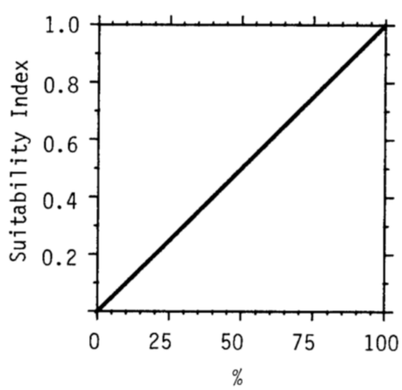
Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Used pine in-growth spreadsheet to estimate the number of large pines starting with a 30-year-old stand. A more closed canopy is anticipated under the FWOP; however, assumed pine trees/ha would be lower under FWOP due to increased hardwood competition.

TY0: 0 (trees/ha)
TY1: 0 (trees/ha)
TY20: 32 (trees/ha)
TY50: 20 (trees/ha)

Mitigation Site – PS-7 (Forested) Pine Warbler

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

TY0: Baseline Conditions – Since prescribed burns are often suppressed on private lands, assumed that a mixed pine/hardwood stand currently exists with a dense canopy cover. While hardwoods comprise a portion of the canopy only pines are considered under this variable.
50%

TY1-TY50: Assumed initial pine savannah construction will be completed by TY1. Pine savannah management practices will result in an open pine canopy over the life of the project.
25%

FWOP

Assumed that without the proposed mitigation activities, the site would not be managed as pine savannah habitat into the future and would consist of mixed pine/hardwood. Without thinnings and prescribed burns, assumed a dense canopy would exist over the life of the project. While hardwoods comprise a portion of the canopy only pines are considered under this variable.

TY0-TY50: 50%

<u>Variable V2:</u> Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

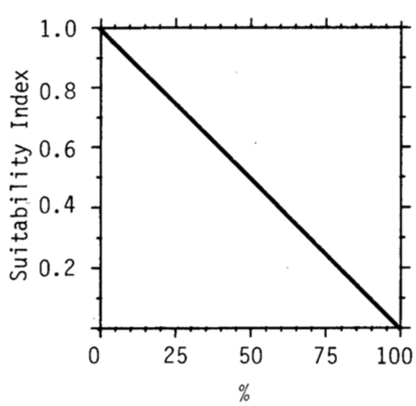
FWP and FWOP

Assumed a mature stand of trees would continue to exist on the site under both the FWP and FWOP scenarios.

TY0-TY50: 1.0 SI

<u>Variable V3:</u> Percent of dominant canopy pines with deciduous understory in the upper $^{1}/_{3}$ layer

Pine forests with a deciduous understory reaching into the top $^{1}/_{3}$ layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

TY0: Baseline Conditions - Since prescribed burns are often suppressed on private lands, assumed that a mixed pine/hardwood stand currently exists a high percentage of hardwoods present in the upper $^{1}/_{3}$ layer.

90%

TY1-TY50: Pine savannah management techniques would limit the percentage of hardwoods in the upper $^{1}/_{3}$ layer.

5%

FWOP

Assumed that in the absence of pine savannah management, the percent of hardwoods would be a significant portion of the canopy, resulting in a large percentage of overstory pines with deciduous understory in the upper $^{1}/_{3}$ layer.

TY0-50: 90%

Mitigation Site – PS-7 (Cleared) RCW

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

		Successional age class				
Landform	Landcover Type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

FWP

Assumed that longleaf pine plantings would take place and the site managed as pine savannah over the project life.

TY0: Baseline Conditions

Floodplain Valley
Low Density Residential
Grass/Forb

0.0 SI

TY1: Assumed recent plantings, therefore, saplings at TY1

Floodplain Valley
Evergreen
Seedlings

0.0 SI

TY20: Assumed that planted longleaf have reached pole size timber.

Floodplain Valley
Evergreen
Pole

0.6 SI

TY50. Assumed that planted longleaf have reached saw size timber.

Floodplain Valley
Evergreen
Saw

0.8 SI

FWOP

TY0: Baseline Conditions

Floodplain Valley
Low Density Residential
Grass/Forb

0.0 SI

TY1: Since prescribed burns are often suppressed on private lands, assumed that burns would not take place under the FWOP scenario resulting in a regenerated mixed pine/hardwood stand. Thus, the currently cleared sites would naturally regenerate as a mixed pine/hardwood stand.

Floodplain Valley

Mixed
Seedlings

0.0 SI

TY20: Assumed the stand is comprised of pole size timber.

Floodplain Valley
Mixed
Pole

0.4 SI

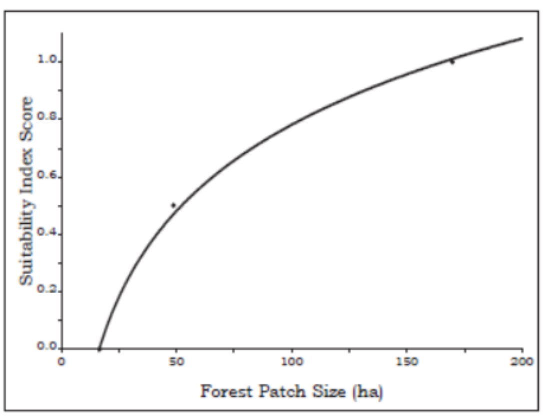
TY50: Assume the stand is comprised of saw size timber.

Floodplain Valley
Mixed
Saw

0.4 SI

<u>Variable V2:</u> Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



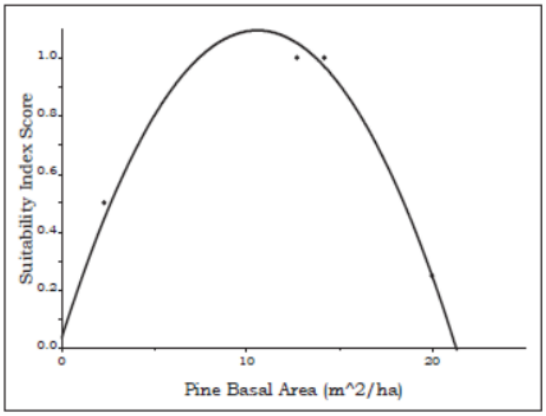
FWP and FWOP

Given the interior location of this mitigation site (north of I-12), RSLR impacts are not expected to extend to this area; therefore, assumed no change to size of contiguous forest under both FWP and FWOP scenarios.

TY0-TY50: 1078.45 ha

Variable V3: Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees.

FWP

Assumed that longleaf pine plantings will be completed by TY1 and pine basal area would increase over time.

TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed that cleared areas are planted with longleaf pine at TY1. As the pines mature on-site the basal area will increase.

TY1: 0.2 m^2/ha
TY20: 20.6 m^2/ha

TY50: Assumed that at TY50 the sight would have been thinned to maintain high quality pine savannah habitat.
11.5 m^2/ha

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand.

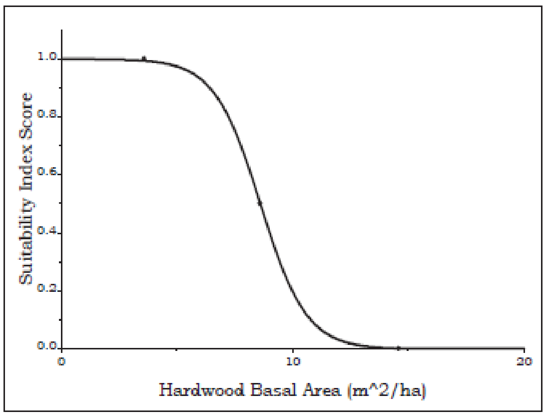
TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed as the site regenerates the basal area of pines will increase over time.

TY1: 0.2 m^2/ha
TY20: 20.6 m^2/ha
TY50: 48.5 m^2/ha

<u>Variable V4:</u> Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed that initial mitigation construction will be completed by TY1. Given that the site would be managed as pine savannah habitat, we assumed that management (i.e., prescribed burns, herbicide treatments, etc.) would result in low hardwood basal areas over the project life.

TY1: .0.2 m^2/ha

TY20-TY50: Assumed hardwood midstory control.
1.15 m^2/ha

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand.

TY0: 0 m^2/ha

TY1-TY50: Assumed that the proposed site would not be managed as pine savannah habitat into the future. Also assumed that as the sites regenerates the basal area of hardwoods would increase

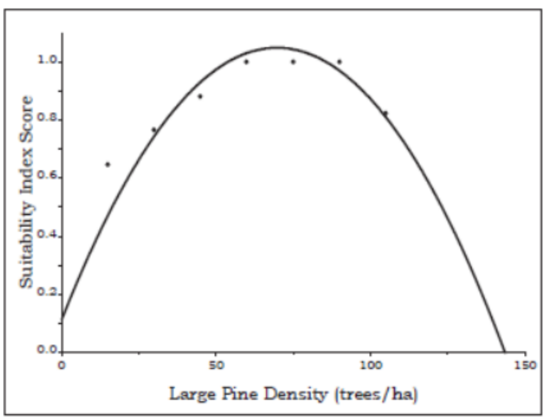
TY1: 0.16 m^2/ha
TY20: 7.58 m^2/ha
TY50: 28.21 m^2/ha

<u>Variable V5:</u> Relationship between distance to nearest habitat patch and SI

The proposed mitigation area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

<u>Variable V6:</u> Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Assumed that pine trees will be planted at TY1. Assume that trees planted at TY0 would reach >35 cm dbh by TY50.

TY0: Baseline Conditions
0 (trees/ha)
TY1-TY20: 0 (trees/ha)
TY50: 74 (trees/ha)

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand. Assume natural regeneration begins at TY1.

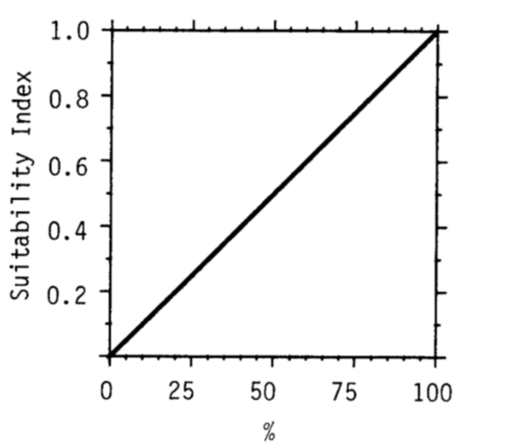
TY0: Baseline Conditions
0 (trees/ha)

TY1-TY50: Assumed that pine trees that have regenerated will not have reached 35 cm or greater until TY50. Under this scenario have hardwoods in the midstory and overstory limiting the number of large pines as compared to the FWP scenario.

TY1-TY20: 0 (trees/ha)
TY50: 32 (trees/ha)

Mitigation Site – PS-7 (Cleared) Pine Warbler

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)
Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

Assumed longleaf pine plantings will be completed by TY1.

TY0: Baseline Conditions
0%

TY1: Planted longleaf pine trees have not reached canopy height
0%

TY20: Assumed first thinnings have been conducted and as pines mature the percent canopy closure would increase.
30%

TY50: Assumed that thinning and burning to reduce vegetative density (to increase habitat quality for RCWs) of the pine savannah habitat present would result in a decrease of pine canopy closure.
25%

FWOP

Assumed that without the proposed mitigation activities, the site would not be managed as pine savannah habitat into the future and would consist of mixed pine/hardwood. Without thinnings and prescribed burns, assumed a dense canopy would exist over the life of the project. While hardwoods comprise a portion of the canopy only pines are considered under this variable.

TY0: Baseline Conditions
0%

TY1: Assumed at TY1 regenerated trees would be 1 year old and would not have reached canopy height.
0%

TY20-TY50: Assumed that without pine savannah management practices a dense pine/hardwood stand would regenerate; therefore, estimated an increasing pine canopy closure over time.

TY20: 40%
TY50: 50%

<u>Variable V2:</u> Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

FWP and FWOP

Assumed regeneration begins at TY0

TY0-TY1: Assumed saplings dominate area
0 SI

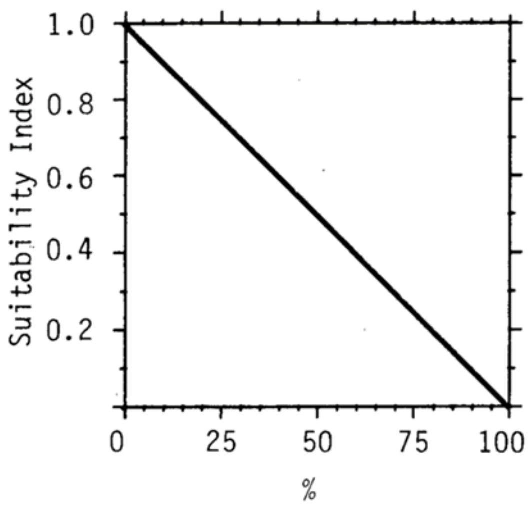
TY20: Assumed young stand
.5 SI

TY50: Assumed mature stand

1.0 SI

Variable V3: Percent of dominant canopy pines with deciduous understory in the upper 1/3 layer

Pine forests with a deciduous understory reaching into the top 1/3 layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

Assumed that pine savannah management techniques would limit the percentage of hardwoods in the upper 1/3 layer.

TY0-TY1: Assumed seedlings present, no trees in the canopy
0%

TY20-TY50: Assumed low density of hardwoods due to pine savannah management.
5%

FWOP

Assumed that in the absence of pine savannah management, the percent of hardwood midstory and understory would be a significant portion of the canopy, resulting in a large percentage of overstory pines with deciduous understory in the upper 1/3 layer.

TY0-TY1: No canopy trees present
0%
TY20: 75%

TY50: 90%

Mitigation Site –PS-6 (Forested) RCW

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

Landform	Landcover Type	Successional age class Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

FWP

TY0: Baseline Conditions

Floodplain Valley
Mixed
Saw Timber

0.4

TY1-TY50: Assumed thinnings and hardwood control in existing forested area would be complete by TY1, resulting in an evergreen stand.

Floodplain Valley
Evergreen
Saw Timber

0.8 SI

FWOP

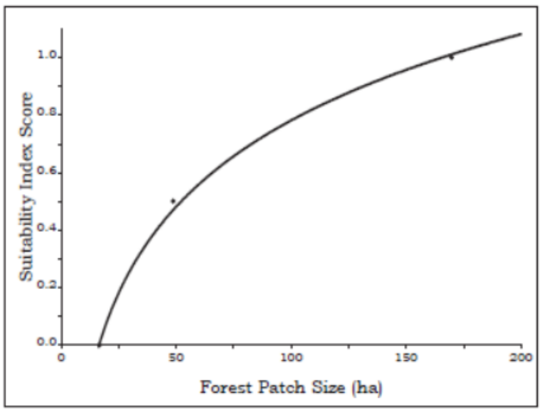
TY0-TY50: Since prescribed burns are often suppressed on private lands, assumed that without the proposed mitigation activities the subject site would consist of a mixed pine/hardwood stand into the future.

Floodplain Valley
Mixed
Saw Timber

0.4 SI

Variable V2: Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



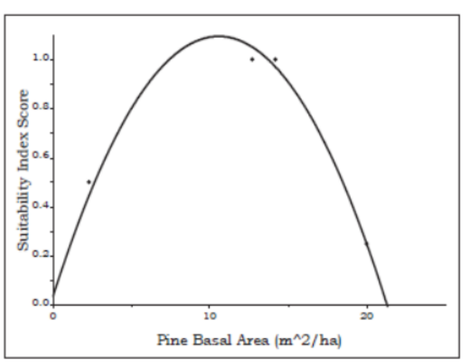
FWP and FWOP

Given the interior location of this mitigation site (north of I-12), RSLR impacts are not expected to extend to this area; therefore, assumed no change to size of contiguous forest under both FWP and FWOP scenarios.

TY0-TY50: 566.67 ha

Variable V3: Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions - Assumed that forested portions of mitigation site were comprised of a mixed pine/hardwood with an average age of 30 years. Used the pine in-growth spreadsheet to estimate BAs.

32.2 m^2/ha

TY1-TY50: Assuming that the site is currently dominated by mature pine trees in the overstory, any necessary thinning and burning would result in pine savannah habitat starting at TY1 and continuing over the life of the project.

11.48 m^2/ha

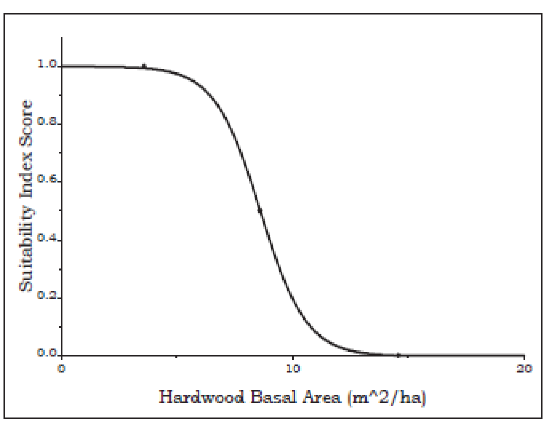
FWOP

Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Assumed site consists of 30 year old pines at TY0 and used the pine in-growth spreadsheet to estimate BA.

TY0: 32.2 m^2/ha
TY1: 33.5 m^2/ha
TY20: 48.5 m^2/ha
TY50: 42.7 m^2/ha

<u>**Variable V4:**</u> Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions - Assumed that forested portions of mitigation site were comprised of a mixed pine/hardwood with an average age of 30 years. Used the hardwood in-growth spreadsheet to estimate BAs.

14.2 m^2/ha

Assumed that mitigation construction will be completed by TY1. Given that the site would be managed as pine savannah habitat, we assumed that hardwood midstory and understory control would be conducted over the life of the project.

TY1-TY50: 1.15 m^2/ha

FWOP

Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Used hardwood in-growth spreadsheet to estimate BA starting with a 30-year-old stand.

TY0: 14.2 m^2/ha
TY1: 14.9 m^2/ha
TY20: 28.2 m^2/ha
TY50: 43.7 m^2/ha

Variable V5: Relationship between distance to nearest habitat patch and SI

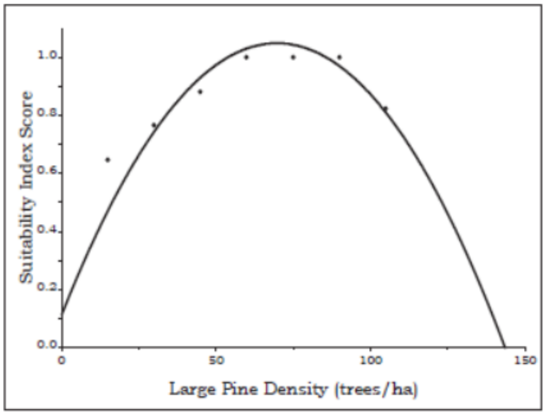
The proposed mitigation area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP and FWOP

TY0-50: 0 m

Variable V6: Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Used pine in-growth spreadsheet to estimate the number of large pines starting with a 30-year-old stand. Assumed that any thinnings necessary would be conducted by TY1 and high quality pine savannah habitat would be maintained over the life of the project. With more open canopy, assumed pine regeneration and trees reaching >35cm by TY20.

TY0: 0 (trees/ha)
TY1: 0 (trees/ha)
TY20: 74 (trees/ha)
TY50: 74 (trees/ha)

FWOP

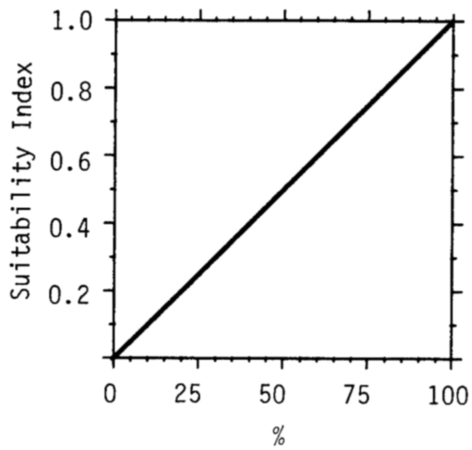
Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Used pine in-growth spreadsheet to estimate the number of large pines starting with a 30-year-old stand. A more closed canopy is anticipated under the FWOP; however, assumed pine trees/ha would be lower under FWOP due to increased hardwood competition.

TY0: 0 (trees/ha)
TY1: 0 (trees/ha)
TY20: 32 (trees/ha)
TY50: 20 (trees/ha)

Mitigation Site – PS-6 (Forested) Pine Warbler

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

TY0: Baseline Conditions – Since prescribed burns are often suppressed on private lands, assumed that a mixed pine/hardwood stand currently exists with a dense canopy cover. While hardwoods comprise a portion of the canopy only pines are considered under this variable.
50%

TY1-TY50: Assumed initial pine savannah construction will be completed by TY1. Pine savannah management practices will result in an open pine canopy over the life of the project.
25%

FWOP

Assumed that without the proposed mitigation activities, the site would not be managed as pine savannah habitat into the future and would consist of mixed pine/hardwood. Without thinnings and prescribed burns, assumed a dense canopy would exist over the life of the project. While hardwoods comprise a portion of the canopy only pines are considered under this variable.

TY0-TY50: 50%

<u>Variable V2:</u> Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

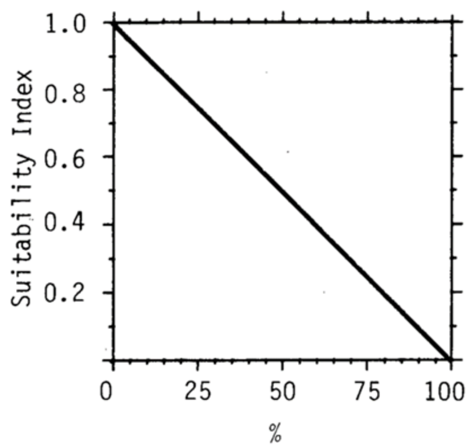
FWP and FWOP

Assumed a mature stand of trees would continue to exist on the site under both the FWP and FWOP scenarios.

TY0-TY50: 1.0 SI

<u>Variable V3:</u> Percent of dominant canopy pines with deciduous understory in the upper $^{1}/_{3}$ layer

Pine forests with a deciduous understory reaching into the top $^{1}/_{3}$ layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

TY0: Baseline Conditions - Since prescribed burns are often suppressed on private lands, assumed that a mixed pine/hardwood stand currently exists a high percentage of hardwoods present in the upper $^{1}/_{3}$ layer.

90%

TY1-TY50: Pine savannah management techniques would limit the percentage of hardwoods in the upper $^{1}/_{3}$ layer.

5%

FWOP

Assumed that in the absence of pine savannah management, the percent of hardwoods would be a significant portion of the canopy, resulting in a large percentage of overstory pines with deciduous understory in the upper $^{1}/_{3}$ layer.

TY0-50: 90%

<u>Mitigation Site – PS-6 (Cleared) RCW</u>

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

		Successional age class				
Landform	Landcover Type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

FWP

Assumed that longleaf pine plantings would take place and the site managed as pine savannah over the project life.

TY0: Baseline Conditions

Floodplain Valley
Low Density Residential
Grass/Forb

0.0 SI

TY1: Assumed recent plantings, therefore, seedlings at TY1

Floodplain Valley
Evergreen
Seedlings

0.0 SI

TY20: Assumed that planted longleaf have reached pole size timber.

Floodplain Valley
Evergreen
Pole

0.6 SI

TY50: Assumed that planted longleaf have reached saw size timber.

Floodplain Valley
Evergreen
Saw

0.8 SI

FWOP

TY0: Baseline Conditions

Floodplain Valley
Low Density Residential
Grass/Forb

0.0 SI

TY1: Since prescribed burns are often suppressed on private lands, assumed that burns would not take place under the FWOP scenario resulting in a regenerated mixed pine/hardwood stand. Thus, the currently cleared sites would naturally regenerate as a mixed pine/hardwood stand.

Floodplain Valley
Mixed
Seedlings

0.0 SI

TY20: Assumed the stand is comprised of pole size timber.

Floodplain Valley
Mixed
Pole

0.4 SI

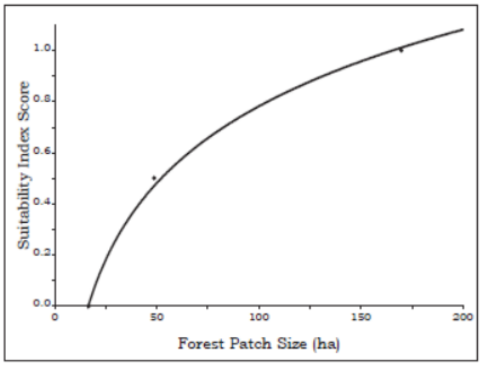
TY50: Assume the stand is comprised of saw size timber.

Floodplain Valley
Mixed
Saw

0.4 SI

<u>Variable V2:</u> Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



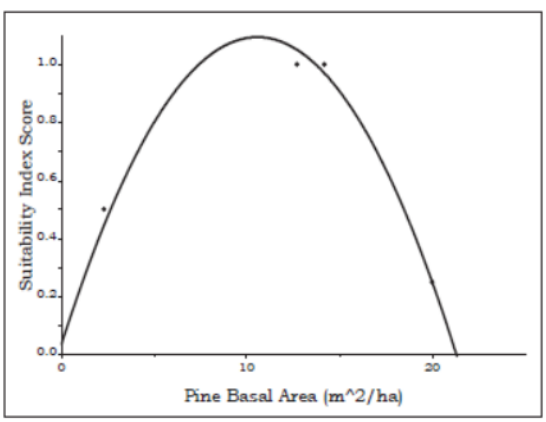
FWP and FWOP

Given the interior location of this mitigation site (north of I-12), RSLR impacts are not expected to extend to this area; therefore, assumed no change to size of contiguous forest under both FWP and FWOP scenarios.

TY0-TY50: 1078.45 ha

<u>Variable V3:</u> Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees.

FWP

Assumed that longleaf pine plantings will be completed by TY1 and pine basal area would increase over time.

TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed that cleared areas are planted with longleaf pine at TY1. As the pines mature on-site the basal area will increase.

TY1: 0.2 m^2/ha
TY20: 20.6 m^2/ha

TY50: Assumed that at TY50 the sight would have been thinned to maintain high quality pine savannah habitat.
11.5 m^2/ha

FWOP

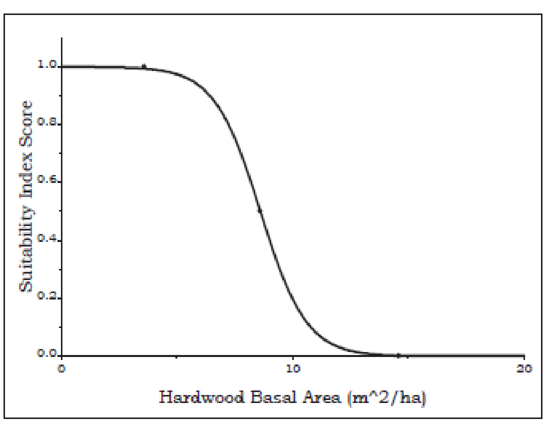
Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand.

TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed as the site regenerates the basal area of pines will increase over time.
TY1: 0.2 m^2/ha
TY20: 20.6 m^2/ha
TY50: 48.5 m^2/ha

<u>Variable V4:</u> Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed that initial mitigation construction will be completed by TY1. Given that the site would be managed as pine savannah habitat, we assumed that management (i.e., prescribed burns, herbicide treatments, etc.) would result in low hardwood basal areas over the project life.

TY1: 0.2 m^2/ha

TY20-TY50: Assumed hardwood midstory control.
1.15 m^2/ha

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand.

TY0: 0 m^2/ha

TY1-TY50: Assumed that the proposed site would not be managed as pine savannah habitat into the future. Also assumed that as the sites regenerates the basal area of hardwoods would increase

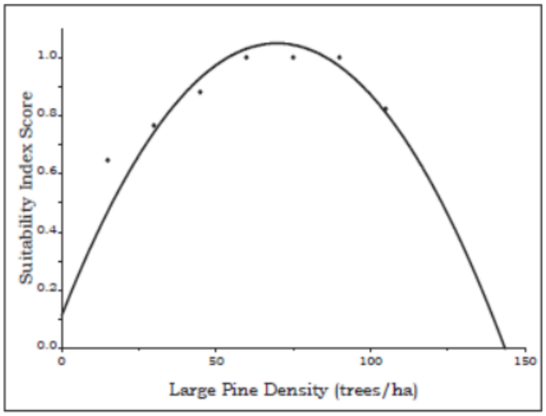
TY1: 0.16 m^2/ha
TY20: 7.58 m^2/ha
TY50: 28.21 m^2/ha

<u>Variable V5:</u> Relationship between distance to nearest habitat patch and SI

The proposed mitigation area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

<u>Variable V6:</u> Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Assumed that pine trees will be planted at TY1. Assume that trees planted at TY0 would reach >35 cm dbh by TY50.

TY0: Baseline Conditions
0 (trees/ha)
TY1-TY20: 0 (trees/ha)
TY50: 74 (trees/ha)

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand. Assume natural regeneration begins at TY1.

TY0: Baseline Conditions
0 (trees/ha)

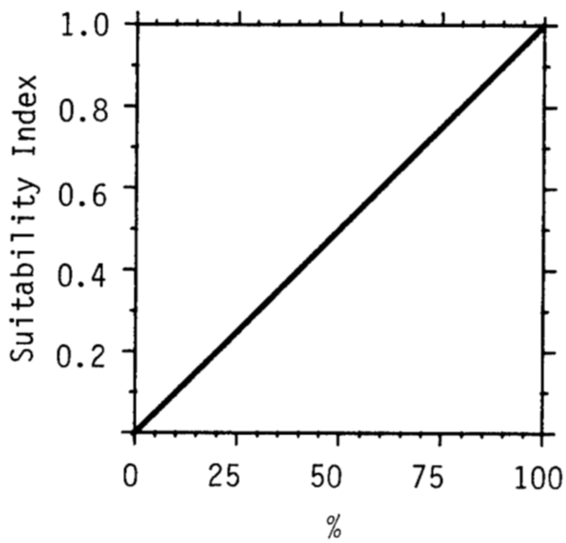
TY1-TY50: Assumed that pine trees that have regenerated will not have reached 35 cm or greater until TY50. Under this scenario have hardwoods in the midstory and overstory limiting the number of large pines as compared to the FWP scenario.

TY1-TY20: 0 (trees/ha)
TY50: 32 (trees/ha)

Mitigation Site – PS-6 (Cleared) Pine Warbler

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

Assumed longleaf pine plantings will be completed by TY1.

TY0: Baseline Conditions
0%

TY1: Planted longleaf pine trees have not reached canopy height
0%

TY20: Assumed first thinnings have been conducted and as pines mature the percent canopy closure would increase.
30%

TY50: Assumed that thinning and burning to reduce vegetative density (to increase habitat quality for RCWs) of the pine savannah habitat present would result in a decrease of pine canopy closure.
25%

FWOP

Assumed that without the proposed mitigation activities, the site would not be managed as pine savannah habitat into the future and would consist of mixed pine/hardwood. Without thinnings and prescribed burns, assumed a dense canopy would exist over the life of the project. While hardwoods comprise a portion of the canopy only pines are considered under this variable.

TY0: Baseline Conditions
0%

TY1: Assumed at TY1 regenerated trees would be 1 year old and would not have reached canopy height.
0%

TY20-TY50: Assumed that without pine savannah management practices a dense pine/hardwood stand would regenerate; therefore, estimated an increasing pine canopy closure over time.

TY20: 40%
TY50: 50%

<u>Variable V2:</u> Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

FWP and FWOP

Assumed regeneration begins at TY0

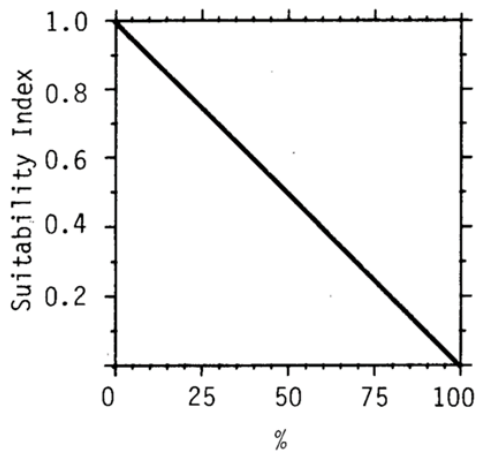
TY0-TY1: Assumed saplings dominate area
0 SI

TY20: Assumed young stand
.5 SI

TY50: Assumed mature stand
1.0 SI

<u>Variable V3:</u> Percent of dominant canopy pines with deciduous understory in the upper 1/3 layer

Pine forests with a deciduous understory reaching into the top 1/3 layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

Assumed that pine savannah management techniques would limit the percentage of hardwoods in the upper 1/3 layer.

TY0-TY1: Assumed seedlings present, no trees in the canopy
0%

TY20-TY50: Assumed low density of hardwoods due to pine savannah management.
5%

FWOP

Assumed that in the absence of pine savannah management, the percent of hardwood midstory and understory would be a significant portion of the canopy, resulting in a large percentage of overstory pines with deciduous understory in the upper 1/3 layer.

TY0-TY1: No canopy trees present
0%
TY20: 75%
TY50: 90%

Mitigation Site –PS-19 (Forested) RCW

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

		Successional age class				
Landform	Landcover Type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

FWP

TY0: Baseline Conditions

Floodplain Valley
Mixed
Saw Timber

0.4

TY1-TY50: Assumed thinnings and hardwood control in existing forested area would be complete by TY1, resulting in an evergreen stand.

Floodplain Valley
Evergreen
Saw Timber

0.8 SI

FWOP

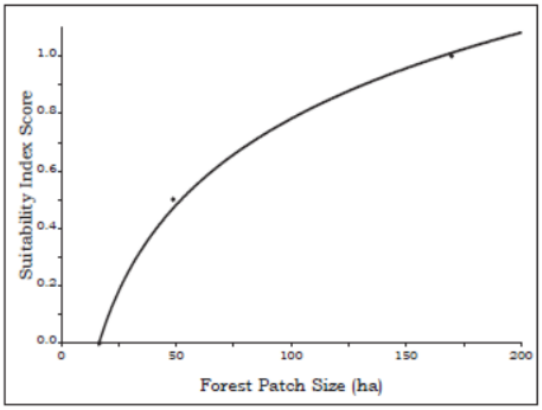
TY0-TY50: Since prescribed burns are often suppressed on private lands, assumed that without the proposed mitigation activities the subject site would consist of a mixed pine/hardwood stand into the future.

Floodplain Valley
Mixed
Saw Timber

0.4 SI

Variable V2: Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



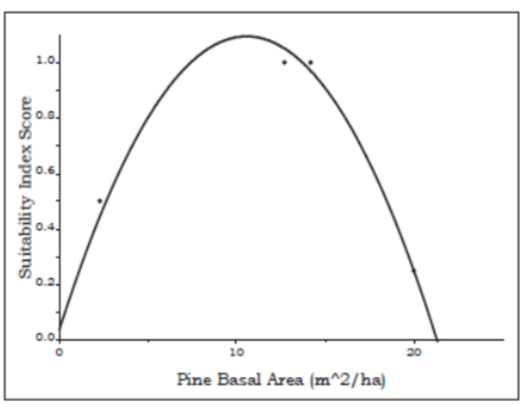
FWP and FWOP

Given the interior location of this mitigation site (north of I-12), RSLR impacts are not expected to extend to this area; therefore, assumed no change to size of contiguous forest under both FWP and FWOP scenarios.

TY0-TY50: 131.77 ha

Variable V3: Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions - Assumed that forested portions of mitigation site were comprised of a mixed pine/hardwood with an average age of 30 years. Used the pine in-growth spreadsheet to estimate BAs.

32.2 m^2/ha

TY1-TY50: Assuming that the site is currently dominated by mature pine trees in the overstory, any necessary thinning and burning would result in pine savannah habitat starting at TY1 and continuing over the life of the project.

11.48 m^2/ha

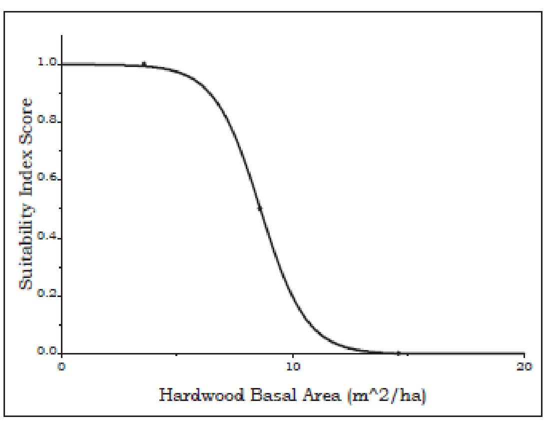
FWOP

Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Assumed site consists of 30 year old pines at TY0 and used the pine in-growth spreadsheet to estimate BA over time.

TY0: 32.2 m^2/ha
TY1: 33.5 m^2/ha
TY20: 48.5 m^2/ha
TY50: 42.7 m^2/ha

Variable V4: Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions - Assumed that forested portions of mitigation site were comprised of a mixed pine/hardwood with an average age of 30 years. Used the hardwood in-growth spreadsheet to estimate BAs.

14.2 m^2/ha

Assumed that mitigation construction will be completed by TY1. Given that the site would be managed as pine savannah habitat, we assumed that hardwood midstory and understory control would be conducted over the life of the project.

TY1-TY50: 1.15 m^2/ha

FWOP

Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Used hardwood in-growth spreadsheet to estimate BA starting with a 30-year-old stand.

TY0: 14.2 m^2/ha
TY1: 14.9 m^2/ha
TY20: 28.2 m^2/ha
TY50: 43.7 m^2/ha

Variable V5: Relationship between distance to nearest habitat patch and SI

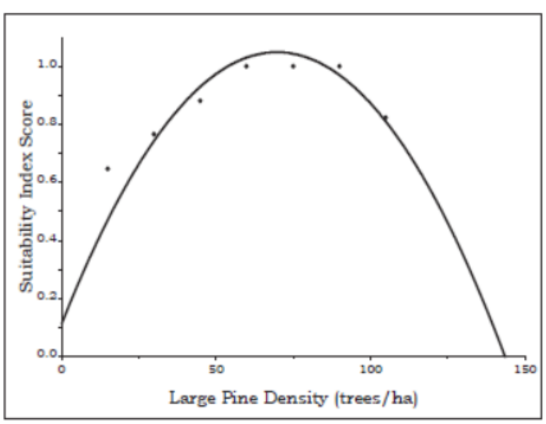
The proposed mitigation area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP and FWOP

TY0-50: 0 m

Variable V6: Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Used pine in-growth spreadsheet to estimate the number of large pines starting with a 30-year-old stand. Assumed that any thinnings necessary would be conducted by TY1 and high quality pine savannah habitat would be maintained over the life of the project. With more open canopy, assumed pine regeneration and trees reaching >35cm by TY20.

TY0: 0 (trees/ha)
TY1: 0 (trees/ha)
TY20: 74 (trees/ha)
TY50: 74 (trees/ha)

FWOP

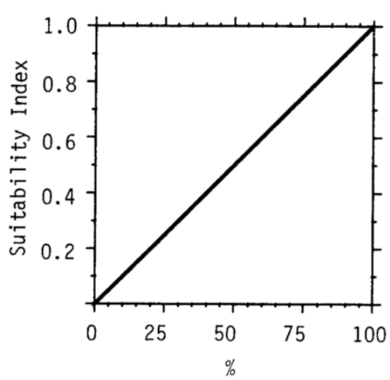
Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Used pine in-growth spreadsheet to estimate the number of large pines starting with a 30-year-old stand. A more closed canopy is anticipated under the FWOP; however, assumed pine trees/ha would be lower under FWOP due to increased hardwood competition.

TY0: 0 (trees/ha)
TY1: 0 (trees/ha)
TY20: 32 (trees/ha)
TY50: 20 (trees/ha)

Mitigation Site – PS-19 (Forested) Pine Warbler

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

TY0: Baseline Conditions – Since prescribed burns are often suppressed on private lands, assumed that a mixed pine/hardwood stand currently exists with a dense canopy cover. While hardwoods comprise a portion of the canopy only pines are considered under this variable.

50%

TY1-TY50: Assumed initial pine savannah construction will be completed by TY1. Pine savannah management practices will result in an open pine canopy over the life of the project.

25%

FWOP

Assumed that without the proposed mitigation activities, the site would not be managed as pine savannah habitat into the future and would consist of mixed pine/hardwood. Without thinnings and prescribed burns, assumed a dense canopy would exist over the life of the project. While hardwoods comprise a portion of the canopy only pines are considered under this variable.

TY0-TY50: 50%

Variable V2: Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

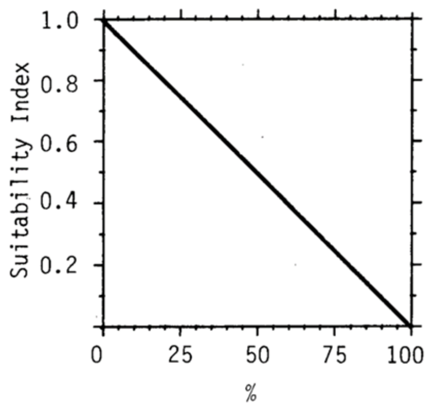
FWP and FWOP

Assumed a mature stand of trees would continue to exist on the site under both the FWP and FWOP scenarios.

TY0-TY50: 1.0 SI

Variable V3: Percent of dominant canopy pines with deciduous understory in the upper $^1/_3$ layer

Pine forests with a deciduous understory reaching into the top $^1/_3$ layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

TY0: Baseline Conditions - Since prescribed burns are often suppressed on private lands, assumed that a mixed pine/hardwood stand currently exists a high percentage of hardwoods present in the upper $^1/_3$ layer.

90%

TY1-TY50: Pine savannah management techniques would limit the percentage of hardwoods in the upper $^1/_3$ layer.

5%

FWOP

Assumed that in the absence of pine savannah management, the percent of hardwoods would be a significant portion of the canopy, resulting in a large percentage of overstory pines with deciduous understory in the upper $^1/_3$ layer.

TY0-50: 90%

Mitigation Site – PS-19 (Cleared) RCW

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

		Successional age class				
Landform	Landcover Type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

FWP

Assumed that longleaf pine plantings would take place and the site managed as pine savannah over the project life.

TY0: Baseline Conditions

Floodplain Valley
Low Density Residential
Grass/Forb

0.0 SI

TY1: Assumed recent plantings, therefore, seedlings at TY1

Floodplain Valley
Evergreen
Seedlings

0.0 SI

TY20: Assumed that planted longleaf have reached pole size timber.

Floodplain Valley
Evergreen
Pole

0.6 SI

TY50: Assumed that planted longleaf have reached saw size timber.

Floodplain Valley
Evergreen
Saw

0.8 SI

FWOP

TY0: Baseline Conditions

Floodplain Valley
Low Density Residential
Grass/Forb

0.0 SI

TY1: Since prescribed burns are often suppressed on private lands, assumed that burns would not take place under the FWOP scenario resulting in a regenerated mixed pine/hardwood stand. Thus, the currently cleared sites would naturally regenerate as a mixed pine/hardwood stand.

Floodplain Valley
Mixed
Seedlings

0.0 SI

TY20: Assumed the stand is comprised of pole size timber.

Floodplain Valley
Mixed
Pole

0.4 SI

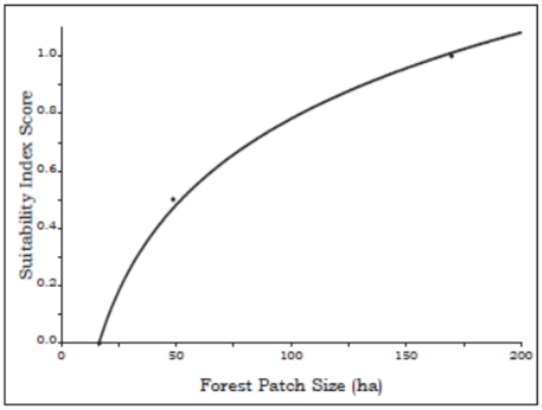
TY50: Assume the stand is comprised of saw size timber.

Floodplain Valley
Mixed
Saw

0.4 SI

Variable V2: Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



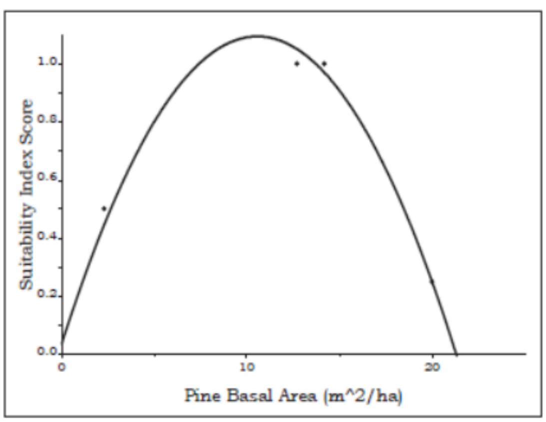
FWP and FWOP

Given the interior location of this mitigation site (north of I-12), RSLR impacts are not expected to extend to this area; therefore, assumed no change to size of contiguous forest under both FWP and FWOP scenarios.

TY0-TY50: 131.77 ha

<u>**Variable V3:**</u> Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees.

FWP

Assumed that longleaf pine plantings will be completed by TY1 and pine basal area would increase over time.

TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed that cleared areas are planted with longleaf pine at TY1. As the pines mature on-site the basal area will increase.

TY1: 0.2 m^2/ha
TY20: 20.6 m^2/ha

TY50: Assumed that at TY50 the sight would have been thinned to maintain high quality pine savannah habitat.
11.5 m^2/ha

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand.

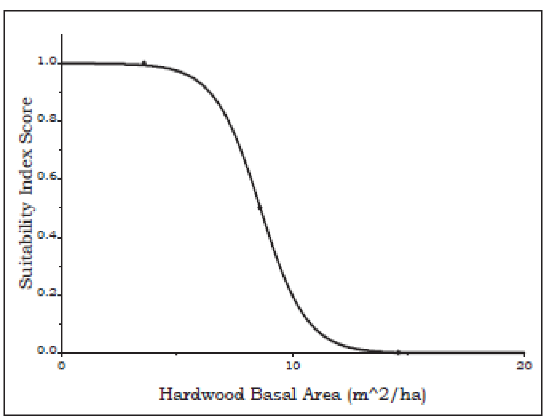
TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed as the site regenerates the basal area of pines will increase over time.

TY1: 0.2 m^2/ha
TY20: 20.6 m^2/ha
TY50: 48.5 m^2/ha

<u>Variable V4:</u> Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions
0 m^2/ha

TY1-TY50: Assumed that initial mitigation construction will be completed by TY1. Given that the site would be managed as pine savannah habitat, we assumed that management (i.e., prescribed burns, herbicide treatments, etc.) would result in low hardwood basal areas over the project life.

TY1: 0.2 m^2/ha

TY20-TY50: Assumed hardwood midstory control.
1.15 m^2/ha

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand.

TY0: 0 m^2/ha

TY1-TY50: Assumed that the proposed site would not be managed as pine savannah habitat into the future. Also assumed that as the sites regenerates the basal area of hardwoods would increase

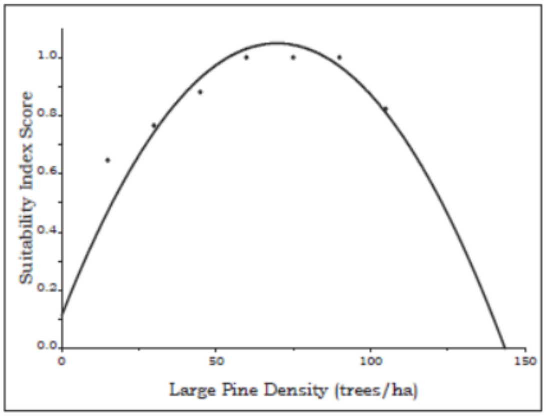
TY1: 0.16 m^2/ha
TY20: 7.58 m^2/ha
TY50: 28.21 m^2/ha

Variable V5: Relationship between distance to nearest habitat patch and SI

The proposed mitigation area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

Variable V6: Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Assumed that pine trees will be planted at TY1. Assume that trees planted at TY0 would reach >35 cm dbh by TY50.

TY0: Baseline Conditions
0 (trees/ha)
TY1-TY20: 0 (trees/ha)
TY50: 74 (trees/ha)

FWOP

Assumed that without the proposed mitigation activities, the cleared areas of the site would regenerate naturally as a pine/hardwood stand. Assume natural regeneration begins at TY1.

TY0: Baseline Conditions
0 (trees/ha)

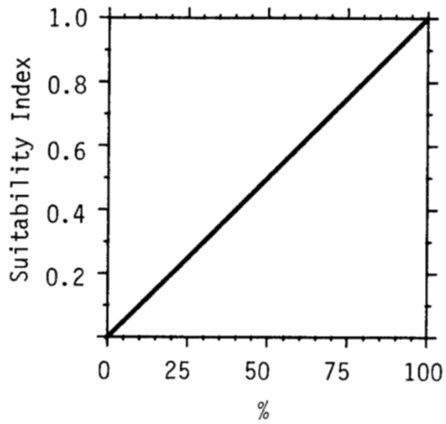
TY1-TY50: Assumed that pine trees that have regenerated will not have reached 35 cm or greater until TY50. Under this scenario have hardwoods in the midstory and overstory limiting the number of large pines as compared to the FWP scenario.

TY1-TY20: 0 (trees/ha)
TY50: 32 (trees/ha)

Mitigation Site – PS-19 (Cleared) Pine Warbler

Variable V1: Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

Assumed longleaf pine plantings will be completed by TY1.

TY0: Baseline Conditions
0%

TY1: Planted longleaf pine trees have not reached canopy height
0%

TY20: Assumed first thinnings have been conducted and as pines mature the percent canopy closure would increase.
30%

TY50: Assumed that thinning and burning to reduce vegetative density (to increase habitat quality for RCWs) of the pine savannah habitat present would result in a decrease of pine canopy closure.
25%

FWOP

Assumed that without the proposed mitigation activities, the site would not be managed as pine savannah habitat into the future and would consist of mixed pine/hardwood. Without thinnings and prescribed burns, assumed a dense canopy would exist over the life of the project. While hardwoods comprise a portion of the canopy only pines are considered under this variable.

TY0: Baseline Conditions
0%

TY1: Assumed at TY1 regenerated trees would be 1 year old and would not have reached canopy height.

0%

TY20-TY50: Assumed that without pine savannah management practices a dense pine/hardwood stand would regenerate; therefore, estimated an increasing pine canopy closure over time.

TY20: 40%
TY50: 50%

<u>Variable V2:</u> Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

FWP and FWOP

Assumed regeneration begins at TY1

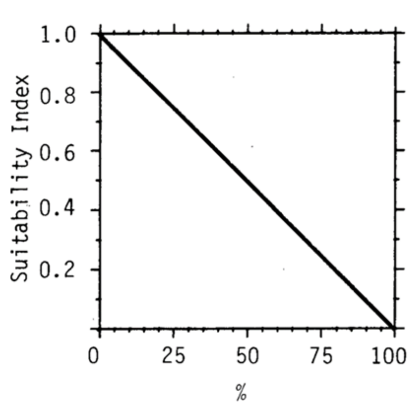
TY0-TY1: Assumed saplings dominate area
0 SI

TY20: Assumed young stand
.5 SI

TY50: Assumed mature stand
1.0 SI

<u>Variable V3:</u> Percent of dominant canopy pines with deciduous understory in the upper 1/3 layer

Pine forests with a deciduous understory reaching into the top 1/3 layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

Assumed that pine savannah management techniques would limit the percentage of hardwoods in the upper 1/3 layer.

TY0-TY1: Assumed seedlings present, no trees in the canopy
0%

TY20-TY50: Assumed low density of hardwoods due to pine savannah management.
5%

FWOP

Assumed that in the absence of pine savannah management, the percent of hardwood midstory and understory would be a significant portion of the canopy, resulting in a large percentage of overstory pines with deciduous understory in the upper 1/3 layer.

TY0-TY1: No canopy trees present
0%
TY20: 75%
TY50: 90%

Mitigation Site – PS-26 RCW

Variable V1: Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat

V_1 = Landform, landcover type, and successional age class

		Successional age class				
Landform	Landcover Type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Terrace-mesic	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0
Xeric-ridge	Low-density residential	0	0	0	0	0
	Transitional-shrubland	0	0	0	0	0
	Deciduous	0	0	0	0	0
	Evergreen	0	0	0.2	0.6	0.8
					-0.7	-1
	Mixed	0	0	0.2	0.4	0.4
	Orchard-vineyard	0	0	0	0	0
	Woody wetlands	0	0	0	0	0

FWP

TY0: Baseline Conditions

Floodplain Valley
Mixed
Saw Timber

0.4

TY1-TY50: Assumed thinnings and hardwood control in existing forested area would be complete by TY1, resulting in an evergreen stand.

Floodplain Valley
Evergreen
Saw Timber

0.8 SI

FWOP

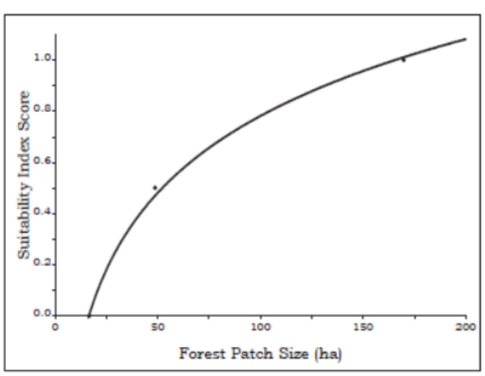
TY0-TY50: Since prescribed burns are often suppressed on private lands, assumed that without the proposed mitigation activities the subject site would consist of a mixed pine/hardwood stand into the future.

Floodplain Valley
Mixed
Saw Timber

0.4 SI

Variable V2: Relationship between forest patch size and SI

RCWs have large home ranges, thus the SI increases as the size of contiguous forested habitat increases.



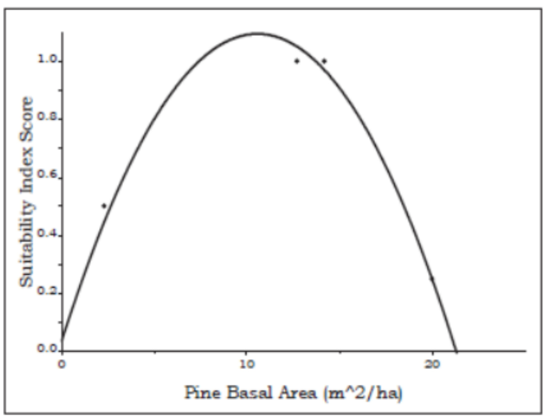
FWP and FWOP

The forest patch size is 1920.4 ha and consists of habitat on and off refuge property. A cursory review of elevations within this area on Google Earth shows a significant portion higher than 3.3 feet (the elevation at which no loss of pine is expected under the intermediate SLR scenario). Therefore, assumed that even with the loss of some lower elevation acreage (mainly occurring within drains) the forest patch size would remain over 170 ha (≥170 ha = 1 SI) over the 50 year project life.

TY0-TY50: 1920.4 ha

Variable V3: Relationship between basal area of pines and SI

Pine basal area is an important component of RCW habitat and basal areas that are either too high or too low are of poor quality.



A pine ingrowth spreadsheet was developed and used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions - Assumed that forested portions of mitigation site were comprised of a mixed pine/hardwood with an average age of 30 years. Used the pine in-growth spreadsheet to estimate BAs.

32.2 m^2/ha

TY1-TY50: Assuming that the site is currently dominated by mature pine trees in the overstory, any necessary thinning and burning would result in pine savannah habitat starting at TY1 and continuing over the life of the project.

11.48 m^2/ha

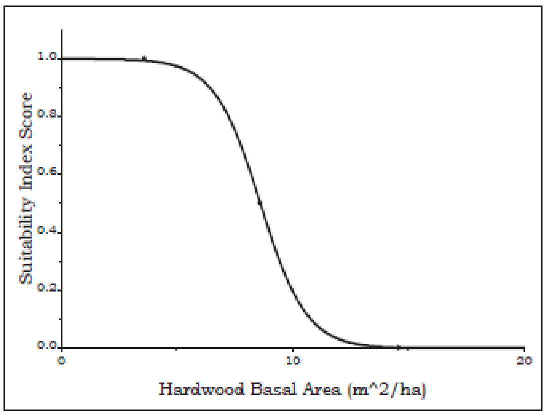
FWOP

Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Assumed site consists of 30 year old pines at TY0 and used the pine in-growth spreadsheet to estimate BA over time.

TY0: 32.2 m^2/ha
TY1: 33.5 m^2/ha
TY20: 48.5 m^2/ha
TY50: 42.7 m^2/ha

<u>Variable V4:</u> Relationship between basal area of hardwoods (m^2/ha) and SI

Overstory and midstory hardwoods reduce habitat suitability for RCWs.



The hardwood ingrowth spreadsheet was used to predict tree growth for individual trees.

FWP

TY0: Baseline Conditions - Assumed that forested portions of mitigation site were comprised of a mixed pine/hardwood with an average age of 30 years. Used the hardwood in-growth spreadsheet to estimate BAs.
14.2 m^2/ha

Assumed that mitigation construction will be completed by TY1. Given that the site would be managed as pine savannah habitat, we assumed that hardwood midstory and understory control would be conducted over the life of the project.

TY1-TY50: 1.15 m^2/ha

FWOP

Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Used hardwood in-growth spreadsheet to estimate BA starting with a 30-year-old stand.

TY0: 14.2 m^2/ha
TY1: 14.9 m^2/ha
TY20: 28.2 m^2/ha
TY50: 43.7 m^2/ha

<u>Variable V5:</u> Relationship between distance to nearest habitat patch and SI

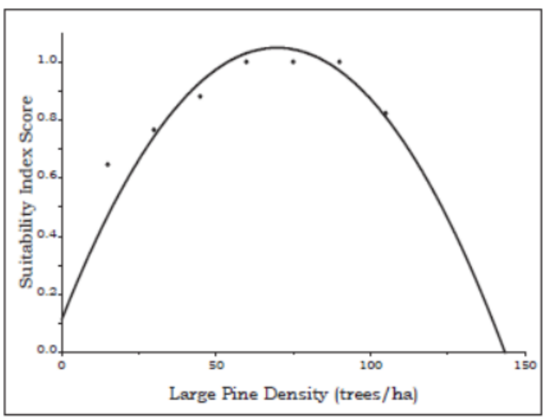
The proposed mitigation area is adjacent to pine savannah habitat under both the FWP and FWOP scenarios.

FWP and FWOP

TY0-50: 0 m

<u>Variable V6:</u> Relationship between large pine (> 35 cm dbh) density (trees/ha) and SI

RCWs use large diameter pines for both foraging and nesting and are, therefore, a necessary component of suitable habitat.



The pine ingrowth spreadsheet was used to determine the number of large pines present at each TY.

FWP

Used pine in-growth spreadsheet to estimate the number of large pines starting with a 30-year-old stand. Assumed that any thinnings necessary would be conducted by TY1 and high quality pine savannah habitat would be maintained over the life of the project. With more open canopy, assumed pine regeneration and trees reaching >35cm by TY20.

TY0: 0 (trees/ha)
TY1: 0 (trees/ha)
TY20: 74 (trees/ha)
TY50: 74 (trees/ha)

FWOP

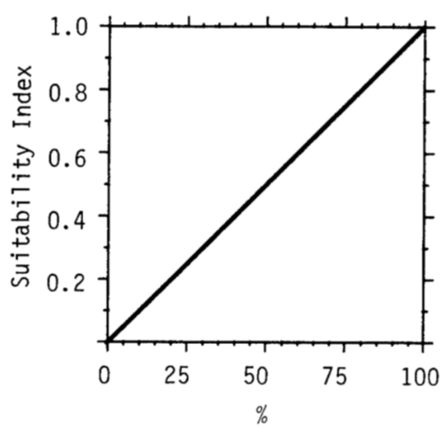
Without the proposed mitigation activities, assumed site would be dominated by a mixed pine/hardwood stand over the life of the project. Used pine in-growth spreadsheet to estimate the number of large pines starting with a 30-year-old stand. A more closed canopy is anticipated under the FWOP; however, assumed pine trees/ha would be lower under FWOP due to increased hardwood competition.

TY0: 0 (trees/ha)
TY1: 0 (trees/ha)
TY20: 32 (trees/ha)
TY50: 20 (trees/ha)

Mitigation Site – PS-26 Pine Warbler

<u>Variable V1:</u> Percent tree canopy closure of overstory pines (excluding white, sand, or pond pine)

Optimal pine warbler habitat contains 100% tree canopy closure of overstory pines, and that suitability will decrease to zero as the percent of overstory pine approaches zero.



FWP

TY0: Baseline Conditions – Since prescribed burns are often suppressed on private lands, assumed that a mixed pine/hardwood stand currently exists with a dense canopy cover. While hardwoods comprise a portion of the canopy only pines are considered under this variable.
50%

TY1-TY50: Assumed initial pine savannah construction will be completed by TY1. Pine savannah management practices will result in an open pine canopy over the life of the project.
25%

FWOP

Assumed that without the proposed mitigation activities, the site would not be managed as pine savannah habitat into the future and would consist of mixed pine/hardwood. Without thinnings and prescribed burns, assumed a dense canopy would exist over the life of the project. While hardwoods comprise a portion of the canopy only pines are considered under this variable.

TY0-TY50: 50%

<u>Variable V2:</u> Successional stage of stand

Mature or old growth forests are assumed to be optimal, while pole-sapling aged forests are unsuitable.

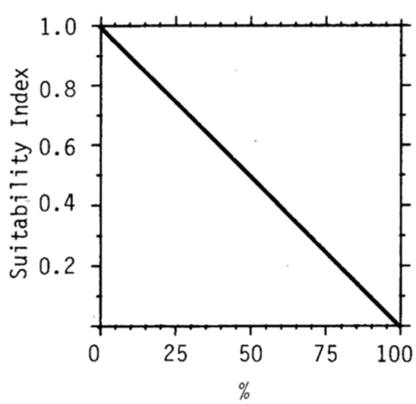
FWP and FWOP

Assumed a mature stand of trees would continue to exist on the site under both the FWP and FWOP scenarios.

TY0-TY50: 1.0 SI

<u>Variable V3:</u> Percent of dominant canopy pines with deciduous understory in the upper $^{1}/_{3}$ layer

Pine forests with a deciduous understory reaching into the top $^{1}/_{3}$ layer of the dominant pines provide poor habitat. It is assumed that optimal conditions exist when no such deciduous understory is present and that habitats with 100% of the dominant pine layer containing a tall deciduous understory will be unsuitable.



FWP

TY0: Baseline Conditions - Since prescribed burns are often suppressed on private lands, assumed that a mixed pine/hardwood stand currently exists a high percentage of hardwoods present in the upper $^{1}/_{3}$ layer.

90%

TY1-TY50: Pine savannah management techniques would limit the percentage of hardwoods in the upper $^{1}/_{3}$ layer.

5%

FWOP

Assumed that in the absence of pine savannah management, the percent of hardwoods would be a significant portion of the canopy, resulting in a large percentage of overstory pines with deciduous understory in the upper $^{1}/_{3}$ layer.

TY0-50: 90%

Mississippi Valley Division,
Regional Planning and Environment Division South

Annex M Modeling
Pine Warbler Certification

Revised Draft Integrated Feasibility Report
and Environmental Impact Statement

Environmental Appendix July 2023

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION
1400 WALNUT STREET
VICKSBURG MS 39180-3262

CEMVD-PDP 15 May 2023

MEMORANDUM FOR CEMVD-PDP (Keefe)

SUBJECT: Recommend Regional Use Approval of the Pine Warbler Habitat Suitability Index (HSI) Model Application Spreadsheet

1. References:

   a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, 31 Mar 2011.

   b. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures, Feb 2012.

   c. Memorandum to Directors of National Planning Centers of Expertise – Subject: Modification of the Model Certification Process and Delegation of Model Approval for Use, 04 Dec 2017.

   d. Memorandum from the Director of Civil Works to MSC Commanders – Subject: Delegation of Model Certification, 11 May 2018.

   e. Application Spreadsheet, Pine Warbler HSI, 8 May 2023 (Encl 1).

2. The Ecosystem Restoration Planning Center of Expertise (ECO-PCX) evaluated the pine warbler Habitat Suitability Index (HIS) model application spreadsheet following references 1.a. and 1.b. Based on the results, the ECO-PCX recommends regional use approval of the spreadsheet calculator within the breeding range of the pine warbler in the eastern United States. In accordance with reference 1.c., please review this recommendation and provide your concurrence or, if appropriate, additional directions to the team.

3. The pine warbler HSI model is approved for regional use per EC 1105-2-412 (Reference 1.a.) and is included in the USACE Ecological Model Library. However, software was lacking which would allow planners to apply the model in a computationally correct fashion for individual projects. Consequently, the New Orleans District (MVN) funded development of the subject Microsoft Excel® spreadsheet calculator. The calculator is an independent spreadsheet built using the same variables, habitat suitability index curves, aggregation equations, and habitat cover types as displayed in the approved model documentation. Furthermore, it employs a standard development scheme to include consistent use of formatting, input requirements, and output display. The calculator is locked from editing and incorporates best spreadsheet development practices (i.e., cell validation, input restrictions, and output assurances).

4. The ECO-PCX reviewed the spreadsheet calculator independently to assess the degree to which it meets the system quality and usability criteria in accordance with EC 1105-2-412.

Through review of the spreadsheet calculator, minor inconsistencies in the variable equations were noted which resulted in inaccuracies in index scores. Additionally, best spreadsheet practices were recommended to prevent incorrect user inputs. The spreadsheet calculator was revised accordingly. The calculator functions well and is formatted in a way that is easy to use. The calculations for each of the variables and for the overall suitability index match the original documentation. The final spreadsheet is in alignment with the requirements of assuring the quality of planning models.

5. The pine warbler HSI model spreadsheet calculator has sufficient system quality and usability. The model is encoded in Microsoft Excel®. The spreadsheet is computationally correct and employs best spreadsheet practices including cell locking, highlighting input/calculation/output cells, and data validation. Error messages display appropriately when erroneous inputs are attempted, and final scoring is displayed and easy to understand. The model is transparent and would allow for verification of inputs and outputs. User documentation is available and sufficient to implement the model and use the spreadsheet. During application, input and output scores should be documented and Agency Technical Review teams charged with review to ensure the application of the model and its associated parts is appropriate. Upon approval, the ECO-PCX will upload the spreadsheet to the Ecosystem Restoration Model Library (https://ecolibrary.planusace.us/#/home).

6. Regarding the individuals who apply the model, Districts are entrusted to confirm that the modeler(s) who are using the model have the experience needed to apply the model correctly and interpret the model outputs. In addition, if the modeler(s) have any uncertainties with the application and/or interpretation of the model then he/she should engage the ECO-PCX.

7. The ECO-PCX team finds the spreadsheet calculator for the pine warbler HSI model has sufficient system quality, meets usability criteria, complies with USACE policy, and maintains the already-approved technical quality of the model. The ECO-PCX evaluation team recommends approval for regional use within the breeding range of the pine warbler in the eastern United States.

Encls (1)

Kathryn McCain, Ph.D.
Acting Operating Director,
Ecosystem Restoration Planning
Center of Expertise

CF
CEMVD-PDP (Lawton, Mallard, Mickal)
CEMVP-PD-P (Hill, Runyon)
CEMVN-PD (Constance, Smith, Meyers, Stiles)

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION
1400 WALNUT STREET
VICKSBURG MS 39180-3262

CEMVD-PDP 31 May 2023

MEMORANDUM FOR Commander, New Orleans District, U.S. Army Corps of Engineers (Attn: Mr. Troy Constance, CEMVN-PD)

SUBJECT: Regional Use Approval of the Pine Warbler Habitat Suitability Index (HSI) Model Application Spreadsheet

1. References:
   a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, 31 March 2011.

   b. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures. Feb 2012.

   c. Memorandum to Directors of National Planning Centers of Expertise – Subject: Modification of the Model Certification Process and Delegation of Model Approval for Use, 04 December 2017.

   d. Memorandum from the Director of Civil Works to MSC Commanders – Subject: Delegation of Model Certification, 11 May 2018.

   e. Memorandum to Director of the Ecosystem Restoration Planning Center of Expertise - Subject: Recommend Regional Use Approval of the Pine Warbler Habitat Suitability Index (HSI) Model Application Spreadsheet, 15 May 2023.

2. An independent review team managed by the Ecosystem Restoration Planning Center of Expertise evaluated the subject model. The application spreadsheet was found to be computationally correct, incorporates best spreadsheet practices, and is usable for Civil Works planning.

3. The Pine Warbler HSI Model application spreadsheet is approved for regional use within the breeding range of the pine warbler in the eastern United States. Independent technical review is complete and the model meets the criteria contained in References 1.a. and 1.b. There are no unresolved issues stemming from the review.

4. Appropriate Use and Quality Control. The appropriateness of the model and its variables must be checked by experienced modeler(s) and biologist(s) before each application of the model. The application of the model will also be described in the Review Plan for studies or similar decision-making efforts. The Review Plan will identify District Quality Control and technical review requirements for the model and its application, per current review guidance. Regarding the individuals who apply the

model, Districts are entrusted to confirm that the modeler(s) and biologist(s) who are using the model have the experience needed to apply the model correctly and interpret the model outputs. In addition, if the modeler(s) have any uncertainties with the application and/or interpretation of the model then he/she should engage the ECO-PCX.

5. The Pine Warbler HSI is approved for regional use with no expiration date; therefore, the application spreadsheet does not expire. Users are entrusted to elevate any model or spreadsheet revisions that are needed to the ECO-PCX.

Signing For:
Kelly J. Keefe, PhD
Chief, MVD Planning and Policy and
Director, Ecosystem Restoration
Planning Center of Expertise

CF
CEMVD-PDP (Lawton, Mallard, Mickal)
CEMVP-PD-P (Hill, Runyon)
CEMVN-PD (Constance, Smith, Meyers, Stiles)

Mississippi Valley Division,
Regional Planning and Environment Division South

Annex M Modeling
Red-Cocked Woodpecker Certification

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION
1400 WALNUT STREET
VICKSBURG MS 39180-3262

CEMVD-PDP 31 May 2023

MEMORANDUM FOR Commander, New Orleans District, U.S. Army Corps of Engineers (Attn: Mr. Troy Constance, CEMVN-PD)

SUBJECT: Regional Use Approval of the Red Cockaded Woodpecker Habitat Suitability Index (HSI) Model

1. References:
   a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, 31 March 2011.

   b. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures. Feb 2012.

   c. Memorandum to Directors of National Planning Centers of Expertise – Subject: Modification of the Model Certification Process and Delegation of Model Approval for Use, 04 December 2017.

   d. Memorandum from the Director of Civil Works to MSC Commanders – Subject: Delegation of Model Certification, 11 May 2018.

   e. Memorandum to Director of the Ecosystem Restoration Planning Center of Expertise - Subject: Recommend Regional Use Approval of the Red Cockaded Woodpecker Habitat Suitability Index (HSI) Model, 15 May 2023.

2. An independent review team managed by the Ecosystem Restoration Planning Center of Expertise evaluated the subject model. The model was found to be technically sound, computationally correct, usable for Civil Works planning, and policy compliant using appropriate functional assessment procedures.

3. The Red Cockaded Woodpecker HSI Model is approved for regional use in open pine ecosystems within the range of the Red Cockaded Woodpecker in the southeastern United States. Independent technical review is complete and the model meets the criteria contained in References 1.a. and 1.b. There are no unresolved issues stemming from the review.

4. Appropriate Use and Quality Control. The appropriateness of the model and its variables must be checked by experienced modeler(s) and biologist(s) before each application of the model. The application of the model will also be described in the Review Plan for studies or similar decision-making efforts. The Review Plan will identify District Quality Control and technical review requirements for the model and its application, per current review guidance. Regarding the individuals who apply the

model, Districts are entrusted to confirm that the modeler(s) and biologist(s) who are using the model have the experience needed to apply the model correctly and interpret the model outputs. In addition, if the modeler(s) have any uncertainties with the application and/or interpretation of the model then he/she should engage the ECO-PCX.

5. This approval expires 31 May 2030.

Signing For:
Kelly J. Keefe, PhD
Chief, MVD Planning and Policy and
Director, Ecosystem Restoration
Planning Center of Expertise

CF
CEMVD-PDP (Lawton, Mallard, Mickal)
CEMVP-PD-P (Hill, Runyon)
CEMVN-PD (Constance, Smith, Meyers, Stiles)
CEERD-EEE (Jung)

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION
1400 WALNUT STREET
VICKSBURG MS 39180-3262

CEMVD-PDP 15 May 2023

MEMORANDUM FOR CEMVD-PDP (Keefe)

SUBJECT: Recommend Regional Use Approval of the Red Cockaded Woodpecker Habitat Suitability Index (HSI) Model

1. References:

    a. Engineer Circular 1105-2-412: Assuring Quality of Planning Models, 31 Mar 2011.

    b. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures. Feb 2012.

    c. Memorandum to Directors of National Planning Centers of Expertise – Subject: Modification of the Model Certification Process and Delegation of Model Approval for Use, 04 Dec 2017.

    d. Memorandum from the Director of Civil Works to MSC Commanders. Delegation of Model Certification, 11 May 2018.

    e. Model Review Plan, Red Cockaded Woodpecker HSI Model and Pine Warbler HSI Model, St. Tammany Parish, LA Feasibility Study, October 2022 (Encl 1).

    f. Peer Review Summary, Red Cockaded Woodpecker HSI Model, 10 May 2023 (Encl 2).

    g. Model Documentation – Multiscale Habitat Suitability Index Models for Priority Landbirds in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions, U.S. Forest Service, July 2009 (Encl 3).

    h. Model Documentation – Justification for Range of Applicability, 8 May 2023 (Encl 4).

    i. Application Spreadsheet, Red Cockaded Woodpecker HSI, 8 May 2023 (Encl 5).

2. The Ecosystem Restoration Planning Center of Expertise (ECO-PCX) evaluated the Red Cockaded Woodpecker Habitat Suitability Index (HSI) Model using references 1.a. and 1.b. Based on the evaluation results, the ECO-PCX review team recommends regional use approval of the model in open pine ecosystems within the range of the Red Cockaded Woodpecker in the southeastern United

States. Please review this recommendation and provide your concurrence, or, if appropriate, additional directions to the review team.

3. The Red Cockaded Woodpecker HSI Model was developed by the U.S. Forest Service as part of a larger conservation planning effort to assess habitat quality of priority bird species (Encl 3). This effort resulted in the development of HSI models for 40 priority bird species, with the goal being a comprehensive, replicable approach to ecoregional habitat assessment that links habitat conditions to the density of priority bird species. Specific objectives of this effort were to:

    a. Assess the ability of landscapes to sustain priority species at prescribed population levels based on the extent and distribution of available habitats.
    b. Monitor changes in the ability of landscapes to sustain species.
    c. Predict how landscape suitability changes under alternative succession and disturbance patterns, land use, conservation strategies, management practices, and development pressures.

    The Red Cockaded Woodpecker HSI Model consists of eight variables: landform, landcover, successional age class, forest patch size, pine basal area, hardwood basal area, connectivity, and large pine density. The original model was developed to be applicable in the Central Hardwoods and West Gulf Coast Plain Bird Conservation Regions. New Orleans District proposed expanding this range (Encl 4) to include open pine ecosystems in the southeastern United States. The New Orleans District team developed a spreadsheet calculator to reflect the variables and calculations of the model (Encl 5).

4. The ECO-PCX managed an intermediate level review of the model in accordance with References 1.a. and 1.b (Encl 2). The review team possessed extensive experience and knowledge of red cockaded woodpecker life history and ecology, USACE planning policy, and spreadsheet best practices. Reviewers included Dr. Jacob Jung, Ph.D. (Research Wildlife Biologist, Engineer Research and Development Center) and Mr. Evan Hill (Wildlife Biologist, Regional Planning and Environmental Division North, St. Louis).

    The review resulted in 6 comments (one high significance, three medium significance, and two low significance). The high and medium significance issues and related updates are summarized below. The full text comments, evaluations, and resolutions can be found in the Peer Review Summary (Encl 2). Additional comments were provided on the spreadsheet calculator regarding minor inconsistencies and best spreadsheet practices. All comments were addressed and incorporated to the satisfaction of the reviewers and ECO-PCX.

    a. The reviewer suggested that the applicable range of the model could be expanded to all open pine forest habitats in the southeastern United

States based on peer-reviewed literature and subject matter expert opinion. The recommended range for regional use approval was adjusted accordingly.

b. Two comments suggested that study teams may want to consider inclusion of other HSI models in addition to the Red Cockaded Woodpecker HSI Model to evaluate the quality of pine ecosystems more thoroughly. No modifications to the Red Cockaded Woodpecker HSI Model were required.

c. The reviewer suggested that USACE projects should prioritize restoration of longleaf pine habitat when possible. No modifications to the Red Cockaded Woodpecker HSI Model were required.

5. The Red Cockaded Woodpecker HSI Model has sufficient technical quality. The model was developed by a team of avian experts. The model development process and documentation are transparent and cover all stages of model development, testing, analysis, and application. The model relationships operate on the theoretical premise that species occupancy is based on the environmental factors/variables required by life history. The model is based on the current state of knowledge regarding the basic environmental conditions and resources required by red cockaded woodpeckers. Documentation includes model assumptions, limitations, and application guidelines. Formulas and calculation routines forming the basis of the model are logical and ecologically correct. The model was verified and validated as part of the original model development process. New Orleans District consulted with the original model developer regarding the appropriateness of expansion of the applicable range of the model to include open pine ecosystems in the southeastern United States and received confirmation that the expansion is appropriate (Encl 4).

6. The Red Cockaded Woodpecker HSI Model has sufficient system quality. Model equations are presented in sufficient detail and are ecologically relevant. The model is operated within a Microsoft Excel® spreadsheet (Encl 5) and is computationally correct. Inputs are readily available, and outputs are easily understandable and useful in supporting USACE civil works planning activities. The model is transparent, and calculations and outputs can be easily verified. The spreadsheet incorporates best spreadsheet practices through cell locking, input validation, and highlighting.

7. The Red Cockaded Woodpecker HSI Model has sufficient usability. The model is well-suited to the tasks for which it was designed. Input requirements are well-specified in the model documentation and require a nominal level of expertise. Model outputs are transparent, easy to understand, and facilitate the evaluation and comparison of alternatives within the planning process.

8. The Red Cockaded Woodpecker HSI Model and methodology are consistent with USACE policies and accepted procedures for conducting functional

assessments. The model does not incorporate, facilitate, or encourage the use of non-ecosystem parameters or values. Upon approval, the ECO-PCX will upload the model documentation to the Ecosystem Restoration Model Library (https://ecolibrary.planusace.us/#/home).

9. Regarding the individuals who apply the model, Districts are entrusted to confirm that the modeler(s) who are using the model have the experience needed to apply the model correctly and interpret the model outputs. In addition, if the modeler(s) have any uncertainties with the application and/or interpretation of the model then he/she should engage the ECO-PCX.

10. The ECO-PCX finds the Red Cockaded Woodpecker HSI Model has sufficient technical and system quality, meets usability criteria, and complies with USACE policy. The ECO-PCX recommends regional use approval of the model in open pine ecosystems within the range of the Red Cockaded Woodpecker in the southeastern United States.

Encls (5)

Kathryn McCain, Ph.D.
Acting Operating Director,
Ecosystem Restoration Planning
Center of Expertise

CF
CEMVD-PDP (Lawton, Mallard, Mickal)
CEMVP-PD-P (Hill, Runyon)
CEMVN-PD (Constance, Smith, Meyers, Stiles)
CEERD-EEE (Jung)

MODEL REVIEW PLAN

RED COCKADED WOODPECKER HABITAT SUITABILITY INDEX MODEL

and

PINE WARBLER HABITAT SUITABILITY INDEX MODEL

ST. TAMMANY PARISH, LA FEASIBILITY STUDY

New Orleans District

October 2022

US Army Corps
of Engineers ®

Model Review Plan

Red Cockaded Woodpecker Habitat Suitability Index Model
and
Pine Warbler Habitat Suitability Index Model Spreadsheet Calculator

USACE, New Orleans District

1. Purpose

The purpose of this Model Review Plan is to outline the review process and requirements necessary to assure the quality of the Red Cockaded Woodpecker Habitat Suitability Index (HSI) model and the Pine Warbler HSI model spreadsheet calculator as submitted by the New Orleans District to the Ecosystem Restoration National Planning Center of Expertise (ECO-PCX) in support of the approval for regional use of the models. The review will consist of an evaluation of the technical quality, system quality, and usability of the models, as well as their conformance with current Corps policy. The review will be managed by the ECO-PCX in accordance with EC 1105-2-412, Assuring Quality of Planning Models. The review team will document the review process and provide an assessment of the technical quality, system quality, and usability of the models.

2. Reference and Guidance

2.1. Engineer Circular 1105-2-412, Assuring Quality of Planning Models, 31 March 2011.

2.2. US Army Corps of Engineers. Assuring Quality of Planning Models - Model Certification/Approval Process: Standard Operating Procedures. February 2012.

3. Background

The St. Tammany Parish, Louisiana Feasibility Study for flood damage reduction includes all of St. Tammany Parish in southeastern Louisiana. St. Tammany Parish has experienced repeated, widespread flooding from both rainfall and coastal storm flood events (i.e., riverine bank overtopping, high tides, waves, drainage, and storm surge) including historic flood impacts during Hurricane Katrina (August 2005) and the flood of August of 2016. The proposed action includes the construction and operation of a total of approximately 18.4 miles of a hurricane and storm damage risk reduction levee and floodwall, eight pump stations, eighteen vehicular/pedestrian/railroad floodgates, eleven ramps, thirteen sluice/lift gates 2.15 miles of channel improvements to Mile Branch in Covington, and nonstructural home elevations and floodproofing for eligible structures in the Parish. The proposed action would reduce flood risk to approximately 15,800 structures in the study area.

The Red Cockaded Woodpecker HSI model was developed by Tirpak et al. (2009). The model consists of eight variables: landform, landcover, successional age class, forest patch size, pine basal area, hardwood basal area, connectivity, and large pine density. The original model was developed to be applicable in the Central Hardwoods and West Gulf Coast Plain Bird Conservation Regions (Tirpak et al. 2009). New Orleans District proposes expanding this range (Smith, 2022) to include open pine ecosystems in the Gulf Coastal Plains based on information in Nordman et al. 2016. The St. Tammany Parish study team developed a spreadsheet calculator to reflect the variables and calculations of the Tirpak et al (2009) model.

The Pine Warbler HSI model spreadsheet calculator is based on the 1982 Fish and Wildlife Service Pine Warbler HSI model (Schroeder 1982). The model was developed to evaluate pine warbler breeding season habitat in deciduous and evergreen forests within the entire breeding range of the pine warbler in the eastern United States. The model includes three habitat variables: percent tree canopy closure of overstory pines, successional stage of stand, and percent of dominant canopy pines with deciduous understory in the upper one-third layer. The St. Tammany Parish study team developed the spreadsheet calculator to reflect the variables and calculations of the 1982 pine warbler model.

4. Documentation Provided by Proponent

4.1. Model Technical Documentation

- Tirpak, J.M., D.T. Jones-Farrand, F.R. Thompson III, D.J. Twedt, W.B. Uihlein III. 2009. Multiscale Habitat Suitability Index Models for Priority Landbirds in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions. USDA General Technical Report NRS-49.
- Nordman, C., R. White, R. Wilson, C. Ware, C. Rideout, M. Pyne, C. Hunter. 2016. Rapid Assessment Metrics to Enhance Wildlife Habitat and Biodiversity within Southern Open Pine Ecosystems. Version 1.0. U.S. Fish and Wildlife Service and NatureServe, for the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative. March 31, 2016.
- Schroeder, R.L. 1982. Habitat suitability index models: pine warbler. U.S. Department of the Interior, Fish and Wildlife Service. FWS/OBS-82/10.28. 8pp.
- Model Application Spreadsheet – Red Cockaded Woodpecker
- Model Application Spreadsheet – Pine Warbler
- Smith, P. 2022. Red Cockaded Woodpecker Geographical Range of Applicability for USACE Civil Works Projects.

4.2. Model User Documentation

- Model user documentation has been included in the technical documentation listed above.

4.3. Model QA/QC Documentation/Activities

- No specific QA/QC documentation exists at this time.

5. Type/Scope of Review

Per EC-1105-2-412, 31 March 2011, the ECO-PCX recommends an Intermediate review, which is applicable to models of lesser complexity with lower risks of making an incorrect investment decision that could result in minimum impacts.

The following language defines the scope of the review and will be provided to the model reviewers.

5.1. Preliminary charge for reviewers

Input is being sought to help the US Army Corps of Engineers ECO-PCX determine the degree to which the subject models can be described as technically sound relative to their design objectives. In addition to the underlying theory, conceptualization, and computational aspects of the model, reviewers are asked to comment on aspects of the model that potentially affect its usability and reliability as a potential producer of information to be used to influence planning decisions.

While the specific review questions included below are intended to prompt the reviewer for information specific to the efforts to Approve for Regional Use, please feel free to offer comments believed relevant and appropriate to any elements of the technical quality and usability of the models as documented in the provided review materials. Accordingly, please provide responses to the sought scientific and technical topics listed below and perform a broad review of the models focusing on your areas of expertise, experience, and technical knowledge. Listed below are the model review charge questions.

5.1.1. Policy Review

1. Comment on the degree to which the model is able to accommodate climate change scenarios consistent with USACE inland hydrology guidance in Civil Works studies, designs, and projects (ECB 2018-14), and incorporating sea level rise scenarios, as appropriate.
2. Comment on the degree to which the model is consistent with USACE policies and accepted procedures for ecosystem restoration and mitigation planning.

5.1.2. Technical Quality

3. Does the model documentation include clear and precise description for the focus of the model? Discussion may include, but is not limited to geographic range, applicability limits, model domain, or boundary conditions.
4. Are the intended uses of the model defined, clear, and appropriate?
5. Are the spatial and temporal resolutions of the model described appropriately?
6. Are interpretations and conclusions sound, justified by the data and consistent with the objectives?
7. Are the assumptions and limitations of the model clearly communicated and supported?
8. Comment on the degree to which the model can be used as a tool to forecast conditions anticipated to occur during the period of analysis.
9. Does the model documentation sufficiently include a precise question or hypothesis and an appropriate underlying theoretical framework?
10. Are the most sensitive parameters or factors of the model identified and supported with sensitivity analyses?
11. Are the model variables, functions, and parameters clearly defined and dimensionalized, preferably in table format?
12. Is the organization of the model documentation satisfactory (e.g., no discussion in Results)?
13. Comment on the degree to which the model facilitates sensitivity, uncertainty, and risk analyses.
14. Comment on the degree to which the model is appropriate for use in the proposed area of geographic applicability.

5.1.3. System Quality

15. Are model computations presented in sufficient detail and ecologically relevant?
16. Does the model documentation sufficiently describe testing steps utilized during model development (i.e., consistency check, sensitivity analyses, calibration, validation)?
17. Has the model programming system been tested for errors? If not, what is the potential for errors to occur?
18. Does the model inform users of erroneous or inappropriate inputs or outputs?

5.1.4. Usability

19. What are the hardware, software, and operating system requirements of the model? To what degree can the hardware, software, and operating system requirements complicate use of the model?
20. Is user documentation user friendly and complete? Comment on the model's ease of use.
21. Are the input requirements evident to the user? Is the data readily available?
22. Is the required level of precision and accuracy of inputs documented?

6. Description of Tasks.

The model review tasks are:

6.1. **Model Review Plan Development.** This model review plan is being developed specifically to manage the independent model review.

6.2. **Conduct Review of Models.** The reviewers will assess the model using all documentation provided by the model proponent and the ECO-PCX. Reviewers will provide comments using the provided comment response template and should follow a four-part structure to include: 1) the review concern, 2) the basis for the concern (reviewer should note if the comment relates to technical quality, system quality, or usability), 3) the significance/impact of the concern, and 4) the probable specific action needed to resolve the concern.

6.3. **Meeting to Discuss Review Results.** The model review team will meet with the ECO-PCX and model proponent to discuss initial review comments and recommendations and outline a plan for resolution. The model proponent will coordinate with the ECO-PCX regarding whether responses are necessary. Responses may include agreement/disagreement with any part of the comment and rationale, and any actions or changes to the model that the proponent will make. The ECO-PCX and model proponent will provide responses to the comments back to the reviewers. The reviewers should backcheck proponent responses.

6.4. **Proponent and ECO-PCX Summary.** Based on the review comments, the ECO-PCX will identify actions or modifications the proponent needs to undertake in order to gain a recommendation for approval. The ECO-PCX will close-out the review when it determines identified issues have been resolved to its satisfaction.

6.5. **ECO-PCX Recommendation Package Development.** The ECO-PCX Model Review Manager compiles a model approval or certification recommendation package for the ECO-PCX Operating Director. The recommendation package should be provided to the Operating Director in an email from the Model Review Manager.

The model recommendation package should include the model review plan, model documentation, comments, comment resolution, a copy of the model software or spreadsheet, as appropriate, and two draft memos.

a) The first draft memo is prepared for the signature of the ECO-PCX Operating Director to transmit the model recommendation to the ECO-PCX Director.

b) The second draft memo is prepared for the signature of the ECO-PCX Director to transmit the model approval or model certification to the District Commander.

6.6. **ECO-PCX Operating Director Review.** The Operating Director of the ECO-PCX reviews the model recommendation package. Any comments on the model review and recommendation should be resolved between the Operating Director and the model review team. Once comments are resolved, the ECO-PCX Operating Director signs a memo to the ECO-PCX Director recommending model approval or model certification under one of the delegated authorities.

The memo should be provided by email from the ECO-PCX Operating Director to the ECO- PCX Director with copies furnished to the ECO-PCX Model Review Manager and the ECO- PCX Account Manager for the MSC where the study is being conducted.

6.7. **ECO-PCX Director Approval.** The ECO-PCX Director reviews the model recommendation package. The Director may request additional information or direct further review as needed prior to signing the memo. If the Director agrees with the recommendation, a memo should be signed documenting the approval/certification. The signed memo is then emailed back to the Operating Director for distribution and record keeping.

6.8. **Approval Memo Distribution.** The ECO-PCX Operating Director distributes the model approval/certification memo by email to the model review team, the model review manager, the home MSC and the Project Delivery Team. After distribution the memo should be filed with the model review documentation in the ECO-PCX electronic files.

6.9. **Model Library Update.** A copy of the model and all relevant documentation will be uploaded onto the Ecosystem Restoration Model Library. The library is housed on the IWR APT site.

7. Review Team Composition

The ECO-PCX proposes review of the model documentation and supporting literature. The review will address all technical quality, system quality and usability certification criteria, including the criteria regarding whether the model properly incorporates Corps policies and accepted procedures.

The ECO-PCX proposes to use reviewers within USACE with the following expertise:

- ECO-PCX Model Review Manager – The review manager will be responsible for facilitation of the model review process through recommendation of the model to the ECO-PCX Operating Director.

- Ecologist – the reviewer should be a senior-level biologist and must have expertise relevant to southeastern U.S. ecology.

- Spreadsheet Modeling Specialist – the reviewer should have expertise in MS Excel and knowledge of habitat suitability index model application within the MS Excel framework.

8. Schedule

The following is a draft schedule for the model review. Revisions to the model to address model deficiencies will require adjustments to the schedule below.

Initial Kick-off Meeting/Begin Model Review	October 2022
Interim Review Teleconference	As needed
Complete Model Review	October 2022

Model Proponent Evaluations Submitted to ECO-PCX	November 2022
Reviewers' Backchecks to ECO-PCX	November 2022
Final Model Comment Response Record	November 2022
ECO-PCX Recommendation Package	December 2022

9. Cost

Estimated cost to complete each level of review is:

Ecologist (Jacob Jung)	$3,000
Spreadsheet Modeling Specialist (Evan Hill)	$2,000
ECO-PCX Model Review Manager (Kip Runyon)	$6,000
Total:	$11,000

10. Points of Contact

ECO-PCX Point of Contact:	Greg Miller	504-481-9683
ECO-PCX Model Review Manager:	Kip Runyon	314-331-8396
Model Proponent Point of Contact:	Patrick Smith	504-862-1583

Model Certification/Approval Review

Comment and Evaluation Responses

Multiscale Habitat Suitability Index Models for Priority Landbirds in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions: Red-cockaded Woodpecker

May/2023

Comment #1
The Habitat Suitability Index (HSI) model developed by Tirpak et al. (2009) is one of 40 models developed for priority bird species in the Central Hardwoods and West Gulf Coastal Plains regions of the southeastern United States. This review focuses exclusively on the Red-cockaded Woodpecker (RCW) and its determination as a suitable model recommended for model certification for use by the U.S. Army Corps of Engineers (USACE) in evaluating current habitat conditions for pine forest habitats where it occurs.
Relevant Assessment Criteria
Technical Quality: Highly functional model for assessing habitat suitability for RCW in pine-dominated habitats. System Quality: Model is easy to understand and interpret with metrics clearly defined for measuring/obtaining data for each variable.
Basis for Comment
The model clearly defines the parameters and methods for determining the HSI score for the 40 priority species. Most importantly, the models have been both verified and validated as defined in the report for most species including the RCW. In addition, these models have been peer-reviewed and accepted into the Journal of Wildlife Management, a highly-regarded journal within the wildlife field and shared with the 2006 Proceedings of the Eighth Annual Forest Inventory and Analysis Symposium. While the metrics within this model appear to perform well and have been verified and validated for determining the HSI, it is strictly related to habitat for RCW. Consideration of incorporating additional HSI models to better evaluate pine ecosystem would better inform overall habitat needs for a variety of species such as those that inhabit the shrub or grassland habitats in the understory.
Significance – Medium
Consider using multiple HSI models that better represent the entire pine-dominated ecosystem that includes assessment of the understory.
Recommendation for Resolution
Models for species such as Northern Bobwhite would better assess a primarily herbaceous understory while pine forests that contain shrubby understories would be captured with models for species such as Prairie Warblers. Other species such as Brown-headed Nuthatch or Bachman's Sparrow may also be useful in assessing the overall pine ecosystem. Alternatives in the future may consider modification of the Field Manual for Rapid Assessment Metrics for Wildlife and Biodiversity in Southern Open Pine Ecosystems 2016 (Appendix C) by White and Nordman.

USACE Evaluator Response
__X__Concur ______Non-Concur The model proponents agree that multiple HSI models is a better approach than the RCW HSI alone. For the St. Tammany Study, the Pine Warbler HSI would be used in addition to the RCW HSI to assess Project impacts. The CEMVN and USFWS are actively seeking funding to develop an ecosystem model for pine savannah habitat(s) that would take an ecosystem approach and consider the entire biological community as well as other ecosystem functions and services. We acknowledge the importance of the herbaceous layer and herbaceous layer variable(s) would be included in this model when it is developed in PED. The current long-term ecosystem modeling plan for this Study is to require a community model to assess impacts during the Pre-Construction Engineering and Design (PED) phase; if one is not available at the beginning of PED, the CEMVN would develop one through coordination with USFWS and other experts (e.g., ERDC). We have reviewed the information in White and Norman (2016) and would use it to help develop this model during PED. We would re-engage the ECO-PCX early in the planning process for this community model.
Reviewer BackCheck Response
Based on the evaluator response above, the panel provides the following response: __X__Concur _____Non-Concur

Comment #2
The RCW HSI model is applicable across a large geographic area where open pine ecosystems occur, primarily that of the southeastern United States; therefore, consideration should be considered at the regional scale for model certification.
Relevant Assessment Criteria
Usability and/or Policy- This model meets the necessary requirements to evaluate RCW habitat in open pine ecosystems not only in the geographic regions where it was initially developed, but also other areas in the southeastern U.S. where these habitats occur. The criteria (parameters within the model) are comparable throughout the Southeast, with other subject matter experts (SME) in agreement for its broader use outside of the Central Hardwoods and West Gulf Coastal Plain regions (see Attachment 3 from John Tirpak).
Basis for Comment
The justification for including open pine forest habitats throughout the entire southeastern U.S. for use with the RCW HSI model on USACE projects is supported by peer-reviewed literature (e.g. Nordman et al. 2016) as well as correspondence from SMEs. Additional support can be providing by examining the overlap of other species such as Bachman's Sparrow, Pine Warbler, and Brown-headed Nuthatch that are dependent on pine ecosystems throughout the Southeast, as well as other species that commonly occupy these open pine ecosystems (e.g. Northern Bobwhite, Prairie Warbler). The prevalence for all of these species to use pine ecosystem regardless of pine species or where they occur throughout the Southeast further supports incorporating the use of the model beyond only the Central Hardwoods and West Gulf Coastal Plain/Ouachitas.
Significance – High
Incorporating the RCW HSI model as a certified model for evaluating open pine ecosystems throughout the entire Southeast as a regional model will have a high impact by providing multiple USACE projects the ability to assess pine-dominated systems.
Recommendation for Resolution
Recommend model for certification by the U.S. Army Corps of Engineers at the regional scale throughout the entire Southeast.
USACE Evaluator Response
__X__Concur ______Non-Concur The model proponents agree that the geographical range of applicability of the RCW HSI should include areas beyond where the model was originally developed to include all southern open pine ecosystems within the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (Nordman et al., 2016). We were conservative in our draft determination of the geographical range of applicability and concur with the reviewer's recommendation to include all southern open pine ecosystems throughout the southeastern United States. The RCW HSI geographic range of applicability justification document has been updated to reflect this.

Reviewer BackCheck Response
Based on the evaluator response above, the panel provides the following response: __X__Concur _____Non-Concur

Comment #3
Future modification of SI2 (forest patch size) may be necessary to determine if there is a threshold for which maximum suitability to sustain the species occurs. Other SI metrics should also be reevaluated as additional research becomes available to better inform modifications of the HSI equation.
Relevant Assessment Criteria
Technical Quality: SI score currently based on best available science
Basis for Comment
SI2 is calculated according to research on home range size for RCW. While studies do provide for the maximum and minimum home range for the species, the maximum size does not always mean that patch size is most suitable given many additional factors that determine optimal habitat. For instance, once forest patch size reaches 80 ha, suitability of 1.0 may generally occur if other suitable conditions within the forest stand are met. The 170 ha forest patch size is documented in the literature as the largest home range size, but may not be necessary to achieve all life requisites. It may in fact be that 170 ha was needed because the overall forest stand was of low quality, thus a larger home range was required to meet needs. Likewise, a smaller home range size that incorporates high quality pine forest may still be of higher suitability than a larger home range that incorporates a lower quality patch of pine forest. Additional metrics within the SI equations should be modified according to the best available science. The model was developed according to past studies that reflect certain maximum and minimum ranges (e.g. forest patch size, density of large trees). As future research further refines these metrics throughout the RCW range, the algorithms should be adjusted and tested for improved model performance.
Significance – Low
Modify equation for SI score as data becomes available
Recommendation for Resolution
Based on current knowledge, I agree with current equation but as additional data becomes available to better inform what is truly optimal patch size, alterations to equation to determine the final HSI and SI2 (and other SI scores) should be adjusted.
USACE Evaluator Response
__X__Concur _____Non-Concur Concur. This model is currently seeking approval for regional use and should be updated in the future as new data becomes available or the state of the science advances.
Reviewer BackCheck Response
Based on the evaluator response above, the panel provides the following response: __X__Concur ____Non-Concur

Comment #4
Define all acronyms within spreadsheets
Relevant Assessment Criteria
Usability: Definition of acronyms needed for better meeting usability of spreadsheet
Basis for Comment
Some acronyms within the associated spreadsheet for calculating the HSI score are not defined such as FWP/FWOP (Future With/Without Project) and TY (Target Year).
Significance – Low
Defining acronyms will assist with HSI calculations
Recommendation for Resolution
Define all acronyms wherever first mentioned in spreadsheet or model assessment
USACE Evaluator Response
__X__Concur ______Non-Concur Spreadsheets have been updated and all acronyms have been defined.
Reviewer BackCheck Response
Based on the evaluator response above, the panel provides the following response: __X__Concur _____Non-Concur

Comment #5
Similar to Comment #1, this model focuses only on habitat suitability for RCW. RCW is considered to be an umbrella species with high quality RCW habitat also benefitting many other species that inhabit both the canopy as well as at the ground and mid-story. However, it may be beneficial to incorporate additional species that rely on other components of the forest not captured in the RCW or Pine Warbler model.
Relevant Assessment Criteria
Policy: Consideration for other species of wildlife or ecosystem models in habitat evaluation for which mitigation may be required to fully evaluate pine ecosystems.
Basis for Comment
The Red-cockaded Woodpecker is considered to be an umbrella species as well as a keystone species. This is in part because RCW habitat generally incorporates fire management to maintain the proper understory which benefits other species such as Northern Bobwhite or Prairie Warblers. I recommend considering additional models to fully assess the habitat quality of open pine ecosystems beyond RCW and Pine Warbler. In general, areas that are assessed as higher-quality based on the RCW HSI model are also likely to rank high for other species. However, it is possible to have lower quality pine habitats for RCW but that are still more suitable for other species inhabiting pine ecosystems. Incorporating additional species that require different components within a pine forest (e.g. snag density, canopy cover) will allow for a more ecosystem approach in the future.
Significance – Medium to High
Consideration for other models that incorporate other metrics for pine forests will improve overall ecosystem assessment
Recommendation for Resolution
Consider incorporating other models such as Northern Bobwhite, Bachman's Sparrow, Brown-headed Nuthatch, Prairie Warbler, or other species that frequent pine forest but are not necessarily dependent on exclusively pine habitats.
USACE Evaluator Response
__X__Concur _____Non-Concur The CEMVN and USFWS are actively seeking funding to develop an ecosystem model for pine savannah habitat(s). This model would take an ecosystem approach and consider the entire biological community as well as other ecosystem functions and services. The current long-term ecosystem modeling plan for this Study is to require a community model to assess impacts during the Pre-Construction Engineering and Design (PED) phase; if one is not available at the beginning of PED, the CEMVN would develop one through coordination with USFWS and other experts (e.g., ERDC). We would re-engage the ECO-PCX early in the planning process for this ecosystem model.
Reviewer BackCheck Response
Based on the evaluator response above, the panel provides the following response: __X__Concur ____Non-Concur

Comment #6
Suggestion rather than a concern. Following mitigation acreage determinations from model analyses, suggestions for reestablishing long-leaf pine stands as are feasible.
Relevant Assessment Criteria
Policy: USACE should strive, as is feasible, to comply with "America's Longleaf Restoration Initiative" when restoring open pine ecosystems
Basis for Comment
Long-leaf pines historically covered much of the coastal plains region of the Southeast. For project lands that occur within the historic native range of long-leaf pine, replanting of this species should be a priority. Consultation with a forester to determine feasibility and planting rates with optimal wildlife habitat in mind should be a goal. In addition to reforestation with long-leaf pine as is feasible, consideration for establishing native warm season grasses and other beneficial herbaceous plants (e.g. legumes) should also be a priority for replanting. Finally, a management plan that incorporates future management actions such as prescribed burning should be implemented with determination of which parties will be primarily responsible for continued management to promote and maintain optimal open pine habitats.
Significance – Medium
Restoration of longleaf pines should be a priority, but is not essential for pine ecosystem restoration as other species are used by pine-dependent species including RCW.
Recommendation for Resolution
See recommendations and references within America's Longleaf Restoration Initiative for additional benefits for reestablishment of longleaf pine ecosystems
USACE Evaluator Response
__X__Concur ______Non-Concur Concur. Restoration of longleaf pines is a priority for mitigation planning. Management of existing pine stands and plantings are a part of the mitigation plan. Longleaf pines would be considered before any other pine species if plantings are implemented. Longleaf pines would be the only pine species planted if practicable (e.g., if it is not cost prohibitive and there are enough commercially available to meet our need).
Reviewer BackCheck Response
Based on the evaluator response above, the panel provides the following response: _X___Concur _____Non-Concur

USDA

United States
Department of
Agriculture

Forest Service

**Northern
Research Station**

General Technical
Report NRS-49

Multiscale Habitat Suitability Index Models for Priority Landbirds in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions

**John M. Tirpak
D. Todd Jones-Farrand
Frank R. Thompson, III
Daniel J. Twedt
William B. Uihlein, III**






Abstract

Ecoregional conservation planning for priority landbirds requires methods that explicitly link populations to habitat conditions at multiple scales. We developed Habitat Suitability Index (HSI) models to assess habitat quality for 40 priority bird species in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions. The models incorporated both site and landscape environmental variables derived from one of six nationally consistent datasets: ecological subsections from the National Ecological Unit Hierarchy, National Land Cover Dataset, National Elevation Dataset, National Hydrography Dataset, State Soil Geographic Database, and Forest Inventory and Analysis data. We initially defined potential habitat for each species from unique landform, landcover, and successional age class combinations. Species-specific environmental variables identified from the literature were used to refine initial habitat estimates. We verified models by comparing subsection-level HSI scores and Breeding Bird Survey (BBS) abundance via Spearman rank correlation. To validate models, we developed generalized linear models that predicted BBS abundance as a function of HSI score and Bird Conservation Region. We considered models that included a significant ($P \leq 0.100$) positive coefficient on the BBS predictor to be valid and useful for conservation planning.

The Authors

JOHN M. TIRPAK is science coordinator for the Lower Mississippi Valley Joint Venture, Vicksburg, MS.

D. TODD JONES-FARRAND is a postdoctoral fellow with the Department of Fisheries and Wildlife Sciences, University of Missouri, Columbia, MO.

FRANK R. THOMPSON, III is a research wildlife biologist and Project Leader with the Northern Research Station, Columbia, MO.

DANIEL J. TWEDT is a research wildlife biologist with the U.S. Geological Survey Patuxent Wildlife Research Center, Vicksburg, MS.

WILLIAM B. UIHLEIN, III is coordinator for the Lower Mississippi Valley Joint Venture, Vicksburg, MS.

Cover Photos

Clockwise from top left:
Cerulean warbler, U.S. Forest Service; Wood thrush, Steve Maslowski, U.S. Fish & Wildlife Service; Pileated woodpecker, U.S Forest Service; Painted bunting, Deanna K. Dawson, Patuxent Bird Identification InfoCenter, Photo used with permission; Kentucky warbler, U.S. Fish & Wildlife Service; Bewick's wren, Dave Menke, U.S. Fish & Wildlife Service.

Manuscript received for publication 27 August 2008

Published by:
U.S. FOREST SERVICE
11 CAMPUS BLVD SUITE 200
NEWTOWN SQUARE PA 19073-3294

July 2009

For additional copies:
U.S. Forest Service
Publications Distribution
359 Main Road
Delaware, OH 43015-8640
Fax: (740)368-0152

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INTRODUCTION

The primary goal of the North American Landbird Conservation Plan (Rich and others 2004) is to create landscapes that can sustain populations of the 448 native landbird species that breed in the United States and Canada. To attain this goal, the Plan advocates a three-phase approach:

1. Establish population objectives at the continental scale.
2. Allocate these population objectives to specific Bird Conservation Regions (BCRs).
3. Translate the regional population objectives to habitat goals within each BCR.

The first two steps of this process have been completed (Panjabi and others 2001, Rosenberg and Blancher 2005), and it is at this third step where the conservation community stands today.

Translating target population numbers into concrete habitat goals requires both knowledge of how landbird populations respond to changing habitat conditions and a method for quantifying this relationship. However, there are few data explicitly linking landbird abundance to specific habitat conditions, nor is there consensus on the optimal methodology to achieve this linkage. The goal of our research is to develop a comprehensive, replicable approach to ecoregional habitat assessment that links habitat conditions to the density of priority bird species. Specific objectives are to:

1. Assess the ability of landscapes to sustain priority species at prescribed population levels based on the extent and distribution of available habitats.
2. Monitor changes in the ability of landscapes to sustain species.
3. Predict how landscape suitability changes under alternative succession and disturbance patterns, land use, conservation strategies, management practices, and development pressures.

To create a replicable and transferable methodology, we selected a Habitat Suitability Index (HSI) modeling approach. HSI models were initially developed by the U.S. Department of the Interior (USDI) Fish and Wildlife Service (FWS) to evaluate habitat quality for a variety of species (Schamberger and others 1982). These models identify and quantify the relationship between key environmental variables and habitat suitability on a scale from 0 to 1. HSI scores are calculated independently for each environmental factor and an appropriate weighting scheme is used to combine individual variables and determine a composite suitability index (SI) score for a particular location. Although the FWS developed HSI models solely with site-specific habitat variables (e.g., canopy cover) for assessing stand-level habitat suitability, researchers are increasingly developing HSI models that incorporate broad-scale metrics (e.g., percent forest in a 1-km radius) for application to large landscapes (Larson and others 2003). The continued use of the HSI approach by both researchers and managers likely is a result of the intuitive nature of these models as well as their scalability and portability to novel situations. HSI models easily incorporate existing information via a priori hypotheses but also allow generalization of habitat relationships across areas and species where empirical data are limited. Currently, few HSI models include environmental variables at both the site and landscape scale due to the limited site-specific data across areas that are large enough to exhibit strong differences in landscape structure or composition. Nevertheless, habitat selection by birds is a multiscale process (Villard and others 1998) and habitat models should reflect conditions at multiple scales. This report begins filling this gap by documenting multiscale HSI models for 40 priority landbird species (Table 1).

Table 1.—Partners in Flight regional combined score and USDI Fish and Wildlife Service Bird of Conservation Concern status for 40 priority landbird species in the Central Hardwoods and West Gulf Coastal Plain/ Ouachitas Bird Conservation Regions

		Central Hardwoods		West Gulf Coastal Plain/Ouachitas	
Species	Alpha code[a]	Regional combined score	Bird of Conservation Concern	Regional combined score	Bird of Conservation Concern
Acadian flycatcher	ACFL	16	No	17	Yes
American woodcock	AMWO	--	No	--	No
Bachman's sparrow	BACS	20	Yes	20	Yes
Bell's vireo	BEVI	15	Yes	16	Yes
Bewick's wren	BEWR	15	Yes	16	Yes
Black-and-white warbler	BAWW	13	No	16	No
Blue-gray gnatcatcher	BGGN	14	No	13	No
Blue-winged warbler	BWWA	19	Yes	--	No
Brown thrasher	BRTH	15	No	13	No
Brown-headed nuthatch	BHNU	19	No	19	Yes
Carolina chickadee	CACH	15	No	16	No
Cerulean warbler	CERW	19	Yes	19	Yes
Chimney swift	CHSW	16	No	14	No
Chuck-will's-widow	CWWI	14	No	16	Yes
Eastern wood-pewee	EAWP	15	No	16	No
Field sparrow	FISP	17	No	15	No
Great crested flycatcher	GCFL	13	No	13	No
Hooded warbler	HOWA	13	No	16	No
Kentucky warbler	KEWA	18	No	19	Yes
Louisiana waterthrush	LOWA	15	Yes	18	Yes
Mississippi kite	MIKI	14	No	16	No
Northern bobwhite	NOBO	16	No	15	No
Northern parula	NOPA	12	No	13	No
Orchard oriole	OROR	17	No	18	Yes
Painted bunting	PABU	16	No	17	No
Pileated woodpecker	PIWO	13	No	16	No
Prairie warbler	PRAW	18	Yes	18	Yes
Prothonotary warbler	PROW	14	No	17	Yes
Red-cockaded woodpecker	RCWO	21	No	21	No
Red-headed woodpecker	RHWO	16	Yes	17	Yes
Swainson's warbler	SWWA	20	Yes	20	Yes
Swallow-tailed kite	STKI	19	No	18	Yes
Whip-poor-will	WPWI	17	Yes	13	No
White-eyed vireo	WEVI	15	No	16	No
Wood thrush	WOTH	16	Yes	15	Yes
Worm-eating warbler	WEWA	18	Yes	15	Yes
Yellow-billed cuckoo	YBCU	13	No	15	No
Yellow-breasted chat	YBCH	16	No	13	No
Yellow-throated vireo	YTVI	16	No	15	No
Yellow-throated warbler	YTWA	15	No	16	No

[a]Pyle and DeSante (2003).

STUDY AREAS

We developed HSI models for landbirds identified as priorities in the Central Hardwoods (CH) and West Gulf Coastal Plain/Ouachitas (WGCP) BCRs (Fig. 1). The CH, approximately 33 million ha straddling the Mississippi River, is dominated by deciduous hardwood forest. This region is bordered to the north and west by the tallgrass prairie ecosystem, to the east by the Appalachian Mountains, and to the south by the southern pine belt along the Coastal Plain. The vast forests of the CH make it an important breeding area for many area-sensitive species,

Figure 1.—Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions.

including the cerulean warbler, Kentucky warbler, Louisiana waterthrush, and worm-eating warbler (Panjabi and others 2001). The WGCP also is predominantly forested but consists primarily of pine: longleaf pine in the south transitioning to loblolly and shortleaf pine in the north. As a result, this region contains large populations of pine specialists (e.g., red-cockaded woodpecker, brown-headed nuthatch, and pine warbler). The WGCP also contains broad swaths of bottomland hardwood forest, particularly along the Arkansas, Ouachita, and Sabine Rivers, which support substantial populations of the hooded warbler, Kentucky warbler, and Swainson's warbler (Conner and Dickson 1997).

METHODS

Priority Bird Species

We selected priority bird species for modeling by identifying a subset of the forest-breeding landbirds in the CH or WGCP with a Partners in Flight (PIF) regional combined score of at least 15 (Panjabi and others 2005) or an FWS designation as a Bird of Conservation Concern (USDI Fish and Wildl. Serv. 2002) (Table 1). Forty-nine species initially met these criteria. We eliminated Bachman's warbler and the ivory-billed woodpecker from consideration due to limited habitat and validation data available within the CH and WGCP for these species. Also, we did not model habitat suitability for the ruffed grouse, broad-winged hawk, eastern kingbird, scissor-tailed flycatcher, loggerhead shrike, summer tanager, or eastern towhee. We added American woodcock, blue-gray gnatcatcher, great crested flycatcher, and northern parula to ensure the species modeled were representative of a cross section of habitat associations (e.g., early successional forest, pine savanna, bottomland hardwoods) and conservation priorities (e.g., critical recovery, management attention, planning and responsibility) within these BCRs.

HSI Model Development

In our adaptation of the HSI approach, we assume that habitat suitability is a function of both composition and structure at the site and landscape scales. To characterize environmental variables at each of these scales, we relied on six nationally consistent datasets:

1. Ecological subsections from the National Ecological Unit Hierarchy.
2. National Landcover Dataset (NLCD) (30-m pixels).
3. National Elevation Dataset (NED) (30-m pixels).
4. National Hydrography Dataset (NHD).
5. State Soil Geographic Database (STATSGO).
6. Forest Inventory and Analysis (FIA) data.

The first five datasets are widely available and commonly used to characterize landscape composition and structure. The sixth, FIA, provides information on the composition and structure of vegetation within forest patches (i.e., site scale) from a national field survey of forest lands undertaken by the USDA Forest Service. A description of the methodology used to integrate these datasets in a spatially explicit framework is available in Tirpak and others (2009b).

Table 2.—Parameters and data sources for inputs in priority forest-breeding landbird Habitat Suitability Index models, Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions; numbers correspond to Suitability Index (SI) functions in text

	Species code[a]					
Data source	ACFL	AMWO	BACS	BEVI	BEWR	BAWW
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)						
NLCD and NHD						
Occurrence of water						
Distance (m) to water	2					
NLCD						
Forest patch size (ha)	4		2			2
Landscape composition (percent forest in 1-km radius)	5					3
Landscape composition (percent forest in 10-km radius)						
Occurrence of edge				3		
Distance (m) to edge						
Interspersion – 1 landcover class						
Interspersion – 2 landcover classes		3		2	2	
Connectivity (km)			4			
Grass-open landcover						
FIA						
Basal area (m^2/ha)						
Hardwood basal area (m^2/ha)						
Pine basal area (m^2/ha)						
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)						
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)					3	
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)	3		3			4
Small stem (< 2.5 cm d.b.h.) density (stems/ha)		2		4		
DEM						
Slope						
NHD						
Distance (m) to stream						
STATSGO						
Soil texture		4				
Soil moisture		5				

continued

As a first step in developing HSI models, we identified key habitat factors for each species from the literature and compiled all pertinent data from these sources. In the interests of parsimony and processing time, we generally limited our HSI models to five or fewer suitability indices (Table 2). The first SI in all models (with the exception of chimney swift) was a function that assigned SI scores to unique combinations of landform, landcover, and successional age classes. Landform comprised three classes (floodplain-valley, terrace-mesic, and xeric-ridge) developed from the digital elevation model-derived metrics of aspect, slope, topographic position (the difference between the elevation value of an individual pixel and the average elevation in a 500- and 1,500-m-radius window around it), and relief. Landcover was classified to seven forest types derived from the NLCD: low-density residential, transitional-shrubland, deciduous, evergreen,

Table 2.—continued

Data source	Species code[a]					
	BGGN	BWWA	BRTH	BHNU	CACH	CERW
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)		2				
NLCD and NHD						
Occurrence of water						
Distance (m) to water						
NLCD						
Forest patch size (ha)	2					2
Landscape composition (percent forest in 1-km radius)						3
Landscape composition (percent forest in 10-km radius)	3		4			
Occurrence of edge	4		2			
Distance (m) to edge						
Interspersion – 1 landcover class						
Interspersion – 2 landcover classes						
Connectivity (km)						
Grass-open landcover						
FIA						
Basal area (m^2/ha)	5					
Hardwood basal area (m^2/ha)				4		
Pine basal area (m^2/ha)						
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)						4
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)				2	2	
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)		3				5
Small stem (< 2.5 cm d.b.h.) density (stems/ha)			3	3		
DEM						
Slope						
NHD						
Distance (m) to stream						
STATSGO						
Soil texture						
Soil moisture						

continued

mixed, orchard-vineyard, and woody wetlands. Finally, successional age class was delineated into five classes based on the average diameter at breast height (d.b.h.) of dominant trees in each stand, ultimately derived from FIA data: grass-forb (trees < 2.5 cm d.b.h.), shrub-seedling (2.5 to 7.5 cm), sapling (7.5 to 12.5 cm), pole (12.5 to 37.5 cm), and sawtimber (> 37.5 cm).

We assigned to each of the 105 unique landform, landcover, and successional age class combinations (three landform classes × seven forest type classes × five successional age classes) an SI value based on the relative habitat suitability rankings reported in the bird habitat matrices in Hamel (1992). These matrices qualitatively assess habitat suitability (marginal, suitable, optimal) for each bird species based on seral stage (4 classes) and forest type (23 classes). To adapt these matrices to our purposes, we crosswalked these forest types to our

Table 2.—continued

Data source	Species code[a]					
	CHSW	CWWI	EAWP	FISP	GCFL	HOWA
DEM, NLCD, and FIA						
Landform, landcover, and successional age class		1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)						
NLCD and NHD						
Occurrence of water						
Distance (m) to water						
NLCD						
Forest patch size (ha)						4
Landscape composition (percent forest in 1-km radius)			2			5
Landscape composition (percent forest in 10-km radius)						
Occurrence of edge						
Distance (m) to edge					3	
Interspersion – 1 landcover class	1					
Interspersion – 2 landcover classes		2				
Connectivity (km)						
Grass-open landcover				4		
FIA						
Basal area (m^2/ha)						
Hardwood basal area (m^2/ha)						
Pine basal area (m^2/ha)						
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)			3			
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)						
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)					2	
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)				2		3
Small stem (< 2.5 cm d.b.h.) density (stems/ha)				3		2
DEM						
Slope						
NHD						
Distance (m) to stream						
STATSGO						
Soil texture						
Soil moisture						

continued

landform-landcover classes and adapted the four seral stages to our five successional age classes (Table 3). First, we identified which of the 23 forest types occurred in the CH or WGCP (seven types: Sandhills longleaf pine, oak-gum-cypress, elm-ash-cottonwood, loblolly pine-shortleaf pine, mixed pine-hardwood, oak-hickory, and cove hardwoods). We then assigned these forest types to specific landform and landcover combinations based on the physiography associated with these forest communities.

However, not all NLCD landcovers have an analogous forest types in the Hamel classification. For example, orchards-vineyards, low-density residential, and transitional-shrubland landcover types provide habitat for many priority species but do not have a specific forest type association. Therefore, we assigned to orchards-vineyards and low-density residential sites the same SI scores

Table 2.—continued

Data source	Species code[a]					
	KEWA	LOWA	MIKI	NOBO	NOPA	OROR
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)						
NLCD and NHD						
Occurrence of water						
Distance (m) to water						
NLCD						
Forest patch size (ha)	3	5	2		2	
Landscape composition (percent forest in 1-km radius)		6			3	2
Landscape composition (percent forest in 10-km radius)	4					
Occurrence of edge						
Distance (m) to edge						
Interspersion – 1 landcover class						
Interspersion – 2 landcover classes			3	5		
Connectivity (km)						
Grass-open landcover				4		
FIA						
Basal area (m^2/ha)						3
Hardwood basal area (m^2/ha)				2		
Pine basal area (m^2/ha)				3		
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)			4			
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)						
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)		3			4	
Small stem (< 2.5 cm d.b.h.) density (stems/ha)	2	4				
DEM						
Slope						
NHD						
Distance (m) to stream		2				
STATSGO						
Soil texture						
Soil moisture						

continued

as those for deciduous landcovers on the assumption that orchards are composed primarily of deciduous species and low-density residential sites typically are planted with deciduous shade trees. Similarly, we assumed that transitional-shrubland sites are regenerating forests. Where there were transitional-shrubland pixels in floodplain-valley landforms, we assumed that they were hardwood forest regeneration. Thus, we assigned to them the same SI scores associated with deciduous habitats. On the higher and drier landforms, transitional-shrubland sites likely are dominated by oak and redcedar in the CH and pine in the WGCP, so we assigned to these sites the same SI scores as those for mixed and evergreen forest in each BCR, respectively (Table 3).

To assign SI scores to specific age classes, we used the relative habitat quality values reported in Hamel (1992) for grass-forb, shrub-seedling, and sawtimber seral stages. However, Hamel

Table 2.—continued

Data source	Species code[a]					
	PABU	PIWO	PRAW	PROW	RCWO	RHWO
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)			3			
NLCD and NHD						
Occurrence of water				2		
Distance (m) to water						
NLCD						
Forest patch size (ha)		3		3	2	
Landscape composition (percent forest in 1-km radius)		4		4		
Landscape composition (percent forest in 10-km radius)						
Occurrence of edge			2			5
Distance (m) to edge	2					
Interspersion – 1 landcover class						
Interspersion – 2 landcover classes	3					
Connectivity (km)					5	
Grass-open landcover						
FIA						
Basal area (m^2/ha)						
Hardwood basal area (m^2/ha)					4	
Pine basal area (m^2/ha)					3	
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						4
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)					6	
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)						
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)				5		2
Large (> 30 cm d.b.h.) snag density (snags/ha)		2				3
Canopy cover (percent)			5			
Small stem (< 2.5 cm d.b.h.) density (stems/ha)	4		4			
DEM						
Slope						
NHD						
Distance (m) to stream						
STATSGO						
Soil texture						
Soil moisture						

continued

combined sapling- and pole-size trees into a single class, whereas we separated these two successional age classes (a segregation we believed was more appropriate for many of our species). To tease apart the SI scores for sapling and pole age classes, we averaged the value for sapling-pole with shrub-seedling (for sapling) or sawtimber (for pole). This approach assumes that sapling and pole stands have an equal weighting by Hamel in assessing the relative habitat quality for the aggregate age class, and that there is a linear relationship across age classes that allows us to discern the relative influence of each by simple averaging.

After crosswalking Hamel's forest types and seral stages to our landform-landcover-successional age class matrix, we assigned SI scores to each unique combination based on Hamel's qualitative assessments. Combinations considered optimal (Hamel 1992) were assigned a value of 1.000;

Table 2.—continued

Data source	SWWA	STKI	WPWI	WEVI	WOTH	WEWA
	Species code[a]					
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)						
NLCD and NHD						
Occurrence of water						
Distance (m) to water						
NLCD						
Forest patch size (ha)	2	2			2	3
Landscape composition (percent forest in 1-km radius)	3				3	4
Landscape composition (percent forest in 10-km radius)						
Occurrence of edge				2		
Distance (m) to edge						
Interspersion – 1 landcover class		3				
Interspersion – 2 landcover classes			2			
Connectivity (km)						
Grass-open landcover						
FIA						
Basal area (m^2/ha)						
Hardwood basal area (m^2/ha)						
Pine basal area (m^2/ha)						
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)		4				
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)						
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)				3	5	
Small stem (< 2.5 cm d.b.h.) density (stems/ha)	4			4	4	5
DEM						
Slope						2
NHD						
Distance (m) to stream						
STATSGO						
Soil texture						
Soil moisture						

continued

those considered suitable were assizned a value of 0.667; and those considered marginal had a value of 0333. We assumed that forest types and age classes not assigned a qualitative habitat ranking were not used and assigned to these combinations an SI score of zero. Where a landform-landcover type was represented by more than one of Hamel's forest types, SI values for the forest types were averaged. For example, deciduous landcover on floodplain-valley landforms are associated with cove hardwood and elm-ash-cottonwood forest communities. Cove hardwood is suitable (SI = 0.667) for the Acadian flycatcher but elm-ash-cottonwood is optimal (SI = 1.000). Thus, this landform-landcover type combination is assigned a base SI score of 0.834 (i.e., 1.667/2) prior to adjusting for successional age class (Table 4). Finally, we standardized all SI scores in the matrix to ensure that the maximum value was 1.000.

Table 2.—continued

Data source	Species code[a]			
	YBCU	YBCH	YTVI	YTWA
DEM, NLCD, and FIA				
Landform, landcover, and successional age class	1	1	1	1
NLCD and FIA				
Early successional patch size (ha)		3		
NLCD and NHD				
Occurrence of water				
Distance (m) to water				3
NLCD				
Forest patch size (ha)	5		2	
Landscape composition (percent forest in 1-km radius)			3	4
Landscape composition (percent forest in 10-km radius)	4			
Occurrence of edge	2	2		
Distance (m) to edge				
Interspersion – 1 landcover class				
Interspersion – 2 landcover classes				
Connectivity (km)				
Grass-open landcover				
FIA				
Basal area (m^2/ha)				
Hardwood basal area (m^2/ha)				
Pine basal area (m^2/ha)				
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)				
Large (> 50 cm d.b.h) tree density (trees/ha)				2
Large (> 35 cm d.b.h) pine density (trees/ha)				
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)				
Midstory (11–25 cm d.b.h.) density (trees/ha)	3			
Snag density (snags/ha)				
Large (> 30 cm d.b.h.) snag density (snags/ha)				
Canopy cover (percent)			4	
Small stem (< 2.5 cm d.b.h.) density (stems/ha)		4		
DEM				
Slope				
NHD				
Distance (m) to stream				
STATSGO				
Soil texture				
Soil moisture				

[a]Pyle and DeSante 2003; see Table 1.

Similarly, we directly assigned SI scores to individual classes for other discrete environmental variables (e.g., occurrence of water). For continuous environmental variables (e.g., canopy cover), we used CurveExpert 1.38 software (Hyams 2001)[1] to fit smoothed functions through known data points derived from the literature that quantify the relationship between each specific environmental factor and HSI scores for particular species. Information sources, assumptions, and functions (type and equation) are detailed in the model accounts.

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or Forest Service of any product or service to the exclusion of others that may be suitable.

Table 3.—Crosswalk between landform-landcover class combinations and vegetation types defined in Hamel (1992)

Landform	Landcover type	Hamel vegetation type[a]
Floodplain-valley	Low-density residential	Same as deciduous
	Transitional-shrubland	Same as deciduous
	Deciduous	Cove hardwoods Elm-ash-cottonwood
	Evergreen	Loblolly pine-shortleaf pine
	Mixed	Mixed pine-hardwood
	Orchards-vineyards	Same as deciduous
	Woody wetlands	Oak-gum-cypress Elm-ash-cottonwood
Terrace-mesic	Low-density residential	Same as deciduous
	Transitional-shrubland	Same as mixed in Central Hardwoods, same as evergreen in West Gulf Coastal Plain/Ouachitas
	Deciduous	Oak-hickory Cove hardwoods
	Evergreen	Loblolly pine-shortleaf pine
	Mixed	Mixed pine-hardwood
	Orchards-vineyards	Same as deciduous
	Woody wetlands	Elm-ash-cottonwood
Xeric-ridge	Low-density residential	Same as deciduous
	Transitional-shrubland	Same as Mixed in Central Hardwoods, same as evergreen in West Gulf Coastal Plain/Ouachitas
	Deciduous	Oak-hickory
	Evergreen	Loblolly pine-shortleaf pine. Also includes Sandhills longleaf pine in West Gulf Coastal Plain/Ouachitas
	Mixed	Mixed pine-hardwood
	Orchards-vineyards	Same as deciduous
	Woody wetlands	Elm-ash-cottonwood

[a]Hamel (1992).

To calculate the overall HSI score, we determined the geometric mean of SI scores for site-scale and landscape-scale variables separately and then the geometric mean of these means together. Use of the geometric mean follows recommendations from the published standards for development of HSI models (USDI Fish and Wildl. Serv. 1981). The equal weighting of individual functions within a spatial scale assumes that all variables are required for a habitat to be suitable and that all variables are nonsubstitutable. Further, the equal weighting of functions across scales assumes that site and landscape variables are equally important. The notable exception to use of the geometric mean was for species where both forest patch size and percent forest in the landscape are included as model parameters. In these cases, we used the maximum SI score from these two variables to account for the use of small forest patches by area-sensitive species when small patches are embedded in predominantly forested landscapes (Rosenberg and others 1999). For each species, we solicited at least five reviewers with an intimate knowledge of the habitat requirements of at least one species. Each reviewer received a standard questionnaire requesting feedback on the appropriateness of the functions included in the model. We revised models based on reviewers' comments.

Model Testing

To test the HSI models for reliability, we followed the three-stage framework (calibration, verification, and validation) outlined by Brooks (1997). We first ensured that the equations

Table 4.—Initial assignment of suitability index scores for Acadian flycatcher habitat to landform, landcover type, and successional age classes based on Hamel (1992)

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.834	0.834	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	1.000	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.667	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.834	0.834	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.333	0.333	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.834	0.834	1.000

used to predict SI scores resulted in the full potential range of SI scores given the habitat conditions within each BCR (i.e., calibration). We then used Spearman rank correlation to compare HSI scores to abundance estimates from Breeding Bird Survey (BBS) data summarized by ecological subsection (i.e., verification). We ranked subsections by HSI score and BBS abundance for each species and within each BCR independently to compensate for geographical differences in these regions not explicitly incorporated in the HSI models. We assessed correlations between these variables based on all subsections and based solely on subsections within which each species was detected. The former analysis provides insight into the overall model performance; the latter addresses the potential bias associated with correctly predicting the absence of a rare species in many subsections.

Following verification, we validated HSI models by developing species-specific generalized linear models that predicted abundance (as indexed by BBS data) from HSI and BCR predictor variables. We considered HSI models validated if the general linear model was significant ($P < 0.100$) and the coefficient on the HSI predictor variable was both significant ($P < 0.100$) and positive. Detailed results of these analyses are documented in Tirpak and others (2009a).

MODEL ACCOUNTS

Acadian Flycatcher

Status

John J. Mosesso, images.nbii.gov

The Acadian flycatcher (*Empidonax virescens*) is a long-distance migrant found throughout most of the eastern United States. While populations have declined in the northern portion of its range (particularly the Appalachians) over the last 40 years, populations in the South, particularly along the Atlantic and East Gulf Coastal Plains, have increased (Sauer and others 2005). However, the Acadian flycatcher has declined in the WGCP (Table 5), and the FWS classifies this species as a Bird of Conservation Concern in the WGCP (Table 1). Similarly, PIF considers the Acadian flycatcher as a planning and responsibility species in the CH (regional combined score of 16). In the WGCP, the flycatcher has a regional combined score of 17, warranting management attention (Table 1).

Natural History

The Acadian flycatcher is a forest-interior species associated with water throughout most of its range: bottomland hardwood and cypress forests in the Southeast and riparian forests and ravines in the deciduous forests of the Midwest and Northeast (Whitehead and Taylor 2002). This species is found in numerous forest types and uses a variety of tree species for nesting. However, this bird typically is associated with mesic forest stands and avoids upland oak-hickory sites (Klaus and others 2005). Breeding territories are small and average 1 ha (Woolfenden and others 2005). The Acadian flycatcher typically nests in midstory trees and large shrubs in mature forests. Canopy cover typically is dense (> 95 percent; Wilson and Cooper 1998), and the understory usually is sparse (Bell and Whitmore 2000, Wood and others 2004).

The Acadian flycatcher is particularly susceptible to forest fragmentation. Aquilani and Brewer (2004) found this species only in forest tracts larger than 55 ha in north-central Mississippi. Blake and Karr (1987) did not observe the Acadian flycatcher in woodlots smaller than 24 ha. In east Texas, the Acadian flycatcher was absent from riparian buffer strips less than 70 m wide (Conner and others 2004). Results were similar in Missouri (Peak and others 2004) and Indiana (Ford and others 2001).

Even in large forested tracts (> 600 ha), nest predation and parasitism rates may be 10 to 20 percent higher if the surrounding landscape is highly fragmented. Nevertheless, Fauth and Cabe (2005) did not observe significant effects of parasitism on a Blue Ridge study site where 75 percent of the landscape was forested, including 45 percent more than 250 m from an edge. Disturbance, whether natural (e.g., tornado or pest outbreak) or anthropogenic (e.g., silvicultural treatments—thinning, selective harvesting, clearcutting, and prescribed burning) reduced the abundance and productivity of the Acadian flycatcher in most landscapes (Artman and others 2001, Duguay and others 2001, Robinson and Robinson 2001, Twedt and others 2001, Prather and Smith 2003, Blake 2005).

Table 5.—Trend estimates (percent change per year) for 40 priority landbird species in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions, 1967 to 2004 (Sauer and others 2005)

	Central Hardwoods			West Gulf Coastal Plain/Ouachitas		
Species	Trend	*P*	*n*[a]	Trend	*P*	*n*
Acadian flycatcher	-0.3	0.56	107	-2.0	0.05	67
American woodcock	-9.1	0.35	3	--[b]	--	--
Bachman's sparrow	--	--	--	-7.8	0.00	27
Bell's vireo	-3.2	0.49	18	-4.7	0.03	14
Bewick's wren	-6.5	0.00	61	0.8	0.88	11
Black-and-white warbler	2.3	0.21	50	-2.9	0.01	60
Blue-gray gnatcatcher	-1.0	0.26	118	-0.9	0.36	75
Blue-winged warbler	-4.0	0.01	62	--	--	--
Brown thrasher	-1.4	0.00	125	-1.4	0.01	64
Brown-headed nuthatch	--	--	--	-1.4	0.18	52
Carolina chickadee	0.2	0.70	123	-2.0	0.00	77
Cerulean warbler	-6.3	0.00	34	-9.5	0.00	5
Chimney swift	-2.6	0.00	124	-1.1	0.15	76
Chuck-will's-widow	-0.9	0.19	64	-1.3	0.04	60
Eastern wood-pewee	-1.4	0.00	124	-4.9	0.00	75
Field sparrow	-3.2	0.00	125	-3.7	0.01	45
Great crested flycatcher	-0.8	0.09	123	-1.3	0.04	77
Hooded warbler	2.7	0.08	31	-3.1	0.35	60
Kentucky warbler	-0.4	0.32	108	-2.2	0.00	73
Louisiana waterthrush	2.6	0.02	66	-1.3	0.49	28
Mississippi kite	16.3	0.16	2	6.4	0.21	16
Northern bobwhite	-3.1	0.00	125	-4.4	0.00	75
Northern parula	3.7	0.00	95	-2.5	0.17	53
Orchard oriole	-0.9	0.01	124	-3.0	0.01	75
Painted bunting	19.8	0.61	5	-0.6	0.48	63
Pileated woodpecker	1.8	0.01	112	-0.9	0.14	72
Prairie warbler	-2.6	0.00	94	-4.4	0.00	60
Prothonotary warbler	0.0	0.98	52	-5.8	0.00	53
Red-cockaded woodpecker	--	--	--	9.0	0.00	6
Red-headed woodpecker	-1.0	0.09	115	-3.2	0.00	68
Swainson's warbler	--	--	--	23.5	0.23	26
Swallow-tailed kite	--	--	--	--	--	--
Whip-poor-will	-1.8	0.05	71	6.6	0.22	11
White-eyed vireo	-0.4	0.20	120	-0.8	0.19	76
Wood thrush	-0.7	0.05	118	-1.4	0.05	67
Worm-eating warbler	0.4	0.77	44	-2.3	0.51	28
Yellow-billed cuckoo	-1.9	0.00	125	-1.1	0.00	77
Yellow-breasted chat	-1.9	0.00	125	1.3	0.01	75
Yellow-throated vireo	0.9	0.25	99	1.1	0.38	62
Yellow-throated warbler	3.8	0.00	76	-0.9	0.65	43

[a]Number of Breeding Bird Survey routes on which trend estimate is based.
[b]No trend estimate available.

Table 6.—Relationship of landform, landcover type, and successional age class to suitability index scores for Acadian flycatcher habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.050	0.917	1.000
	Deciduous	0.000	0.000	0.050	0.917	1.000
	Evergreen	0.000	0.000	0.017	0.167	0.333
	Mixed	0.000	0.000	0.017	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.050	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.017	0.333	0.333
	Deciduous	0.000	0.000	0.042	0.667	0.834
	Evergreen	0.000	0.000	0.017	0.167	0.333
	Mixed	0.000	0.000	0.017	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.050	1.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.017	0.333	0.333
	Deciduous	0.000	0.000	0.033	0.500	0.667
	Evergreen	0.000	0.000	0.017	0.167	0.333
	Mixed	0.000	0.000	0.017	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.050	1.000	1.000

Model Description

Our Acadian flycatcher model includes seven variables related to density: landform, landcover type, successional age class, distance to water, canopy cover, forest patch size, and percent forest in a 1-km radius window.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 6). We directly assigned SI scores to these combinations on the basis of habitat suitability data from Hamel (1992) on the relative quality of different vegetation types and successional stages for the Acadian flycatcher. However, we reduced SI scores for sapling and evergreen habitats on the basis of data from Hazler (1999).

Because the Acadian flycatcher typically is found near water (Whitehead and Taylor 2002), we fit an inverse logistic function to describe the relationship between SI scores for this species and increasing distance to water (SI2; Fig 2). The flycatcher often aligns at least one edge of its 1-ha territory along a stream or wetland (Woolfenden and others 2005).

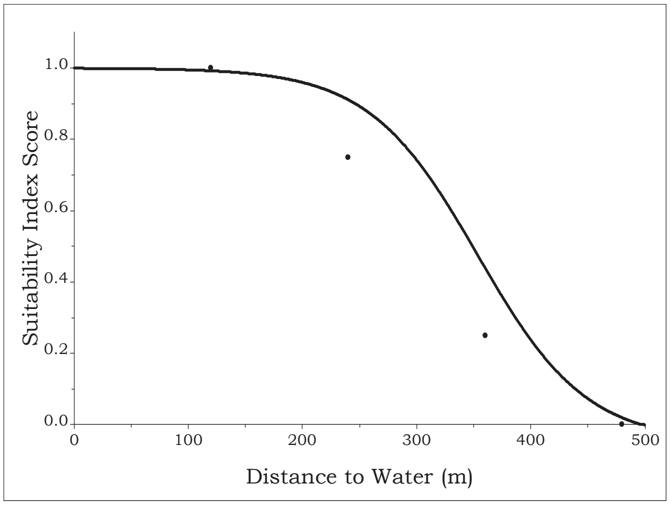


Figure 2.—Relationship between distance to water and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 1 - (1.049 / (1 + (1664.953 * $e^{-0.021 * \text{distance to water}}$))).

Table 7.—Relationship between distance to water and suitability index (SI) scores for Acadian flycatcher habitat

Distance to water (m)[a]	SI score
0[b]	1.00
120[c]	1.00
240[b]	0.75
360[b]	0.25
480[b]	0.00

[a]Water defined as streams from the National Hydrography Dataset (medium resolution) or classified as water, woody wetlands, or emergent herbaceous wetlands in the National Land Cover Dataset.

[b]Assumed value.

[c]Woolfenden and others (2005).

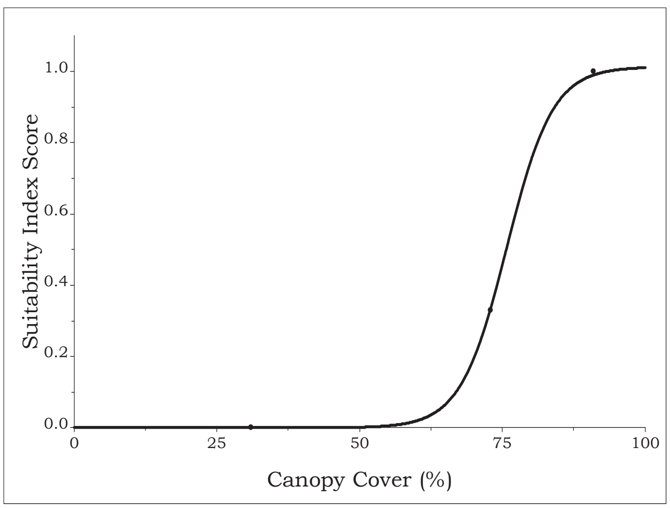


Figure 3.—Relationship between canopy cover and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 1.013 / (1.000 + (144082770 * $e^{-0.248 * \text{canopy cover}}$)).

Table 8.—Relationship between canopy cover and suitability index (SI) scores for Acadian flycatcher habitat

Canopy cover (percent)	SI score
0[a]	0.00
31[b]	0.00
73[b]	0.33
91[b]	1.00
100[a]	1.00

[a]Assumed value.

[b]Prather and Smith (2003).

Assuming a circular home range, the diameter of the home range (112.8 m) represents the farthest distance from water a bird could be within the home range. On the basis of this assumption, we assigned all locations less than 120 m from water SI scores of 1.000 (Table 7). The Acadian flycatcher also uses sites that are more than 120 m from water but generally are found at lower densities there. Thus, we considered areas 360 m from water (a distance of three home range diameters) as having an SI score that is one-quarter of the optimal value (0.250) and sites at least 480 m from water as nonhabitat (SI score of zero).

The habitat suitability model for the Acadian flycatcher also included canopy closure (SI3) as a variable because of the strong affinity of this species for closed-canopy forests (Prather and Smith 2003). For this variable, we used a logistic function (Fig. 3) to extrapolate between known break points in the canopy cover-relative density relationship (Table 8).

We also included forest patch size (SI4) as a variable because of the sensitivity of the Acadian flycatcher to fragmentation (Robbins and others 1989) and increasing edge density (Parker and others 2005). We used a logarithmic function (Fig. 4) to describe the relatively quick increase in suitability of a forest patch with increasing area (Robbins and others 1989) (Table 9). We assumed that 312 ha, the minimum forest patch size on which Wallendorf and others (2007) always observed the Acadian flycatcher, was representative of optimal habitat (SI score = 1.000). Nevertheless, the effects of forest patch size on suitability are influenced by the percentage of forest in the landscape. In predominantly forested landscapes, small forest patches that may not be used in predominantly nonforested landscapes may provide habitat due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 5) to data (Table 10) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum value of SI4 or SI5 to assess area sensitivity and to account for small patches in predominantly forested landscapes and large patches in predominantly non-forested landscapes.

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI3) and landscape attributes (maximum value of SI4 or SI5 and SI2) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI3)^{0.500} * (Max(SI4 \text{ or } SI5) * SI2)^{0.500})^{0.500}$

Verification and Validation

The Acadian flycatcher was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.47$) between average HSI score and mean BBS abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the Acadian flycatcher was significant ($P = 0.095$; $R^2 = 0.054$), and the coefficient on the HSI predictor variable was both positive ($\beta = 4.250$) and significantly different from zero ($P = 0.043$). Therefore, we considered the HSI model for the Acadian flycatcher both verified and validated (Tirpak and others 2009a).

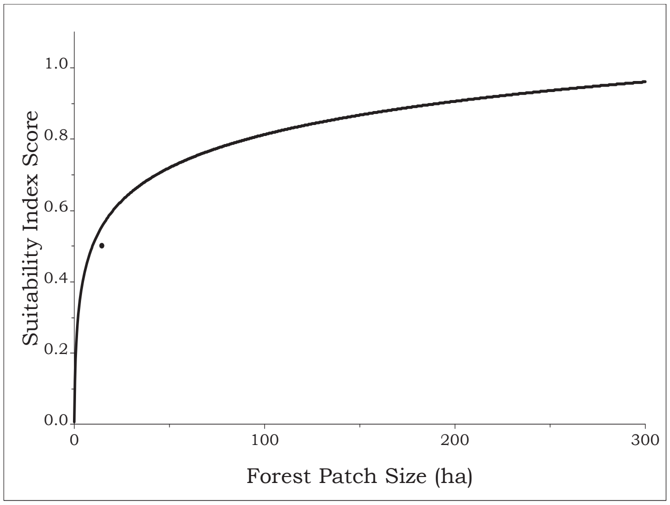


Figure 4.—Relationship between forest patch size and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 0.174 * ln(forest patch size) + 0.010.

Table 9.—Relationship between forest patch size and suitability index (SI) scores for Acadian flycatcher habitat

Forest patch size (ha)	SI score
0.2[a]	0.0
15[a]	0.5
312[b]	1.0

[a]Robbins and others (1989).
[b]Wallendorf and others (2007).

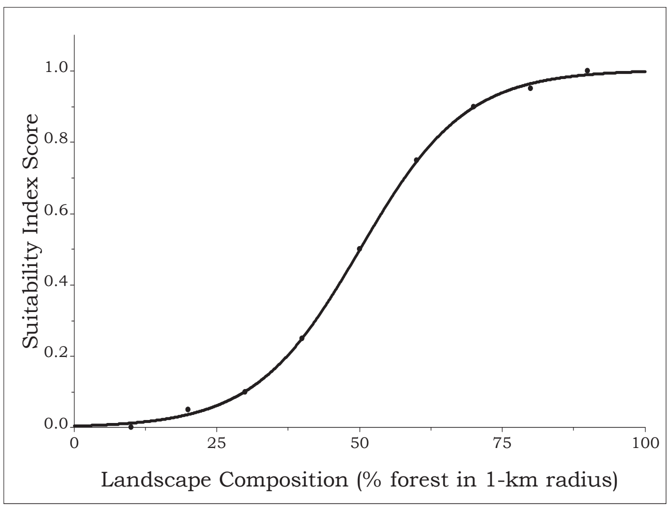


Figure 5.—Relationship between landscape composition and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (landscape composition)}$)).

Table 10.—Relationship between local landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for Acadian flycatcher habitat

Local landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed that value.
[b]Dononvan and others (1997).

American Woodcock

U.S. Fish & Wildlife Service

Status

The American woodcock (*Scolopax minor*) is a popular gamebird found throughout the eastern United States and southeastern Canada. Although this species breeds primarily in the northern portion of its continental range, small numbers breed regularly throughout the wintering range in the Southeast. Singing ground surveys and wing collections from northern latitudes in the Central United States document annual 1.8 percent declines in woodcock since 1968 (Kelley 2003). The status of the relatively small breeding population in the Southeast is unknown.

Natural History

The American woodcock breeds in early successional habitat throughout its range (Keppie and Whiting 1994). Typically, these young forest stands are on moist, uncompacted soils that allow the woodcock to probe for earthworms, the bird's preferred food (Steketee 2000). Equally important is an interspersion of the forest with openings that provide sites for both courtship displays and roosting (Sepik and Derleth 1993). Openings used by woodcock in Maine generally were at least 1.2 ha (Dunford and Owen 1973). Given the affinity of the woodcock for openings and early successional habitat, Sprankle and others (2000) recommended even-age forest management in rotational blocks to ensure that both habitat requirements are met.

Most of the available quantitative information on breeding habitat for the American woodcock is from the Northeast, particularly Maine and Pennsylvania (Straw and others 1986, McAuley and others 1996). Shrub cover generally is high (75 to 87 percent; Morgenweck 1977), while overstory cover typically is moderate (50 to 64 percent; Dunford and Owen 1973, Gregg and others 2000). Nests are in young forest stands (Morgenweck 1977). McAuley and others (1996) compared nest sites to random sites and found lower basal area and fewer coniferous saplings, but higher densities of deciduous saplings and shrub stems around nests sites. Young broods inhabit young to mid-age forest interspersed with openings; older broods occupy sites with greater basal area but fewer mature trees (Morgenweck 1977).

Many habitat variables have been associated with the presence of woodcock (Storm and others 1995; Klute and others 2002). Landcover variables were the best predictors at fine scales whereas indices of landscape heterogeneity were the most important predictors at large spatial scales (Klute and others 2000). Murphy and Thompson (1993) developed a model to predict the density of males on singing grounds in central Missouri that contained small stem density (≤ 2.5 cm d.b.h.), tree density (> 2.5 cm d.b.h.), and field size as predictor variables.

Table 11.—Relationship of landform, landcover type, and successional age class to suitability index scores for American woodcock habitat

Landform	Landcover type	Successional age class				
		Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	1.000	0.667	0.333
	Deciduous	0.000	0.000	1.000	0.667	0.333
	Evergreen	0.000	0.000	0.500	0.250	0.125
	Mixed	0.000	0.000	0.667	0.333	0.167
	Orchard-vineyard	0.000	0.000	0.667	0.333	0.167
	Woody wetlands	0.000	0.000	1.000	0.667	0.333
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.834	0.500	0.250
	Deciduous	0.000	0.000	0.834	0.500	0.250
	Evergreen	0.000	0.000	0.400	0.200	0.100
	Mixed	0.000	0.000	0.500	0.250	0.125
	Orchard-vineyard	0.000	0.000	0.500	0.250	0.125
	Woody wetlands	0.000	0.000	0.834	0.500	0.250
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.750	0.400	0.167
	Deciduous	0.000	0.000	0.750	0.400	0.167
	Evergreen	0.000	0.000	0.333	0.167	0.083
	Mixed	0.000	0.000	0.400	0.200	0.100
	Orchard-vineyard	0.000	0.000	0.500	0.417	0.000
	Woody wetlands	0.000	0.000	0.750	0.400	0.167

Model Description

The American woodcock HSI model includes seven variables: landform, landcover, successional age class, small stem density (< 2.5 cm d.b.h.), composition of appropriately sized foraging-nesting and courtship-roosting habitat patches in the landscape, soil moisture, and soil texture.

The first suitability function combines landform, landcover type, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 11). Because the woodcock prefers moist habitats with high deciduous stem densities, we assigned the highest SI scores to sapling-aged transitional, deciduous, and woody wetland cover types in floodplain-valley landforms. We considered mixed and evergreen forests as well as xeric-ridge landforms as poor habitat for the American woodcock.

We included small stem density (SI2) as a model function because the woodcock relies on vertical structure to provide security from predators as it forages, nests, and loafs during the day. McAuley and others (1996) summarized habitat attributes around woodcock nest sites from seven studies in which stem density ranged from 5,051 to 49,250 stems per ha. Due to the relatively small sample size and the lack of geographic representation within the samples

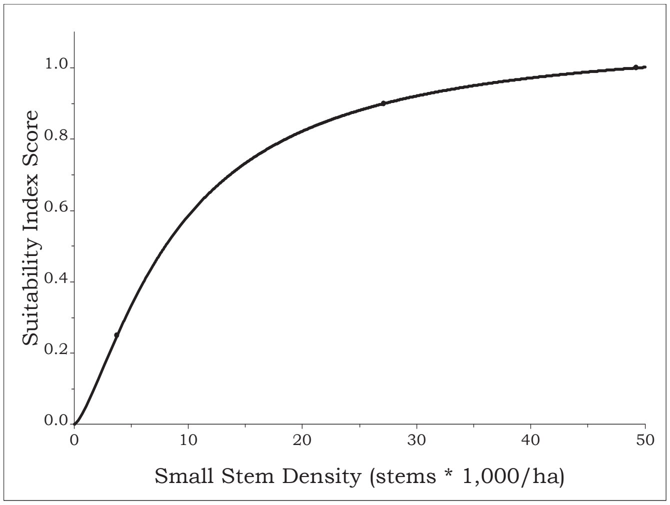


Figure 6.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems*1000/ha) and suitability index (SI) scores for American woodcock habitat. Equation: SI score = 1.029 * $(0.998 - e^{-0.076 * (\text{small stem density} / 1000)})$.

Table 12.—Influence of small stem (< 2.5 cm d.b.h.) density (stems*1,000/ha) on suitability index (SI) scores for American woodcock habitat

Small stem density	SI score
0[accc]	0.00
3.767[b]	0.25
27.125[c]	0.90
49.250[d]	1.00

[a]Assumed value.
[b]Murphy and Thompson (1993).
[c]McAuley and others (1996).
[d]Coon and others (1982).

(both New York and Pennsylvania are represented twice), we used the midpoint of this range rather than the average to summarize these data. With three of the studies observing stem densities of at least 44,000 and three observing densities of approximately 14,000 stems per ha (+/- 600 stems/ha), we believed there was adequate evidence to assign to the midpoint of this range (27,125 stems/ha) a higher SI score than average (0.500). Therefore, we assigned 27,125 stems per ha an SI score of 0.900, the maximum stem density (49,250) an SI score of 1.000 and the minimum density (3,767 stems/ha, as reported by Murphy and Thompson [1993]) an SI score of 0.250 (Table 12). We fit a logistic function through these data points to quantify the small stem density-SI score relationship (Fig. 6).

The next two variables relate to the minimum size of habitat patches used by the American woodcock. Movement rates within diurnal foraging and nesting habitats often are low, resulting in small diurnal home ranges (≤ 0.3 ha; Hudgins and others 1985). Conversely, the woodcock displays and roosts in relatively large openings at night (≥ 1.6 ha; Keppie and Whiting 1994). We used these data to establish minimum area thresholds for forests and openings, respectively. Nevertheless, the ultimate suitability of either of these habitat types is related to their interspersion with one another, as the woodcock requires both. Ideally, these habitats should be separated by less than 400 m (Hudgins and others 1985) even though the average home range may be at least 74 ha (485-m radius; Keppie and Whiting 1994). Because home ranges may encompass areas of nonhabitat, the American woodcock sometimes is found where the proportion of these habitat types within a typical home range is relatively small (e.g., 0.1; Table 13). We assumed that the woodcock derives greater benefit from increasing proportions of early successional forest habitat than field habitat within its home ranges due to greater foraging opportunities and increased protection from predators. Thus, our table defining the relationship between landscape composition (SI3)

Table 13.—Suitability index scores for American woodcock habitat based on composition of open and forest habitat within 500-m radius

Proportion forest[b]	Proportion open[a] 0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	
0.20	0.10	0.10	0.10	0.10	0.10	0.05	0.05	0.05	0.00		
0.30	0.20	0.20	0.20	0.20	0.20	0.10	0.10	0.05			
0.40	0.40	0.40	0.40	0.40	0.40	0.20	0.10				
0.50	0.60	0.60	0.60	0.60	0.60	0.40					
0.60	0.80	0.80	0.80	0.80	0.80						
0.70	1.00	1.00	1.00	1.00							
0.80	1.00	1.00	1.00								
0.90	1.00	1.00									
1.00	1.00										

[a]Merged grasslands, pasture/hay, fallow, urban/recreational grasses, emergent herbaceous wetlands, grass-forb, and shrub-seedling forests ≥1.6 ha.

[b]Sites with a positive SI1 score (Table 11) and ≥ 0.3 ha.

and SI scores shows greater increases in suitability with relatively modest increases in diurnal habitat compared to the increases in suitability associated with similar proportional increases in openings.

Soil properties also influence American woodcock habitat suitability. This species feeds nearly exclusively on earthworms, which it probes for preferentially in moist loamy soils (Rabe and others 1983). Because soils with excessive clay or sand contain insufficient, accessible earthworms with which to support a foraging woodcock, we included both soil texture (SI4) and soil drainage (SI5) as variables in the habitat suitability model. We used the STATSGO database to define soil characteristics. Soil texture classes from STATSGO were crosswalked to soil texture classes from the soil triangle (Table 14) and then assigned SI scores on the basis of texture descriptions in Rabe and others (1983) (Table 15). We also assumed that soil drainage class was associated with soil moisture content and similarly assigned SI scores to these drainage classes (Table 16) based on observations from Rabe and others (1983), who documented higher probing rates in soils with greater moisture contents.

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI2) and landscape factors (SI3, SI4 and SI5) separately and then the geometric mean of these means together.

$$\text{Overall HSI} = ((SI1 * SI2)^{0.500} * (SI3 * SI4 * SI5)^{0.333})^{0.500}$$

Table 14.—Crosswalk of soil texture classes defined in STATSGO soil database to soil texture triangle classes

STATSGO soil texture class	Soil texture triangle class
Clayey	Clay
Clayey over loamy	Clay
Clayey-skeletal	Clay
Coarse-loamy	Sandy loam
Coarse-silty	Sandy loam
Fine	Silt
Fine-loamy	Silt loam
Fine-loamy over clayey	Silty clay loam
Fine-loamy over sandy or sandy-skeletal	Silt loam
Fine-silty	Silt
Fine-silty over clayey	Silt
Loamy	Loam
Loamy-skeletal	Loam
Loamy-skeletal over clayey	Loam
Not used	None
Sandy	Sand
Very-fine	Silty clay
All others	None

Table 15.—Suitability index (SI) scores for American woodcock habitat based on soil texture triangle classes

Soil texture triangle class	SI score
Clay	0.0[a]
Silty clay	0.0[a]
Silty clay loam	0.2[a]
Silt loam	0.4[a]
Silt	0.0[a]
Loam	1.0[b]
Sandy loam	0.8[b]
Loamy sands	0.0[a]
Sands	0.0[b]
Sandy clay loam	0.4[a]
Sandy clay	0.0[a]
Clay loam	0.1[b]
None	0.0[a]

[a]Assumed value.
[b]Rabe and others (1983).

Table 16.—Suitability index (SI) scores for American woodcock habitat based on soil moisture, as defined by drainage class in the STATSGO soil database

Soil moisture	SI score
Very poorly	1.0[a]
Poorly	1.0[a]
Somewhat poorly	0.5[a]
Moderately well	0.1[a]
Well	0.0[a]
Somewhat excessively	0.0[a]
Excessively	0.0[a]

[a]Rabe and others (1983).

Verification and Validation

The American woodcock was observed only in 50 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.36$) between average HSI score and mean BBS route abundance across all subsections. When the 38 subsections in which the American woodcock was not found were removed from the analysis, the correlation not only remained significant ($P \leq 0.001$) but also was more strongly positive ($r_s = 0.68$). Thus, the HSI model is predicting habitat for this species in subsections where it was not detected on BBS routes. The generalized linear model predicting BBS abundance from BCR and HSI for the American woodcock was significant ($P \leq 0.001$; $R^2 = 0.218$), and the coefficient on the HSI predictor variable was both positive ($\beta = 0.090$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the American woodcock both verified and validated (Tirpak and others 2009a).

Bachman's Sparrow

U.S. Forest Service

Status

Bachman's sparrow (*Aimophila aestivalis*) is a resident bird associated with pine savannas and other open habitats throughout the Southeastern United States. Although its range expanded north to include Illinois, Indiana, and Ohio at the turn of the 20th century (likely in response to widespread land clearing), the range of this species has contracted steadily over the last 100 years. Today, the Bachman's sparrow is restricted to the extreme Southeast. BBS data from the central United States indicates significant annual declines (8.1 percent) over the past 40 years; declines have been particularly steep since 1980 (20.8 percent/year). This species is a Bird of Conservation Concern in both the CH and WGCP (Table 1). Similarly, this bird has a regional combined score of 20 in both regions, and PIF considers this species in need of critical recovery in the CH and immediate management in the WGCP (Table 1).

Natural History

Bachman's sparrow occupies two primary habitats in the Southeast: mature (> 80 year old) pine stands that are frequently burned (< 3-year burn interval) and recently cutover areas (< 5 year old; Dunning and Watts 1990). However, productivity is lower in these latter habitats (one vs. three offspring/pair/year; Liu and others 1995, Perkins and others 2003a). On the basis of this lower productivity and the poor colonizing ability of this species—suitable clearcut habitats more than 3 km from a source population generally remained unoccupied in South Carolina (Dunning and others 1995)—Tucker and others (2004) considered Bachman's sparrow as endemic to mature longleaf pine stands.

In all studies of Bachman's sparrow habitat, two features are identified repeatedly: a dense grass understory and an open overstory, both of which are maintained through frequent fires (Haggerty 1998, Plentovich and others 1998, Tucker and others 2004, Wood and others 2004). Stands managed for the red-cockaded woodpecker via prescribed burning typically provide excellent habitat for the Bachman's sparrow as well because the fires are frequent enough to suppress dense woody understories and maintain sparse canopies (Wilson and others 1995, Plentovich and others 1998, Provencher and others 2002, Wood and others 2004).

Model Description

Our habitat suitability model for the Bachman's sparrow includes six variables: landform, landcover type, successional age class, forest patch size, canopy cover, and connectivity.

The first suitability function combines landform, landcover type, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 17). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the relative quality of different vegetation types in different successional stages for this species.

Table 17.—Relationship of landform, landcover type, and successional age class to suitability index scores for Bachman's sparrow habitat

Landform	Landcover type	Successional age class: Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	1.000	0.333	0.000	0.000	1.000
	Deciduous	1.000	0.333	0.000	0.000	0.000
	Evergreen	1.000	0.333	0.000	0.000	1.000
	Mixed	1.000	0.333	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	1.000	0.333	0.000	0.000	1.000
	Deciduous	1.000	0.333	0.000	0.000	0.000
	Evergreen	1.000	0.333	0.000	0.000	1.000
	Mixed	1.000	0.333	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	1.000	0.333	0.000	0.000	1.000
	Deciduous	1.000	0.333	0.000	0.000	0.000
	Evergreen	1.000	0.333	0.000	0.000	1.000
	Mixed	1.000	0.333	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

We also included forest patch size (SI2) as a variable because of the relatively large home range for this species (mean = 2.5 ha; Haggerty 1998). Home ranges varied among regions and habitat types (reviewed in Mitchell 1998). They were slightly larger in evergreen stands (4.8 ha) than in ephemeral, early successional habitats (2.2 ha). We fit a logistic function (Fig. 7) through these data points, assuming that the former represented a stand area that would be occupied reliably and that the latter value was a minimum below which the sparrow would be absent (Table 18).

We included canopy cover (SI3) as a third suitability function to satisfy the two-fold requirement for open canopies and dense understories, two habitat components often well correlated (Table 19). Haggerty (1998) observed an average canopy cover of 9.5 percent at sites occupied by the Bachman's sparrow and 40 percent canopy cover at unoccupied sites. Wood and others (2004) observed 20 times more Bachman's sparrows in habitats with 25 to 50 percent canopy cover than sites with 50 to 75 percent cover. We fit an inverse logistic function to these data to extrapolate values between these known points (Fig. 8).

Because this resident species is restricted to a specialized habitat, occupancy of a site by the Bachman's sparrow is affected by the ability of dispersers to colonize it. This ability is

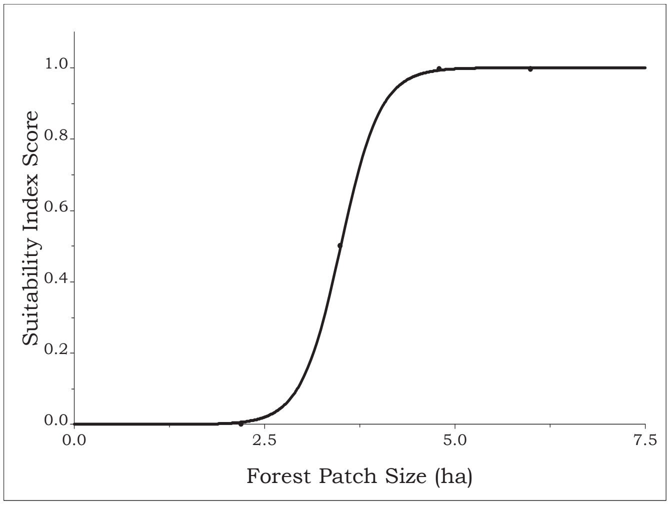


Figure 7.—Relationship between forest patch size and suitability index (SI) scores for Bachman's sparrow habitat. Equation: SI score = 1.000 / (1 + (699817.120 * $e^{-3.845 * \text{forest patch size}}$)).

Table 18.—Relationship between forest patch size and suitability index (SI) scores for Bachman's sparrow habitat

Forest patch size (ha)	SI score
0.0[a]	0.0
2.2[b]	0.0
3.5[b]	0.5
4.8[b]	1.0
6.0[a]	1.0

[a]Assumed value.
[b]Stober (1996), reviewed in Mitchell (1998).

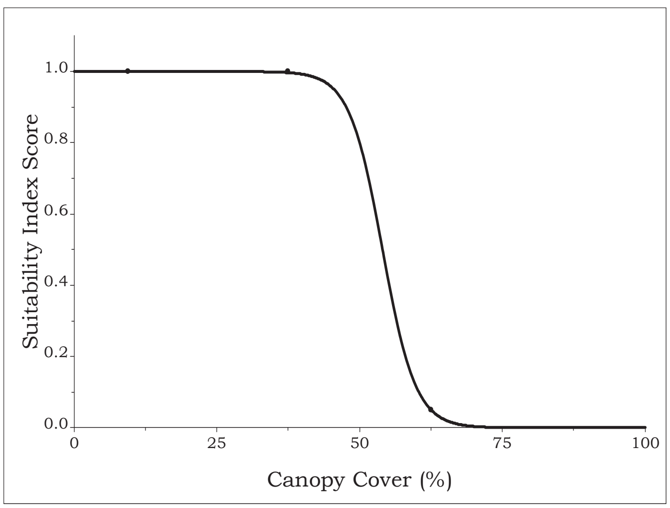


Figure 8.—Relationship between canopy cover and suitability index (SI) scores for Bachman's sparrow habitat. Equation: SI score = 1 - (1.000 / (1 + (126024970 * $e^{-0.3455 * \text{canopy cover}}$))).

Table 19.—Relationship between canopy cover and suitability index (SI) scores for Bachman's sparrow habitat

Canopy cover (percent)	SI score
0.0[a]	1.00
9.5[b]	1.00
37.5[c]	1.00
62.5[c]	0.05
100.0[a]	0.00

[a]Assumed value.
[b]Haggerty (1998).
[c]Wood and others (2004).

directly affected by the connectivity (or conversely the isolation) of habitat patches (SI4). Birds are unable to colonize clearcuts more than 3 km distant before succession renders habitat conditions within them unsuitable (Dunning and others 1995). Although isolation also may affect the occupancy of mature evergreen stands, habitat conditions within them are less ephemeral. Thus, the Bachman's sparrow has a potentially longer time to colonize these stands. To compensate for this differential temporal window in accessibility, we used a 15-km distance threshold to fit a longer tail to the function relating connectivity of patches to their suitability as Bachman's sparrow habitat (Table 20, Fig. 9). We also assumed that source populations were restricted to mature evergreen forest stands with a preliminary overall SI score (calculated from SI1, SI2, and SI3) that was greater than 0.8.

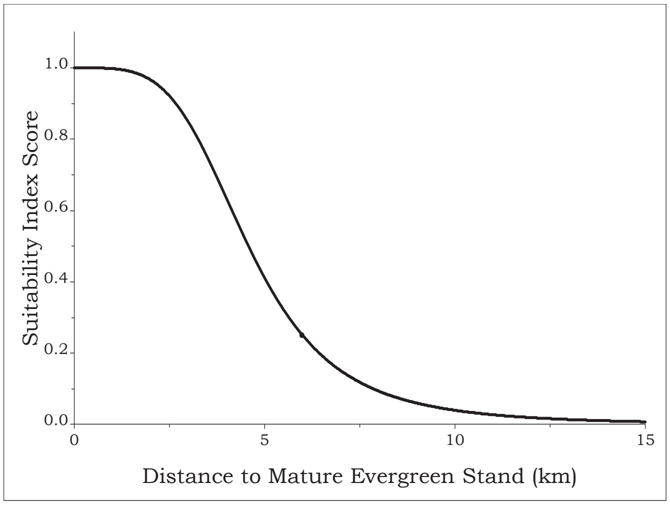


Figure 9.—Relationship between distance to nearest evergreen sawtimber habitat with initial suitability index (SI) score >0.8 and SI scores for Bachman's sparrow habitat. Equation: SI score = 1 / (1.000 + (0.002 * (distance to evergreen sawtimber habitat with initial SI score >0.8)$^{4.066}$)).

Table 20.—Relationship between distance to nearest evergreen sawtimber habitat with initial suitability index (SI) score > 0.8 and SI scores for Bachman's sparrow habitat

Habitat connectivity (km)	SI score
0[a]	1.00
6[b]	0.25
15[b]	0.00

[a]Dunning and others (1995).
[b]Assumed value.

To calculate the overall HSI score, we calculated the geometric mean of the two SIs related to forest structure (SI1 and SI3) and landscape attributes (SI2 and SI4) separately and then the geometric mean of these values together.

Overall HSI = $((SI1 * SI3)^{0.500} * (SI2 * SI4)^{0.500})^{0.500}$

Verification and Validation

Bachman's sparrow was found only in 29 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.62$) between average HSI score and mean BBS route abundance across all subsections. However, when subsections where the Bachman's sparrow was not found were removed from the analysis, the relationship was not significant ($r_s = 0.24$; P = 0.208). Thus, the HSI model predicts the absence of the Bachman's sparrow better than its abundance in subsections where it is found. The generalized linear model predicting BBS abundance from BCR and HSI for the Bachman's sparrow was significant ($P \leq 0.001$; $R^2 = 0.567$), and the coefficient on the HSI predictor variable was both positive (β = 0.908) and significantly different from zero ($P = 0.079$). Therefore, we considered the HSI model for the Bachman's sparrow both verified and validated (Tirpak and others 2009a).

Bell's Vireo


Steve Maslowski, U.S. Fish & Wildlife Service

Status

Bell's vireo (*Vireo bellii*) is a scrubland specialist that reaches the eastern limit of its range in the CH and WGCP. Throughout both regions this species has declined over the past 40 years, with the most severe declines in the southern portion of the eastern range (-4.7, -6.6, and -10.1 percent annually in Missouri, Oklahoma, and the Ozark-Ouachita Plateau, respectively; Sauer and others 2005). Bell's vireo has a regional combined score of 15 in the CH and 16 in the WGCP, and PIF considers the species as requiring management attention in both regions (Table 1). The FWS also recognizes Bell's vireo as a Bird of Conservation Concern in both BCRs (Table 1).

Natural History

Bell's vireo is a small, Neotropical migrant associated with dense, low, shrubby vegetation (Brown 1993). It uses a variety of early successional scrubland habitats that meet these requirements (e.g., riparian woods, brushy fields, and regenerating forest). Most of the research on this species was conducted in the West, where Bell's vireo is alternately described as a riparian specialist (particularly the federally endangered subpopulation of least Bell's vireo in California) or a scrub-shrub generalist. This bird nests in dense shrub or understory vegetation 0.5 to 1.5 m above the ground, making its nests susceptible to both terrestrial and avian predators. Predation and brood parasitism are the primary causes of nest failure (Budnik and others 2000, 2002; Powell and Steidl 2000). Increasing the density of large shrub patches may improve Bell's vireo habitat in Missouri (Budnik and others 2002).

Model Description

The model for Bell's vireo includes six variables: landform, landcover, successional age class, interspersion of forest and open areas, edge, and small stem density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 21). We directly assigned SI values to these combinations on the basis of data from Hamel (1992) relating vegetation types and successional age class to habitat suitability estimates for Bell's vireo.

Both landcover and age class data were used to identify upland shrublands in grassland landscapes, the preferred habitat for this species in its eastern range (Budnik and others 2000). We used a 10-ha moving window (an average home range; Budnik and others 2000) to assess the interspersion of shrubland and grassland habitats (SI2). We assumed that an area containing 50 percent of each habitat type was ideal (Table 22). To extrapolate from this point we used broad incremental changes in habitat suitability (20 percent) and applied these symmetrically to 10-percent incremental changes in the proportion of scrubland or grassland. Landscapes lacking shrublands or grasslands were unsuitable and assigned an SI score of zero.

Table 21.—Relationship of landform, landcover type, and successional age class to suitability index scores for Bell's vireo habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.500	0.250	0.125	0.000	0.000
	Deciduous	0.500	0.250	0.125	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.500	0.250	0.125	0.000	0.000
	Woody wetlands	0.500	0.500	0.250	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.500	1.000	0.750	0.000	0.000
	Deciduous	0.250	0.500	0.375	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.250	0.500	0.375	0.000	0.000
	Woody wetlands	1.000	0.500	0.250	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.500	1.000	0.750	0.000	0.000
	Deciduous	0.500	1.000	0.750	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.500	1.000	0.750	0.000	0.000
	Woody wetlands	1.000	0.500	0.250	0.000	0.000

Table 22.—Relative composition of scrubland and grassland within 10-ha moving window on suitability index scores for Bell's vireo habitat

	Proportion grassland[a]										
Proportion scrubland[b]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	
0.2	0.0	0.0	0.1	0.2	0.4	0.4	0.4	0.4	0.4		
0.3	0.0	0.1	0.2	0.4	0.6	0.6	0.6	0.6			
0.4	0.0	0.2	0.4	0.6	0.8	0.8	0.8				
0.5	0.0	0.2	0.4	0.6	0.8	1.0[c]					
0.6	0.0	0.2	0.4	0.6	0.8						
0.7	0.0	0.2	0.4	0.6							
0.8	0.0	0.2	0.4								
0.9	0.0	0.2									
1.0	0.0										

[a]Grasslands/herbaceous, pasture/hay, and grass-forb successional age class.
[b]Shrub-seedling and sapling successional age classes.
[c]Budnik and others (2000); all other values assumed.

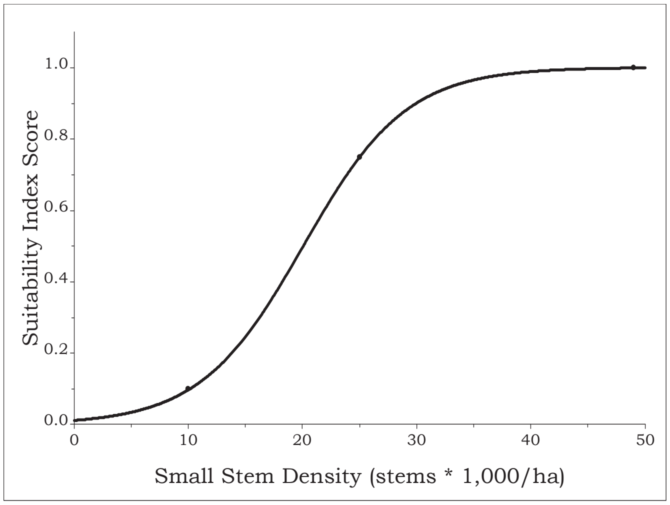


Figure 10.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for Bell's vireo habitat. Equation: SI score = 1.001 / (1.000 + (85.005 * $e^{-0.222 * (\text{small stem density} / 1000)}$)).

Table 23.—Influence of edge occurrence on suitability index (SI) scores for Bell's vireo habitat

3 × 3 pixel window around forest pixel includes field[a]	SI score
Yes[b]	1.0
No	0.0

[a]Field defined as any shrub-seedling or grass-forb age class pixel, natural grasslands/herbaceous, or pasture/hay. Forest defined as any used sapling age class pixel of transitional, shrublands, deciduous, orchard, or woody wetlands.

[b]Grass-forb and seedling-shrub habitats used regardless of edge.

Table 24.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) and suitability index (SI) scores for Bell's vireo habitat

Small stem density	SI score
0[a]	0.00
10[a]	0.10
25[a]	0.75
49[b]	1.00

[a]Assumed value.
[b]Farley (1987).

Bell's vireo uses a variety of young woody habitats (Brown 1993); however, birds also nest along the edges of sapling stands and in hedgerows (Budnik and others 2002). Therefore, we included edge (SI3) as a parameter in the Bell's vireo HSI model. To identify edges, we examined the eight pixels surrounding each sapling age class pixel to determine whether any were classified as shrub-seedling or grass-forb age class forest or as a nonforest landcover class. If so, the central pixel in the 3 × 3 pixel window (90 x 90 m) was assigned an SI score of 1.000; if not, it was assigned a zero. We assigned to grass-forb and shrub-seedling pixels an SI score of 1.000 regardless of edge (Table 23). Similarly, we always assigned to pole and sawtimber pixels an SI score of zero regardless of edge.

We also included small stem density (SI4) as a component of the overall Bell's vireo HSI model because of the importance of dense woody shrub cover for this species. Farley (1987) measured an average of 9.8 stems greater than 2 mm per 1-m diameter plot (approximately 392,000 stems/ha) in Bell's vireo territories. This relatively high stem value included woody and nonwoody stems of all sizes greater than 2 mm; therefore, we assumed that that only one-eighth of these stems (49,000 = ⅛ * 392,000) were woody and less than 2.5 cm d.b.h. and that this value represented optimal habitat (Table 24, Fig. 10).

To calculate the overall HSI score for Bell's vireo, we first determined the geometric mean of the suitability indices related to forest structure (SI1 and SI4) and landscape attributes (SI2 and SI3) separately and then determined the geometric mean of these values together. Because SI3 applies only to sapling habitats, HSI scores were calculated differently for sapling successional age class stands than for grass-forb or shrub-seedling successional age class stands. To determine the overall SI score across the entire BCR, we added suitability scores from individual age classes across the entire landscape.

For grass-forb and shrub-seedling habitats:

$$HSI_{GF\ and\ SS} = (((SI1 * SI4)^{0.500}) * (SI2))^{0.500}$$

For sapling habitats:

$$HSI_{Sap} = ((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$$

$$Overall\ HSI = HSI_{GF\ and\ SS} + HSI_{Sap}$$

Verification and Validation

Bell's vireo was found in 54 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.44$) between average HSI score and mean BBS route abundance across all subsections. Removing subsections in which Bell's vireo was not observed had a minimal effect on these results ($r_s = 0.46$; $P \leq 0.001$). The generalized linear model predicting BBS abundance from BCR and HSI for the Bell's vireo was significant ($P = 0.042$; $R^2 = 0.072$); however, the coefficient on the HSI predictor variable was negative ($\beta = -19.906$) and not significantly different from zero ($P = 0.544$). Therefore, we considered the HSI model for the Bell's vireo verified but not validated (Tirpak and others 2009a).

Bewick's Wren

Dave Menke, U.S. Fish & Wildlife Service

Status

Bewick's wren (*Thryomanes bewickii*) was once a common resident throughout the Southeast and mid-Atlantic. However, its range has contracted steadily over the last century and today this species is virtually absent east of the Mississippi River (Kennedy and White 1997). BBS data from FWS Region 4 indicates that populations have declined by 12.8 percent per year over the last 40 years (Sauer and others 2005). The decline of this species coincided with the range expansion of the house wren, which often destroys Bewick's wren nests in areas where the species' ranges overlap (Kennedy and White 1996). Bewick's wren is a Bird of Conservation Concern in both the CH and WGCP (Table 1). PIF identifies the species as requiring both critical recovery in the WGCP (regional combined score = 16) and immediate management attention in the CH (regional combined score = 15).

Natural History

Bewick's wren is a small resident passerine that breeds in a variety of vegetation types, including brushy areas, scrub and thickets in open country, and open and riparian woodlands (Kennedy and White 1997). This plasticity has produced conflicting reports of habitat associations in the literature (e.g., dry vs. riparian, open woodlands vs. shrub thickets). However, this species likely responds most strongly to the availability of nest sites. Bewick's wren nests in cavities or opportunistically in crevices up to 10 m high. In the eastern portion of its range, this bird often lives near human habitation, particularly farmland. As mentioned, population declines of this species may be partly the result of competition with the house wren (Kennedy and White 1996). Bewick's wren is found primarily in grassland scrub while the house wren occurs primarily in secondary growth on abandoned agricultural land and in residential areas. Both species exploit the full range of these habitat types, and populations of both expanded as these latter types increased. However, as scrub habitats declined, Bewick's wren may have declined because its primary source habitat no longer was abundant.

Model Description

Our model for Bewick's wren includes five variables: landform, landcover, successional age class, interspersion of forest and open habitats, and snag density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 25). We then directly assigned an SI score to these combinations on the basis of data from Hamel (1992) on the relative quality of Bewick's wren habitat based on vegetation type and successional age class.

We also considered as important for this species the interspersion of forest and grassland habitats (SI2), as Bewick's wren is most abundant in semi-open areas containing about 40 percent woodland (Pogue and Schnell 1994; Table 26). We relied on data from Pogue and Schnell to define SI values along the diagonal axis of our interspersion table (where forest and grassland totaled 100 percent) and completed the table from these values.

Table 25.—Relationship of landform, landcover type, and successional age class to suitability index scores for Bewick's wren habitat

Landform	Landcover type	Successional age class				
		Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	1.000	1.000	0.500	0.000	0.000
	Transitional-shrubland	1.000	1.000	0.500	0.000	0.000
	Deciduous	0.500	0.500	0.250	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	1.000	1.000	0.500	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	1.000	1.000	0.500	0.000	0.000
	Transitional-shrubland	1.000	1.000	0.500	0.000	0.000
	Deciduous	0.500	0.500	0.250	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	1.000	1.000	0.500	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	1.000	1.000	0.500	0.000	0.000
	Transitional-shrubland	1.000	1.000	0.500	0.000	0.000
	Deciduous	0.500	0.500	0.250	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	1.000	1.000	0.500	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

Table 26.—Influence of interspersion between forest and open habitats (as indexed by relative composition within 10-ha moving window) on suitability index scores for Bewick's wren habitat

Proportion forest[b]	Proportion open[a]										
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00[c]
0.1	0.00	0.00	0.05	0.10	0.10	0.20	0.20	0.20	0.20	0.20[c]	
0.2	0.00	0.05	0.10	0.15	0.20	0.25	0.40	0.40	0.40[c]		
0.3	0.00	0.05	0.20	0.25	0.60	0.80	0.80	0.80[c]			
0.4	0.00	0.05	0.20	0.40	0.80	1.00	1.00[c]				
0.5	0.00	0.05	0.20	0.40	0.80	1.00[c]					
0.6	0.00	0.10	0.20	0.40	0.80[c]						
0.7	0.00	0.10	0.20	0.40[c]							
0.8	0.00	0.10	0.20[c]								
0.9	0.00	0.10[c]									
1.0	0.00[c]										

[a]Open = grasslands, herbaceous planted (pasture-hay, fallow, and urban-recreational grasses), emergent herbaceous wetlands.
[b]Forest = forested upland, low-density residential, shrubland, transitional, and woody wetlands.
[c]Pogue and Schnell (1994); all other values assumed.

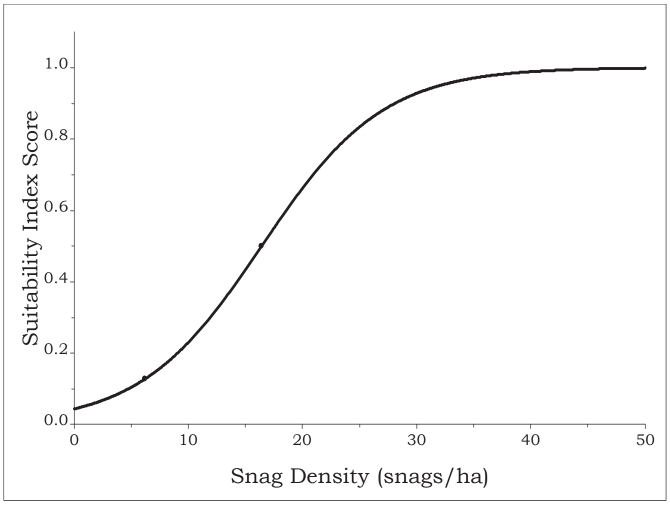


Figure 11.—Relationship between snag density and suitability index (SI) score for Bewick's wren habitat. Equation: SI score = 1.0011 / (1 + (21.9129 * e $^{-0.1881 * \text{snag density}}$)).

Table 27.—Influence of snag density on suitability index scores for Bewick's wren habitat

Snag density (snags/ha)	SI score
6.2[a]	0.128
16.4[b]	0.500
52.8[a]	1.000

[a]Rumble and Gobeille (2004).
[b]Sedgwick and Knopf (1990).

We also included snag density (SI3) in our model of Bewick's wren habitat because as a secondary cavity nester, this species responds strongly to nest-site availability. We assumed that higher snag densities would decrease competition with other cavity nesters, improving habitat quality. Specific data relating snag density to Bewick's wren habitat suitability were not available, so we assumed that the average snag density observed by Sedgwick and Knopf (1990) (16.4 snags/ha) within home ranges of the house wren, a secondary cavity nester of similar size, represented average habitat suitability (SI score = 0.500) for the Bewick's wren. We coupled this information with data from Rumble and Gobeille (2004) (Table 27) on the relative density of the house wren in habitats with different snag densities to build a logistic function quantifying the relationship between habitat suitability and snag density (Fig. 11).

To calculate the overall HSI score, we first calculated the geometric mean of the two suitability indices related to forest structure attributes (SI1 and SI3), and then the geometric mean of this result and the SI related to interspersion (SI2).

Overall HSI = $((SI1 * SI3)^{0.500} * SI2)^{0.500}$

Verification and Validation

Bewick's wren was found in 74 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.40$) between average HSI score and mean BBS route abundance across subsections. However, this relationship was weaker ($r_s = 0.35$; $P = 0.002$) when subsections in which the Bewick's wren was not detected were removed from the analysis. The generalized linear model predicting BBS abundance from BCR and HSI for the Bewick's wren was not significant ($P = 0.517$; $R^2 = 0.015$), and the coefficient on the HSI predictor variable was negative (ß = -3.193) and not significantly different from zero ($P = 0.857$). Therefore, we considered the HSI model for the Bewick's wren verified but not validated (Tirpak and others 2009a).

Black-and-white Warbler

Charles H. Warren, images.nbii.gov

Status

The black-and-white warbler (*Mniotilta varia*) is a neotropical migrant found throughout the eastern United States and southern Canada. This is a forest-interior species and the annual declines of 1.2 percent observed in the United States over the last 40 years likely are the result of increasing forest fragmentation (Sauer and others 2005). This species has a regional combined score of 16 in the WGCP, where it is a species requiring management attention (Table 1). The black-and-white warbler has a regional combined score of only 13 in the CH. The FWS does not recognize the black-and-white warbler as a Bird of Conservation Concern in either BCR (Table 1).

Natural History

As a forest-interior specialist, the black-and-white warbler is found in the mature deciduous hardwood forests of the eastern United States and Canada (Kricher 1995). It is highly sensitive to fragmentation in the landscape (Robbins and others 1989) and typically is absent from small woodlots (< 7.5 ha; Galli and others 1976). Hamel (1992) suggested that 550 ha was the minimum tract size for this species in the Southeast.

Few studies have focused exclusively on the habitat ecology of this bird, though Conner and others (1983) found that the black-and-white warbler is associated with mature forest stands with high densities of large (> 32 cm d.b.h.) trees. Although a ground-nesting bird, this species is associated with high densities of hardwood saplings. Conversely, pine saplings negatively affect both the presence and abundance of the black-and-white warbler.

This bird occupies upland and bottomland forests but reaches greater densities in the former, with oak-hickory and cove forests considered optimal (Hamel 1992). Nevertheless, successional age may be the most critical habitat factor affecting the black-and-white warbler. Dettmers and others (2002) validated Hamel's (1992) habitat suitability model for the black-and-white warbler, finding the model performed well due to the restriction of the black-and-white warbler to older age class forests. However, Thompson and others (1992) and Annand and Thompson (1997) observed the black-and-white warbler in sapling and clearcut stands in Missouri.

Model Description

Our HSI model for the black-and-white warbler includes six variables: landform, landcover, successional age class, forest patch size, percent forest in a 1-km radius, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 28). We directly assigned SI scores to these combinations based on vegetation type and age class associations of the black-and-white warbler reported by Hamel (1992). However, we assigned higher values to shrub-seedling stands based on data from Thompson and others (1992) and Annand and Thompson (1997).

Table 28.—Relationship between landform, landcover type, age class, and suitability index scores for black-and-white warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.167	0.333	0.333	0.667
	Deciduous	0.000	0.167	0.333	0.333	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	0.333
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.333 (0.000)
	Deciduous	0.000	0.167	0.333	0.333	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	0.333
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.333 (0.000)
	Deciduous	0.000	0.167	0.333	0.333	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	0.333

Forest patch size (SI2) affects occurrence of this species as it is notably absent from small forest blocks. Therefore, we fit a logarithmic function (Fig. 12) relating forest patch size to SI scores derived from probability of occurrence data from Robbins and others (1989) (Table 29). The relative value of a forest block of a specific size is influenced by its landscape context. In predominantly forested landscapes, small forest patches that may not be used in predominantly nonforested landscapes may provide habitat due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 13) to data (Table 30) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. Because of the extreme sensitivity of the black-and-white warbler to fragmented landscapes, we assumed that the midpoint between moderately and lightly fragmented forest defined the specific cutoff for average (SI score = 0.500) hatitat. We used the maximum value of SI2 or SI3 to account for small patches in predominantly forested landscapes and large patches in predominantly nonforested landscapes.

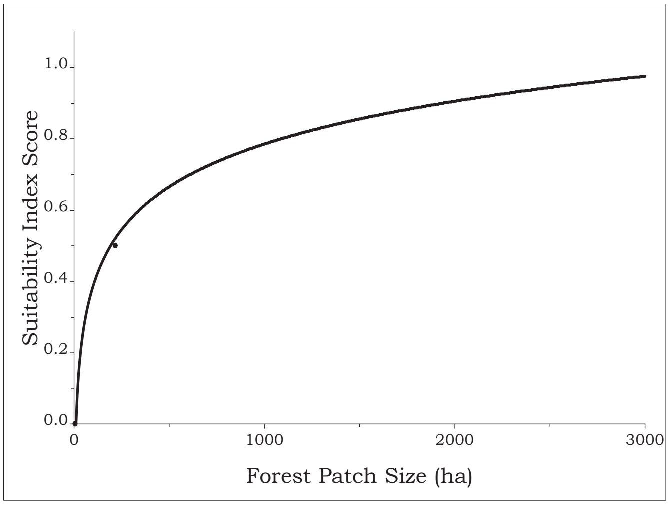


Figure 12.—Relationship between forest patch size and suitability index (SI) scores for black-and-white warbler habitat. Equation: SI score = 0.1731 * ln(forest patch size) – 0.4096.

Table 29.—Influence of forest patch size on suitability index (SI) scores for black-and-white warbler habitat

Forest patch size (ha)	SI score
10[a]	0.0
220[b]	0.5
3,200[b]	1.0

[a]Assumed value.
[b]Robbins and others (1989).

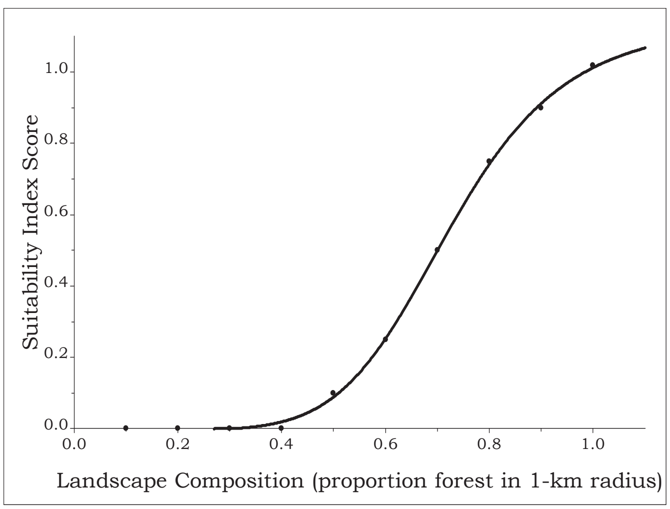


Figure 13.—Relationship between landscape composition and suitability index (SI) scores for black-and-white warbler habitat. Equation: SI score = 1.047 / (1.000 + (1991.516 * e $^{-10.673 * \text{landscape composition}}$)).

Table 30.—Relationship between landscape composition (proportion forest in 1-km radius) and suitability index (SI) scores for black-and-white warbler habitat

Landscape composition[a]	SI score
0.00[a]	0.00
0.10[a]	0.00
0.20[a]	0.00
0.30[a]	0.00
0.40[a]	0.00
0.50[a]	0.10
0.60[a]	0.25
0.70[b]	0.50
0.80[a]	0.75
0.90[a]	0.90
1.00[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

Canopy cover (SI4) also may affect the quality of black-and-white warbler habitat. Thus, we included it as a factor in our HSI model. Prather and Smith (2003) reported higher densities of the black-and-white warbler in forests with relatively open canopies, so we used their data (Table 31) to derive an inverse logistic function (Fig. 14) that quantified the relationship between canopy cover and SI scores.

We calculated the overall HSI score as the geometric mean of the geometric mean of individual SI functions related to forest structure (SI1 and SI4) multiplied by the maximum SI score for forest patch size or percent forest in the 1-km radius landscape.

Overall HSI = $((SI1 * SI4)^{0.500} * Max(SI2 \text{ or } SI3))^{0.500}$

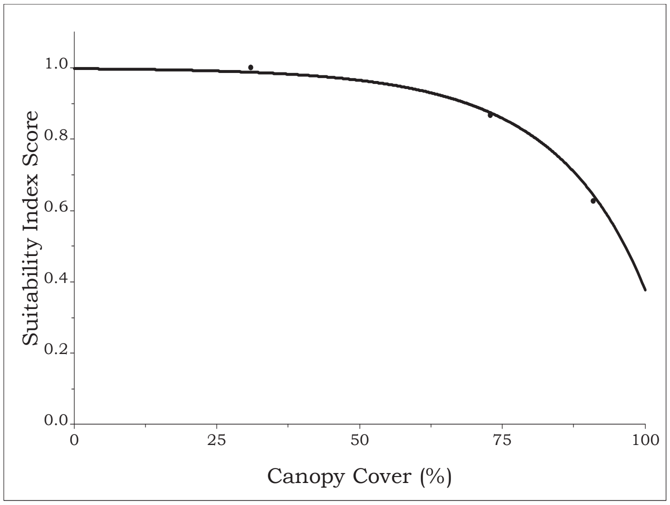


Figure 14.—Relationship between canopy cover and suitability index (SI) scores for black-and-white warbler habitat. Equation: SI score = 1 - (-4.190 / (1 + (-1890.213 * e $^{-0.055 * \text{canopy cover}}$))).

Table 31.—Influence of canopy cover on suitability index (SI) scores for black-and-white warbler habitat.

Canopy cover (percent)[a]	SI score
31	1.000
73	0.866
91	0.627

[a]Prather and Smith (2003).

Verification and Validation

The black-and-white warbler was found in 85 of the 88 subsections within the CH and WGCP. Not surprisingly, Spearman rank correlations based on all subsections and only subsections in which this species was found produced similar results: significant ($P \leq 0.001$ for both analyses) positive relationships (r_s = 0.54 and 0.53, respectively) between average HSI score and mean BBS route abundance. The generalized linear model predicting BBS abundance from BCR and HSI for the black-and-white warbler was significant ($P \leq 0.001$; R^2 = 0.380), and the coefficient on the HSI predictor variable was both positive (β = 3.194) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the black-and-white warbler both verified and validated (Tirpak and others 2009a).

Blue-gray Gnatcatcher

Charles H. Warren, images.nbii.gov

Status

The blue-gray gnatcatcher (*Polioptila caerulea*) is a short-distance migrant found throughout eastern North America and the Southwest. Populations are relatively stable in both the CH and WGCP (Table 5). The FWS does not recognize this species as a Bird of Conservation Concern in either region (Table 1). This bird requires management attention in the CH (regional combined score = 14) but does not have any special designation in the WGCP (regional combined score =13; Table 1).

Natural History

The blue-gray gnatcatcher is a small passerine that inhabits woodland types ranging from shrubland to mature forest (Ellison 1992). It prefers deciduous habitats and is rare or absent in evergreen forests. This species attains its highest numbers in mesic and low-lying areas, but is also found in xeric forests and along ridges.

Kershner and others (2001) did not identify specific microhabitat requirements for this species in Illinois, and considerable variation in nest height (0.8 to 24.4 m) and territory size (0.5 to 8 ha) has been documented across the range.

Although often associated with edges, this bird may be area sensitive (Knutson 1995, Kilgo and others 1998). Nest success was greater for nests placed higher and farther from an edge in Illinois (Kershner and others 2001) but did not differ between bottomland hardwood stands and cottonwood plantations in the Mississippi Alluvial Valley (Twedt and others 2001). The abundance of the blue-gray gnatcatcher was higher in bottomland hardwood stands surrounded by fields than those surrounded by pine forest (Kilgo and others 1998).

Model Description

The HSI model for the blue-gray gnatcatcher includes seven variables in five functions: landform, landcover, successional age class, forest patch size, percent forest in a 1-km radius landscape, edge, and basal area.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 32). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the relative quality of vegetation associations and successional age classes for this species. We adjusted Hamel's values for shrub-seedling and sapling-aged stands to account for the higher densities observed in young forests by Thompson and others (1992) and Annand and Thompson (1997).

We included forest patch size (SI2) as a variable to account for the area sensitivity of the blue-gray gnatcatcher. We fit a logarithmic function (Fig. 15) to data from Robbins and others (1989) on the probability of occurrence for this bird in stands of various sizes (Table 33). Nevertheless, the actual use of a forest patch reflects both its area and its landscape

Table 32.—Relationship of landform, landcover type, and successional age class to suitability index scores for blue-gray gnatcatcher habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.333	0.667	0.667	1.000
	Transitional-shrubland	0.000	0.333	0.667	0.667	1.000
	Deciduous	0.000	0.333	0.667	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.083	0.167	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	1.000
Terrace-mesic	Low-density residential	0.000	0.333	0.667	0.667	1.000
	Transitional-shrubland	0.000	0.333 (0.000)	0.667 (0.000)	0.667 (0.000)	1.000 (0.000)
	Deciduous	0.000	0.333	0.667	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.083	0.167	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	1.000
Xeric-ridge	Low-density residential	0.000	0.333	0.667	0.667	1.000
	Transitional-shrubland	0.000	0.333 (0.000)	0.667 (0.000)	0.667 (0.000)	1.000 (0.000)
	Deciduous	0.000	0.333	0.667	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.083	0.167	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	1.000

context (SI3). In predominantly forested landscapes, a small forest patch that otherwise may not be suitable may be occupied due to its proximity to a larger forest block (Rosenberg and others 1999). Because the gnatcatcher also is associated with edges, it may not be as abundant in predominantly forested landscapes that lack significant edge habitat. Thus, we assumed that the relationship between habitat suitability of the blue gray gnatcatcher and the amount of forest in the landscape followed a Gaussian function (Fig. 16), with landscapes containing 70 to 80 percent forest as optimal and suitability declining as the proportion of forest in the landscape moved from this ideal (Table 34). We used the maximum suitability score of SI2 or SI3 to simultaneously account for patch area and landscape composition.

We also included edge (SI4) in our HSI model because of the association of the blue-gray gnatcatcher with edges within large forest blocks. This species nests along both hard and soft edges (typically within 30 m; Kershner and others 2001). Therefore, we defined edge as the interface among sapling, pole, and sawtimber stands and herbaceous and nonforest landcovers (hard edge) or seedling and grass-forb stands (soft edge). We used a 7 × 7 pixel moving window (210 x 210 m) to identify where these adjacencies occurred but recognized that the blue-gray gnatcatcher is not restricted to edge habitats and applied a residual SI score (0.010) to sites that did not meet this criterion (Table 35).

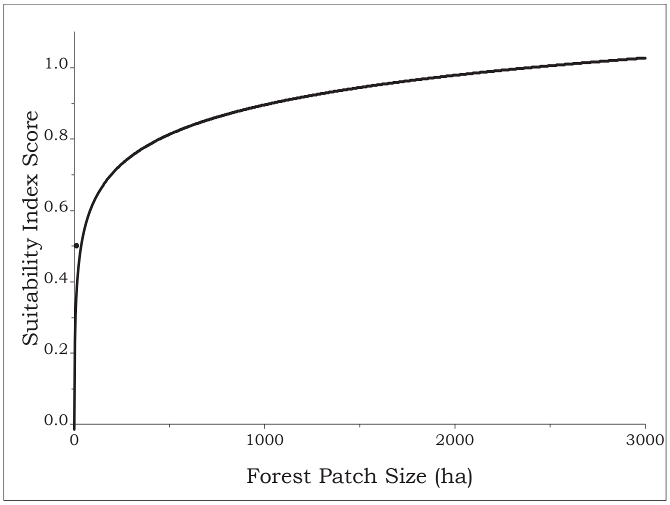


Figure 15.—Relationship between forest patch size and suitability index (SI) scores for blue-gray gnatcatcher habitat. Equation: SI score = 0.137 * ln(forest patch size) + 0.186.

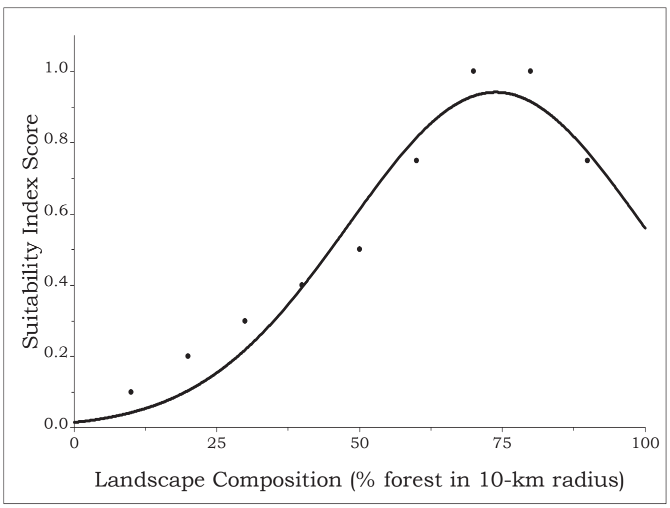


Figure 16.—Relationship between landscape composition and suitability index (SI) scores for blue-gray gnatcatcher habitat. Equation: SI score = 1.002 * $e^{((0 – ((\text{landscape composition}) – 74.165) ^ 2) / 1064.634)}$.

Table 33.—Influence of forest patch size on suitability index (SI) scores for blue-gray gnatcatcher habitat

Forest patch size (ha)[a]	SI score
6.8	0.0
15	0.5
3,200	1.0

[a]Robbins and others (1989).

Table 34.—Relationship between landscape composition (percent forest in 10-km radius) and suitability index (SI) scores for blue-gray gnatcatcher habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.10
20[a]	0.20
30[b]	0.30
40[a]	0.40
50[b]	0.50
60[a]	0.75
70[b]	1.00
80[a]	1.00
90[b]	0.75
100[a]	0.50

[a]Assumed value.
[b]Dononvan and others (1997).

Table 35.—Influence of edge on suitability index (SI) scores for blue-gray gnatcatcher habitat

7 × 7 pixel window around forest pixel includes field[a]	SI score
Yes	1.00
No	0.01

[a]Field defined as any shrub-seedling or grass-forb age class forest, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any used sapling, pole, or sawtimber age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands (i.e., SI1 > 0).

We fit a quadratic function to data from Annand and Thompson (1997) on the response of the blue-gray gnatcatcher to basal area (SI5; Table 36, Fig. 17), reflecting the preference of this species for open forest conditions.

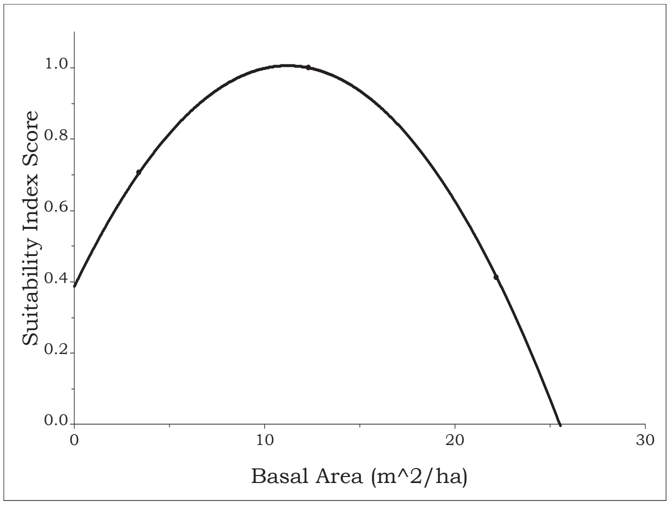


Figure 17.—Relationship between basal area and suitability index (SI) scores for blue-gray gnatcatcher habitat. Equation: SI score = 0.3863 + 0.1105 * (basal area) – 0.0049 * (basal area)^2.

Table 36.—Influence of basal area (m^2/ha) on suitability index (SI) scores for blue-gray gnatcatcher habitat

Basal area[a]	SI score
3.41	0.706
12.33	1.000
22.20	0.412

[a]Annand and Thompson (1997).

To calculate the HSI score for sapling, pole, and sawtimber age classes, we determined the geometric mean of SI scores for forest structure (SI1 and SI5) and landscape composition attributes (Max(SI2 or SI3) and SI4) separately and then the geometric mean of these means together. Because edge occurrence (SI4) was not applicable to the shrub-seedling age class, we calculated HSI scores separately for this age class and summed across age classes to determine the overall HSI score for the landscape.

Sapling, pole, and sawtimber successional age classes:

$$HSI_{Old} = (((SI1 * SI5)^{0.500}) * ((Max\ (SI2\ or\ SI3)) * SI4)^{0.500})^{0.500}$$

Shrub-seedling successional age classes:

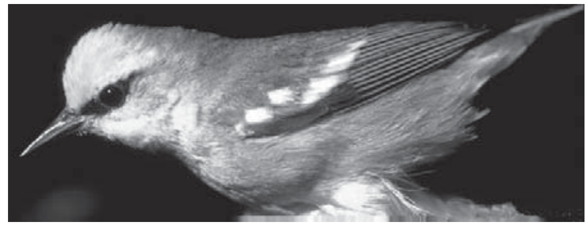
$$HSI_{Shrub} = ((SI1 * SI5)^{0.500} * (Max\ (SI2\ or\ SI3)))^{0.500}$$

$$Overall\ HSI = HSI_{Old} + HSI_{Shrub}$$

Verification and Validation

The blue-gray gnatcatcher was found in all 88 subsections of the CH and WGCP. Spearman rank correlation analysis on average HSI score and mean BBS route abundance across subsections resulted in a significant ($P \leq 0.001$) positive relationship ($r_s = 0.58$) between these variables. The generalized linear model predicting BBS abundance from BCR and HSI for the blue-gray gnatcatcher was significant ($P \leq 0.001$; $R^2 = 0.210$), and the coefficient on the HSI predictor variable was both positive ($\beta = 19.625$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the blue-gray gnatcatcher both verified and validated (Tirpak and others 2009a).

Blue-winged Warbler



Chandler S. Robbins, Patuxent Bird Identification InfoCenter
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Status

The blue-winged warbler (*Vermivora pinus*) is a neotropical migrant found from southern New England west to the Lake States and south through the southern Appalachians and Ozarks. Across most of its range, this species has been stable and has even increased in some areas (possibly to the detriment of the golden-winged warbler, with which it sometimes interbreeds; Gill 1980). Once limited to a mostly Midwestern range, this bird expanded into southern New England as forests were cleared and farms were abandoned. However, as the forest has matured in this region, the blue-winged warbler has experienced declines (3.3 and 5.3 percent annually from 1966 to 2004 in the increasingly residential Connecticut and New Jersey, respectively). A similar phenomenon has occurred in the Southeast and BBS data indicate a 3.7 percent decline in FWS Region 4 during this same period (Sauer and others 2005). This species is designated a Bird of Conservation Concern in the CH but not in the WGCP (Table 1), where it rarely breeds. It has a regional combined score of 19 in the CH and requires management attention in that region (Table 1).

Natural History

The blue-winged warbler is an early successional species (Gill and others 2001) that benefited from European settlement by expanding its range following the initial clearing of forests for agriculture and the subsequent abandonment of farms. Breeding habitat includes early to midsuccessional forest containing dense low growth (shrubs, young trees, thickets). This species makes use of a variety of landform conditions from wetland edges to dry uplands, though mated males have more xeric territories than unmated males. Territories range from 0.2 to 5 ha, with boundaries often aligned along edges. Nests typically are within 30 m of a forest edge in grassy areas with high numbers of small (< 10 cm d.b.h.) trees. Density is inversely related to successional age class, fragmentation, and the abundance of the golden-winged warbler and brown-headed cowbird.

Model Description

The blue-winged warbler model includes five variables: landform, landcover, successional age class, early successional patch size, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 37). We directly assigned SI scores to these combinations based on habitat associations reported in Hamel (1992) for the blue-winged warbler. We modified Hamel's data to maximize SI scores in the transitional-shrubland landcover class in the xeric landform.

We also included early successional patch size (SI2) in our model on the basis of data from Rodewald and Vitz (2005) on the relative abundance of the blue-winged warbler in small and large clearcuts (Table 38; Fig. 18). We defined early successional forest by age class and included only grass-forb, shrub-seedling, and sapling age classes in the calculation of patch area.

Table 37.—Relationship of landform, landcover type, and successional age class to suitability index scores for blue-winged warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333	0.167	0.000	0.000
	Deciduous	0.000	0.333	0.167	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.083	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.667	0.333	0.000	0.000
	Deciduous	0.000	0.667	0.333	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000	0.500	0.000	0.000
	Deciduous	0.000	1.000	0.500	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000

Table 38.—Influence of early successional patch size on suitability index scores for blue-winged warbler habitat; early successional patches include all adjacent grass-forb, shrub-seedling, and sapling successional age class forest

Early successional patch size (ha)	SI score
0[a]	0.000
4[b]	0.786
13[b]	1.000

[a]Assumed value.
[b]Rodewald and Vitz (2005).

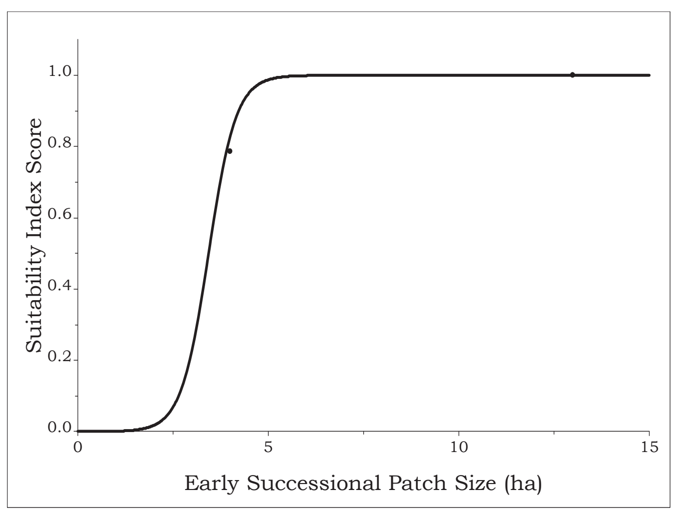

Figure 18.—Relationship between early successional patch size and suitability index (SI) scores for blue-winged warbler habitat. Equation: SI score = 1.000 / (1 + (14353.617 * e $^{-2.788 \text{ * forest patch size}}$)).

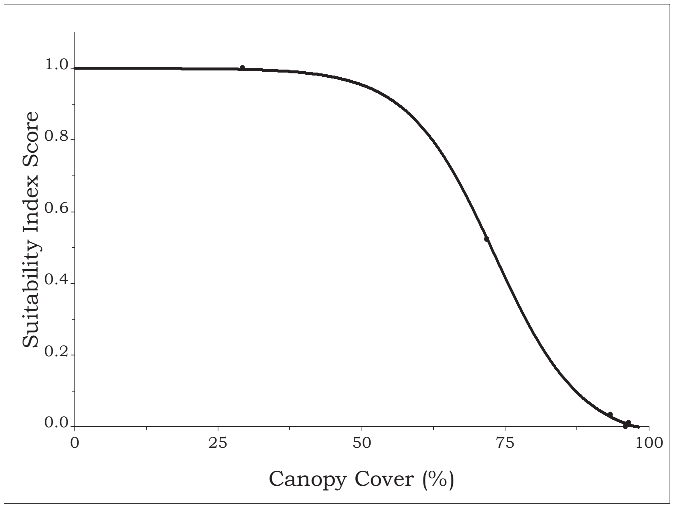

Figure 19.—Relationship between canopy cover and suitability index (SI) scores for blue-winged warbler habitat. Equation: SI score = 1 - (1.0381 / (1 + (16277.383 * e $^{-0.1327 * \text{canopy cover}}$))).

Table 39.—Influence of canopy cover on suitability index (SI) scores for blue-winged warbler habitat

Canopy cover (percent)[a]	SI score
29.26	1.000
71.86	0.523
93.38	0.034
95.58	0.000
96.59	0.011

[a]Annand and Thompson (1997).

We used an inverse logistic function (Fig. 19) to quantify the relationship between canopy cover (SI3) and SI scores to reflect the lower densities of the blue-winged warbler in forests with increasingly closed canopies. We defined this function by fitting a curve to data from Annand and Thompson (1997) on the relative density of this bird in forest stands with different estimates of canopy cover (Table 39).

To calculate the overall HSI score for this species , we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI3) and then calculated the geometric mean of this value and early successional patch size (SI2).

Overall HSI = $((SI1 * SI3)^{0.500} * SI2)^{0.500}$

Verification and Validation

The blue-winged warbler was found in 64 of the 88 subsections within the CH and WGCP. We used Spearman rank correlations between average HSI score and mean BBS route abundance at the subsection scale to verify this model. We observed significant positive relationships when analyses included all subsections (r_s = 0.26; P = 0.014) or only those subsections where this species was detected (r_s = 0.28; P = 0.026). The generalized linear model predicting BBS abundance from BCR and HSI for the blue-winged warbler was significant ($P \leq 0.001$; R^2 = 0.232), and the coefficient on the HSI predictor variable was positive (β = 1.717) but not significantly different from zero (P = 0.334). Therefore, we considered the HSI model for the blue-winged warbler verified but not validated (Tirpak and others 2009a).

Brown Thrasher


Jeffrey A Spendelow, Patuxent Bird Identification InfoCenter
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Status

The brown thrasher (*Toxostoma rufum*) is a short-distance migrant found throughout eastern North America. Although populations in the CH and WGCP declined by 1.4 percent per year between 1966 and 2004 (Table 5), this species is not considered a Bird of Conservation Concern in either BCR (Table 1). The brown thrasher has a regional combined score of 13 and 15 in the WGCP and CH, respectively, and is a species warranting management attention in the CH (Table 1).

Natural History

A ground-foraging passerine, the brown thrasher is associated with edge habitats throughout the eastern United States and Canada (Cavitt and Haas 2000). Breeding habitat includes a variety of vegetation types, but this species reaches its highest densities in shrublands and midsuccessional forests. Grand and Cushman (2003) found that thrashers in Massachusetts were associated predominately with the amount of scrub oak in the landscape. Rumble and Gobeille (2004) found no significant difference in brown thrasher occurrence among seral stages of cottonwood floodplains in South Dakota, though this bird was detected most often in younger forest classes. Savanna restoration efforts increase thrasher abundance by reducing tree density (Davis and others 2000).

Nests are typically low in a tree or shrub but some may be on the ground. Territory size and thrasher density vary according to habitat quality (0.5 to 1.1 ha and 0.1 to 0.4/ha, respectively). The FWS (Cade 1986) developed an HSI model for this species that included three site-specific variables: density of woody stems, canopy cover, and litter cover.

Model Description

Our brown thrasher model includes six variables: landform, landcover, successional age class, edge occurrence, small stem density (<2.5 cm d.b.h.), and forest composition in a 10-km radius.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 40). We directly assigned SI scores to these combinations on the basis of habitat associations reported by Hamel (1992) for the brown thrasher in the Southeast.

This edge species inhabits thickets and hedgerows in deciduous forests. Because the brown thrasher uses both hard and soft edges, we defined edge (SI2) as the interface between pole age forest and herbaceous or non-forest landcovers (hard edge) and seedling or grass-forb age forest (soft edge). To be suitable, we required pole age forest sites to be adjacent to an edge (Table 41). However, we relaxed this requirement for seedling-shrub and sapling stands, which we considered suitable regardless of edge.

Table 40.—Relationship of landform, landcover type, and successional age class to suitability index scores for brown thrasher habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

Landform	Landcover type	Successional age class				
		Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.500	0.333	0.083	0.000
	Transitional-shrubland	0.000	0.500	0.333	0.083	0.000
	Deciduous	0.000	0.500	0.333	0.083	0.000
	Evergreen	0.000	0.667	0.500	0.167	0.000
	Mixed	0.000	1.000	0.667	0.167	0.000
	Orchard-vineyard	0.000	0.500	0.333	0.083	0.000
	Woody wetlands	0.000	0.667	0.417	0.083	0.000
Terrace-mesic	Low-density residential	0.000	0.667	0.417	0.083	0.000
	Transitional-shrubland	0.000	1.000 (0.667)	0.667 (0.500)	0.167	0.000
	Deciduous	0.000	0.667	0.417	0.083	0.000
	Evergreen	0.000	0.667	0.500	0.167	0.000
	Mixed	0.000	1.000	0.667	0.167	0.000
	Orchard-vineyard	0.000	0.667	0.417	0.083	0.000
	Woody wetlands	0.000	0.667	0.500	0.167	0.000
Xeric-ridge	Low-density residential	0.000	1.000	0.667	0.167	0.000
	Transitional-shrubland	0.000	1.000 (0.334)	0.667 (0.250)	0.167 (0.083)	0.000
	Deciduous	0.000	1.000	0.667	0.167	0.000
	Evergreen	0.000	0.667 (0.334)	0.500 (0.250)	0.167 (0.083)	0.000
	Mixed	0.000	1.000	0.667	0.167	0.000
	Orchard-vineyard	0.000	1.000	0.667	0.167	0.000
	Woody wetlands	0.000	0.667	0.500	0.167	0.000

Table 41.—Influence of edge on suitability index (SI) scores for brown thrasher habitat

3 × 3 pixel window around forest pixel includes field[a]	SI score
Yes[b]	1.0
No	0.0

[a]Field defined as any shrub-seedling or grass-forb age class pixel, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any used pole age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands.

[b]Seedling-shrub and sapling habitats used regardless of edge.

Table 42.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for brown thrasher habitat

Small stem density[a]	SI score
0	0.1
10	1.0
40	0.5

[a]Cade (1986).

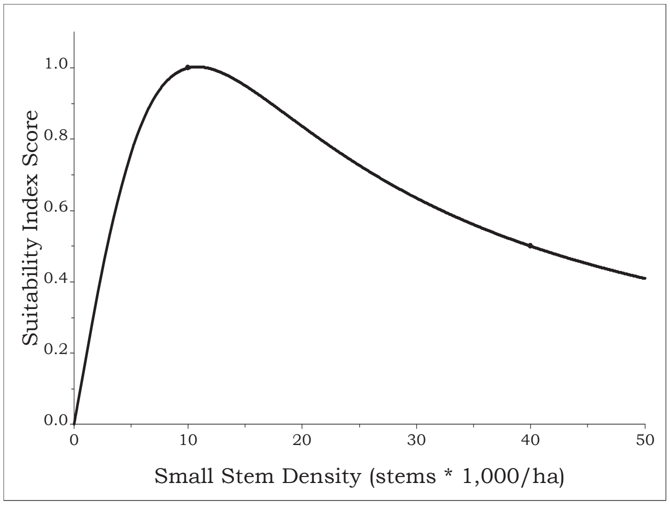


Figure 20.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for brown thrasher habitat. Equation: SI score = (0.1 + (0.165 * (small stem density / 1000))) / (1 + (-0.003 * (small stem density / 1000)) + (0.0078 * ((small stem density / 1000))^2)).

The brown thrasher occupies habitats with numerous small stems (SI3). We fit a smoothed quadratic function (Fig. 20) to HSI cutoff values from the FWS HSI model for this species (Cade 1986; Table 42) to quantify the relationship between small stem density and habitat suitability.

Although the brown thrasher is associated with edges, it prefers modestly forested landscapes (Haas 1997). We included forest composition (SI4) in our model, assuming that habitat suitability would be low if there were no woodland (i.e., 0 percent forest, the left side of the function; Fig. 21) or no edges (i.e., 100 percent forest, the right side of the function). Haas (1997) observed higher reproductive success for birds in more isolated shelterbelts and Robbins and others (1989) observed negative relationships between the occurrence of the gray catbird and American robin (species that share similar habitat preferences to those of the brown thrasher) and forest patch size. Further, Perkins and others (2003b) observed an increase in abundance of edge-associated birds as the total amount of woody cover decreased. However, the brown thrasher responded positively to the amount of forest cover in the study area. We interpreted these observations as evidence that this species would exhibit a preference for landscapes with moderate forest landcover. We fit a Gaussian function to landscape proportions reflecting this pattern and assumed that landscapes that were 70 percent forested were associated with the maximum SI score (Table 43).

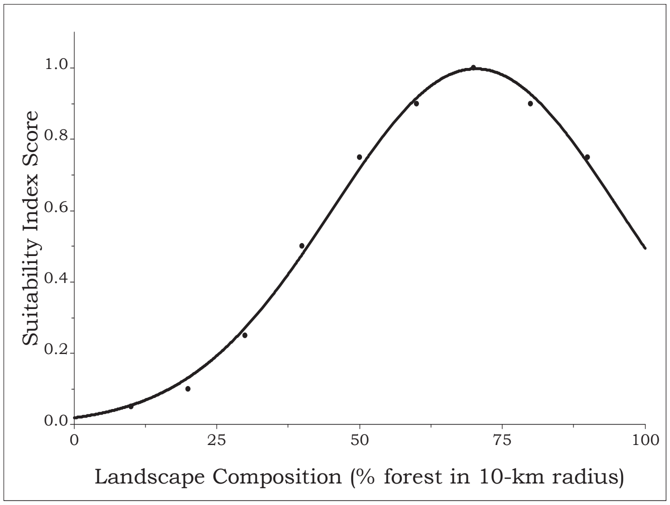


Figure 21.—Relationship between landscape composition and suitability index (SI) scores for brown thrasher habitat. Equation: SI score = 0.998 * e $^{((0 - ((\text{landscape composition}) - 70.304)\ \hat{}\ 2) / 1253.402)}$.

Table 43.—Relationship between landscape composition (percent forest in 10-km radius) and suitability index (SI) scores for brown thrasher habitat

Landscape composition[a]	SI score
0	0.00
10	0.05
20	0.10
30	0.25
40	0.50
50	0.75
60	0.90
70	1.00
80	0.90
90	0.75
100	0.50

[a]Assumed value.

We assumed that the brown thrasher used edge as a surrogate to early successional habitat, so we calculated HSI scores separately for young (seedling-shrub and sapling) and old (pole) age class forests. In the former, the geometric mean of forest structure and landscape composition variables defines the suitability score. For the latter, we included edge occurrence in the calculation. We summed the age class-specific HSI scores to determine the overall HSI score for all sites.

Seedling-shrub and sapling successional age classes:

HSI_{Young}: $((SI1 * SI3)^{0.500} * SI4)^{0.500}$

Pole successional age class:

HSI_{Pole}: $((SI1 * SI3)^{0.500} * SI4)^{0.500} * SI2$

Overall SI = $HSI_{Young} + HSI_{Pole}$

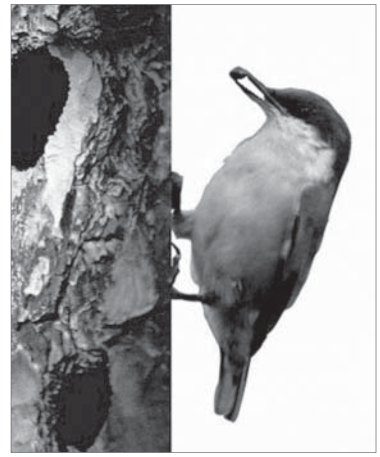
Verification and Validation

The brown thrasher was found in all 88 subsections of the CH and WGCP. Spearman rank correlation did not identify a positive relationship between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the brown thrasher was significant ($P \leq 0.001$; $R^2 = 0.719$); however, the coefficient on the HSI predictor variable was negative ($\beta = -7.087$). Therefore, we considered the HSI model for the brown thrasher neither verified nor validated (Tirpak and others 2009a).

Brown-headed Nuthatch

Status

The brown-headed nuthatch (*Sitta pusilla*) is a resident species of mature pine forests along the Piedmont and Coastal Plains of the southeastern United States. Although this species has experienced modest declines throughout most of its range over the last 40 years (1.2 percent per year), only in Florida has the decline been significant (4.2 percent annually from 1966 to 2004; Sauer and others 2005). This species is an FWS Bird of Conservation Concern in the WGCP (Table 1), where it has a regional combined score of 19. The brown-headed nuthatch is a rare breeder in the CH (regional combined score = 19), and PIF considers this species one that warrants critical recovery in that region.



Fernbank Science Center
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Natural History

The brown-headed nuthatch is closely associated with pine: it breeds in mature pine forests and forages almost exclusively in pine trees (> 98 percent of observations; Withgott and Smith 1998). Although often associated with the longleaf pine savanna characteristic of the habitat for red-cockaded woodpecker and Bachman's sparrow, the brown-headed nuthatch has a broader niche than these species (Hamel 1992, Dornak and others 2004). The habitat of this species is defined by two habitat elements: mature pines for foraging and cavities for nesting (Wilson and Watts 1999, Dornak and others 2004). Specific composition of pine species is not as critical as d.b.h., with an average d.b.h. of 25.6 cm considered optimal (O'Halloran and Conner 1987 cited in Dornak and others 2004). The brown-headed nuthatch nests primarily in large-diameter snags < 3 m tall and may require seven to eight snags per ha to ensure adequate nest and roost sites, particularly in the presence of interspecific competition for cavities. In urban areas, the brown-headed nuthatch readily adopts nest boxes and may use other manmade cavities, such as streetlights.

This species prefers open pine stands with few hardwoods (≤ 17.4 stems/ha and basal area ≤ 5 m^2/ha) and an open midstory (Wilson and Watts 1999). Optimal canopy cover is highly variable (15 to 85 percent) but stands with closed canopies are not preferred (O'Halloran and Conner 1987, Wilson and Watts 1999). Undergrowth typically is sparse (roughly 35 percent; Dornak and others 2004). The nuthatch regularly breeds at low densities in suboptimal habitats, including stands with small pines, a large fraction of hardwoods, and dense understories (Withgott and Smith 1998). Area sensitivity apparently is not an issue for this species, which is not an acceptable host for the brown-headed cowbird (Withgott and Smith 1998).

Model Description

The HSI model for the brown-headed nuthatch includes six variables: landform, landcover, successional age class, snag density, small stem (< 2.5 cm d.b.h.) density, and hardwood basal area.

Table 44.—Relationship of landform, landcover type, and successional age class to suitability index scores for brown-headed nuthatch habitat

Landform	Landcover type	Successional age class: Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 44). We directly assigned SI scores to these combinations on the basis of habitat associations of the brown-headed nuthatch described by Hamel (1992).

We included snag density (SI2) in our HSI model because of the importance of cavities to this species. We assumed that the SI score was zero when eight or fewer snags of any size were present (Dornak and others 2004). We fit a logistic function (Fig. 22) to data from Wilson and Watts (1999) (Table 45) to quantify the relationship between snag density and SI scores.

We also used small stem density as a function (SI3) in the HSI model to account for the preference of the brown-headed nuthatch for open understories. We fit an inverse logistic function (Fig. 23) to hypothetical data reflecting this preference (Table 46). The shape of this function is supported by observations from Wilson and others (1995), who observed a higher abundance of the brown-headed nuthatch in stands immediately following wildlife stand improvements and prescribed burns (when stem density was lowest) with subsequent declines in abundance as stem density increased through time.

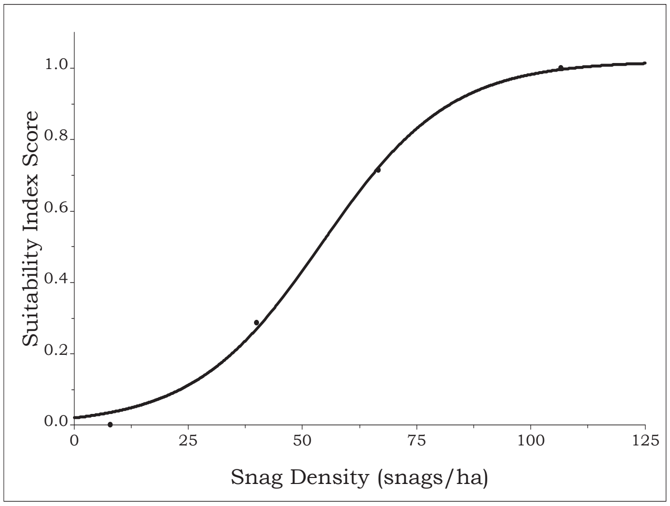

Figure 22.—Relationship between snag density and suitability index (SI) scores for brown-headed nuthatch habitat. Equation: SI score = 1.000 / (1 + (49.165 * e $^{(-0.073 * \text{snag density})}$)).

Table 45.—Influence of snag density on suitability index (SI) scores for brown-headed nuthatch habitat

Snag density (snags/ha)	SI score
8[a]	0.000
40[b]	0.286
66.67[b]	0.715
106.67[b]	1.000

[a]Dornak and others (2004).
[b]Wilson and Watts (1999).

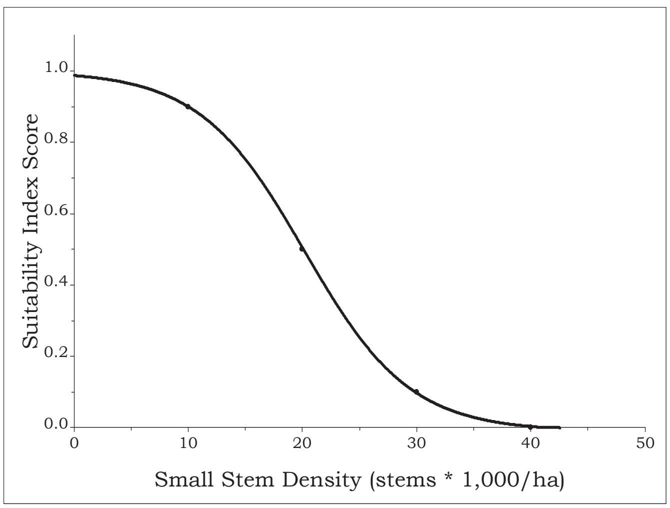

Figure 23.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for brown-headed nuthatch habitat. Equation: SI score = 1 - (1.010 / (1 + (79.565 * e $^{(-0.217 * (\text{small stem density} / 1000))}$))).

Table 46.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for brown-headed nuthatch habitat

Small stem density[a]	SI score
0[1]	1.0
10[1]	0.9
20[1]	0.5
30[1]	0.1
40[1]	0.0

[a]Assumed value.

Finally, we incorporated hardwood basal area (SI4) as a model variable as birds are less abundant in habitats with a greater hardwood component (Wilson and others 1995, Withgott and Smith 1998, Wilson and Watts 1999). Again, we relied on data from Wilson and Watts (1999) (Table 47) to develop an inverse logistic function to describe the relationship between hardwood basal area and SI score (Fig. 24).

To determine the overall HSI score for the brown-headed nuthatch, we calculated the geometric mean of the four individual functions related to forest structure attributes.

Overall HSI = $(SI1 * SI2 * SI3 * SI4)^{0.250}$

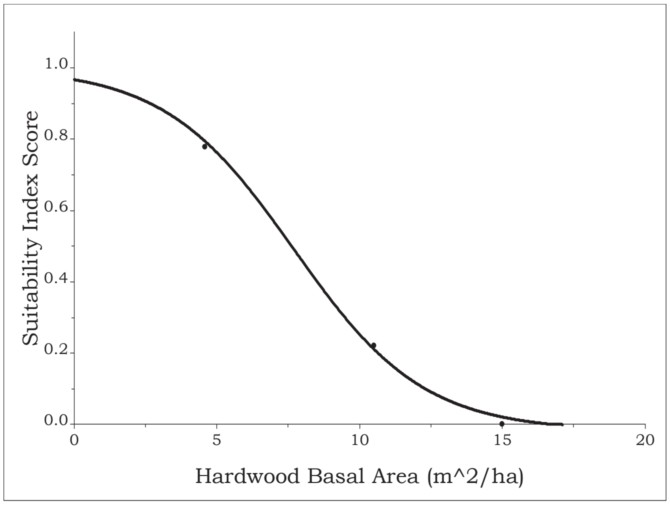

Figure 24.—Relationship between hardwood basal area and suitability index (SI) scores for brown-headed nuthatch habitat. Equation: SI score = 1 - (1.018 / (1 + (29.747 * e $^{(-0.441 * \text{hardwood basal area})}$))).

Table 47.—Influence of hardwood basal area on suitability index (SI) scores for brown-headed nuthatch habitat

Hardwood basal area (m^2/ha)	SI score
0.0[a]	1.000
4.6[a]	0.778
10.5[a]	0.222
15.0[b]	0.000
20.0[b]	0.000

[a]Wilson and Watts (1999).
[b]Assumed value.

Verification and Validation

The brown-headed nuthatch was found in 37 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.58$) between average HSI score and mean BBS route abundance across subsections. This relationship was even stronger ($r_s = 0.80$) when subsections in which the brown-headed nuthatch was not detected were removed from the analysis. The generalized linear model predicting BBS abundance from BCR and HSI for the brown-headed nuthatch was significant ($P \leq 0.001$; $R^2 = 0.738$), and the coefficient on the HSI predictor variable was both positive (β = 4.712) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the brown-headed nuthatch both verified and validated (Tirpak and others 2009a).

Carolina Chickadee


Charles H. Warren, images.nbii.gov

Status

The Carolina chickadee (*Parus carolinensis*) is a resident species of the southeastern United States. Although populations have been stable in the CH, this species has declined by about 2 percent annually over the last 40 years in the WGCP (Table 5). This bird is a planning and responsibility species in both the CH (regional combined score = 15) and WGCP (regional combined score = 16; Table 1).

Natural History

The Carolina chickadee is a generalist species that breeds in a variety of forest types across a broad spectrum of landforms (Mostrom and others 2002). It nests in cavities of live and dead trees within multilayered forests containing well developed shrub, midstory, and overstory canopies (Hamel 1992). Abundance declines following reduction of hardwoods in pine stands, likely as a result of the loss of midstory trees (Provencher and others 2002). Nest success and adult survival is positively correlated with woodlot area but is lower on edges regardless of patch size (Doherty and Grubb 2002). Nest destruction by the house wren is a major cause of nest failure in areas where the ranges of these species overlap. Territory size ranges from 1.6 to 2.4 ha.

Model Description

The Carolina chickadee model includes four variables: landform, landcover, successional age class, and snag density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 48). We directly assigned SI scores to these combinations on the basis of vegetation and successional age class associations of the Carolina chickadee reported in Hamel (1992).

We included snag density (SI2) as a variable because of the importance of nest and roost cavities for the chickadee, a secondary cavity nester. Data for the Carolina chickadee were not available but Rumble and Gobeille (2004) and Sedgwick and Knopf (1990) observed the black-capped chickadee in habitats with six snags per hectare (Table 49). Therefore, we assumed that stands with six or more snags per ha were representative of optimal habitat. Because the chickadee can use cavities in live trees, we assumed that stands with no snags were not necessarily nonhabitat and assigned to them a small but non-zero SI score (0.03). We fit a logistic function through these data points to quantify the relationship between snag density and habitat suitability (Fig. 25).

We calculated the overall HSI score as the geometric mean of the two individual functions:

Overall HSI = $(SI1 * SI2)^{0.500}$

Table 48.—Relationship of landform, landcover type, and successional age class to SI scores for Carolina chickadee habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.167	0.500	0.667
	Transitional-shrubland	0.000	0.000	0.167	0.500	0.667
	Deciduous	0.000	0.000	0.167	0.500	0.667
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.500	0.667
	Woody wetlands	0.000	0.000	0.167	0.500	0.667
Terrace-mesic	Low-density residential	0.000	0.000	0.167	0.500	0.667
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.167	0.500	0.667
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.500	0.667
	Woody wetlands	0.000	0.000	0.167	0.500	0.667
Xeric-ridge	Low-density residential	0.000	0.000	0.167	0.500	0.667
	Transitional-shrubland	0.000	0.000	0.334 (0.250)	0.834 (0.667)	1.000 (0.834)
	Deciduous	0.000	0.000	0.167	0.500	0.667
	Evergreen	0.000	0.000	0.334 (0.250)	0.834 (0.667)	1.000 (0.834)
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.500	0.667
	Woody wetlands	0.000	0.000	0.167	0.500	0.667

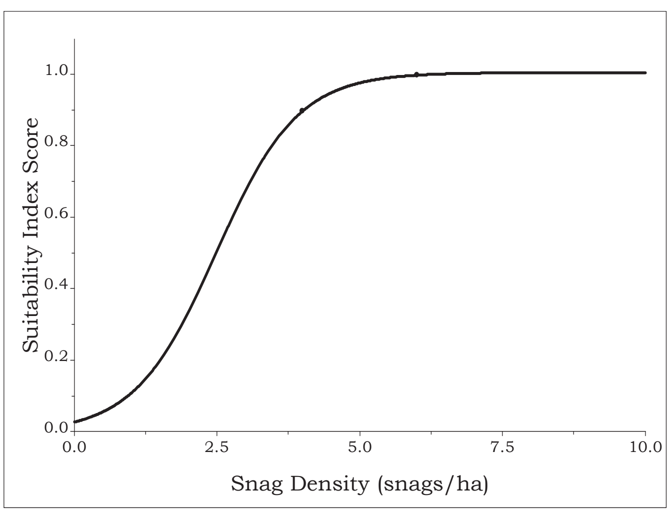

Figure 25.—Relationship between snag density and suitability index (SI) scores for Carolina chickadee habitat. Equation: SI score = 1.007 / (1.000 + (32.567 * e $^{(-1.403 * \text{snag density})}$)).

Table 49.—Influence of snag density on suitability index (SI) scores for Carolina chickadee habitat

Snag density (snags/ha)	SI score
0[a]	0.03
4[b]	0.90
6[a, c]	1.00

[a]Rumble and Gobeille (2004).
[b]Assumed value.
[c]Sedgwick and Knopf (1990).

Verification and Validation

The Carolina chickadee was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.55$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the Carolina chickadee was significant ($P \leq 0.001$; $R^2 = 0.473$), and the coefficient on the HSI predictor variable was both positive ($\beta = 5.142$) and significantly different from zero ($P = 0.038$). Therefore, we considered the HSI model for the Carolina chickadee both verified and validated (Tirpak and others 2009a).

Cerulean Warbler


U.S. Forest Service

Status

The cerulean warbler (*Dendroica cerulea*) is a long-distance migrant to the eastern United States. Densities are highest in the Ohio River Valley and along the Cumberland Plateau. This species has declined across most of its range, including the CH and WGCP (6.3 and 9.5 percent per year from 1966 to 2004, respectively; Table 5). The cerulean warbler is classified as a Bird of Conservation Concern requiring critical recovery in the WGCP (regional combined score = 19) and immediate management in the CH (regional combined score = 19) (Table 1). Concern for this species culminated in a petition to the FWS to list the cerulean warbler as threatened. However, this action was deemed unwarranted on the basis of current scientific information (Federal Register 71:234 [6 December 2006] p. 70717).

Natural History

A forest interior specialist, the cerulean warbler has experienced some of the most dramatic declines of any songbird over the last 30 years (Hamel 2000). This species has a broad geographic range but is abundant only locally. It may nest semi-colonially, with territories in good habitat highly clumped. The cerulean warbler seems to be highly sensitive to forest fragmentation. Robbins and others (1989) found a 50 percent reduction in observations of this species as forest patch size declined from 3,000 to 700 ha. No birds were detected on forest patches less than 138 ha. Estimates from other researchers suggest that forest tracts as large as 8,000 ha may be required to ensure sustainable populations in the Mississippi Alluvial Valley (summarized in Hamel [2000]).

Although it requires large forest tracts, the cerulean warbler establishes territories near interior forest gaps. Weakland and Wood (2005) observed a positive association between this species and forest roads or snags that created small canopy openings. Aside from canopy gaps (a measure of horizontal canopy structure), the cerulean warbler also may respond to the vertical canopy profile. Canopy cover of 6 to 12 m and more than 24 m was preferred in West Virginia (Weakland and Wood 2005). In Ontario, canopy cover of 12 to 18 m and more than 18 m was preferred (Jones and Robertson 2001). The difference in preferred canopy heights between these studies likely reflects differences in local vegetation structure rather than an absolute difference in preferred canopy height. The key habitat feature in both is the multilayered character of the overstory canopy.

Closed-canopy stands with large trees (both in height and d.b.h.) are commonly associated with the cerulean warbler but likely are a crude proxy for the aforementioned canopy features that provide the true selection criteria for this bird (Hamel 2000). This species is associated with bottomland hardwoods in the Southeast and ridges in West Virginia (Hamel 2000, Weakland and Wood 2005). Again, specific landforms probably are not directly selected for but are correlated with the location of large tracts of deciduous forest containing large trees and favorable canopy conditions in these landscapes.

Table 50.—Relationship of landform, landcover type, and successional age class to suitability index scores for cerulean warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.400	0.800
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.400	0.800
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.400	0.800
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.400	0.800

In "Birds of North America," Hamel (2000) stated: "Important habitat elements for this species thus appear to be large tracts with big deciduous trees in mature to old-growth forest with horizontal heterogeneity of the canopy. The pattern of vertical distribution of foliage in the canopy is also important."

Model Description

The HSI model for the cerulean warbler includes seven variables: landform, landcover, successional age class, forest patch size, percent forest in a 1-km radius, dominant tree density, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 50). We directly assigned SI scores to these combinations on the basis of habitat associations of the cerulean warbler outlined in Hamel (1992).

We derived the suitability function for forest patch size (SI2) by fitting a logistic curve (Fig. 26) to data from Robbins and others (1989) and Rosenberg and others (2000), who

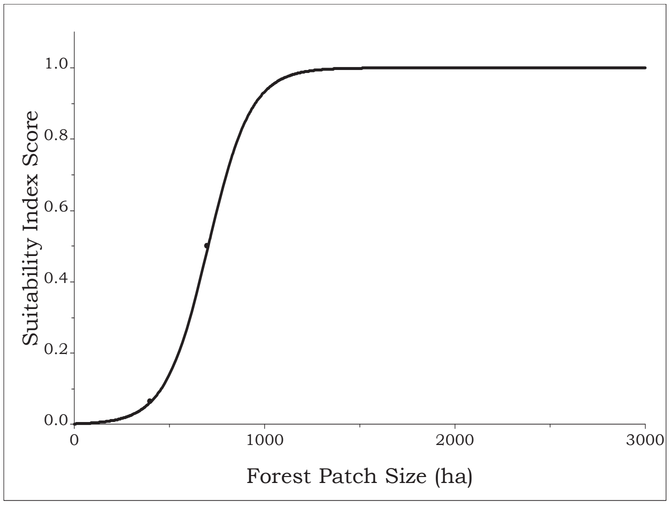

Figure 26.—Relationship between forest patch size and suitability index (SI) scores for cerulean warbler habitat. Equation: SI score = 1.000 / (1.000 + (524.457 * e $^{-0.0089 \text{ * forest patch size}}$)).

Table 51.—Influence of forest patch size on suitability index (SI) scores for cerulean warbler habitat

Forest patch size (ha)	SI score
400[a]	0.064
700[b]	0.500
3,000[b]	1.000
5,000[c]	1.000

[a]Rosenberg and others (2000).
[b]Robbins and others (1989).
[c]Assumed value.

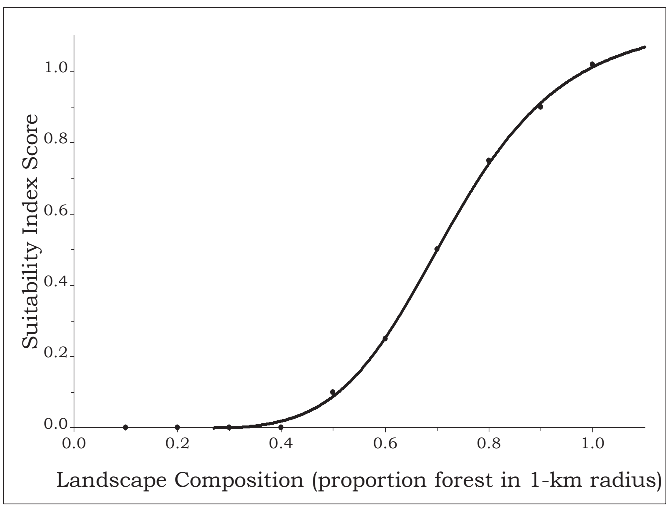

Figure 27.—Relationship between landscape composition and suitability index (SI) scores for cerulean warbler habitat. Equation: SI score = 1.047 / (1.000 + (1991.516 * e $^{-10.673 \text{ * landscape composition}}$)).

Table 52.—Relationship between landscape composition and suitability index (SI) scores for cerulean warbler habitat

Landscape composition	SI score
0.00[a]	0.00
0.10[a]	0.00
0.20[a]	0.00
0.30[a]	0.00
0.40[a]	0.00
0.50[a]	0.10
0.60[a]	0.25
0.70[b]	0.50
0.80[a]	0.75
0.90[a]	0.90
1.00[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

observed that about 95 percent of all birds in FWS Region 4 were on tracts of at least 400 ha (Table 51). Recognizing the suitability of a forest patch is affected by its landscape context (Rosenberg and others 1999), we fit a logistic function (Fig. 27) to data (Table 52) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoint between moderately and lightly fragmented forest defined the specific cutoff for average (SI score = 0.500) habitat. We used the maximum value from SI2 or SI3 to account for the suitability of small patches in predominantly forested landscapes.

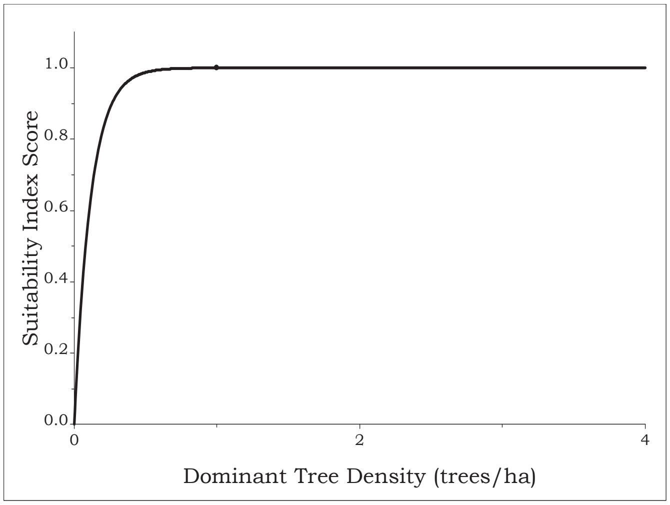

Figure 28.—Relationship between dominant tree density and suitability index (SI) scores for cerulean warbler habitat. Equation: SI score = 1 – e $^{-8.734 * \text{dominant tree density}}$.

Table 53.—Influence of dominant tree density on suitability index (SI) scores for cerulean warbler habitat

Dominant tree density (trees/ha)[a]	SI score
0	0.0
1	1.0
14	1.0

[a]Assumed value.

We used the density of dominant trees (SI4) in the HSI model and assumed that trees with a d.b.h. greater than 76.2 cm would produce the heterogeneous vertical canopy structure preferred by the cerulean warbler. On the basis of qualitative habitat descriptions by Rosenberg and others (2000), we assumed that the cerulean warbler reached its highest density in stands containing at least one dominant tree per ha. Because this bird nests almost exclusively in these trees (Weakland and Wood 2005), we also assumed that it would be absent from stands with a uniform canopy height (i.e., no dominant trees). We fit an exponential function (Fig. 28) to these data points and assumed that stands with at least 14 dominant trees per ha (the maximum number observed in the WGCP during the FIA surveys of the 1990s) were associated with maximum habitat suitability (Table 53).

We used data from Rosenberg and others (2000), Jones and others (2001), and Weakland and Wood (2005) to derive an inverse quadratic function (Fig. 29) that predicted habitat suitability for the cerulean warbler from canopy cover (SI5; Table 54). Canopy cover of 50 percent or less is associated with failed reproduction by this species (Jones and others 2001), so we considered these values as nonhabitat (SI score = 0.000). Rosenberg and others (2000) identified “a tall, but broken, canopy” as one of the few common denominators of cerulean warbler habitat rangewide, and we maximized the SI score at 90 percent canopy closure. However, Weakland and Wood (2005) observed the cerulean warbler selecting internal edges, so we also discounted habitat suitability for closed canopies. Nonetheless, we recognize that a dense upper canopy is needed by this species (Hamel 2000) and assigned to sites with 80 and 100 percent canopy cover an average SI score (0.500).

To calculate overall HSI scores for cerulean warbler habitat, we calculated the geometric mean of the three suitability indices related to forest structure (SI1, SI4, and SI5) and the maximum value for the two suitability indices related to landscape composition (SI2 and SI3) separately and then the geometric mean of these values together.

Overall SI = $((\text{SI1} * \text{SI4} * \text{SI5})^{0.333} * \text{Max}(\text{SI2 or SI3}))^{0.500}$

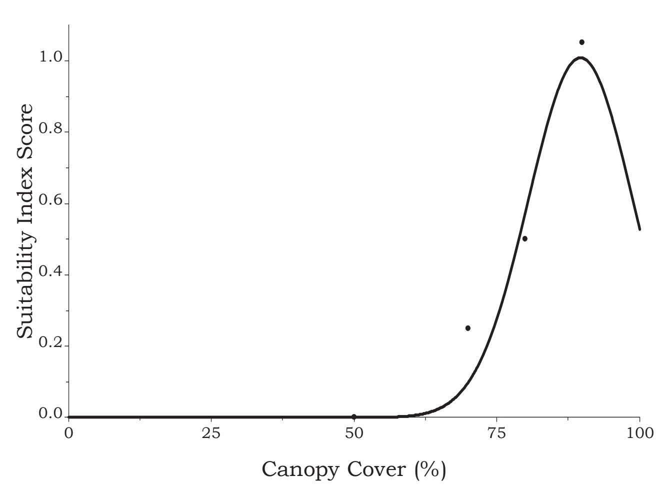

Figure 29.—Relationship between canopy cover and suitability index (SI) scores for cerulean warbler habitat. Equation: SI score = 1 / (62.548 – (1.369 * canopy cover) + (0.007612 * $(\text{canopy cover})^2$)).

Table 54.—Influence of canopy cover on suitability index (SI) scores for cerulean warbler habitat

Canopy cover (percent)	SI score
50[a]	0.00
70[b]	0.25
80[b]	0.50
90[c]	1.00
100[d]	0.50

[a]Jones and others (2001).
[b]Hamel (2000).
[c]Rosenberg and others (2000).
[d]Weakland and Wood (2005).

Verification and Validation

The cerulean warbler was found in 60 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant positive relationship between average HSI score and mean BBS route abundance across all subsections ($P \leq 0.001$; $r_s = 0.44$) and those in which this species was detected ($P \leq 0.001$; $r_s = 0.42$). The generalized linear model predicting BBS abundance from BCR and HSI for the cerulean warbler was significant ($P \leq 0.001$; $R^2 = 0.205$), and the coefficient on the HSI predictor variable was both positive ($\beta = 0.627$) and significantly different from zero ($P = 0.023$). Therefore, we considered the HSI model for the cerulean warbler both verified and validated (Tirpak and others 2009a).

Chimney Swift


Ron Austing, used with permission

Status

The chimney swift (*Chaetura pelagica*) is a familiar bird found across most of North America east of the Rocky Mountains. Populations have declined in both the CH and WGCP over the last 40 years (2.6 and 1.1 percent per year). However, the high annual variability in abundance for this species prevents the identification of significant trends (Sauer and others 2005; Table 5). This bird has a regional combined score of 16 and requires management attention in the CH. However, in the WGCP, the chimney swift is only a planning and responsibility species with a regional combined score of 14 (Table 1).

Natural History

The range of the chimney swift, a small, long-distance migrant, expanded dramatically with European settlement and the increase in artificial nest structures (e.g., chimneys) that followed (Cink and Collins 2002). Prior to European settlement, this species probably was distributed thinly and relied on tree cavities for nesting. Nesting in trees is now rare (Graves 2004) and most nests and roosts are concentrated in urban areas (Cink and Collins 2002). This species is weakly territorial (typically one nest per cavity), and population declines may be due to the loss of nest sites as large, open chimneys become scarce. Home ranges are largely unknown.

Model Description

For a bird that occurs in such close association with humans, few data are available on the habitat preferences of the chimney swift. We assumed that habitat suitability for this species was primarily a function of the availability of nest and roost sites within the proper landscape context (i.e., open chimneys near foraging areas). To identify these locations, we estimated the proportion of foraging habitats in a 1-km buffer around each pixel of developed landcover. We assumed that this bird could travel 1 km from nesting-roosting areas to foraging habitats (defined as water, grassland, pasture-hay, recreational grasses, or forest landcover classes) and that these habitats had to be more than 1 ha to accommodate the aerial foraging maneuvers of this species. Because the chimney swift is semi-colonial, we also assumed that that as foraging habitat increased in the 1-km buffer, developed pixels were increasingly isolated and would be of lower suitability (Table 55). We used a quadratic curve (Fig. 30) to quantify the relationship between landscape composition and habitat suitability for this species.

Verification and Validation

The chimney swift occurred in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.50$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the chimney swift was significant ($P \leq 0.001$; $R^2 = 0.208$), and the coefficient on the HSI predictor variable was positive ($\beta = 5.043$) but not significantly different from zero ($P = 0.524$). Therefore, we considered the HSI model for the chimney swift verified but not validated (Tirpak and others 2009a).

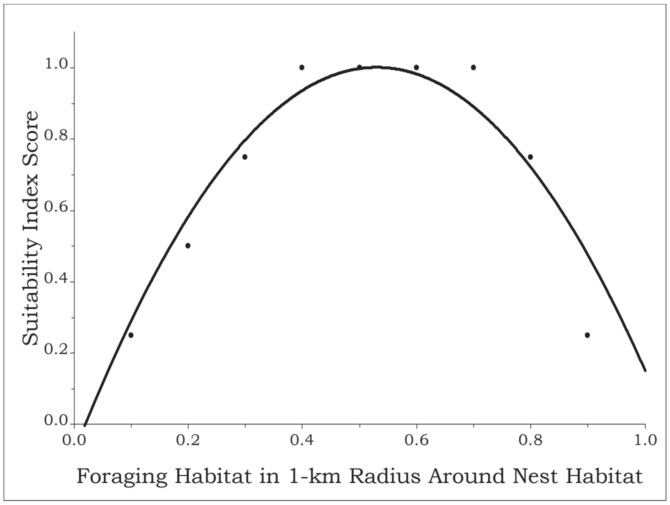

Figure 30.—Relationship between proportion of foraging habitat within 1-km buffer around potential nesting/roosting sites on suitability index (SI) scores for chimney swift habitat. Equation: SI score = (-0.0769 + (4.0734 * proportion foraging cover) - (3.8462 * (proportion foraging cover^2))).

Table 55.—Influence of proportion of foraging habitat[a] within 1-km buffer around potential nesting-roosting sites[b] on suitability index (SI) scores for chimney swift habitat

Proportion[c] of foraging habitat around potential nesting-roosting sites	SI score
0.0	0.00
0.1	0.25
0.2	0.50
0.3	0.75
0.4	1.00
0.5	1.00
0.6	1.00
0.7	1.00
0.8	0.75
0.9	0.25
1.0	0.25

[a]Foraging habitat = water, grassland, pasture-hay, recreational grasses, forest > 1 ha.

[b]Nesting-roosting site = any developed landcover.

[c]Assumed value.

Chuck-will's-widow

Chandler S. Robbins, Patuxent Bird Identification InfoCenter
Photo used with permission

Status

The chuck-will's-widow (*Caprimulgus carolinensis*) is a neotropical migrant that breeds in the southeastern United States. It has experienced small yet significant declines in the WGCP over the last 40 years (1.3 percent per year; Sauer and others 2005). Populations in the CH have remained relatively stable during the same period (Table 5). Chuck-will's-widow is as Bird of Conservation Concern and a PIF species in need of management attention in the WGCP (regional combined score = 16). This species has no special conservation status in the CH (regional combined score = 14; Table 1).

Natural History

The chuck-will's-widow, like all nightjars, is nocturnal and most active on moonlit nights. Because of this behavior and its cryptic coloration, this species is difficult to study and few systematic investigations of its habitat, demography, or population status have been conducted. Most of the information on chuck-will's-widow is anecdotal and coincident to studies of other species (Straight and Cooper 2000).

The chuck-will's-widow occupies woodland habitats interspersed with large openings in which the bird forages at night. Calling males are equally abundant among suburban, pasture, and forested landscapes (Cooper 1981). Urban habitats are unsuitable (Straight and Cooper 2000). The chuck-will's-widow prefers more open habitats than the whip-poor-will (Cooper 1981) and is unaffected by forest fragmentation (it may even benefit from it). Drier sites also are preferred.

Model Description

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 56). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the habitat associations of the chuck-will's-widow in the Southeast.

The realized suitability of the sites identified in SI1 depends largely on landscape context. Cooper (1981) found that the abundance of chuck-will's-widow was highest in areas with equal amounts of forest and agriculture. Therefore, we used the proportion of these two habitats in a 500-m radius window (SI2) in the HSI model. We assigned the maximum SI score to landscapes characterized by 50 percent forest and 50 percent agriculture. We reduced these scores as landscapes varied from this optimal configuration towards a more open or a more forested composition with a stronger reduction in suitability for increasingly forested landscapes (Table 57).

The overall HSI score for chuck-will's-widow is based solely on SI2, which incorporates the results from SI1.

Overall HSI = SI2

Table 56.—Relationship of landform, landcover type, and successional age class to suitability index scores for chuck-will's-widow habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.083	0.167	0.167
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.083	0.167	0.167
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334 (0.250)	0.834 (0.583)	1.000 (0.667)
	Deciduous	0.000	0.000	0.167	0.333	0.333
	Evergreen	0.000	0.000	0.334 (0.250)	0.834 (0.583)	1.000 (0.667)
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

Verification and Validation

The chuck-will's-widow was found in 86 of the 88 subsections within the CH and WGCP. Spearman rank correlations yielded similar results when analysis included all subsections and only those subsections in which this species was detected: significant ($P \leq 0.001$ and 0.003, respectively) positive associations ($r_s = 0.34$ and 0.32, respectively) between average HSI score and mean BBS route abundance. The generalized linear model predicting BBS abundance from BCR and HSI for the chuck-will's-widow was significant ($P \leq 0.001$; $R^2 = 0.312$), and the coefficient on the HSI predictor variable was positive (β = 0.569) but not significantly different from zero ($P = 0.415$). Therefore, we considered the HSI model for the chuck-will's-widow verified but not validated (Tirpak and others 2009a).

Table 57.—Suitability index scores for chuck-will's-widow habitat based on proportion of nesting-roosting and foraging habitat within 500-m radius landscape

	Proportion foraging[a]										
Proportion nest and roost[b]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	
0.2	0.0	0.0	0.1	0.2	0.4	0.6	0.6	0.6	0.5		
0.3	0.0	0.1	0.2	0.4	0.6	0.6	0.8	0.8			
0.4	0.0	0.2	0.4	0.6	0.8	0.8	1.0				
0.5	0.0	0.2	0.4	0.6	0.8	1.0[c]					
0.6	0.0	0.2	0.4	0.6	0.8						
0.7	0.0	0.2	0.4	0.6							
0.8	0.0	0.2	0.4								
0.9	0.0	0.2									
1.0	0.0										

[a]Foraging = pasture-hay, recreational grasses, grasslands, and emergent herbaceous wetland landcovers or grass-forb and shrub-seedling successional age classes.

[b]Nest and roost = habitats identified in SI1 (Table 56).

[c]Cooper (1981).

Eastern Wood-pewee

Jeffrey A Spendelow, Patuxent Bird Identification InfoCenter
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Status

The eastern wood-pewee (*Contopus virens*) is a long-distance neotropical migrant that breeds throughout the temperate regions of eastern North America (McCarty 1996). This species reaches its highest densities in the Ozark Mountain region of the CH, where it has a regional combined score of 15 (Table 1). In the WGCP, the eastern wood-pewee has a regional combined score of 16. This bird is one requiring management attention in both BCRs, with declining populations in both regions (Sauer and others 2005) (Table 5).

Natural History

The eastern wood-pewee is a common species in woodlands of all types (deciduous, mixed, and evergreen). However, this species consistently selects open park-like conditions on xeric sites with limited canopy cover and low shrub densities (Robbins and others 1989; McCarty 1996). The eastern wood-pewee is positively associated with increasing density of sawtimber trees, reaching a threshold at 100 trees per ha where a negative relationship develops (Best and Stauffer 1986, Robbins and others 1989).

The eastern wood-pewee, common in both forest interiors and edges, generally is area-insensitive, and may occupy fragments as small as 0.3 ha (Blake and Karr 1987, Robbins and others 1989). Its cryptic nests high in the canopy may limit predation and parasitism, allowing the pewee to occupy small fragments without the adverse effects on reproduction common to other open-cup nesters (McCarty 1996, Knutson and others 2004, Underwood and others 2004). This species is not found in riparian corridors with less than 24 percent forest cover in the landscape (Perkins and others 2003b).

Model Description

The HSI model for the eastern wood-pewee includes five variables: landform, landcover, successional age class, percent forest in a 1-km radius, and density of sawtimber trees (> 28 cm d.b.h.).

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 58). We directly assigned SI scores to these combinations on the basis of habitat associations of the eastern wood-pewee reported by Hamel (1992).

This species can occupy small forest fragments but may require a minimum amount of forest in the landscape. Therefore, our model did not include a forest patch size function but relied solely on landscape composition (SI2). We used a logistic function (Fig. 31) to predict SI scores from the percentage of forest in the landscape (Table 59).

Table 58.—Relationship of landform, landcover type, and successional age class to suitability index scores for eastern wood-pewee habitat. Values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.167	0.250	0.500	0.667
	Transitional-shrubland	0.000	0.167	0.250	0.500	0.667
	Deciduous	0.000	0.167	0.250	0.500	0.667
	Evergreen	0.000	0.250	0.333	0.667	1.000
	Mixed	0.000	0.000	0.167	0.667	1.000
	Orchard-vineyard	0.000	0.167	0.250	0.500	0.667
	Woody wetlands	0.000	0.250	0.333	0.417	0.500
Terrace-mesic	Low-density residential	0.000	0.000	0.167	0.583	0.834
	Transitional-shrubland	0.000	0.000 (0.333)	0.167 (0.333)	0.667	1.000
	Deciduous	0.000	0.000	0.167	0.583	0.834
	Evergreen	0.000	0.250	0.333	0.667	1.000
	Mixed	0.000	0.000	0.167	0.667	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.583	0.834
	Woody wetlands	0.000	0.250	0.333	0.500	0.667
Xeric-ridge	Low-density residential	0.000	0.000	0.167	0.667	1.000
	Transitional-shrubland	0.000	0.000 (0.167)	0.167 (0.250)	0.667	1.000
	Deciduous	0.000	0.000	0.167	0.667	1.000
	Evergreen	0.000	0.250 (0.167)	0.333 (0.250)	0.667	1.000
	Mixed	0.000	0.000	0.167	0.667	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.667	1.000
	Woody wetlands	0.000	0.250	0.333	0.500	0.667

We included density of sawtimber trees in the HSI model and used the threshold of 100 trees per ha observed by Best and Stauffer (1986) as the optimal value in a quadratic function (Fig. 32) that links density of sawtimber trees (SI3) to habitat suitability. Because Best and Stauffer (1986) observed a reduction in wood-pewee abundance at sawtimber tree densities less than 100 trees per ha and Robbins and others (1989) observed a negative relationship between occurrence and tree density, we assumed a symmetrical decline in habitat quality as sawtimber tree density increased or decreased above or below the optimum (Table 60).

To calculate the overall HSI score, we determined the geometric mean of individual SI functions relating to forest structure (SI1 and SI3) and then calculated the geometric mean of this value and landscape composition (SI2).

Overall HSI = $((SI1 * SI3)^{0.500} * SI2)^{0.500}$

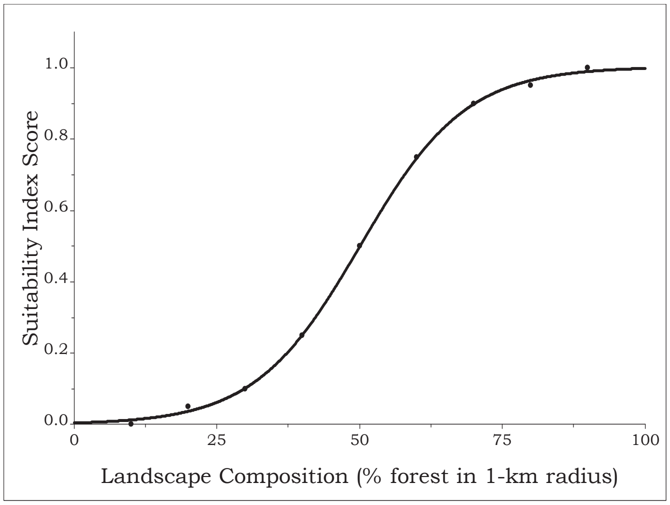

Figure 31.—Relationship between landscape composition and suitability index (SI) scores for eastern wood-pewee habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * $e^{-0.108 * (landscape\ composition)}$)).

Table 59.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for eastern wood-pewee habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Dononvan and others (1997).

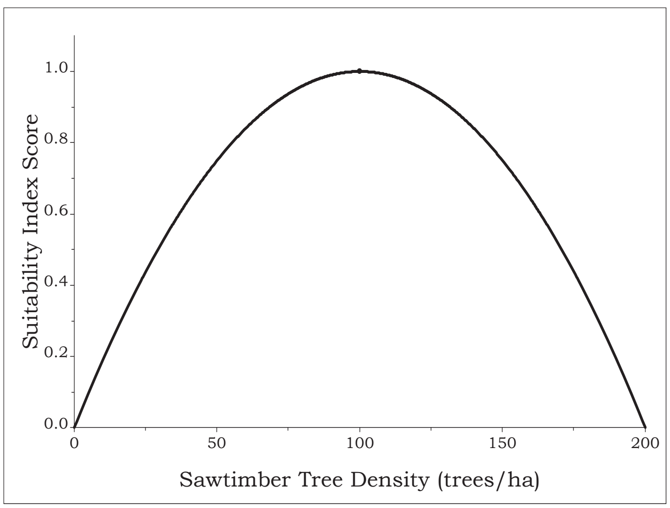

Figure 32.—Relationship between sawtimber tree (≥ 28 cm d.b.h.) density and suitability index (SI) scores for eastern wood-pewee habitat. Equation: SI score = (0.0200 * sawtimber tree density) - (0.0001 * (sawtimber tree density^2)).

Table 60.—Influence of sawtimber tree (≥ 28 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for eastern wood-pewee habitat

Sawtimber tree density	SI score
0[a]	0.0
100[b]	1.0
200[a]	0.0

[a]Assumed value.
[b]Best and Stauffer (1986).

Verification and Validation

The eastern wood-pewee was found in all 88 subsections of the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance identified a significant ($P \leq 0.001$) positive association ($r_s = 0.46$) between these two variables at the subsection scale. The generalized linear model predicting BBS abundance from BCR and HSI for the eastern wood-pewee was significant ($P \leq 0.001$; $R^2 = 0.472$), and the coefficient on the HSI predictor variable was both positive (β = 5.183) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the eastern wood-pewee both verified and validated (Tirpak and others 2009a).

Field Sparrow

Deanna K. Dawson, Patuxent Bird Identification InfoCenter
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Status

The field sparrow (*Spizella pusilla*) is a short-distance migrant found throughout North America east of the Rocky Mountains. Associated with early successional habitats, this species has experienced the sharp declines typical of many scrub-shrub and grassland species in the East. BBS data indicate declines in populations of the field sparrow in both the CH and WGCP (Sauer and others 2005; Table 5). The field sparrow has a regional combined score of 17 and 15 in the CH and WGCP, respectively, but is not a Bird of Conservation Concern in either BCR (Table 1). About 20 percent of the continental population occurs in the CH (Panjabi and others 2001).

Natural History

The field sparrow breeds in a variety of vegetation types, including brushy pastures, second-growth scrub, forest openings and edges, Christmas tree farms, orchards, nurseries, and roadsides and railroads near open fields (Carey and others 1994). Abundance increases in forested landscapes managed for early successional habitat (Yahner 2003), and this bird commonly occupies reclaimed mines (DeVault and others 2002) and savanna restoration sites (Davis and others 2000). Abundance is positively related to the size of old fields in Arkansas (Bay 1994). The field sparrow nests on or near the ground in early spring but may nest in saplings or shrubs later in the year. Brood parasitism rates vary geographically but the field sparrow generally is a poor cowbird host. Parasitism rates are higher in thinned forest stands than in regenerating plantations (Barber and others 2001).

This species also uses grasslands, though at lower densities than in shrub-scrub habitats (Horn and others 2002). Grass type affects habitat suitability, with warm-season grasses supporting higher abundance (Giuliano and Daves 2002, Walk and Warner 2000), nest density (Farrand 2005), and productivity than cool-season grasses (Giuliano and Daves 2002). Conservation Reserve Program fields serve as source habitat for the field sparrow in Missouri (McCoy and others 1999).

Model Description

The model predicting habitat suitability for the field sparrow includes six variables: landform, land cover, successional age class, canopy cover, density of small stems (< 2.5 cm d.b.h.), and the presence of grassy landcover.

The first suitability function of the field sparrow HSI model combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 61). We used habitat associations of the field sparrow reported by Hamel (1992) to assign SI scores to these combinations.

Table 61.—Relationship of landform, landcover type, and successional age class to suitability index scores for field sparrow habitat

Landform	Landcover type	Successional age class: Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333	0.000	0.000	0.000
	Deciduous	0.000	0.333	0.000	0.000	0.000
	Evergreen	0.667	1.000	0.000	0.000	0.000
	Mixed	0.667	1.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.333	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.667	1.000	0.000	0.000	0.000
	Deciduous	0.000	0.667	0.000	0.000	0.000
	Evergreen	0.667	1.000	0.000	0.000	0.000
	Mixed	0.667	1.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.667	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.667	1.000	0.000	0.000	0.000
	Deciduous	0.000	1.000	0.000	0.000	0.000
	Evergreen	0.667	1.000	0.000	0.000	0.000
	Mixed	0.667	1.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	1.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.000	0.000	0.000

We included canopy cover (SI2) and small stem density (SI3) as SIs in our model to account for the absence of the field sparrow from closed-canopy forests or forested sites with an open understory. We used data from Annand and Thompson (1997) (Tables 62 and 63) to fit a quadratic function to canopy cover and a Gaussian function to small stem density for predicting SI scores (Fig. 33 and 34). The negative relationship between the field sparrow and stem density is supported by Carey and others (1994), who observed a reduction in habitat suitability as "thickets of trees spread in the habitat." Sousa (1983) constructed an HSI model that contained a negative relationship between habitat suitability and percent shrub cover. Suitability of habitat for the field sparrow declined from optimal at 50 percent shrub cover (defined as the percentage of ground shaded by a vertical projection of the canopies of woody vegetation less than 5 m) to unsuitable at 75 percent shrub cover. We did not have a quantitative estimate of the relationship between small stem density and shrub cover, so we assumed that 40,000 stems per ha would shade 75 percent of the ground. We were conservative with this estimate; lacking quantitative data, we did not want to exclude stands that might provide habitat for this species.

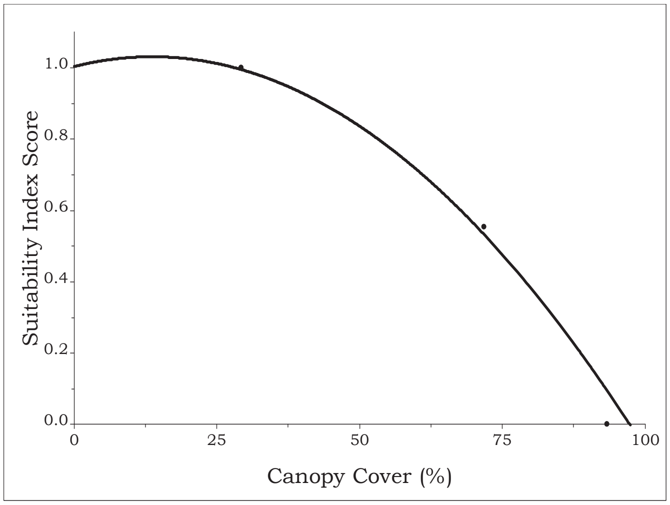

Figure 33.—Relationship between canopy cover and suitability index (SI) scores for field sparrow habitat. Equation: SI score = 1.0038 + 0.0040 * (canopy cover) – 0.0001475 * (canopy cover)^2.

Table 62.—Influence of canopy cover on suitability index (SI) scores for field sparrow habitat

Canopy cover (percent)	SI score
0.00[a]	1.000
29.26[b]	1.000
71.86[b]	0.555
93.38[b]	0.000
100.00[a]	0.000

[1]Assumed value.
[2]Annand and Thompson (1997).

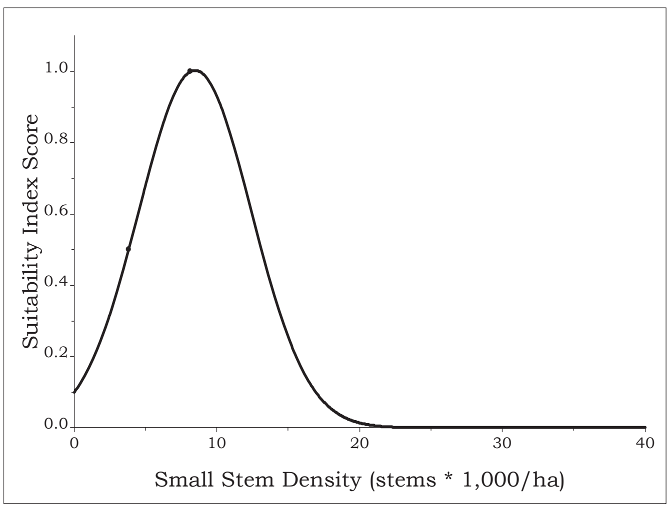

Figure 34.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for field sparrow habitat. Equation: SI score = 1.003 * e ($^{-((\text{small stem density} / 1000) - 8.461)\hat{}2)/ 31.0472}$.

Table 63.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for field sparrow habitat

Small stem density	SI score
0[a]	0.1
3.812[b]	0.5
8.148[b]	1.0
40.000[a]	0.0

[a]Sousa (1983).
[b]Annand and Thompson (1997).

Table 64.—Relationship between grass landcover and suitability index (SI) scores for field sparrow habitat

Landcover	SI score
Grassland-herbaceous[a]	1.0
Pasture-hay[a]	0.5

[a]Must occur ≤ 170 meters from forested landcover.

The field sparrow often is associated with grasslands with sufficient perches (Carey and others 1994, Kahl and others 1985). Therefore, we included an SI function related to grasslands (SI4) in the model. Many useable grassland sites may have insufficient woody cover to be classified as shrublands in the NLCD, so we required all grassland types (natural as well as pasture and hayfields) to be within 170 m of a wooded edge—a distance approximating a large field sparrow territory (Best 1974)—to be considered useable. Natural grasslands also are more likely to contain dense grass nesting sites than pastures and hayfields (Giuliano and Daves 2002, Farrand 2005), so we assigned to useable natural grasslands an SI score of 1.000 and to useable pasture-hayfields a score of 0.500 (Table 64).

To calculate the HSI score for field sparrow habitat in forested landcovers, we calculated the geometric mean of the SI scores relating to forest structure (SI1, SI2, and SI3). We added the SI score for grasslands (SI4) to this value to determine the overall HSI score.

Overall HSI = $((SI1 * SI2 * SI3)^{0.333} + SI4)$

Verification and Validation

The field sparrow was found in 87 of the 88 subsections within the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance identified a significant ($P \leq 0.001$) positive association ($r_s = 0.55$) between these two variables within subsections where this species was detected. The generalized linear model predicting BBS abundance from BCR and HSI for the field sparrow was significant ($P \leq 0.001$; $R^2 = 0.690$), and the coefficient on the HSI predictor variable was both positive (β = 37.060) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the field sparrow both verified and validated (Tirpak and others 2009a).

Great Crested Flycatcher

Deanna K. Dawson,
Patuxent Bird Identification InfoCenter
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Status

The great crested flycatcher (*Myiarchus crinitus*), a neotropical migrant, is found throughout the forests of eastern North America and the riparian habitats of the Mississippi River watershed. Populations have remained relatively stable across most of its range, though in the WGCP they have declined by 1.3 percent per year since 1966 (Sauer and others 2005) (Table 5). This species has a regional combined score of 13 in both the CH and WGCP (Table 1).

Natural History

The great crested flycatcher is an obligate cavity nester in deciduous forest habitats of the eastern United States; it generally is absent in pure evergreen stands (Lanyon 1997). This species is not area sensitive but does require a minimum amount of forested habitat in the landscape. It may nest in patches as small as 0.2 ha and abundance may decline in forest interiors (Robbins and others 1989). The great crested flycatcher does not occupy riparian corridors surrounded by less than 14.7 percent forest (Perkins and others 2003b), and detection probabilities steadily increase with increasing corridor width (Groom and Grubb 2002).

The great crested flycatcher forages by sallying from exposed perches (Lanyon 1997), so open forest stands are preferred. Holmes and others (2004) found that abundance was highest in heavily cut stands where one-third or more of the basal area was removed. Similarly, Moorman and Guynn (2001) found that the great crested flycatcher was associated with large (0.5 ha) canopy gaps in bottomland hardwood forest in South Carolina. Snags not only provide exposed perches for foraging but also cavities for nesting, and the great crested flycatcher is negatively affected by the removal of snags associated with certain forestry practices (Lohr and others 2002). Where snags are lacking, this species will use nest boxes and other artificial cavities; this enables it to occupy cemeteries, suburban parks, and wooded pastures. Wakeley and Roberts (1996) found that this bird is associated with mesic sites, but this may reflect a preference for bottomland hardwoods over evergreen uplands in the Southeast.

Model Description

The HSI model for great crested flycatcher includes five variables: landform, landcover, successional age class, snag density, and distance to edge.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 65). We directly assigned SI scores to these combinations on the basis of relative habitat quality associations reported by Hamel (1992) for the great crested flycatcher.

Table 65.—Relationship of landform, landcover type, and successional age class to suitability index scores for great crested flycatcher habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.167	0.500	0.667
	Transitional-shrubland	0.000	0.000	0.167	0.500	0.667
	Deciduous	0.000	0.333	0.333	0.500	0.667
	Evergreen	0.000	0.333	0.333	0.500	0.667
	Mixed	0.000	0.333	0.333	0.667	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.500	0.667
	Woody wetlands	0.000	0.333	0.333	0.667	1.000
Terrace-mesic	Low-density residential	0.000	0.333	0.333	0.583	0.834
	Transitional-shrubland	0.000	0.333	0.333	0.667 (0.500)	1.000 (0.667)
	Deciduous	0.000	0.333	0.333	0.583	0.834
	Evergreen	0.000	0.333	0.333	0.500	0.667
	Mixed	0.000	0.333	0.333	0.667	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.583	0.834
	Woody wetlands	0.000	0.333	0.333	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.167	0.667	1.000
	Transitional-shrubland	0.000	0.333 (0.250)	0.333 (0.250)	0.667 (0.500)	1.000 (0.667)
	Deciduous	0.000	0.333	0.333	0.667	1.000
	Evergreen	0.000	0.333 (0.250)	0.333 (0.250)	0.500	0.667
	Mixed	0.000	0.333	0.333	0.667	1.000
	Orchard-vineyard	0.000	0.333	0.333	0.667	1.000
	Woody wetlands	0.000	0.333	0.333	0.667	1.000

The great crested flycatcher relies on snags (SI2) for nesting and foraging. We fit a logistic function (Fig. 35) through average snag values (8.5/ha) observed by Lohr and others (2002), assuming that this value represented average habitat suitability (SI score = 0.500) and that a higher abundance of snags would not be detrimental but increase the likelihood that this bird will use a site (Table 66).

This species is associated with edges (Lanyon 1997), and its abundance declines with increasing distance from an edge (SI3). Small and Hunter (1989) found that more than 60 percent of all flycatchers were less than 60 m from an edge. We assumed maximum habitat suitability at the edge and modeled the relationship between distance to edge and SI score as an inverse logistic function through these data points (Fig. 36, Table 67).

To calculate the overall HSI, we determined the geometric mean of SI scores for forest structure (SI1 and SI2) and then calculated the geometric mean of this value with the edge function (SI3).

Overall HSI = $((SI1 * SI2)^{0.500} * SI3)^{0.500}$

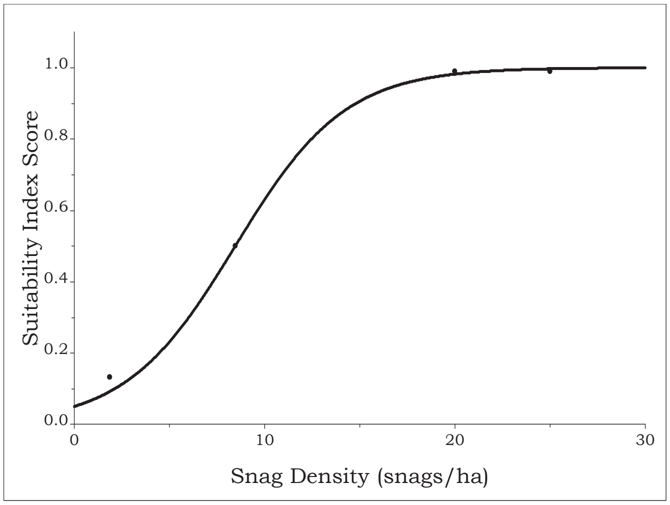


Figure 35.—Relationship between snag density and suitability index (SI) scores for great crested flycatcher habitat. Equation: SI score = 1.001 / (1 + (18.704 * e $^{(-0.346 * \text{snag density})}$)).

Table 66.—Influence of snag density on suitability index (SI) scores for great crested flycatcher habitat

Snag density (snags/ha)	SI score
0.0[a]	0.000
1.9[a]	0.133
8.5[a]	0.500
20.0[b]	1.000
25.0[b]	1.000

[a]Lohr and others (2002).
[b]Assumed value.

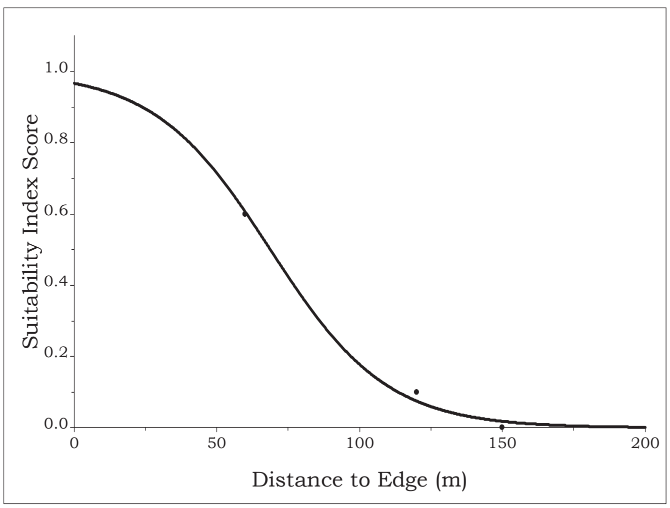


Figure 36.—Relationship between distance to edge and suitability index (SI) scores for great crested flycatcher habitat. Equation: SI score = 1 - (1.000 / (1 + (28.950 * e $^{-0.049 * \text{distance to edge}}$))).

Table 67.—Influence of distance (m) to edge[a] on suitability index (SI) scores for great crested flycatcher habitat

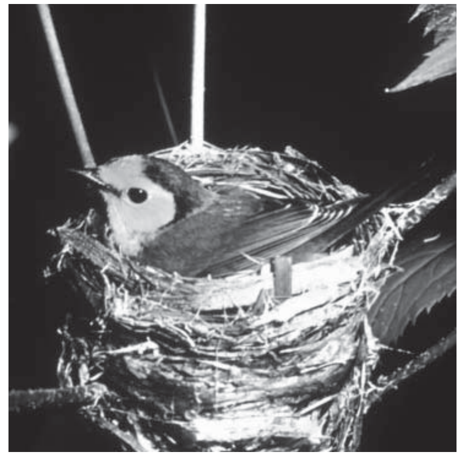
Distance to edge	SI score
0[b]	1.0
60[c]	0.6
120[b]	0.1
150[b]	0.0

[a]Edge defined by nonhabitat pixels adjacent to habitat pixels (defined by SI1).
[b]Assumed value.
[c]Small and Hunter (1989).

Verification and Validation

The great crested flycatcher was found in all 88 subsections within the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance failed to identify a significant ($P \leq 0.001$) association ($r_s = 0.55$) between these two variables. The generalized linear model predicting BBS abundance from BCR and HSI for the great crested flycatcher was not significant ($P = 0.152$; $R^2 = 0.043$), and the coefficient on the HSI predictor variable was negative (β = -2.740) and not significantly different from zero ($P = 0.151$). Therefore, we considered the HSI model for the great crested flycatcher neither verified nor validated (Tirpak and others 2009a).

Hooded Warbler



U.S. Fish & Wildlife Service

Status

The hooded warbler (*Wilsonia citrina*) is a long-distance migrant found throughout the deciduous forests of eastern North America. Because of area sensitivity, it is restricted to forested landscapes and disappears from the forest-prairie ecotone at the western edge of its range faster than other silvicolous species (e.g., eastern wood-pewee). Populations in the WGCP declined prior to 1990 but have since remained stable. Conversely, populations in the CH have increased (Sauer and others 2005) (Table 5). This species is not a Bird of Conservation Concern in either BCR (Table 1) but it is a planning and responsibility species in the WGCP (regional combined score = 16; Table 1). Nearly 30 percent of the continental population of the hooded warbler breeds in the WGCP (Panjabi and others 2001).

Natural History

The hooded warbler breeds in a variety of habitats, from mixed-hardwood forests in the northern portion of its range to cypress-gum swamps in the South. Regardless of forest type, it prefers mesic sites in large forest tracts (> 15 ha; Evans-Ogden and Stutchbury 1994). Although nest success in small forest patches is not significantly lower than in large patches (Buehler and others 2002), females may avoid small fragments and males use edge less than its availability (Norris and Stutchbury 2002, Norris and others 2000). Occupancy of a site by a nesting pair increases with shrub height and the percentage of vegetation between 1 and 2 m.

This species nests in shrubs within small forest clearings or in the dense understories of closed-canopied forests. As a result, territories often include a mix of open and closed canopies. Gaps created by tree fall or selective logging are particularly attractive (≤ 0.5 ha; Annand and Thompson 1997, Moorman and others 2002, Whittam and others 2002), and the hooded warbler colonizes these sites within 1 to 5 years. Nest sites in Canada had denser ground vegetation, fewer tree stems, lower basal area of small trees, and greater basal area of large trees than control sites (Whittam and others 2002). Bisson and Stutchbury (2000) concluded that canopy gaps and density of understory vegetation were the most important factors affecting site selection. Repeated burning, which removed understory vegetation, reduced hooded warbler abundance in Ohio (Artman and others 2001). This species is a common cowbird host, which may explain its sensitivity to fragmentation (Donovan and Flather 2002).

Model Description

The HSI model for the hooded warbler includes seven variables: landform, land cover, successional age class, small stem (< 2.5 cm d.b.h.) density, canopy cover, forest patch size, and percent forest in a 1-km landscape.

Table 68.—Relationship of landform, landcover type, and successional age class to suitability index scores for hooded warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.167	0.667	1.000
	Deciduous	0.000	0.000	0.167	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.334	0.667
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.167 (0.000)	0.500 (0.334)	0.667
	Deciduous	0.000	0.000	0.167	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.334	0.667
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.167 (0.000)	0.500 (0.167)	0.667 (0.334)
	Deciduous	0.000	0.000	0.167	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.334 (0.167)	0.667 (0.334)
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 68). We directly assigned SI scores to these combinations on the basis of relative habitat quality rankings from Hamel (1992) for the hooded warbler in the Southeast.

This species occupies dense understories in mature forested habitats, so we included both small stem density (SI2) and canopy cover (SI3) in our model. We fit a logistic function (Fig. 37) that links small stem density to SI scores on the basis of data from Annand and Thompson (1992) and Moorman and others (2002) (Table 69). We assumed that the average stem density measured at nest sites by Moorman and others (2002) (4,700 stems/ha) was representative of ideal habitat conditions for the hooded warbler and that there was no upper threshold above which habitat suitability declined. We also fit a logistic function (Fig. 38) to data from Annand and Thompson (1997) (Table 70) to link canopy cover values to SI scores.

We included forest patch size (SI4) as a model predictor because of the negative effect of fragmentation on this species. We used an exponential curve (Fig. 39) to predict habitat

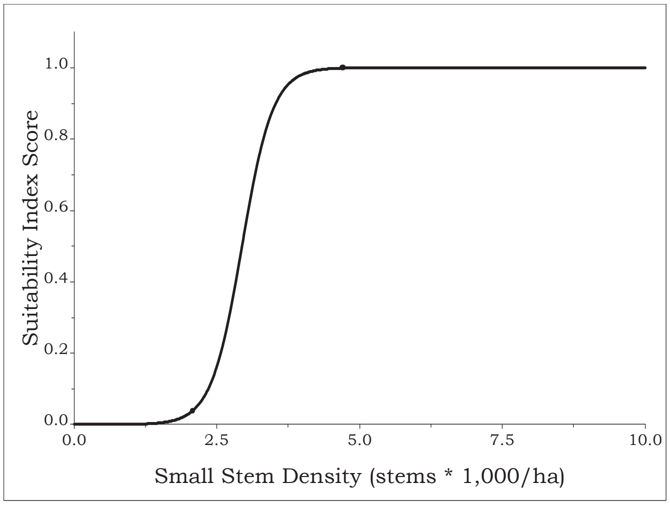


Figure 37.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) on suitability index (SI) scores for hooded warbler habitat. Equation: SI score = 1.000 / (1.000 + (102634.340 * e $^{-4.017 * (\text{small stem density} / 1000)}$)).

Table 69.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for hooded warbler habitat

Small stem density	SI score
0.000[a]	0.000
2.077[b]	0.039
4.700[c]	1.000
4.717[b]	1.000
10.000[a]	1.000

[a]Assumed value.
[b]Annand and Thompson (1992).
[c]Moorman and others (2002).

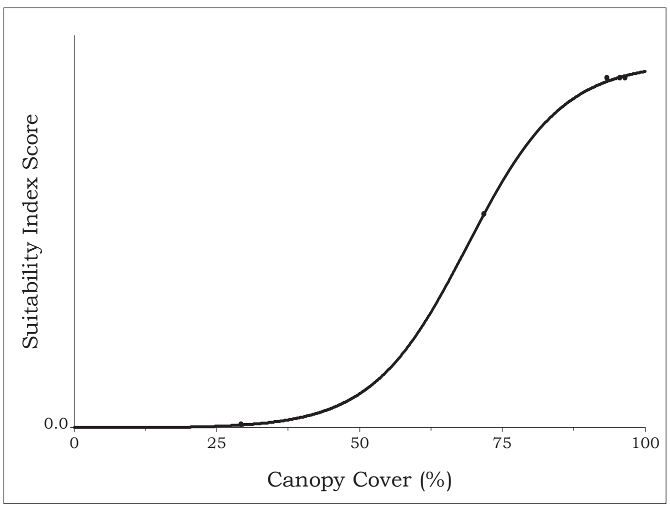


Figure 38.—Relationship between canopy cover on suitability index (SI) scores for hooded warbler habitat. Equation: SI score = 1.024 / (1.000 + (3823.776 * e $^{-0.120 * \text{canopy cover}}$)).

Table 70.—Influence of canopy cover on suitability index (SI) scores for hooded warbler habitat

Canopy cover (percent)	SI score
0.00[a]	0.0
29.26[b]	0.0
71.86[b]	0.6
93.38[b]	1.0
95.58[b]	1.0
96.59[b]	1.0

[a]Assumed value.
[b]Annand and Thompson (1997).

suitability from forest patch size on the basis of data from Evans-Ogden and Stutchbury (1994) and Kilgo and others (1998). To convert riparian widths reported by Kilgo and others (1998) to forest patch sizes, we assumed that all riparian strips were 10 km long (Table 71). The suitability of a specific forest patch is influenced by the percentage of forest in the landscape (SI5). Small patches that otherwise would be unsuitable may be occupied when in close proximity to a large forest block or in a predominantly forested landscape (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 40) to data (Table 72) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent

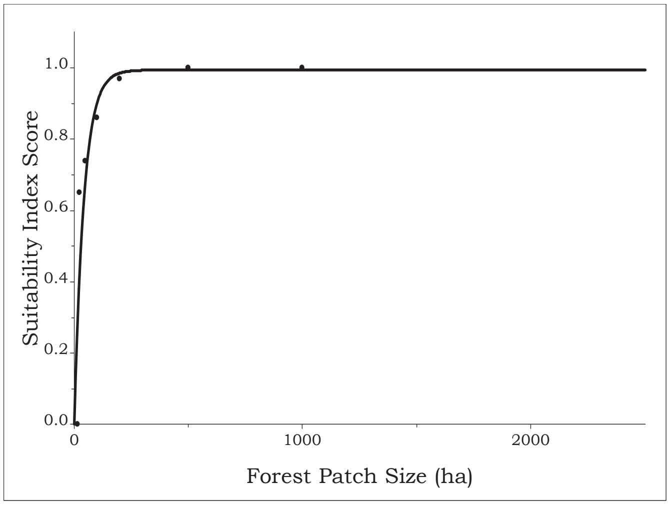


Figure 39.—Relationship between forest patch size and suitability index (SI) scores for hooded warbler habitat. Equation: SI score = 0.994 * (1 - e $^{-0.024\ *\ \text{forest patch size}}$).

Table 71.—Influence of forest patch size on suitability index (SI) scores for hooded warbler habitat

Forest patch size (ha)	SI score
15[a]	0.00
25[b]	0.65
50[b]	0.74
100[b]	0.86
200[b]	0.97
500[b]	1.00
1,000[b]	1.00
2,500[b]	1.00

[a]Evans-Ogden and Stutchbury (1994).
[b]Kilgo and others (1998).

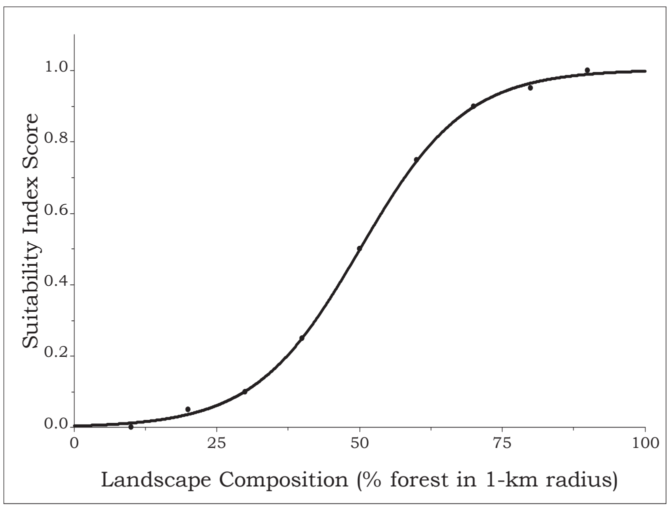


Figure 40.—Relationship between landscape composition and suitability index (SI) scores for hooded warbler habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108\ *\ (\text{landscape composition})}$)).

Table 72.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for hooded warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Dononvan and others (1997).

forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from SI4 or SI5 to account for the higher suitability of small forest patches in a heavily forested landscape.

The overall HSI score was calculated as the geometric mean of the geometric mean of the SI values from the landform, landcover, and successional age class matrix, small stem density, and canopy cover functions (SI1, SI2, and SI3) multiplied by the maximum value of either the forest patch size or percent forest in the 1-km radius landscape functions (SI4 and SI5).

Overall HSI = $((SI1 * SI2 * SI3)^{0.333} * Max(SI4 \text{ or } SI5))^{0.500}$

Verification and Validation

The hooded warbler was found in 84 of the 88 subsections within the CH and WGCP. Spearman rank correlations identified significant positive associations between average HSI score and mean BBS route abundance across all subsections ($P \leq 0.001$; $r_s = 0.49$) and subsections within which this species was detected ($P \leq 0.001$; $r_s = 0.42$). The generalized linear model predicting BBS abundance from BCR and HSI for the hooded warbler was significant ($P \leq 0.001$; $R^2 = 0.551$), and the coefficient on the HSI predictor variable was both positive ($\beta = 8.190$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the hooded warbler both verified and validated (Tirpak and others 2009a).

Kentucky Warbler


U.S. Fish & Wildlife Service

Status

The Kentucky warbler (*Oporornis formosus*) breeds throughout the southeastern United States; densities are highest west of the Appalachian front. Populations have been stable in the CH over the last 40 years, but have declined in the WGCP by 2.2 percent per year during this period (Table 5). This species requires management attention in both regions (regional combined score = 18 and 19 in the CH and WGCP, respectively). A high percentage of the continental population breeds in both BCRs (28 and 22 percent, respectively; Panjabi and others 2001). The species is an FWS Bird of Conservation Concern in the WGCP (Table 1).

Natural History

The Kentucky warbler, a long-distance migrant, breeds in mature moist deciduous forests of the Southeast. It is a forest-interior specialist, primarily because of low productivity and survival in edge and early successional habitats (Morse and Robinson 1999; Robinson and Robinson 2001). The Kentucky warbler occupies fragments as small as 2.4 ha (Blake and Karr 1987) but tracts larger than 500 ha are considered the minimum size necessary to support sustainable populations (McDonald 1998). A dense understory is a common feature of nesting sites. Ground cover averaged 46 percent in Kentucky warbler territories in Missouri (Wenny and others 1993), and vegetation of less than 1.5 m was denser around nests than random sites in South Carolina (Kilgo and others 1996). Dense vegetation (0.3 to 1 m) was also associated with higher numbers of the Kentucky warbler in Maryland (Robbins and others 1989). Mesic sites are universally selected (McShea and others 1995, McDonald 1998, Gram and others 2003).

Model Description

The habitat suitability model for the Kentucky warbler includes six variables: landform, landcover, successional age class, small stem (< 2.5 cm d.b.h.) density, forest patch size, and percent forest in the landscape.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 73). We relied on relative habitat quality associations reported by Hamel (1992) to assign SI scores to these combinations. However, we increased SI scores for shrub-seedling stands on the basis of data from Thompson and others (1992).

The Kentucky warbler nests at the base of shrubs and occupies habitats containing high densities of small stems (SI2). We used data on the relative abundance of this species from Wenny and others (1993), Kilgo and others (1996), and Annand and Thompson (1997) to derive a logistic function (Fig. 41) that predicts habitat suitability from small stem density (Table 74).

Table 73.—Relationship of landform, landcover type, and successional age class to suitability index scores for Kentucky warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.667	0.417	0.667	0.667
	Deciduous	0.000	0.667	0.417	0.667	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	1.000	0.667	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333	0.167	0.333	0.333
			(0.000)	(0.000)	(0.000)	(0.000)
	Deciduous	0.000	0.667	0.334	0.667	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	1.000	0.667	1.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333	0.167	0.333	0.333
			(0.000)	(0.000)	(0.000)	(0.000)
	Deciduous	0.000	0.500	0.250	0.500	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	1.000	0.667	1.000	1.000

We used a logarithmic function (Fig. 42) to quantify the relationship between forest patch size (SI3) and habitat suitability on the basis of minimum patch size observations by Hayden and others (1985) and occupancy rates in different patch sizes reported by Robbins and others (1989) (Table 75). However, the suitability of a specific forest patch is influenced by its landscape context (SI4). Because the Kentucky warbler is particularly sensitive to fragmentation (Lynch and Whigham 1984), we used a 10-km window to characterize the landscape. We fit a logistic function (Fig. 43) to data (Table 76) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively.

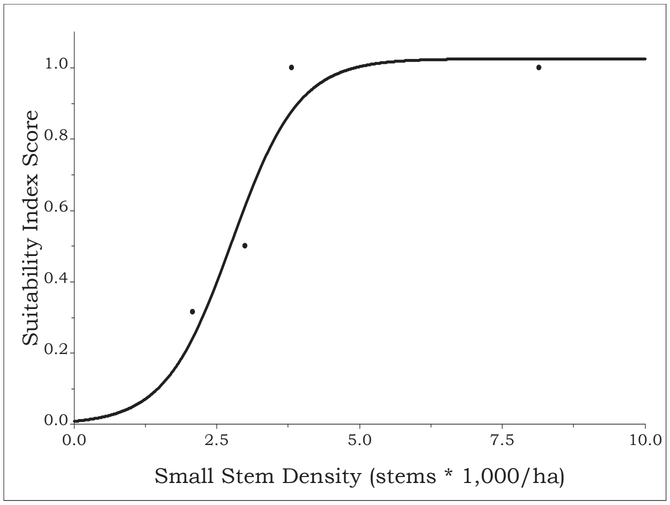


Figure 41.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for Kentucky warbler habitat. Equation: SI score = 1.026 / (1.000 + (111.558 * e -1.707 * $^{(\text{small stem density / 1000})}$)).

Table 74.—Influence of small stem (< 2.5 cm d.b.h.) density (stems/ha) on suitability index (SI) scores for Kentucky warbler habitat

Small stem density	SI score
0.000[a]	0.000
2.077[b]	0.316
3.000[c]	0.500
3.812[b]	1.000
8.148[b]	1.000
47.600[d]	1.000

[a]Assumed value.
[b]Annand and Thompson (1997).
[c]Wenny and others (1993).
[d]Kilgo and others (1996).

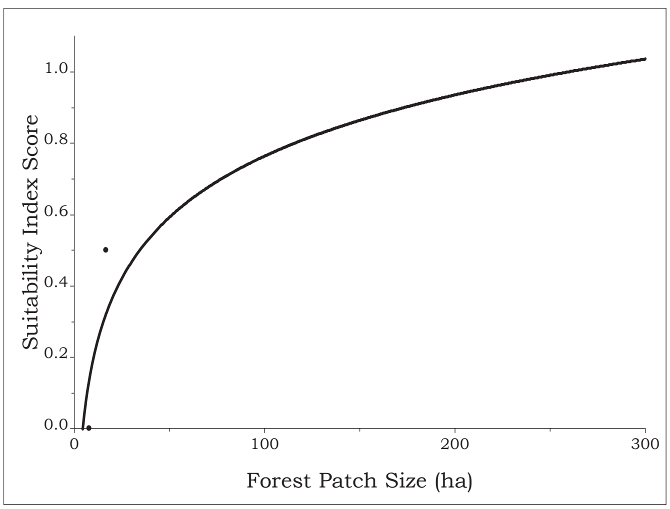


Figure 42.—Relationship between forest patch size and suitability (SI) scores for Kentucky warbler habitat. Equation: SI score = 0.248 * ln(forest patch size) – 0.377.

Table 75.—Influence of forest patch size on suitability index (SI) scores for Kentucky warbler habitat

Forest patch size (ha)	SI score
8[a]	0.0
17[b]	0.5
300[b]	1.0

[a]Hayden and others (1985).
[b]Robbins and others (1989).

To calculate the overall HSI score, we determined the geometric mean of SI scores for functions relating to forest structure (SI1 and SI2) and landscape composition (SI3 and SI4) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI2)^{0.500} * (SI3 * SI4)^{0.500})^{0.500}$

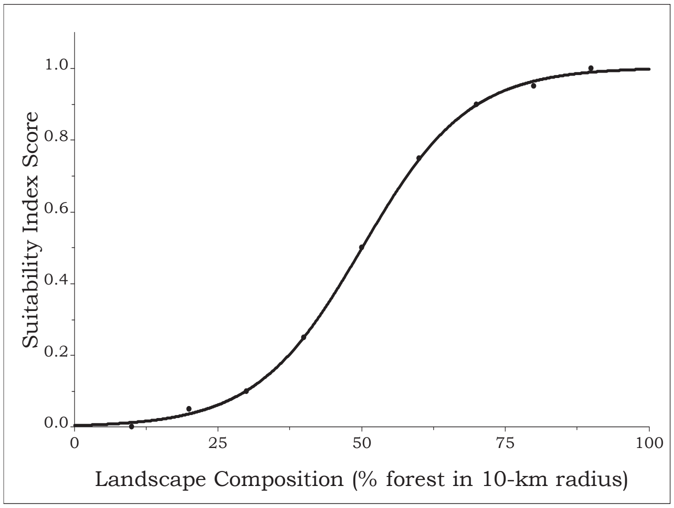


Figure 43.—Relationship between landscape composition and suitability index (SI) scores for Kentucky warbler habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 76.—Relationship between landscape composition (percent forest in 10-km radius) and suitability index (SI) scores for Kentucky warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Dononvan and others (1997).

Verification and Validation

The Kentucky warbler was found in all 88 subsections of the CH and WGCP. Spearman rank correlations identified a significant positive association between average HSI score and mean BBS route abundance across all subsections ($P \leq 0.001$; $r_s = 0.71$). The generalized linear model predicting BBS abundance from BCR and HSI for the Kentucky warbler was significant ($P \leq 0.001$; $R^2 = 0.346$), and the coefficient on the HSI predictor variable was both positive ($\beta = 6.351$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the Kentucky warbler both verified and validated (Tirpak and others 2009a).

Louisiana Waterthrush

Charles H. Warren, images.nbii.gov

Status

The Louisiana waterthrush (*Seirus motacilla*) is a long-distance neotropical migrant found throughout the deciduous forests of the eastern and central United States. The small population in the WGCP has remained relatively stable since 1966 while the larger population in the CH has increased by 2.6 percent annually (Sauer and others 2005) (Table 5). This species is a Bird of Conservation Concern in both regions (Table 1). However, PIF differentiates the priority for this species in the CH (planning and responsibility, regional combined score = 15) and WGCP (management attention, regional combined score = 18; Table 1).

Natural History

As its name implies, the Louisiana waterthrush is associated with water throughout its range (Robinson 1995). Densities are highest along gravel-bottomed, first- and second-order streams flowing through large (> 350 ha) tracts of mature deciduous forest (Robbins and others 1989, Robinson 1995). Birds also breed at lower densities along mud-bottomed streams in cypress swamps and bottomland hardwood forests (Hamel 1992, Robinson 1995).

Prosser and Brooks (1998) developed and validated an HSI model for the Louisiana waterthrush in central Pennsylvania that included eight variables: canopy cover (> 80 percent considered ideal), shrub cover (< 25 percent), ratio of deciduous to conifer cover (30 to 69 percent, mostly reflecting hemlock dominance along streams in the Northeast), herbaceous cover (< 25 percent), stream order (first- or second-order with well developed pools and riffles), water clarity and substrate (clear and rocky or sandy), nesting cover (presence of uprooted trees or creviced, steep banks), and forest area (> 350 ha).

Model Description

Our HSI model for the Louisiana waterthrush included eight variables: landform, landcover, successional age class, distance to stream, canopy cover, small stem (< 2.5 cm d.b.h.) density, forest patch size, and percent forest in a 1-km radius.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 77). We directly assigned SI scores to these combinations on the basis of vegetation and successional age class associations outlined in Hamel (1992).

We included distance to stream (SI2) as a variable because the waterthrush uses streams and creeks for foraging and nesting. The Louisiana waterthrush restricts its foraging to the streambed and bank, so we assumed a sharp decline in suitability with increasing distance to a stream (Table 78). We used an inverse logistic function to characterize this relationship (Fig. 44).

Table 77.—Relationship of landform, landcover type, and successional age class to suitability index (SI) scores for Louisiana waterthrush habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.500	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.500	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.250	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.334	0.667

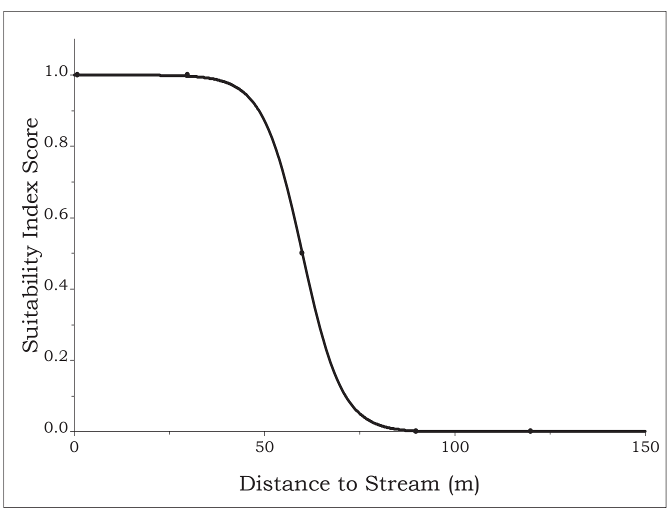


Figure 44.—Relationship between distance to stream and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = $1 - (1.0015 / (1 + (104411.5 * e^{-0.1926 * \text{distance to stream}})))$.

Table 78.—Relationship between distance to stream and suitability index (SI) scores for Louisiana waterthrush habitat.

Distance to stream (m)[a]	SI score
0	1.0
30	1.0
60	0.5
90	0.0
120	0.0

[a]Assumed value.

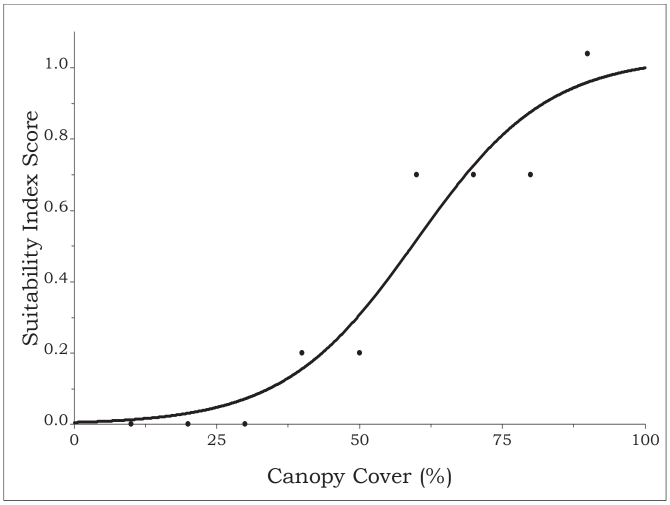


Figure 45.—Relationship between canopy cover and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = (1.0313 / (1 + (175.8083 * e $^{-0.0864 * \text{canopy cover}}$))).

Table 79.—Relationship between canopy cover and suitability index (SI) scores for Louisiana waterthrush habitat

Canopy cover (percent)[a]	SI score
0	0.0
10	0.0
20	0.0
30	0.0
40	0.2
50	0.2
60	0.7
70	0.7
80	0.7
90	1.0

[a]Prosser and Brooks (1998).

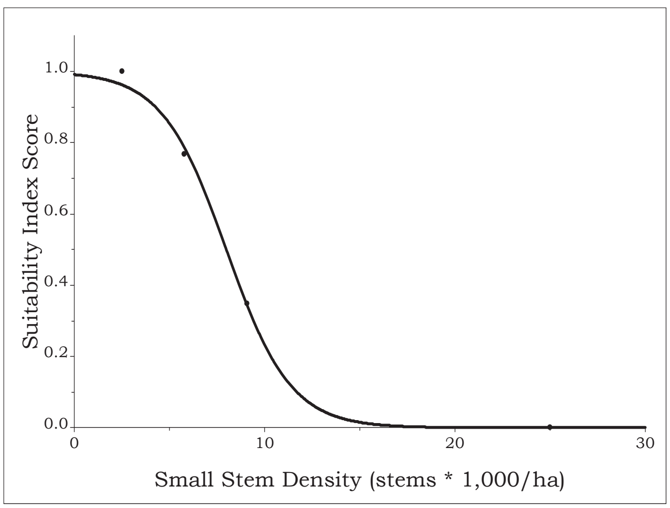


Figure 46.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = 1 - (1.000 / (1 + (113.261 * e $^{-0.592 * (\text{small stem density} / 1000)}$))).

Table 80.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) and suitability index (SI) scores for Louisiana waterthrush habitat

Small stem density	SI score
0[a]	1.000
2.519[a]	1.000
5.803[a]	0.767
9.086[a]	0.349
25.000[b]	0.000

[a]Prosser and Brooks (1998).
[b]Assumed value.

We also included canopy cover (SI3) and small stem density (SI4) as variables based on the preference of this species for mature forested sites with closed canopies and open understories. We fit logistic (Fig. 45) and inverse logistic (Fig. 46) functions to data adapted from the HSI model of Prosser and Brooks (1998) for canopy cover (Table 79) and small stem density (Table 80), respectively.

Forest patch size (SI5) affects the occupancy of habitats by the Louisiana waterthrush. To predict habitat suitability from forest patch size, we fit a logarithmic function (Fig. 47) to data from Hayden and others (1985) and Robbins and others (1989) (Table 81)

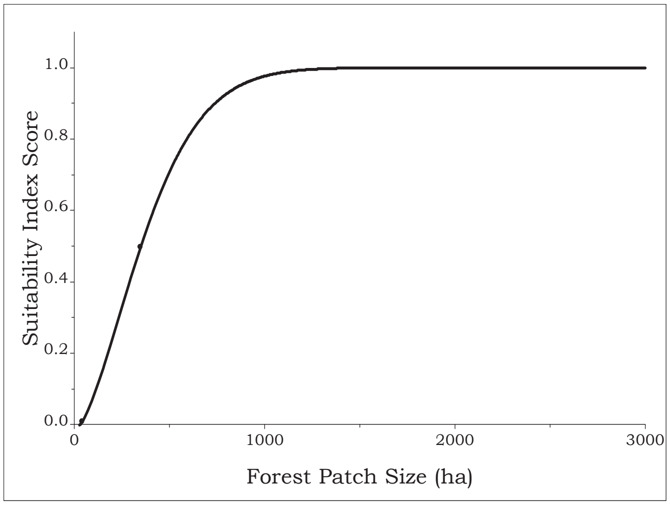


Figure 47.—Relationship between forest patch size and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = 1.000 – (1.010 * e $^{-0.0003 * (\text{forest patch size} \wedge 1.321)}$).

Table 81.—Relationship between forest patch size and suitability index (SI) scores for Louisiana waterthrush habitat

Forest patch size (ha)	SI score
42.2[a]	0.0
350[b]	0.5
3,200[b]	1.0

[a]Hayden and others (1985).
[b]Robbins and others (1989).

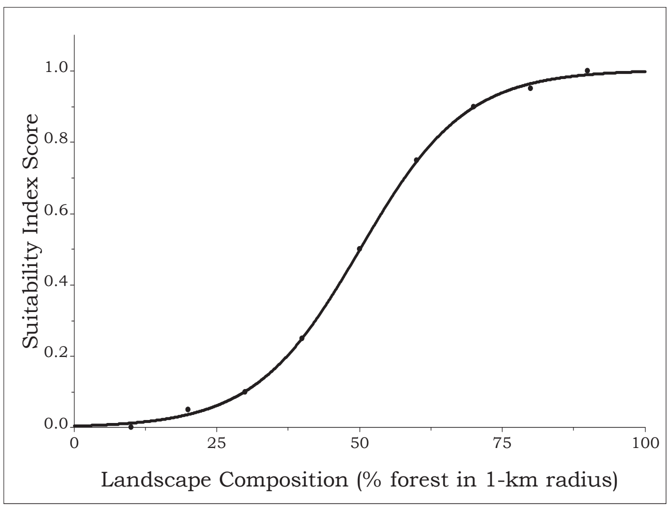


Figure 48.—Relationship between landscape composition and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 82.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for Louisiana waterthrush habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

on the detection probabilities of the Louisiana waterthrush in patches of varying size. However, forest patch size alone may not be an appropriate measure of a site's suitability. In predominantly forested landscapes, small patches otherwise not suitable may be occupied due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 48) to data (Table 82) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from

SI5 or SI6 to ensure that small forest blocks in predominantly forested landscapes were assigned an appropriate suitability score.

To calculate the overall HSI, we determined the geometric mean of SI scores for forest structure (SI1, SI3, and SI4) and landscape composition (Max (SI5 or SI6) and SI2) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI3 * SI4)^{0.333} * (Max (SI5 or SI6) * SI2)^{0.500})^{0.500}$

Verification and Validation

The Louisiana waterthrush was found in all 88 subsections of the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance per subsection identified a significant ($P \leq 0.001$) positive association ($r_s = 0.56$) between these two variables. The generalized linear model predicting BBS abundance from BCR and HSI for the Louisiana waterthrush was significant ($P \leq 0.001$; $R^2 = 0.263$), and the coefficient on the HSI predictor variable was both positive (β = 3.664) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the Louisiana waterthrush both verified and validated (Tirpak and others 2009a).

Mississippi Kite

Peter S. Weber, www.wildbirdphotos.com
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Status

The Mississippi kite (*Ictinia mississippiensis*), a neotropical migrant raptor, is restricted to the Coastal Plains as well as the lower Mississippi and Red River Valleys. Like many birds of prey, this species has exhibited dramatic recoveries over the last 25 years from historical lows in the 1970s. However, its general scarcity prevents BBS from detecting statistically significant trends (Sauer and others 2005; Table 5). The Mississippi kite is not a Bird of Conservation Concern in the CH or WGCP (Table 1). It has a regional combined score of 14 in the CH and 16 in the WGCP.

Natural history

The Mississippi kite exhibits two breeding strategies within its range. In the southern Great Plains, it is a colonial nester that often inhabits urban areas. In the Mississippi Valley and farther east, this bird is less colonial and nests singly in large trees in bottomland forest and riparian woodlands. Nests from birds within the eastern population generally are located in large (> 22 ha) unfragmented forest near open habitats where birds forage aerially (Parker 1999).

Model Description

The HSI model for the Mississippi kite includes six variables: landform, land cover, successional age class, forest patch size, interspersion of forest and open habitats, and density of dominant trees.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 83). We directly assigned SI scores to these combinations on the basis of relative habitat quality ranks reported by Hamel (1992) for this species. However, we restricted the Mississippi kite to sawtimber stands based on its preference for mature forest stands (Parker 1999).

We also included forest patch size (SI2) in the model and used the range and mean of patch sizes reported by Barber and others (1998) to define the minimum, maximum, and average patch sizes associated with nonhabitat, optimal, and average habitat suitability for this function, respectively (Table 84; Fig. 49).

The Mississippi kite requires large patches of forest and grassland in a specific landscape context (Parker 1999, Coppedge and others 2001). We used the relative amount of these habitats within a 1-km radius as an index to their interspersion at the landscape scale (SI3). We assumed that habitat suitability was optimal in open habitats with few trees (70 to 90 percent agriculture or grassland) or landscapes containing moderate forest cover interspersed with open habitats (60 to 70 percent forest; Table 85).

Table 83.—Relationship of landform, landcover type, and successional age class to suitability index scores for Mississippi kite habitat. Values in parentheses apply to West Gulf Coastal Plain/Ouachitas.

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.500
	Deciduous	0.000	0.000	0.000	0.000	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.333
	Mixed	0.000	0.000	0.000	0.000	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.500
	Woody wetlands	0.000	0.000	0.000	0.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.333
	Deciduous	0.000	0.000	0.000	0.000	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.333
	Mixed	0.000	0.000	0.000	0.000	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.500
	Woody wetlands	0.000	0.000	0.000	0.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.333 (0.167)
	Deciduous	0.000	0.000	0.000	0.000	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.333 (0.167)
	Mixed	0.000	0.000	0.000	0.000	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.500
	Woody wetlands	0.000	0.000	0.000	0.000	1.000

The Mississippi kite nests in dominant trees (SI4) that extend above the canopy. Parker (1999) identified old-growth stands and isolated trees as preferred nesting substrates for this species, and Barber and others (1998) observed the Mississippi kite using nest trees that were higher and larger in d.b.h. than those in the surrounding overstory. We assumed that a tree with a d.b.h. greater than 76.2 cm in a sawtimber stand would extend above the canopy and provide an adequate nest substrate for this species. We further assumed that one dominant tree per ha would satisfy this requirement and that the Mississippi kite would be absent from stands with a uniform canopy (zero dominant trees/ha). We fit an exponential function (Fig. 50) to the values between these data points. Stands with 14 dominant trees per ha (the maximum observed in the WGCP during the FIA surveys of the 1990s) were associated with maximum habitat suitability (Table 86).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI4) and landscape composition (SI2 and SI3) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$

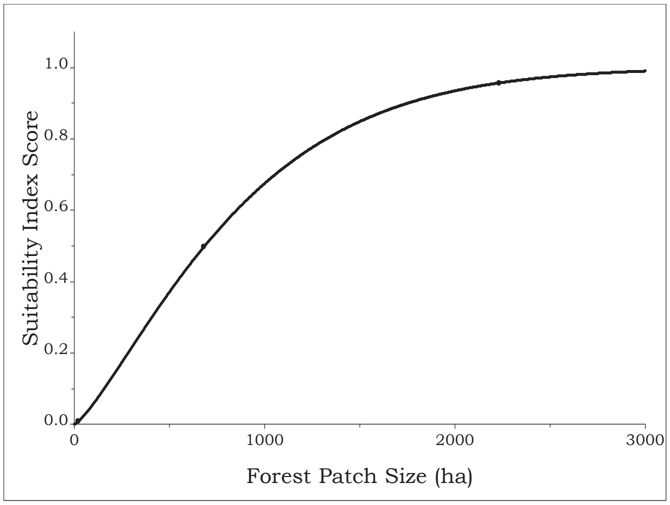

Figure 49.—Relationship between forest patch size and suitability index (SI) scores for Mississippi kite habitat. Equation: SI score = 1.002 – (1.000 * $e^{-0.0002 * (\text{forest patch size} \wedge 1.278)}$).

Table 84.—Influence of forest patch size on suitability index (SI) scores for Mississippi kite habitat

Forest patch size (ha)[a]	SI score
22	0.0
683	0.5
3,000	1.0

[a]Barber and others (1998).

Table 85.—Suitability index scores for Mississippi kite habitat based on proportion of cells providing roosting and nesting habitat within 1-km radius

	Proportion forest[a]										
Proportion agriculture-grassland[b]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50
0.1	0.00	0.00	0.00	0.00	0.20	0.20	0.40	0.60	0.60	0.60	
0.2	0.00	0.00	0.00	0.00	0.40	0.40	0.60	0.80	0.80		
0.3	0.00	0.00	0.00	0.00	0.60	0.60	0.80	1.00			
0.4	0.35	0.40	0.40	0.60	0.80	0.80	1.00				
0.5	0.50	0.50	0.55	0.70	0.70	0.60					
0.6	0.60	0.70	0.75	0.90	0.80						
0.7	0.70	0.75	1.00	1.00							
0.8	0.80	0.90	1.00								
0.9	0.80	1.00									
1.0	0.80										

[a]Woody wetlands, deciduous forest, low-density residential.

[b]Open water, open fields (natural or cultivated), emergent herbaceous wetland.

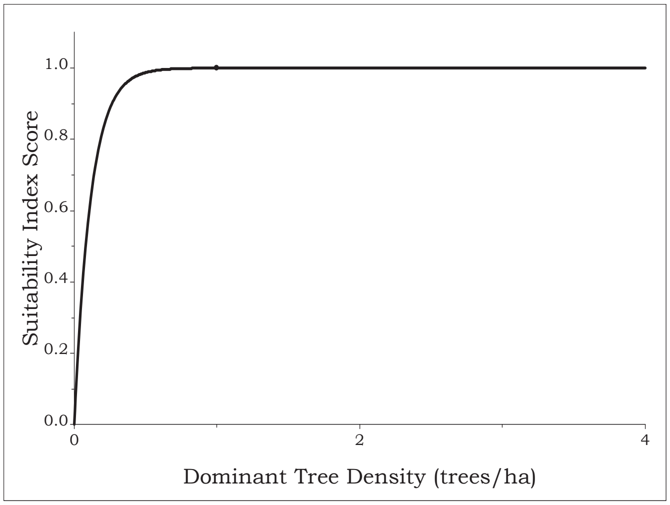

Figure 50.—Relationship between dominant tree (> 76.2 cm d.b.h.) density and suitability index (SI) scores for Mississippi kite habitat. Equation: SI score = $1 - e^{-8.734 * \text{dominant tree density}}$.

Table 86.—Influence of dominant tree (d.b.h. > 76.2 cm) density (trees/ha) on suitability index (SI) scores for Mississippi kite habitat

Dominant tree density[a]	SI score
0	0.0
1	1.0
14	1.0

[a]Assumed value.

Verification and Validation

The Mississippi kite was found in 49 of the 88 subsections within the CH and WGCP. Spearman rank correlations based on all subsections yielded a significant ($P = 0.003$) positive association ($r_s = 0.31$) between average HSI score and mean BBS route abundance. However, this association was not evident when the correlation considered only subsections in which this species was found. The generalized linear model predicting BBS abundance from BCR and HSI for the Mississippi kite was significant ($P \leq 0.001$; $R^2 = 0.287$); however, the coefficient on the HSI predictor variable was negative ($\beta = -0.176$). Therefore, we considered the HSI model for the Mississippi kite verified but not validated (Tirpak and others 2009a).

Northern Bobwhite


U.S. Forest Service

Status

The northern bobwhite (*Colinus virginianus*) is a resident gamebird found throughout the eastern United States and Great Plains. Populations have declined by 3 percent per year since 1966 (Sauer and others 2005). Declines in the CH and WGCP have been equally dramatic (3.1 and 4.4 percent per year, respectively) during this period (Table 5). As a resident gamebird, this species is not afforded special status by the FWS (protection is relegated to state wildlife agencies). Nevertheless, PIF has designated this bird as one requiring management attention in both the CH and WGCP (regional combined scores = 16 and 15, respectively) (Table 1). To address rangewide declines in populations, the Northern Bobwhite Conservation Initiative was established in 2002.

Natural History

The northern bobwhite is an economically important gamebird in the southern and central United States (Brennan 1999). It is associated with early successional vegetation, making use of agricultural fields, grasslands, grass-shrub rangelands, park-like pine forests and mixed pine-hardwood forests. At the county scale in Texas, the area in cultivated land and livestock density show curvilinear relationships to bobwhite population indices (Lusk and others 2002a). In Oklahoma, bobwhite indices decrease with the proportion of the landscape in mature woodland, but increase with the proportion of brushy prairie or early successional habitat (Guthery and others 2001). Guthery and others (2001) found that populations were highest in areas lacking cropland agriculture. However, Williams and others (2000) found that the bobwhite selected cropland when it accounted for a small proportion of the landscape. Patterns of use and survival differ between crop-dominated and rangeland-dominated areas during the hunting season in Kansas (Williams and others 2000). Bobwhite densities vary across the range depending on habitat quality but are highest in areas with small (0.5 to 5.0 ha) interspersed patches of habitat.

Frequency and intensity of disturbance are important for this species, especially in southern pine forests where prescribed burning is a useful management tool. Cram and others (2002) reported higher bobwhite abundance in pine-grassland restoration areas in Arkansas as conifer and hardwood basal area decreased and woody structure less than 2 m tall increased. The bobwhite also occupies cottonwood reforestation plots less than 4 years old in Mississippi and Louisiana (Twedt and others 2002). Most management for this species has been at the local scale, but Guthery (1999) showed that optimal configuration of patch types and sizes has variability (slack), and Williams and others (2004) promoted a regional management strategy that focused on useable space (i.e., more patches of native prairies, savanna, and other favored vegetation types).

Weather affects bobwhite populations, including positive effects of summer temperature and fall precipitation (Lusk and others 2002a) and negative effects of spring flooding and low winter temperatures (Applegate and others 2002). Bridges and others (2001) found a negative correlation between drought indices in dry regions and bobwhite abundance, but this pattern did not hold in wetter regions of Texas. Lusk and others (2002b) also found that climatic variables were more important than landscape variables for predicting bobwhite abundance in Oklahoma.

Nests are constructed of litter (grass or pine needles) in areas of high structural complexity (Townsend and others 2001); brood cover is found in open areas with dense forbs that still permit mobility at ground level. Nevertheless, Taylor and others (1999) did not find any habitat attributes associated with higher probabilities of adult survival or nest success. White and others (2005) examined multiple landscape buffers (radii of 250 to 1,000 m) around nest sites and random points to examine landscape effects on nest site selection. Bobwhite responded to both composition and configuration of landscapes, including proportions of open-canopy planted pine and fallow fields, interspersion-juxtaposition index, and patch density. A model containing all four of these variables applied at the largest landscape had the best predictive ability, but was closely followed by a model containing only proportion of open-canopy planted pine applied at the smallest landscape size. Several other types of habitat models have been developed for the bobwhite: HSI (Schroeder 1985), PATREC (Roseberry and Sudkamp 1998), and logistic regression (Burger and others 2004). Tests of these models showed that they perform poorly (Roseberry and Sudkamp 1998, Burger and others 2004, Jones-Farrand and Millspaugh 2006).

Model Description

Habitat quality for bobwhite is affected by many parameters that are not measured easily at any scale: the proportion of forbs or open areas in grasslands, herbaceous vegetation height, grasslands and crop-field management, and intra- and inter-annual climatic variations. Therefore, we restricted our habitat suitability model to aspects of landscape composition and forest structure that were quantifiable from available datasets. Our final model includes seven variables: landform, landcover, successional age class, hardwood basal area, evergreen basal area, grass landcover, and interspersion of open and forest habitats.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 87). We directly assigned SI scores to these combinations on the basis of habitat associations for the northern bobwhite outlined in Hamel (1992).

Forested sites used by the northern bobwhite typically are woodlands with low hardwood and pine basal area (SI2 and SI3, respectively). We used data from Cram and others (2002) and Palmer and Wellendorf (2006) to inform inverse logistic functions that predict SI scores for the bobwhite at various basal area levels (Tables 88-89; Figs 51-52).

We directly assigned SI scores to grass landcover (SI4) classes based on their potential to provide feeding, nesting, and brood-rearing habitat (Guthery 1997) (Table 90). We assumed that natural grassland-herbaceous landcovers had the greatest potential to provide these habitats, though it is likely that a given patch can satisfy only two of the three requisites

Table 87.—Relationship of landform, landcover type, and successional age class to suitability index (SI) scores for northern bobwhite habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.167	0.167	0.083	0.000	0.000
	Deciduous	0.167	0.167	0.083	0.000	0.000
	Evergreen	1.000	1.000	0.667	0.500	0.667
	Mixed	0.667	1.000	0.667	0.333	0.333
	Orchard-vineyard	0.167	0.167	0.083	0.000	0.000
	Woody wetlands	0.334	0.334	0.250	0.250	0.334
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.667 (1.000)	1.000	0.667	0.333 (0.500)	0.333 (0.667)
	Deciduous	0.333	0.667	0.333	0.000	0.000
	Evergreen	1.000	1.000	0.667	0.500	0.667
	Mixed	0.667	1.000	0.667	0.333	0.333
	Orchard-vineyard	0.333	0.667	0.333	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.667 (0.834)	1.000 (0.834)	0.667	0.333 (0.667)	0.333 (0.667)
	Deciduous	0.333	1.000	0.500	0.000	0.000
	Evergreen	1.000 (0.834)	1.000 (0.834)	0.667	0.500 (0.667)	0.667
	Mixed	0.667	1.000	0.667	0.333	0.333
	Orchard-vineyard	0.333	1.000	0.500	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

at any point in time (Stoddard 1931). We assumed that areas in small grain production provided foraging opportunities but had little residual value for nesting or brood rearing. Similarly, fallow fields provide marginal nest and brood habitat but little forage. Finally, pasture-hay and row crops may provide foraging, nesting, and brood-rearing habitat but their value likely is limited due to management practices that produce unsuitable vegetative structure during most of the breeding season.

The bobwhite relies on landscapes comprised of interspersed vegetation types (White and others 2005, Guthery 2000). We used the composition of open and forest landcovers within a 1-km landscape (SI5) to index the interspersion of these cover types. Guthery (1999, 2000) and others before him (see Schroeder 1985 and references therein) have noted that this species can tolerate a broad range of landscape configurations. On the basis of suggestions from Fred Guthery (2006, Oklahoma State University, pers. commun.), we assumed that high quality habitat was characterized by 10 to 40 percent forest land and 60 to 90 percent open habitat (Table 91).

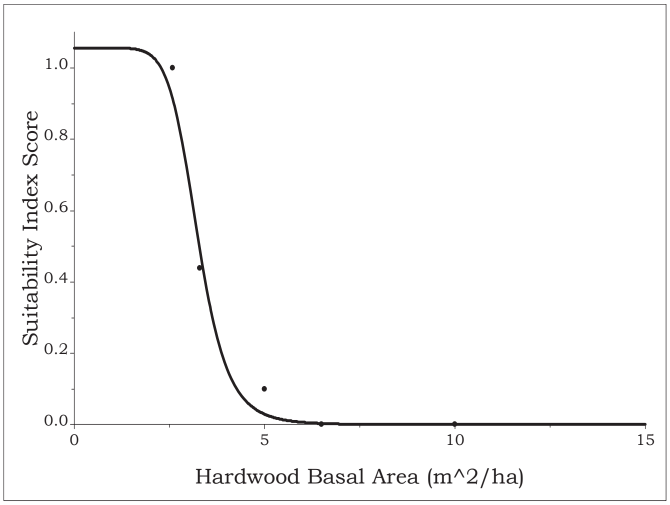

Figure 51.—Relationship between hardwood basal area and suitability index (SI) scores for northern bobwhite habitat. Equation: SI score = 1/ (1.000 + (0.053 * (hardwood basal area)$^{5.068}$)).

Table 88.—Influence of hardwood basal area on suitability index (SI) scores for northern bobwhite habitat

Hardwood basal area (m^2/ha)	SI score
0.0[a]	1.000
2.6[b]	1.000
3.3[b]	0.439
5.0[a]	0.100
6.5[b]	0.000
10.0[a]	0.000

[a]Assumed value.
[b]Cram and others (2002).

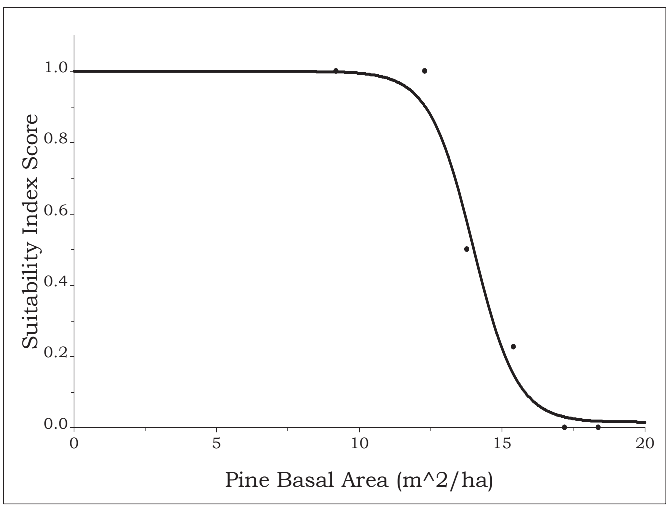

Figure 52.—Relationship between pine basal area and suitability index (SI) scores for northern bobwhite habitat. Equation: SI score = 1 - (0.984 / (1 + (83605490 * e$^{-1.305 * \text{pine basal area}}$))).

Table 89.—Influence of pine basal area on suitability index (SI) scores for northern bobwhite habitat

Pine basal area (m^2/ha)	SI score
0.00[a]	1.000
9.20[b]	1.000
12.30[a]	1.000
13.78[b]	0.500
15.40[c]	0.228
17.20[c]	0.000
18.37[b]	0.000

[a]Assumed value.
[b]Palmer and Wellendorf (2006).
[c]Cram and others (2002).

We calculated the overall HSI score by first determining the geometric mean of SI scores for forest structure attributes (SI1, SI2, and SI3). Open habitats lacking forest structure were assigned SI score independently (SI4). The landscape context of these forest and open habitats were incorporated into the HSI calculation by determining the geometric mean of these site-level and landscape-level variables (SI5) together.

Overall HSI = $(((SI1 * SI2 * SI3)^{0.333} + SI4) * SI5)^{0.500}$

Table 90.—Relationship between open and grassy landcover and suitability index (SI) scores for northern bobwhite habitat

Landcover type[a]	SI score
Grassland-herbaceous	1.0
Pasture-hay	0.1
Row crops	0.1
Small grains	0.4
Fallow	0.2

[a]Assumed value.

Table 91.—Suitability index scores for northern bobwhite habitat based on the proportion of cells providing: 1) good nesting, feeding, and brood-rearing habitat (open landcovers); 2) escape and thermal cover (forest landcovers) within 1-km radius

Proportion	Proportion forest[a]										
open[b]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.00	0.00	0.10	0.15	0.25	0.25	0.25	0.20	0.15	0.10	
0.2	0.00	0.10	0.15	0.25	0.35	0.35	0.30	0.25	0.20		
0.3	0.00	0.30	0.35	0.45	0.45	0.45	0.40	0.30			
0.4	0.00	0.50	0.50	0.50	0.50	0.50	0.50				
0.5	0.00	0.70	0.70	0.70	0.70	0.70					
0.6	0.00	0.90	0.90	0.90	0.90						
0.7	0.00	0.90	1.00	1.00							
0.8	0.00	0.90	1.00								
0.9	0.00	0.90									
1.0	0.00										

[a]Forest = landcovers with positive SI1 score (Table 87).

[b]Open = landcovers identified in SI4 (Table 90).

Verification and Validation

The northern bobwhite was found in all 88 subsections of the CH and WGCP. Spearman rank correlation support a significant (P = 0.006) positive association (r_s = 0.29) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the northern bobwhite was significant ($P \leq 0.001$; R^2 = 0.440); however, the coefficient on the HSI predictor variable was negative (β = -37.119). Therefore, we considered the HSI model for the northern bobwhite verified but not validated (Tirpak and others 2009a).

Northern Parula


Chandler S. Robbins, Patuxent Bird Identification InfoCenter
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Status

The northern parula (*Parula americana*), a long-distance neotropical migrant, breeds in two disjunct zones of eastern North America: New England-southern Canada and the southeastern United States. This species is notably absent from the southern Great Lakes. It depends on epiphytes—Spanish moss in the south and old man's beard in the north—as a nesting substrate. Parula populations have been stable in most regions during the last 40 years and have increased in some areas including the CH (Table 5). This species is not considered a Bird of Conservation Concern in the CH or WGCP (regional combined score = 12 and 13, respectively; Table 1).

Natural History

The northern parula is common in the bottomland hardwood and riverine forests of the Southeastern United States (Moldenhauer and Regelski 1996). It also occupies mixed pine-hardwoods, though at lower densities (Moldenhauer and Regelski 1996). The northern parula has two competing habitat requirements: a preference for canopy gaps and large forest blocks. Moorman and Guynn (2001) found that this species is more abundant near canopy gaps than forest-interior sites with an unbroken canopy in bottomland hardwoods, and Annand and Thompson (1997) observed the highest northern parula densities in forests with canopy gaps resulting from single-tree selection. However, the probability of detecting the northern parula increases with riparian buffer width (Kilgo and others 1998) and forest patch size (Robbins and others 1989).

The northern parula forages in the mid- to upper canopy layers (Moldenhauer and Regelski 1996), so it is not surprising that it prefers microsites with high basal area (Robbins and others 1989), high canopy cover, and tall canopies (James 1971), and avoids areas with dense understories (often associated with open canopies) (Torres and Leberg 1996). In the Southeast, this species nests almost exclusively in Spanish moss (Moldenhauer and Regelski 1996). However, no studies have identified Spanish moss as limiting.

Model Description

The HSI model for the northern parula includes six variables: landform, landcover, successional age class, forest patch size, percent forest in a 1-km radius, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 92). We directly assigned SI scores to these combinations on the basis of habitat associations of northern parulas reported by Hamel (1992) for the Southeast.

We derived a logarithmic function (Fig. 53) from data on the occupancy rate of northern parulas in forest blocks of varying size (SI2; Hayden and others 1985, Robbins and others 1989) (Table 93) to predict habitat suitability from patch area. However, small forest

Table 92.—Relationship of landform, landcover type, and successional age class to suitability index scores for northern parula habitat

Landform	Landcover type	Successional age class				
		Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.083	0.500	0.834
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.250	0.750	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.250	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.167	0.333
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000

patches in predominantly forested landscapes may provide habitat due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 54) to data (Table 94) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from SI2 or SI3 to account for small patches in predominantly forested landscapes.

We included canopy cover (SI4) in our model to capture the preference of the northern parula for interior edges. James (1971), Collins and others (1982), and Morgan and Freedman (1986) found that the northern parula is associated with increased canopy cover. Nonetheless, there seems to be a threshold above which suitability declines. Robbins and others (1989) observed an inverse relationship between canopy cover and northern parula abundance, and Annand and Thompson (1997) observed a threefold increase of parulas in single-tree selection stands characterized by a heterogeneous canopy than in mature forest habitats with closed canopies. On the basis of these studies, we assumed that

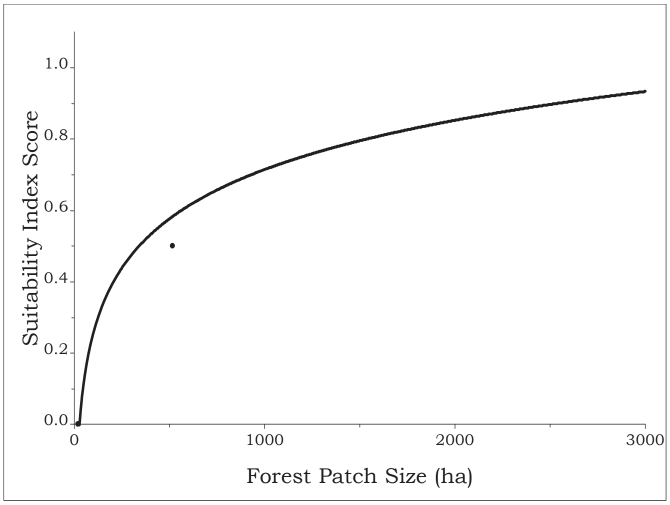

Figure 53.—Relationship between forest patch size and suitability index (SI) scores for northern parula habitat. Equation: SI score = 0.199 * ln(forest patch size) – 0.661.

Table 93.—Influence of forest patch size on suitability index (SI) scores for northern parula habitat

Forest patch size (ha)	SI score
23.6[a]	0.0
520[b]	0.5
3,200[b]	1.0

[a]Hayden and others (1985).
[b]Robbins and others (1989).

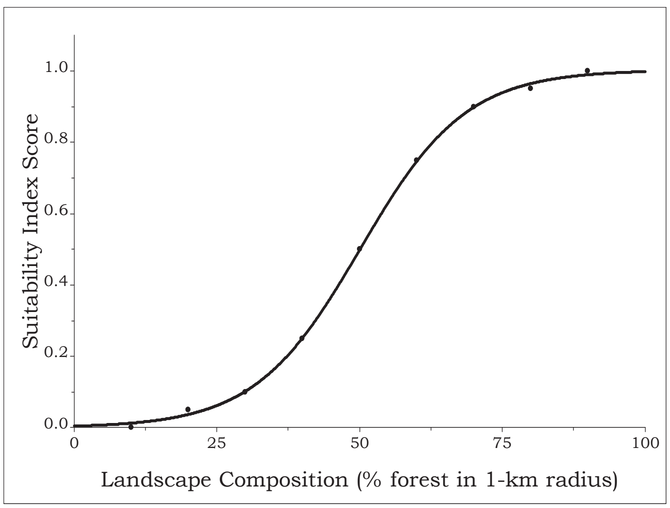

Figure 54.—Relationship between local landscape composition and suitability index (SI) scores for northern parula habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * \text{(local landscape composition)}}$)).

Table 94.—Relationship between local landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for northern parula habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

habitat suitability was optimal at 90 percent canopy cover and decreased as the canopy became increasingly open or closed. We fit an inverse quadratic function (Fig. 55) to data demonstrating this relationship (Table 95).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI4) and then calculated the geometric mean of this value and landscape composition (Max of SI2 or SI3).

$$\text{Overall HSI} = ((\text{SI1} * \text{SI4})^{0.500} * \text{Max(SI2 or SI3)})^{0.500}$$

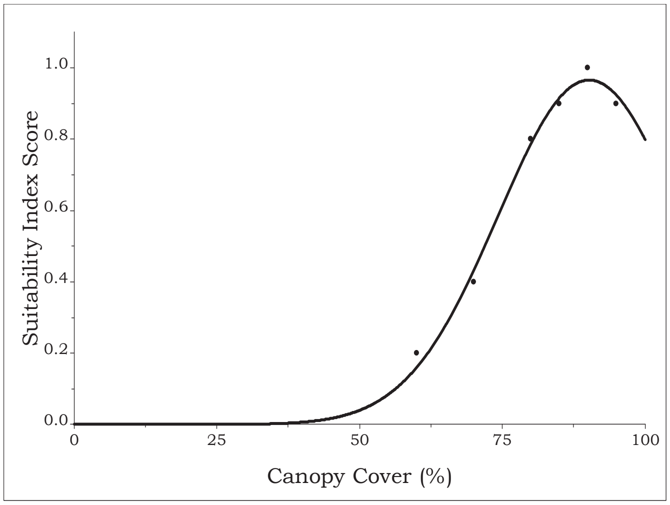

Figure 55.—Relationship between canopy cover and suitability index (SI) scores for northern parula habitat. Equation: SI score = 1 / (37.3645 – (0.8127 * canopy cover) + (0.00454 * (canopy cover^2))).

Table 95.—Influence of canopy cover on suitability index (SI) scores for northern parula habitat

Canopy cover (percent)[a]	SI score
60	0.2
70	0.4
80	0.8
85	0.9
90	1.0
95	0.9
100	0.8

[a]Assumed value.

Verification and Validation

The northern parula was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.51$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the northern parula was significant ($P \leq 0.001$; $R^2 = 0.276$), and the coefficient on the HSI predictor variable was both positive ($\beta = 5.250$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the northern parula both verified and validated (Tirpak and others 2009a).

Orchard Oriole

Deanna K. Dawson,
Patuxent Bird Identification InfoCenter
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Status

The orchard oriole (*Icterus spurius*), a neotropical migrant, is found throughout most of the United States east of the Rocky Mountains except for New England and the northern Great Lakes. Although this species has experienced increases along the edges of its distribution, populations have declined in the core of its range where densities are highest. In the WGCP, populations have declined by 3 percent per year since 1967 (Table 5). Populations in the adjacent Mississippi Alluvial Valley have declined 4 percent. The orchard oriole is a Bird of Conservation Concern in the WGCP and has been identified as a species requiring management attention in both the CH and WGCP (regional combined score = 17 and 18, respectively; Table 1).

Natural History

The orchard oriole breeds in wooded riparian zones, floodplains, marshes, and shorelines (Scharf and Kren 1996) but also in open shrublands and low-density human-dominated areas (e.g., farms and parklands). It is semi-colonial in optimal habitat but relatively solitary in marginal areas. This species is a common host of the brown-headed cowbird.

Model Description

The HSI model for the orchard oriole includes five variables: landform, landcover, successional age class, forest within a 1-km radius, and basal area.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 96). We directly assigned SI scores to these combinations based on vegetation and successional age class associations in Hamel (1992). However, we adjusted Hamel's values to account for the preference of the orchard oriole for mesic habitats (e.g., riparian zones, floodplains, and marshes; Scharf and Kren 1996).

The orchard oriole is not area sensitive but generally is restricted to forested landscapes. Therefore, we included only local forest composition (SI2) in our model to discount forest patches that were isolated within a matrix of nonforest landcover. Conversely, this is an edge species whose abundance declines in heavily forested regions (Scharf and Kren 1996). Therefore, we assumed that landscapes with 70 to 80 percent forest provided optimal habitat suitability and reduced suitability symmetrically as landscape composition shifted from these optima (Table 97, Fig. 56).

This species is most abundant in areas with scattered trees. Heltzel and Leberg (2006) observed significantly fewer orioles in stands with an average basal area of 25 m^2 per ha than in recently harvested stands with an average basal area of 18 m^2 per ha. We assumed that habitat suitability was optimal for the orchard oriole at lower basal areas and modeled

Table 96.—Relationship of landform, landcover type, and successional age class to suitability index scores for orchard oriole habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.500	1.000	1.000
	Transitional-shrubland	0.000	0.000	0.500	1.000	1.000
	Deciduous	0.000	0.000	0.500	1.000	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.500	1.000	1.000
	Woody wetlands	0.000	0.000	0.500	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.333	0.667	0.667
	Transitional-shrubland	0.000	0.000	0.250	0.500	0.500
	Deciduous	0.000	0.000	0.250	0.500	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.333	0.667	0.667
	Woody wetlands	0.000	0.000	0.500	1.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.333	0.667	0.667
	Transitional-shrubland	0.000	0.000	0.250	0.500	0.500
	Deciduous	0.000	0.000	0.250	0.500	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.333	0.667	0.667
	Woody wetlands	0.000	0.000	0.500	1.000	1.000

the basal area (SI3)-habitat suitability relationship as a quadratic function (Fig. 57) that maximized SI scores at intermediate basal area values (12.5 m^2/ha; Table 98).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure indices (SI1 and SI3) and then determined the geometric mean of this value and landscape composition (SI2).

Overall HSI = $((SI1 * SI3)^{0.500} * SI2)^{0.500}$

Verification and Validation

The orchard oriole was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.34$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the orchard oriole was significant ($P = 0.088$; $R^2 = 0.056$), and the coefficient on the HSI predictor variable was positive (β = 2.442) but not significantly different from zero ($P = 0.221$). Therefore, we considered the HSI model for the orchard oriole verified but not validated (Tirpak and others 2009a).

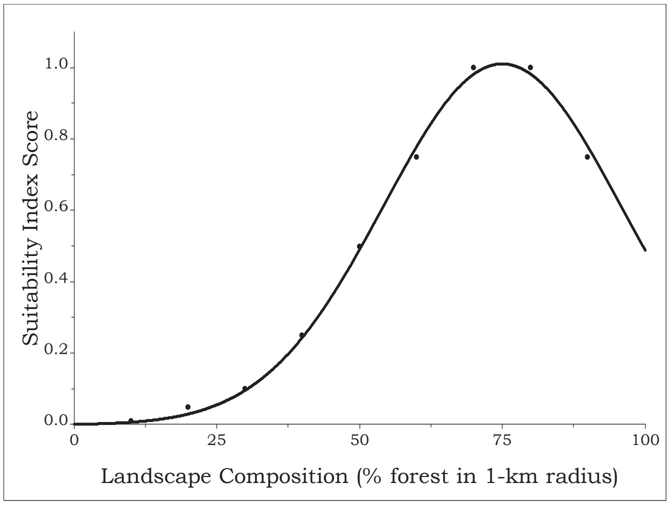

Figure 56.—Relationship between landscape composition and suitability index (SI) scores for orchard oriole habitat. Equation: SI score = 1.011 * e $^{((0 – ((\text{landscape composition} * 100) – 74.945) \wedge 2) / 863.949)}$.

Table 97.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for orchard oriole habitat

Landscape composition[a]	SI score
0	0.00
10	0.00
20	0.05
30	0.10
40	0.25
50	0.50
60	0.75
70	1.00
80	1.00
90	0.75
100	0.50

[a]Assumed value.

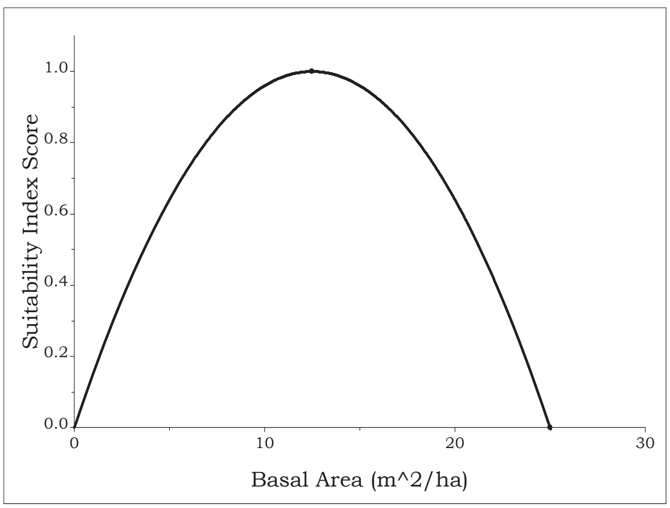

Figure 57.—Relationship between basal area and suitability index (SI) scores for orchard oriole habitat. Equation:
SI score = (0.16 * basal area) - (0.00639 * (basal area^2)).

Table 98.—Influence of basal area (m^2/ha) on suitability index (SI) scores for orchard oriole habitat

Basal area (m^2/ha)	SI score
0.0[a]	0.0
12.5[a]	1.0
25.0[b]	0.0

[a]Assumed value.
[b]Heltzel and Leberg (2006).

Painted Bunting

Deanna K. Dawson,
Patuxent Bird Identification InfoCenter
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Status

The painted bunting (*Passerina cyanea*) occurs as two allopatric populations that may represent separate species (Lowther and others 1999). The western population inhabits the southern Great Plains and the western edges of the CH and WGCP, while the eastern population inhabits the Atlantic Coastal Plain from North Carolina to Florida. Populations have been relatively stable across the WGCP as a whole (Table 5), but populations have declined in Arkansas (5.8 percent per year from 1967 to 2004), Louisiana (3.5 percent), and Texas (2.4 percent) but increased in Oklahoma (1.3 percent; Sauer and others 2005). The painted bunting is not an FWS Bird of Conservation Concern but is a PIF management attention priority in both the CH and WGCP (regional combined score = 16 and 17, respectively; Table 1).

Natural History

The habitat requirements of the painted bunting are poorly understood. This species generally occupies areas of scattered woody vegetation. Kopachena and Crist (2000a) characterized painted bunting habitat in northeast Texas as "wooded areas in otherwise open habitat" as opposed to the indigo bunting, which occurs in "open areas in otherwise wooded habitat." The painted bunting use smaller, more heterogeneous groups of trees than the indigo bunting, but microhabitats differ little between these species (Kopachena and Crist 2000b). The painted bunting occupies narrow riparian strips in eastern Texas and its abundance decreases quickly as widths exceed 70 m (Conner and others 2004).

The painted bunting nests in low, woody vegetation (Lowther and others 1999) and its territory size varies with its population density. In Missouri, territories ranged from 0.64 to 6.66 ha and included 80 percent pasture and 20 percent woodland. This species is a common host of both the brown-headed and bronzed cowbird.

Model Description

The HSI model for the painted bunting includes six variables: landform, landcover, successional age class, distance to edge, interspersion of open and forested lands, and small stem (< 2.5 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 99). We directly assigned SI scores to these combinations on the basis of relative habitat rankings for vegetation and successional age class associations of painted buntings reported by Hamel (1992). We assigned higher values to the shrub-seedling age class than Hamel (1992) on the basis of qualitative descriptions in Lowther and others (1999).

An early-successional species, the painted bunting is associated with edges. We used data on territory density from Lanyon and Thompson (1986; Table 100) to define an inverse logistic function linking SI scores to distance from an edge (SI2; Fig. 58).

Table 99.—Relationship of landform, landcover type, and successional age class to suitability index scores for painted bunting habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.500	0.500	0.250	0.000
	Deciduous	0.000	0.500	0.500	0.250	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.500	0.500	0.250	0.000
	Woody wetlands	0.000	1.000	0.750	0.500	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.500	0.500	0.250	0.000
	Deciduous	0.000	0.500	0.500	0.250	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.500	0.500	0.250	0.000
	Woody wetlands	0.000	1.000	0.750	0.500	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.500	0.500	0.250	0.000
	Deciduous	0.000	0.500	0.500	0.250	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.500	0.500	0.250	0.000
	Woody wetlands	0.000	1.000	0.750	0.500	0.000

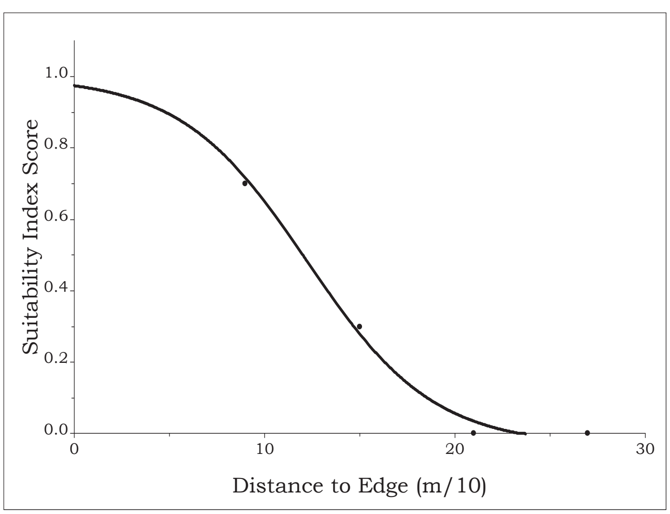


Figure 58.—Relationship between distance to edge and suitability index (SI) scores for painted bunting habitat. Equation: SI score = 1 - (1.034 / (1 + (39.685 * e $^{-0.301 * (\text{distance to edge} / 10\text{ m})}$))).

Table 100.—Influence of distance to edge on suitability index (SI) scores for painted bunting habitat

Distance to edge (m)	SI score
0[a]	1.0
90[a]	0.7
150[a]	0.3
210[a]	0.0
270[b]	0.0

[a]Lanyon and Thompson (1986).
[b]Assumed value.

Table 101.—Suitability index scores for painted bunting habitat based on the proportion of open and forest landcovers within 5-ha area

Proportion forest[b]	Proportion open[a]										
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.2	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
0.3	0.0	0.0	0.5	0.7	0.7	0.7	0.7	0.7			
0.4	0.0	0.0	0.5	0.7	0.9	0.9	0.9				
0.5	0.0	0.0	0.5	0.7	0.9	1.0[c]					
0.6	0.0	0.0	0.5	0.7	0.9						
0.7	0.0	0.0	0.5	0.7							
0.8	0.0	0.0	0.5								
0.9	0.0	0.0									
1.0	0.0										

[a]Open = herbaceous natural, cultivated, and emergent herbaceous wetland.

[b]Forest = upland forested, transitional, woody wetland, and orchard/vineyard.

[c]Unpublished data.

The presence of both forest and open landcovers in the landscape (SI3) is perhaps the most important component of painted bunting habitat. We maximized SI scores for this species in landscapes containing 50 percent forest and 50 percent open habitats based on unpublished data (Jeffrey Kopachena, 2006, Texas A&M University—Commerce, pers. commun.). Norris and Elder (1982, cited in Lowther and others 1999) observed the painted bunting in landscapes with forest cover of 20 to 80 percent forest. We used these values as cutoffs for forest cover in our interspersion function for the painted bunting (Table 101).

As an early successional species, the painted bunting occupies habitats containing high densities of small stems (SI4). We assumed that the mean stem density values (6,400 stems/ha) reported by Kopachena and Crist (2000b) were characteristic of average habitat suitability (SI score = 0.500). However, because of the high standard error (6,300 stems/ha) associated with this estimate, we assumed that a stem density that was twice the mean was necessary to ensure optimal habitat (Table 102). We fit a smoothed logistic function through these data points (Fig. 59) to quantify the relationship between small stem density and SI scores for painted bunting habitat.

To calculate the HSI score for sapling and pole successional age class stands, we determined the geometric mean of SI scores for forest structure (SI1 and SI4) and landscape composition (SI2 and SI3) separately and then the geometric mean of these means together.

$$HSI_{Sap\text{-}pole} = ((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$$

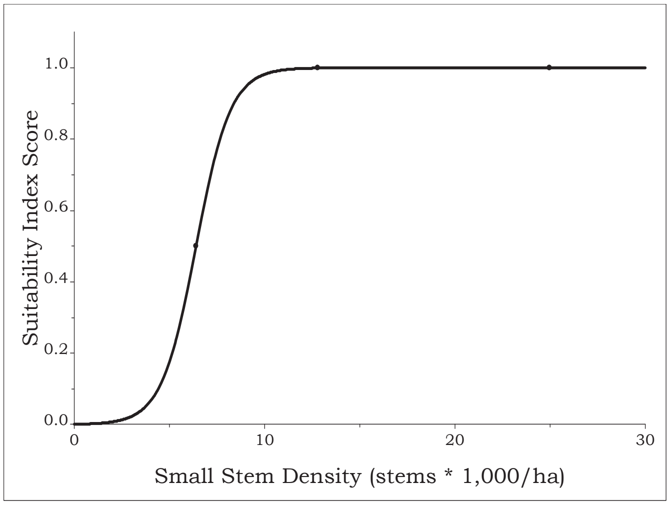


Figure 59.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for painted bunting habitat. Equation: SI score = (1.000 / (1 + (1178.674 * $e^{-1.105 * (\text{small stem density} / 1000)}$))).

Table 102.—Influence of small stem density (stems * 1,000/ha) on suitability index (SI) scores for painted bunting habitat

Small stem density	SI score
0.0[a]	0.0
6.4[b]	0.5
12.8[a]	1.0
25.0[a]	1.0

[a]Assumed value.
[b]Kopachena and Crist (2000b).

We assumed that shrub-seedling successional age class stands were suitable regardless of edge or landscape composition. Thus, we calculated the HSI score as the geometric mean of forest structure attributes alone (SI1 and SI4).

$HSI_{Shrub} = (SI1 * SI4)^{0.500}$

The overall HSI score is the sum of the two age class specific SIs:

Overall HSI = $SI_{Sap\text{-}pole} + SI_{Shrub}$

Verification and Validation

The painted bunting was found in only 38 of the 88 subsections within the CH and WGCP. Nevertheless, Spearman rank correlations based on either all subsections or only subsections in which the painted bunting occurred produced similar results: significant ($P \leq 0.001$ in both analyses) positive associations (r_s = 0.56 and 0.58, respectively) between average HSI score and mean BBS route abundance at the subsection scale. The generalized linear model predicting BBS abundance from BCR and HSI for the painted bunting was significant ($P \leq 0.001$; $R^2 = 0.480$), and the coefficient on the HSI predictor variable was both positive (β = 70.737) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the painted bunting both verified and validated (Tirpak and others 2009a).

Pileated Woodpecker

U.S Forest Service

Status

The pileated woodpecker (*Dryocopus pileatus*) breeds throughout eastern North America, southern Canada, and the montane forests of the West. Populations have been stable across most of its range, including the WGCP, over the last 40 years and have increased along the northern limit of this bird's distribution. In the CH, populations have increased by 1.8 percent per year since 1967 (Sauer and others 2005) (Table 5). This species is a management attention priority in the WGCP (regional combined score = 16) but has no special conservation status in the CH (regional combined score = 13; Table 1).

Natural History

The pileated woodpecker uses a variety of forest types across its range but typically is associated with older successional age classes (Bull and Jackson 1995, Annand and Thompson 1997). The key component to pileated woodpecker habitat is an abundance of large snags—the more the better. Different researchers define "large" differently (Renken and Wiggers 1989, Savignac and others 2000, Showalter and Whitmore 2002) but the pileated woodpecker is invariably associated with the largest available size class. In Missouri, this species is associated with bottomland hardwood forest (Renken and Wiggers 1993); in east Texas, the pileated woodpecker is equally abundant in bottomland hardwoods, longleaf pine savanna, and mixed pine-hardwood stands, so long as suitable snags are available (Shackelford and Conner 1997). Closed canopies (canopy cover of 75 to 96 percent) are the norm (Renken and Wiggers 1989). Because it has a large home range (53 to 160 ha), it is not surprising that the pileated woodpecker is sensitive to forest area. Robbins and others (1989) did not detect this species in woodlots less than 42 ha and larger areas likely are required for breeding pairs. Schroeder (1982) considered 130 ha as the minimum forest patch size for this species.

Model Description

The pileated woodpecker model includes six variables: landform, land cover, successional age class, large snag (> 30 cm d.b.h.) density, forest patch size, and percentage of forest in a 1-km radius.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 103). We used the habitat associations of the pileated woodpecker outlined in Hamel (1992) to assign SI scores to these combinations.

Large snags (SI2) are used for roosting, nesting, and foraging and are an important component of pileated woodpecker habitat. We fit a logistic function (Fig. 60) to data from Renken and Wiggers (1989) on the relative density of this species on sites with varying large snag densities to predict SI scores based on this habitat feature (Table 104).

Table 103.—Relationship of landform, landcover type, and successional age class to suitability index scores for pileated woodpecker habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.042	0.083	0.167
	Transitional-shrubland	0.000	0.000	0.083	0.583	1.000
	Deciduous	0.000	0.000	0.083	0.583	1.000
	Evergreen	0.000	0.000	0.167	0.333	0.333
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.042	0.083	0.167
	Transitional-shrubland	0.000	0.000	0.167	0.500 (0.333)	0.667 (0.333)
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.167	0.333	0.333
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.042	0.083	0.167
	Transitional-shrubland	0.000	0.000	0.167 (0.083)	0.500 (0.167)	0.667 (0.167)
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.167 (0.083)	0.333 (0.167)	0.333 (0.167)
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000

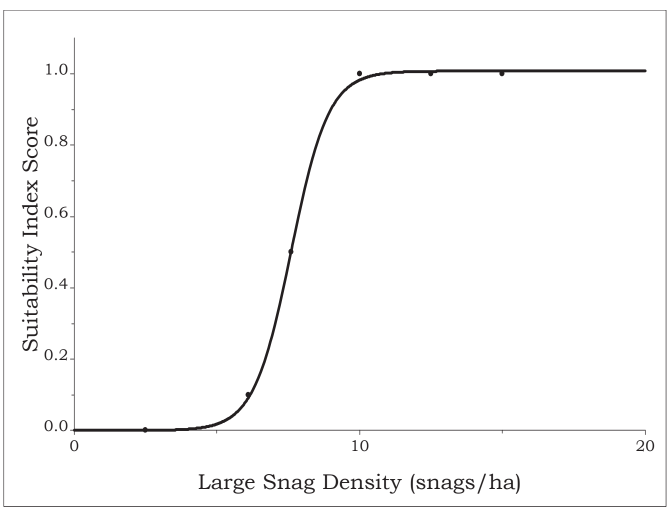


Figure 60.—Relationship between large snag (> 30 cm d.b.h.) density and suitability index (SI) scores for pileated woodpecker habitat. Equation: SI score = (1.0054 / (1 + (747.0936 * e $^{-0.8801 * \text{large snag density}}$))).

Table 104.—Influence of large snag (> 30 cm d.b.h.) density (snags/ha) on suitability index (SI) scores for pileated woodpecker habitat

Large snag density	SI score
0.[a]	0.0
2.5[a]	0.0
6.1[b]	0.1
7.6[b]	0.5
10.0[b]	1.0
15.0[a]	1.0
12.5[a]	1.0

[a]Assumed value.

[b]Renken and Wiggers (1989).

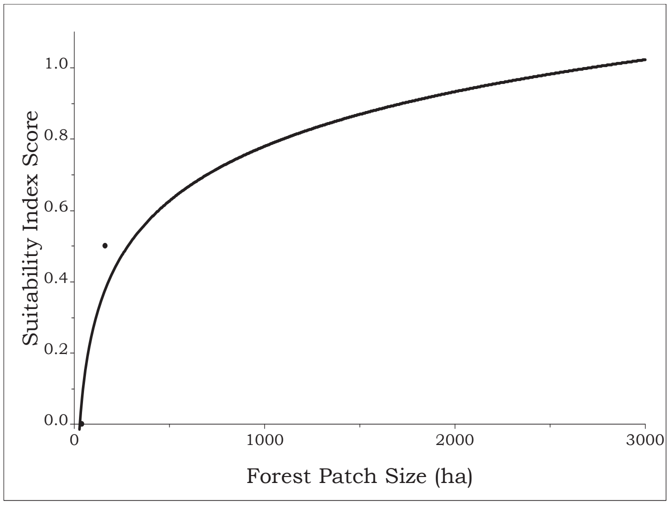


Figure 61.—Relationship between forest patch size and suitability index (SI) scores for pileated woodpecker habitat. Equation: SI score = 0.230 * ln(forest patch size) – 0.877.

Table 105.—Influence of forest patch size on suitability index (SI) scores for pileated woodpecker habitat

Forest patch size (ha)[a]	SI score
42.2	0.0
165	0.5
3,200	1.0

[a]Robbins and others (1989).

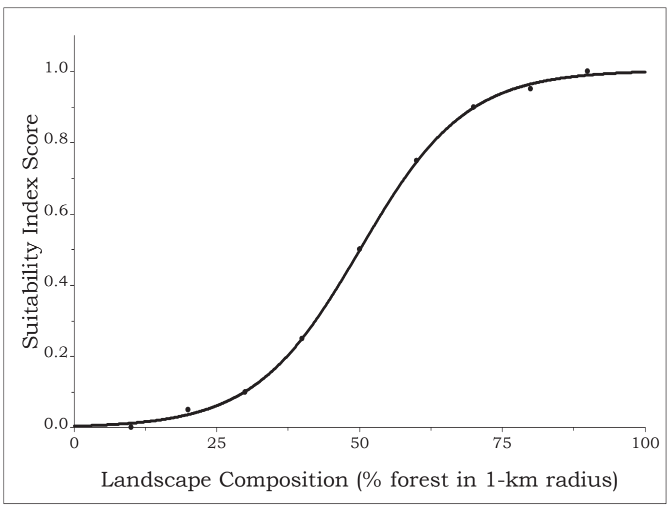


Figure 62.—Relationship between landscape composition and suitability index (SI) scores for pileated woodpecker habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{local landscape composition})}$)).

Table 106.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for pileated woodpecker habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

We incorporated forest patch size (SI3) and percent forest in the local landscape (SI4) as predictors of habitat suitability. Large home ranges for the pileated woodpecker necessitate large forest patches. We fit a logarithmic function (Fig. 61) to data from Robbins and others (1989) on the effect of forest patch size on occupancy rates (Table 105). We also included percent forest in the landscape because small forest patches that may not be used in predominantly nonforested landscapes may provide habitat in predominantly forested landscapes due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 62) to data (Table 106) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from SI3 or SI4 to account for the higher suitability of small forest patches in predominantly forested landscapes.

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI2) and multiplied that by the maximum value of forest patch size (SI3) or percent forest in the 1-km radius landscape (SI4) and calculated the geometric mean of that product.

$$\text{Overall HSI} = ((\text{SI1} * \text{SI2})^{0.500} * \text{Max}(\text{SI3 or SI4}))^{0.500}$$

Verification and Validation

The pileated woodpecker was observed in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.002$) positive association (r_s = 0.33) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the pileated woodpecker was significant ($P \leq 0.001$; $R^2 = 0.313$), and the coefficient on the HSI predictor variable was both positive (β = 8.852) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the pileated woodpecker both verified and validated (Tirpak and others 2009a).

Prairie Warbler


Deanna K. Dawson,
Patuxent Bird Identification InfoCenter
Photo used with permission

Status

The prairie warbler (*Dendroica discolor*), a neotropical migrant, occupies early successional habitats throughout the eastern United States. Like many early successional species, populations of this bird have declined throughout the eastern and central United States since 1967, including a drop of 2.6 percent per year in the CH and 4.4 percent per year in the WGCP (Table 5). The prairie warbler is an FWS Bird of Conservation Concern and a management attention priority in both BCRs (regional combined score = 18 in the CH and WGCP; Table 1).

Natural History

The prairie warbler breeds in shrubby vegetation under an open canopy (Nolan and others 1999). Typical associations in the CH and WGCP include shrubby southern pine forest, pine barrens, scrub oak barrens, abandoned fields and pastures, regenerating forest, abandoned orchards, grassland-forest edge, Christmas tree farms, and reclaimed strip mine spoils. The prairie warbler uses a variety of landforms from xeric uplands in Arkansas to palustrine swamps in Virginia. In comparison to other early successional warblers, this bird occupies sites with fewer dense shrubs than the blue-winged warbler, more dense vegetation and drier areas than the yellow warbler, and less dense vegetation and higher vegetation strata than the common yellowthroat or yellow-breasted chat (Nolan and others 1999).

The prairie warbler nests in shrubs and small trees that are more than 20 m from a field-forest edge (Nolan and others 1999, Woodward and others 2001). However, in eastern Texas this species typically occurs in narrow riparian zones, with abundance decreasing quickly as widths increase (Conner and others 2004). Mean territory size varies inversely with population density, ranging from 0.2 to 3.5 ha in Indiana (Nolan and others 1999). Territory size also varies with shape of forest patch; it is larger in more linear patches. Although males do not limit movements to their defended territory, a female's home range usually is contained within a male's defended territory. This species is a cowbird host. Although parasitism has little effect on hatching success, it can significantly reduce fledging rates.

Model Description

Our HSI model for the prairie warbler includes seven variables: landform, landcover, successional age class, early-successional patch size, small stem (< 2.5 cm d.b.h.) density, edge occurrence, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 107). We directly assigned SI scores to these combinations on the basis of habitat associations for the prairie warbler documented in Hamel (1992).

Table 107.—Relationship of landform, landcover type, and successional age class to suitability index scores for prairie warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333	0.167	0.000	0.000
	Deciduous	0.000	0.333	0.167	0.000	0.000
	Evergreen	0.000	0.667	0.334	0.000	0.000
	Mixed	0.000	1.000	0.500	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000 (0.667)	0.500 (0.334)	0.000	0.000
	Deciduous	0.000	0.667	0.333	0.000	0.000
	Evergreen	0.000	0.667	0.334	0.000	0.000
	Mixed	0.000	1.000	0.500	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000 (0.500)	0.500 (0.250)	0.000	0.000
	Deciduous	0.000	1.000	0.500	0.000	0.000
	Evergreen	0.000	0.667 (0.500)	0.334 (0.250)	0.000	0.000
	Mixed	0.000	1.000	0.500	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000

Both Woodward and others (2001) and Rodewald and Vitz (2005) observed edge avoidance by this species. Thus, we used a 3 × 3 pixel (90 x 90 m) window to identify early successional habitats (i.e., grass-forb, shrub-seedling, or sapling successional age class forest) adjacent to mature forest stands (i.e., pole or sawtimber successional age class) and reduced the suitability of locations adjacent to edges by half (SI2; Table 108).

We also included early successional patch size (SI3) as an explanatory variable because the prairie warbler is absent from small clearings and edge habitats. We used data from Larson and others (2003) (Table 109) to fit a logistic function (Fig. 63) that characterized the relationship between habitat suitability and early successional patch size.

We also included small stem density (SI4) as a variable because the prairie warbler is associated with dense understory vegetation. We used point count and habitat data reported by Annand and Thompson (1997) (Table 110) to derive a logistic function (Fig. 64) that predicted habitat suitability for the prairie warbler from small stem density.

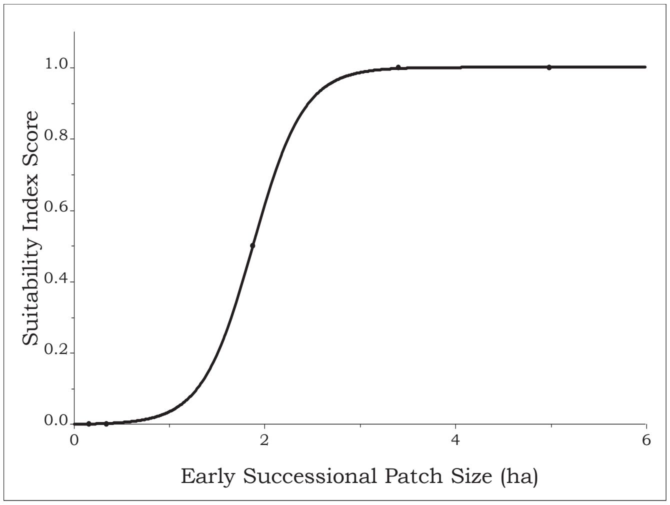


Figure 63.—Relationship between early successional patch size and suitability index (SI) scores for prairie warbler habitat. Equation: SI score = $(1.002 / (1 + (1207.332 * e^{-3.757 * \text{forest patch size}})))$.

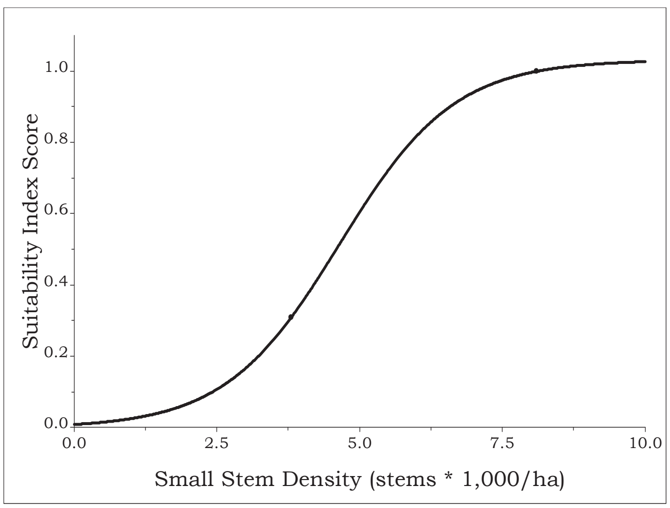


Figure 64.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for prairie warbler habitat. Equation: SI score= $(1.000 / (1 + (99.749 * e^{-1.001 * (\text{small stem density} / 1000)})))$.

Table 108.—Influence of edge on suitability index (SI) scores for prairie warbler habitat

3 × 3 pixel window around early successional habitat includes mature forest[a]	SI score
Yes	0.5
No	1.0

[a]Early successional = grass-forb, shrub-seedling, and sapling successional age classes; mature forest = pole or sawtimber successional age classes.

Table 109.—Influence of early successional patch size on suitability index (SI) scores for prairie warbler habitat; early successional patches only include grass-forb, shrub-seedling, and sapling successional age classes

Early successional patch size (ha)[a]	SI score
0.18	0.0
0.36	0.0
1.89	0.5
3.42	1.0
5.00	1.0

[a]Larson and others (2003).

Table 110.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for prairie warbler habitat

Small stem density	SI score
0.0[a]	0.00
3.8[b]	0.31
8.1[b]	1.00

[a]Assumed value.
[b]Annand and Thompson (1997).

Finally, we used data from Sheffield (1981) to inform an inverse logistic function (Fig. 65) that discounted SI scores at increasingly high canopy closures (SI5; Table 111).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1, SI4, and SI5) and landscape composition (SI2 and SI3) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI4 * SI5)^{0.333} * (SI2 * SI3)^{0.500})^{0.500}$

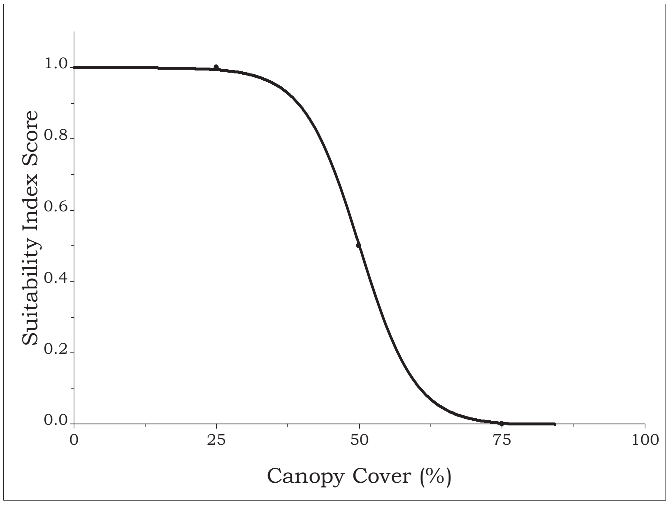


Figure 65.—Relationship between canopy cover and suitability index (SI) scores for prairie warbler habitat. Equation: SI score = 1 - (1.003 / (1 + (26950.420 * e $^{-0.204 * \text{canopy cover}}$))).

Table 111.—Influence of canopy cover on suitability index (SI) scores for prairie warbler habitat

Canopy cover (percent)[a]	SI score
0	1.0
25	1.0
50	0.5
75	0.0
100	0.0

[a]Sheffield (1981).

Verification and Validation

The prairie warbler was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.41$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the prairie warbler was significant ($P = 0.005$; $R^2 = 0.117$), and the coefficient on the HSI predictor variable was both positive ($\beta = 15.317$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the prairie warbler both verified and validated (Tirpak and others 2009a).

Prothonotary Warbler

John and Karen Hollingsworth,
U.S. Fish & Wildlife Service

Status

The prothonotary warbler (*Protonotaria citrea*) is a long-distance neotropical migrant associated with bottomland hardwood and floodplain forests of the Southeast. Densities are highest in the Mississippi Alluvial Valley; this species is notably absent from the central and southern Appalachians. Populations in the CH have remained relatively stable while those in the WGCP, where the prothonotary warbler is a Bird of Conservation Concern (Table 1), have declined by 5.8 percent per year since 1967 (Table 5). This bird is a planning and responsibility species in the CH (regional combined score = 14) and a management attention species in the WGCP (regional combined score = 17).

Natural History

Because it nests in cavities and readily accepts nest boxes, the prothonotary warbler has been well-studied.

Petit (1999) provided an excellent, detailed description of this bird's habitat requirements:

> Key (and nearly universal) features are presence of water near wooded area with suitable cavity nest sites. Nest usually placed over or near large bodies of standing or slow-moving water, including seasonally flooded bottomland hardwood forest, baldcypress swamps, and large rivers or lakes (Walkinshaw 1953, Blem and Blem 1991). Many other forms of water also chosen, such as creeks, streams, backyard ponds, and even swimming pools. Nests located away from permanent water are usually in low-lying, temporarily flooded spots (Walkinshaw 1953).
>
> Other important habitat correlates include low elevation, flat terrain, shaded forest habitats with sparse understory, and in some places, presence of baldcypress (Kahl and others 1985, Robbins and others 1989). Common overstory trees in nesting habitat include willows, maples, sweet gum, willow oak, ashes, elms, river birch, black gum, tupelo, cypress, and other species associated with wetlands. Buttonbush is the most common subcanopy species. Canopy height 12-40 m (usually 16-20), canopy cover usually 50-75 percent; ground vegetation usually very sparse and of low stature (< 0.5 m; Kahl and others 1985).
>
> Exhibits area sensitivity, avoiding forests <100 ha in area and avoiding waterways with wooded borders <30 m wide (Kahl and others 1985).

Model Description

The HSI model for prothonotary warbler includes seven variables: landform, landcover, successional age class, water, forest patch size, percentage of forest in the local (1-km radius) landscape, and snag density.

Table 112.—Relationship of landform, landcover type, and successional age class to suitability index scores for prothonotary warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.100	0.300	0.400
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.100	0.300	0.400
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.300	0.800	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.600	0.800
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.600	0.800

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 112). We directly assigned SI scores to these combinations on the basis of relative rankings of habitat associations reported by Hamel (1992) for the prothonotary warbler in the Southeast.

This species is rarely found more than 200 m from water during the breeding season, so we used a 9 × 9 pixel window (270 x 270 m) to examine whether water was close enough to each site to make it suitable (SI2). If water was present in any of the 81 pixels comprising the window, we assigned the center pixel a value of 1.000. If water was absent, we assigned the center pixel a value of zero (Table 113).

We also included forest patch size (SI3) as a variable in the HSI model because prothonotary warbler abundance is lower in small isolated fragments and thin riparian buffer strips (Table 114; Fig. 66). However, this species occupies small forest fragments within heavily forested landscapes so we included the percentage of forest in the local landscape as a variable (SI4). To capture this relationship, we fit a logistic function (Fig. 67) to data (Table 115) derived

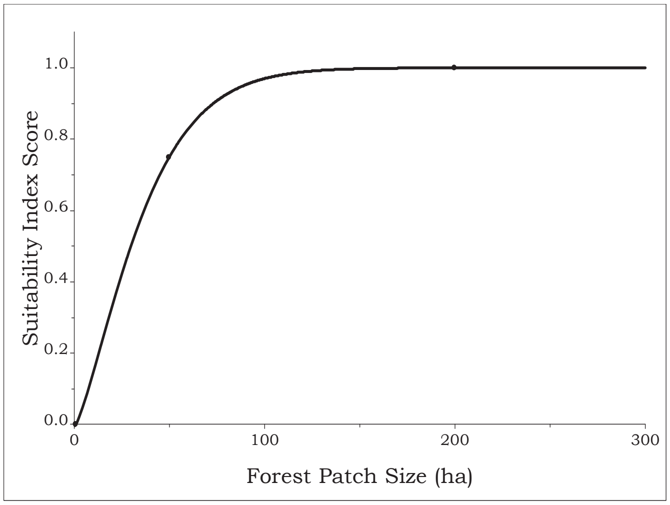


Figure 66.—Relationship between forest patch size and suitability index (SI) scores for prothonotary warbler habitat. Equation: SI score = 1.002 – 1.001 * e $^{-0.031 * (\text{forest patch size} \wedge 0.968)}$.

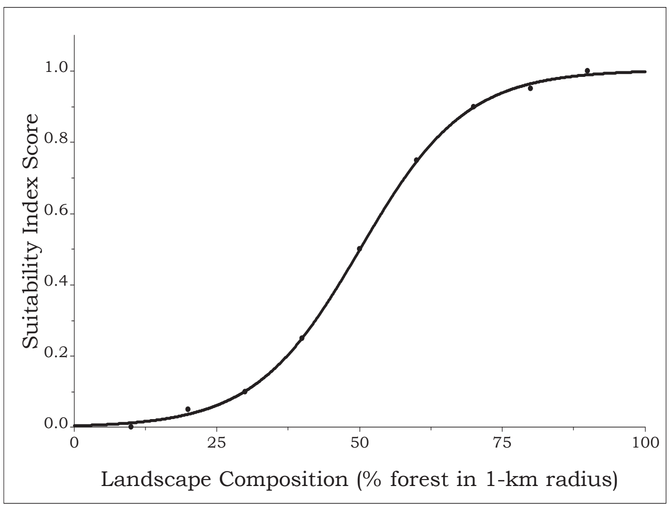


Figure 67.—Relationship between landscape composition and suitability index (SI) scores for prothonotary warbler habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 113.—Influence of occurrence of water on suitability index (SI) scores for prothonotary warbler habitat

9 × 9 pixel window contains water	SI score
Yes	1.0
No	0.0

Table 114.—Influence of forest patch size on suitability index (SI) scores for prothonotary warbler habitat

Forest patch area (ha)[a]	SI score
0	0.00
50	0.75
200	1.00
500	1.00

[a]Assumed value.

Table 115.—Relationship between local landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for prothonotary warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We applied the maximum value of SI3 or SI4 to all sites to compensate for the higher suitability of small forest blocks in predominantly forested landscapes.

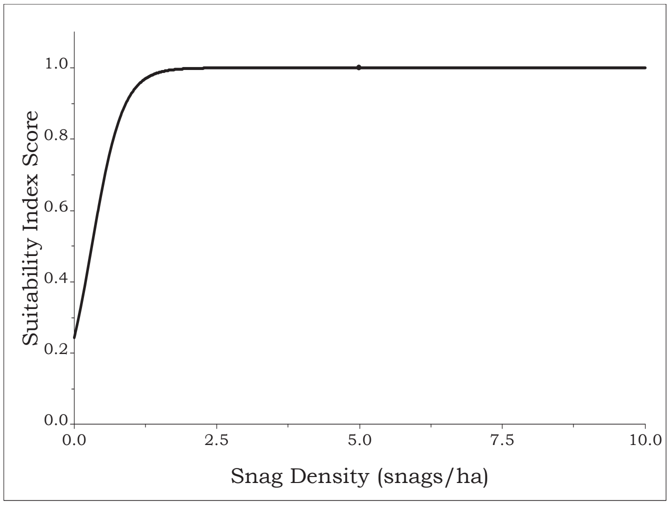


Figure 68.—Relationship between snag density and suitability index (SI) scores for prothonotary warbler habitat. Equation: SI score = 1.000 / (1 + (3.113 * e $^{-3.689 * \text{snag density}}$)).

Table 116.—Influence of snag density on suitability index (SI) scores for prothonotary warbler habitat

Snag density (snags/ha)	SI score
0[a]	0.25
5[b]	1.00
20[a]	1.00

[a]Assumed value.
[b]McComb and others (1986).

The prothonotary warbler is a cavity nester and uses snags (SI5) for nesting. McComb and others (1986) recommended 212 snags per 40 ha to satisfy the requirements of the primary cavity-nesting bird guild. We assumed that five snags per ha (Table 116) was sufficient for this bird (a secondary cavity-nesting species), but we recognized that this species also uses both cavities in live trees and crevices as nest sites. Therefore, we assigned a residual SI score (0.25) to sites lacking snags. We fit a logistic function through these points to quantify the snag density-habitat suitability relationship (Fig. 68).

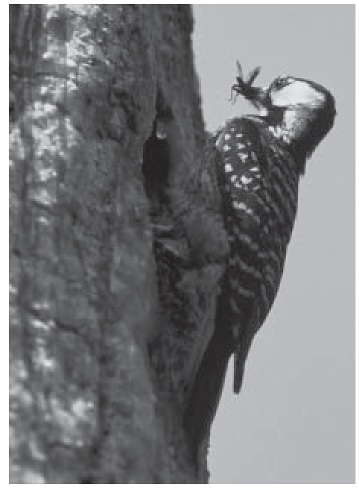
To calculate the overall HSI, we calculated the geometric mean of the two SIs related to forest structure (SI1 and SI5) and the product of the maximum of the two SIs related to landscape composition (SI3 or SI4) and SI2 separately and then the geometric mean of these values together.

Overall HSI = $((SI1 * SI5)^{0.500} * (Max(SI3 \text{ or } SI4) * SI2))^{0.500}$

Verification and Validation

The prothonotary warbler was found in 83 of the 88 subsections within the CH and WGCP. Spearman rank correlations identified significant positive associations between average HSI score and mean BBS route abundance across all subsections ($P \leq 0.001$; r_s = 0.39) and subsections within which the prothonotary warbler were detected ($P \leq 0.001$; r_s = 0.41). The generalized linear model predicting BBS abundance from BCR and HSI for the prothonotary warbler was significant ($P \leq 0.001$; $R^2 = 0.249$), and the coefficient on the HSI predictor variable was both positive (β = 2.271) and significantly different from zero (P = 0.002). Therefore, we considered the HSI model for the prothonotary warbler both verified and validated (Tirpak and others 2009a).

Red-cockaded Woodpecker



John and Karen Hollingsworth, U.S. Fish & Wildlife Service

Status

The red-cockaded woodpecker (*Picoides borealis*) is a federally endangered, nonmigratory resident of old-growth pine forest (particularly longleaf pine) throughout the Southeast (Jackson 1994). Due to the low detection rate for this species (0.05 bird/ route in the WGCP), BBS data poorly estimates population trends (Table 5). The red-cockaded woodpecker is designated as a species warranting critical recovery in both the WGCP and CH (regional combined score = 21), though it is extirpated from the latter region.

Natural History

Due to the limited availability of suitable habitat, the red-cockaded woodpecker lives in loose family groups and engages in cooperative breeding (Jackson 1994). Home ranges are large (average = 76.1 ha) but highly variable (17.2 to 159.5 ha; reviewed in Doster and James 1998).

Suitable habitat is defined by two primary habitat components. The first is the presence of large pines. Pines at least 35 cm d.b.h. generally are required for a stand to be occupied by the red-cockaded woodpecker (Davenport and others 2000, James and others 2001, Walters and others 2002). However, once large pine density exceeds 80 per ha, family group size (a demographic parameter related to productivity; Heppell and others 1994) declines (Walters and others 2002). Similarly, as the average d.b.h. of overstory pines increases above 35 cm, habitat quality declines (Davenport and others 2000), though these declines likely are linked to the maturation of the forests rather than to the negative effects of large trees directly. Similar patterns have been observed for overstory pine basal area and small pine tree density in occupied stands, where values for these habitat attributes are lower than local maxima (James and others 2001, Rudolph and others 2002, Walters and others 2002).

Open midstory is the second notable feature of high-quality habitat for the red-cockaded woodpecker. Hardwood midstory trees should be less than 3.26 m tall and ideally less than 1.8 m (Davenport and others 2002, Walters and others 2002). The open midstory typically is maintained through periodic fire (burn interval of 1 to 3 years), which also facilitates a wiregrass understory (James and others 2001). Because this species is nonmigratory and suitable habitat is disjunct, connectivity of patches is critical for the long-term persistence of this species across the landscape.

Model Description

The HSI model for the red-cockaded woodpecker includes eight variables: landform, landcover, successional age class, forest patch size, pine basal area, hardwood basal area, connectivity, and large pine (> 35 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 117).

Table 117.—Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.200	0.600	0.800
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.200	0.600	0.800
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.200	0.600 (0.700)	0.800 (1.000)
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

We directly assigned SI scores to these combinations on the basis of relative rankings of vegetation types and successional age classes for red-cockaded woodpeckers reported by Hamel (1992).

We included forest patch size (SI2) as a variable because of the large home ranges of the red-cockaded woodpecker. We assumed that the minimum and maximum home range sizes reported by Doster and James (1998) represented patch size thresholds for nonsuitable and optimal habitat, respectively. To inform the shape of the curve between these points, we assumed that the minimum area requirement of habitat identified in the red-cockaded woodpecker recovery plan (USDI Fish and Wildl. Serv. 2003) defined average (SI score = 0.500) habitat suitability. We used these data (Table 118) to define a logarithmic function to predict SI scores from forest patch size (Fig. 69).

Pine basal area (SI3) is a key component of red-cockaded woodpecker habitat, and sites with pine basal areas that are too low or too high are of poor quality. We fit a quadratic function (Fig. 70) to data from Conner and others (1995) and Walters and others (2002; Table 119) on the relative abundance of this species in habitats with varying levels of pine basal area.

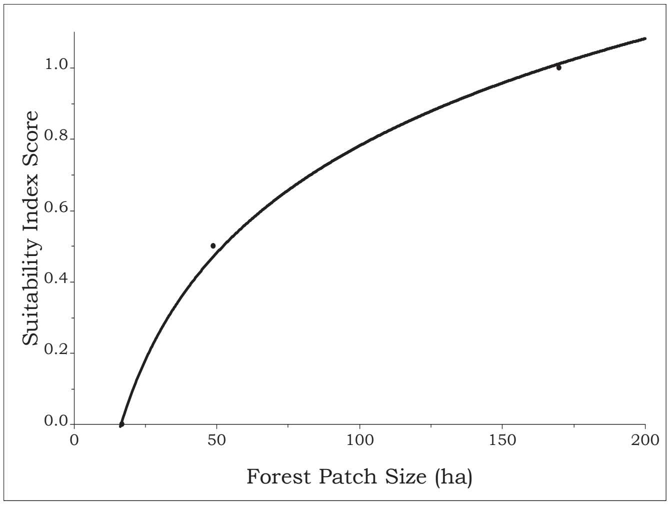


Figure 69.—Relationship between forest patch size and suitability index (SI) scores for red-cockaded woodpecker habitat. Equation: SI score = 0.4334 * ln(forest patch size) – 1.2133.

Table 118.—Relationship between forest patch size and suitability index (SI) scores for red-cockaded woodpecker habitat

Forest patch size (ha)	SI score
17[a]	0.0
49[b]	0.5
170[a]	1.0

[a]Doster and James (1998).

[b]USDI Fish and Wildl. Serv. (2003).

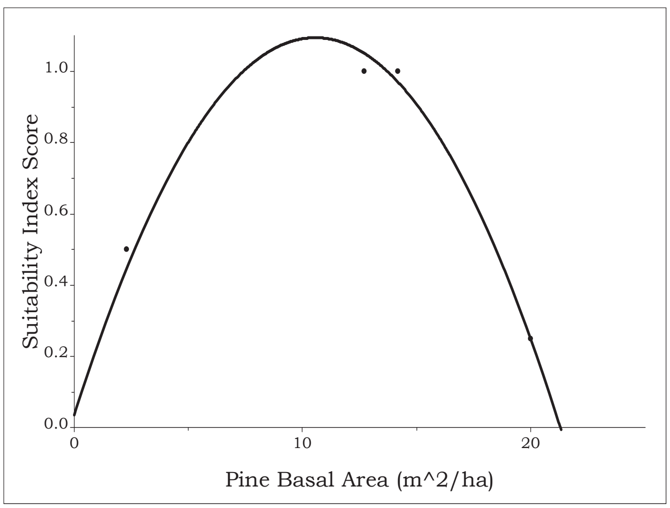


Figure 70.—Relationship between pine basal area and suitability index (SI) scores for red-cockaded woodpecker habitat. Equation: SI score = 0.0367 + 0.2006 * (pine basal area) – 0.009507 * (pine basal area)^2.

Table 119.—Relationship between basal area of pines and suitability index (SI) scores for red-cockaded woodpecker habitat

Pine basal area (m^2/ha)	SI score
0.0[a]	0.00
2.3[b]	0.50
12.7[c]	1.00
14.2[c]	1.00
20.0[a]	0.25

[a]Assumed value.

[b]Walters and others (2000).

[c]Conner and others (1995).

Mid- and overstory hardwoods reduce habitat suitability for red-cockaded woodpeckers. We fit an inverse logistic function (Fig. 71) to data from Kelly and others (1993) and Wilson and others (1995) (Table 120) on the amount of hardwood basal area (SI4) around woodpecker nest cavities to predict habitat suitability based on this habitat feature.

As a resident species occupying disjunct habitat patches, the red-cockaded woodpecker exists in metapopulations. Therefore, dispersal between suitable forest patches is critical for the persistence of this species on the landscape. Isolated patches lacking a breeding female have no productivity, so we used the median dispersal distance for females (3.2 km; Jackson

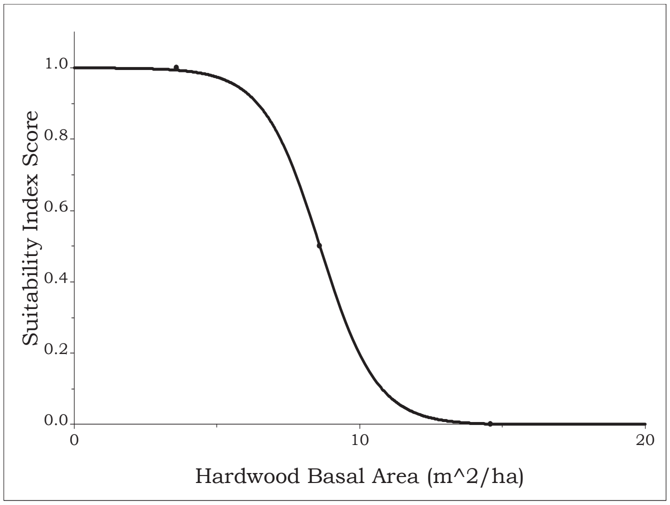


Figure 71.—Relationship between hardwood basal area and suitability index (SI) scores for red-cockaded woodpecker habitat. Equation: SI score = $1 - (1.001 / (1 + (5745.304 * e^{-1.006 * \text{hardwood basal area}})))$.

Table 120.—Relationship between basal area of hardwoods (m^2/ha) and suitability index (SI) scores for red-cockaded woodpecker habitat

Hardwood basal area (m^2/ha)	SI score
0.0[a]	1.0
3.9[b]	1.0
8.6[c]	0.5
14.6[c]	0.0
20.0[a]	0.0

[a]Assumed value.
[b]Wison and others (1995).
[c]Kelly and others (1993).

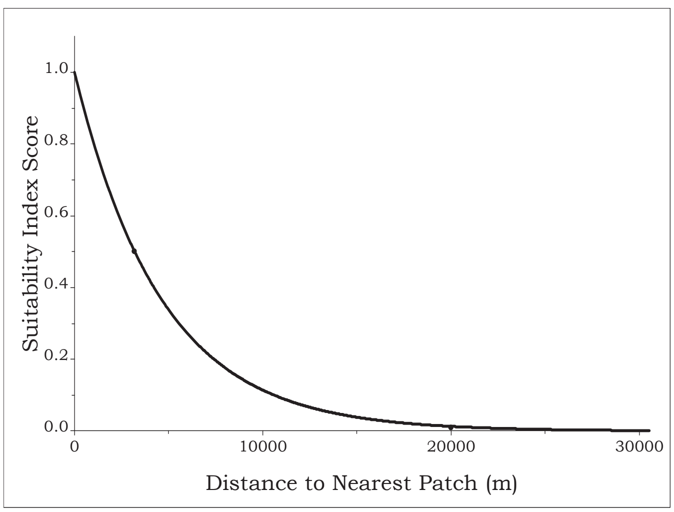


Figure 72.—Relationship between habitat connectivity and suitability index (SI) scores for red-cockaded woodpecker habitat. Equations: SI score = $e^{-0.0002 * \text{distance to nearest habitat patch}}$.

Table 121.—Relationship between distance to nearest habitat patch and suitability index (SI) scores for red-cockaded woodpecker habitat

Distance to nearest habitat patch (m)	SI score
0[a]	1.00
3,200[b]	0.50
20,000[a]	0.01

[a]Assumed value.
[b]Jackson (1994).

1994) to define average SI score (0.500). However, long-distance dispersal does occur (Larry Hedrick, 2006, U.S. Forest Service, pers. commun.), so we assigned to patches isolated more than 20 km from any other suitable site at least some residual suitability (0.010). We fit an exponential relationship (Fig. 72) through these data points (Table 121) to describe how the connectivity of patches influences habitat suitability.

Large pines (SI6) are a necessary component of red-cockaded woodpecker habitat because this bird disproportionately forages and nests in large pines. However, there is a threshold above which habitat suitability declines and increasingly large trees reduce the preferred open

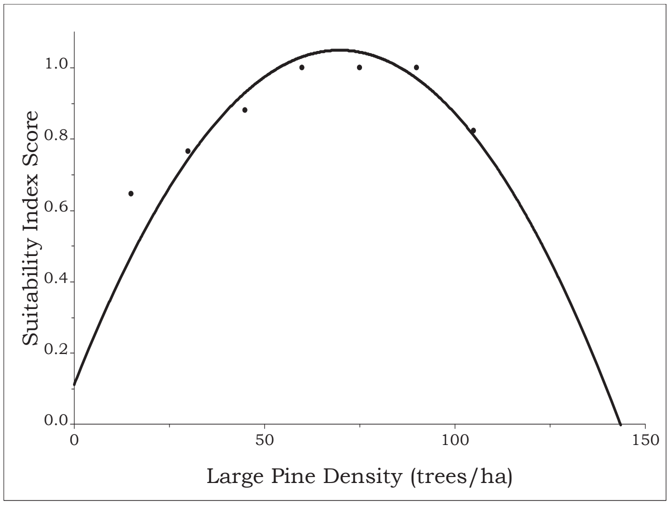


Figure 73.—Relationship between large pine tree (> 35 cm d.b.h.) density and suitability index (SI) scores for red-cockaded woodpecker habitat. Equation: SI score = 0.0269 * (pine tree density) – 0.000193 * (pine tree density)^2 + 0.1127.

Table 122.—Relationship between large pine (> 35 cm d.b.h.) density (trees/ha) and suitability index (SI) scores for red-cockaded woodpecker habitat

Large pine density	SI score
0[a]	0.000
15[b]	0.647
30[b]	0.765
45[b]	0.882
60[b]	1.000
75[b]	1.000
90[b]	1.000
105[b]	0.824

[a]Assumed value.
[b]Walters and others (2002).

character of the forest. We fit a quadratic function (Fig. 73) to data from Walters and others (2002), who identified this threshold at 60 to 90 large pines per ha (Table 122).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1, SI3, SI4, and SI6) and landscape composition (SI2 and SI5) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI3 * SI4 * SI6)^{0.250} * (SI2 * SI5)^{0.500})^{0.500}$

Verification and Validation

The red-cockaded woodpecker was found in only 10 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.49$) between average HSI score and mean BBS route abundance across all subsections. However, when subsections where the red-cockaded woodpecker was not found were removed from the analysis, the relationship was not significant ($P = 0.645$; $r_s = 0.17$). Thus, the HSI model predicts the absence of the red-cockaded woodpecker better than its abundance in subsections where it is found. The generalized linear model predicting BBS abundance from BCR and HSI for the red-cockaded woodpecker was significant ($P \leq 0.001$; $R^2 = 0.203$), and the coefficient on the HSI predictor variable was both positive (β = 0.094) and significantly different from zero ($P = 0.042$). Therefore, we considered the HSI model for the red-cockaded woodpecker both verified and validated (Tirpak and others 2009a).

Red-headed Woodpecker

Dave Menke, U.S. Fish & Wildlife Service

Status

The red-headed woodpecker (*Melanerpes erythrocephalus*) is found throughout North America east of the Rocky Mountains; however, it is absent from New England and the higher elevations of the central and southern Appalachians. Since 1967, populations have declined by 3.2 percent per year in the WGCP and by 1 percent in the CH (Sauer and others 2005) (Table 5). This species is a Bird of Conservation Concern and a management attention priority in both the CH and WGCP (regional combined score = 16 and 17, respectively; Table 1).

Natural History

The red-headed woodpecker is one of the most recognizable birds of the eastern United States and southern Canada, but few in-depth studies of this species have been conducted (Smith and others 2000). Nesting habitat consists of deciduous woodlands, including upland and bottomland hardwoods, riparian strips, open woods, open wooded swamps, groves of dead and dying trees, orchards, shelterbelts, parks, open agricultural lands, savannas, forest edges, roadsides, and utility poles (Smith and others 2000). It prefers xeric sites with large, tall trees, high basal area, and a sparse understory.

The red-headed woodpecker exhibits seasonal shifts in habitat use. Population dynamics are linked to annual fluctuations in oak acorn crops, and migration occurs in northern and western populations when hard mast is limited (Rodewald 2003). More locally, winter territories are established around small food caches within forest interiors; breeding territories are larger (3.1 to 8.5 ha in Florida) and concentrated along edges (Smith and others 2000).

Occurrence of the red-headed woodpecker varies with mean patch dimension, edge density of agricultural land, and the area of urban landcover (Lukomski 2003). It is a primary cavity excavator and snag availability may drive habitat selection (Giese and Cuthbert 2003). This species often is associated with high snag densities (Conner and others 1994) in mature stands near openings (Conner and Adkisson 1977, Brawn and others 1984). Snag density and basal area of dead elm distinguish nest sites from random sites in Minnesota (Giese and Cuthbert 2003). Similarly, loblolly pine stands with both standing and down dead woody debris removed contain fewer birds (Lohr and others 2002). Snags retained as groups provide multiple snags for roosting and foraging. Hardwood snags are used predominantly for foraging, whereas pine snags are more commonly used for nesting (Smith and others 2000). Thinnings and prescribed fires that open the understory and create snags are beneficial.

Model Description

The HSI model for the red-headed woodpecker includes seven variables: landform, landcover, successional age class, snag density, large snag (> 20 cm d.b.h.) density, sawtimber tree (> 28 cm d.b.h.) density, and the occurrence of edge.

Table 123.—Relationship of landform, landcover type, and successional age class to suitability index scores for red-headed woodpecker habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.125	0.250	0.250
	Transitional-shrubland	0.000	0.000	0.125	0.250	0.250
	Deciduous	0.000	0.000	0.125	0.250	0.250
	Evergreen	0.000	0.000	0.250	0.500	0.500
	Mixed	0.000	0.000	0.250	0.500	0.500
	Orchard-vineyard	0.000	0.000	0.125	0.250	0.250
	Woody wetlands	0.000	0.000	0.250	0.625	0.750
Terrace-mesic	Low-density residential	0.000	0.000	0.125	0.375	0.500
	Transitional-shrubland	0.000	0.000	0.250	0.500	0.500
	Deciduous	0.000	0.000	0.125	0.375	0.500
	Evergreen	0.000	0.000	0.250	0.500	0.500
	Mixed	0.000	0.000	0.250	0.500	0.500
	Orchard-vineyard	0.000	0.000	0.125	0.375	0.500
	Woody wetlands	0.000	0.000	0.250	0.500	0.500
Xeric-ridge	Low-density residential	0.000	0.000	0.250	0.750	1.000
	Transitional-shrubland	0.000	0.000	0.250	0.500 (0.750)	0.500 (1.000)
	Deciduous	0.000	0.000	0.250	0.750	1.000
	Evergreen	0.000	0.000	0.250	0.500 (0.750)	0.500 (1.000)
	Mixed	0.000	0.000	0.250	0.500	0.500
	Orchard-vineyard	0.000	0.000	0.250	0.750	1.000
	Woody wetlands	0.000	0.000	0.250	0.750	1.000

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 123). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the relative value of various vegetation types and successional age classes as red-headed woodpecker habitat in the Southeast.

This species relies heavily on snags for nesting, foraging, and roosting. King and others (2007) observed 31.8 snags per ha in savanna habitat used by the red-headed woodpecker, though basal area was only 0.9 m^2 per ha in that study. Therefore, we adjusted snag densities to reflect the intermediate basal area values (12 to 15 m^2/ha; Heltzel and Leberg 2006) characteristic of stands used by the red-headed woodpecker in the WGCP and CH BCRs. We assumed that 500 snags per ha represented an upper threshold above which maximal suitability was achieved and that 200 snags per ha represented a threshold below which sites were unsuitable (Table 124). We fit a logistic function (Fig. 74) through these data to predict how habitat suitability varied with snag density (SI2). Because the snag density in SI2 includes all dead trees greater than 2.5 cm d.b.h., we also included large snag (> 20 cm d.b.h.) density (SI3) as a variable. This additional requirement ensured the presence of snags suitable for nesting

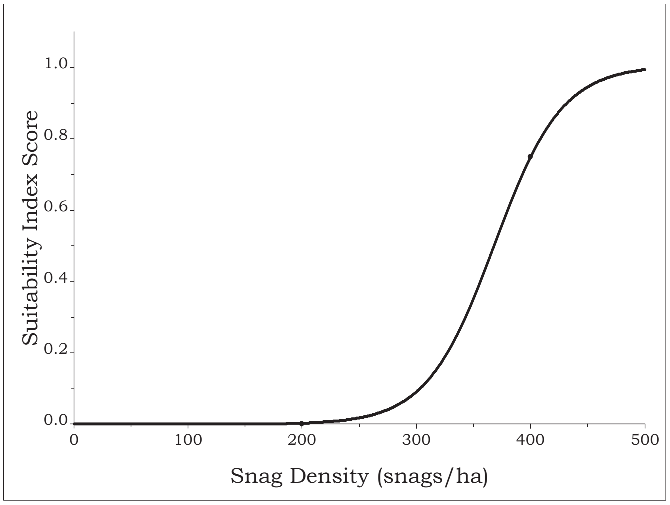


Figure 74.—Relationship between snag density (snags * 100/ha) and suitability index (SI) scores for red-headed woodpecker habitat. Equation: SI score = 1.006 / (1 + (249051.2 * e $^{(-0.0338 * \text{snag density})}$)).

Table 124.—Influence of snag density on suitability index (SI) scores for red-headed woodpecker habitat

Snag density (snags/ha)[a]	SI score
0	0.00
200	0.00
400	0.75
500	1.00

[a]Assumed value.

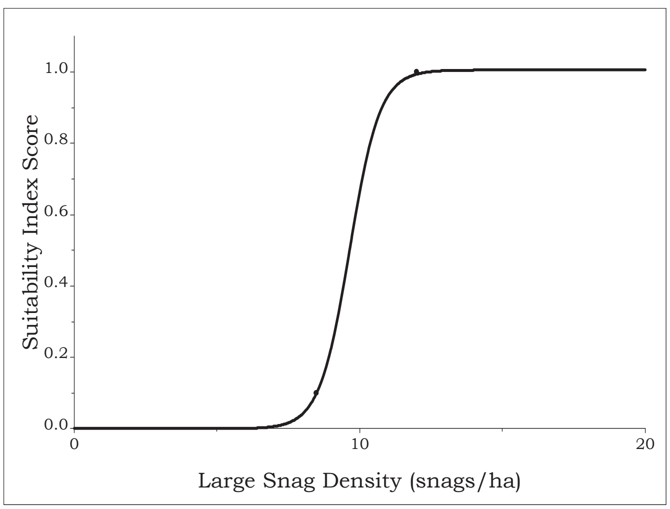


Figure 75.—Relationship between large snag (> 20 cm d.b.h.) density and suitability index (SI) scores for red-headed woodpecker habitat. Equation: SI score = 1.006 / (1 + (90614077 * e $^{(-1.899 * \text{large snag density})}$)).

Table 125.—Influence of large snag (> 20 cm d.b.h.) density (snags/ha) on suitability index (SI) scores for red-headed woodpecker habitat

Large snag density	SI score
0.0[a]	0.0
8.5[b]	0.1
12.0[a]	1.0

[a]Assumed value.
[b]Lohr and others (2002).

in high-quality habitats. We relied on data from Lohr and others (2002) to inform an inverse logistic function (Fig. 75) that linked habitat suitability to large snag density (Table 125).

The red-headed woodpecker breeds in relatively open habitats with widely spaced large trees near openings (King and others 2007). Therefore, we included sawtimber tree density (SI4) and edge occurrence (SI5) as variables. We assumed that habitat suitability was highest when sawtimber tree density was 20 or fewer trees per ha and lowest when sawtimber tree density exceeded 50 trees per ha (Table 126). We fit a logistic function (Fig. 76) through these data points to quantify the relationship between sawtimber tree density and SI scores. To identify edges, we used a 7 × 7 pixel moving window (210 x 210 m) to locate the transitions between

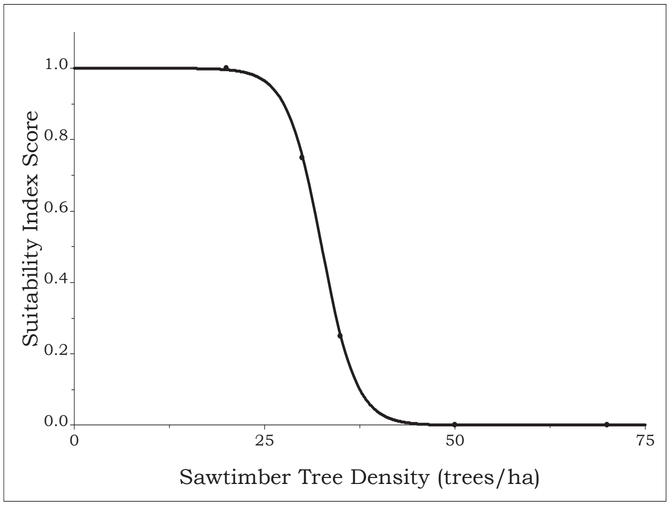


Figure 76.—Relationship between sawtimber tree (≥ 28 cm d.b.h.) density (trees * 10/ha) and suitability index (SI) scores for red-headed woodpecker habitat. Equation: SI score =1 – (1.000 / (1 + (1615169 * $e^{(-0.4398 * \text{sawtimber tree density})}$))).

Table 126.—Influence of sawtimber tree (> 28 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for red-headed woodpecker habitat

Sawtimber tree density[a]	SI score
0	1.00
20	1.00
30	0.75
35	0.25
50	0.00
70	0.00

[a]Assumed value.

Table 127.—Influence of edge on suitability index (SI) scores for red-headed woodpecker habitat

7 × 7 window around forest pixel includes field[a]	SI score
Yes	1.0
No	0.1

[a]Field defined as any shrub-seedling or grass-forb age class pixel, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any used sapling, pole, or sawtimber age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands.

forest and non-forest landcovers or sapling-pole-sawtimber and grass-forb-shrub-seedling successional age class stands. We assigned to edge habitats the maximal SI score and discounted areas with no edge (Table 127).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1, SI2, SI3, and SI4) and multiplied this product by the SI score for edge occurrence (SI5).

Overall HSI = $((SI1 * SI2 * SI3 * SI4)^{0.250}) * SI5$

Verification and Validation

The red-headed woodpecker was found in all 88 subsections of the CH and WGCP. Spearman rank correlation failed to identify a positive association between average HSI score and mean BBS abundance. The generalized linear model predicting BBS abundance from BCR and HSI for the red-headed woodpecker was significant ($P \leq 0.001$; $R^2 = 0.225$); however, the coefficient on the HSI predictor variable was negative (β = -3.359). Therefore, we considered the HSI model for the red-headed woodpecker neither verified nor validated (Tirpak and others 2009a).

Swainson's Warbler

Status

The Swainson's warbler (*Limnothlypis swainsonii*) is a neotropical migrant that breeds in dense thickets across the Southeast. Due to its overall low density and occurrence in habitats not well sampled by BBS, estimates of population trends based on this dataset are not reliable (Sauer and others 2005) (Table 5). Nonetheless, this species is a Bird of Conservation Concern and has a regional combined score of 20 in both the CH and WGCP (Table 1). An estimated 46 percent of the continental population of the Swainson's warbler breeds in the WGCP (Panjabi and others 2001).

Chandler S. Robbins,
Patuxent Bird Identification InfoCenter
Photo used with permission

Natural History

The Swainson's warbler is distributed locally across the Southeast (Brown and Dickson 1994). Once believed to be restricted to canebrakes in bottomland hardwood and swamp forests of the Atlantic and Gulf Coastal Plains, it now has been documented breeding at low densities in regenerating clearcuts in Texas and rhododendron-mountain laurel thickets in the southern Appalachians (Graves 2002). Territory size is large for a wood warbler (3.2 ha) (Brown and Dickson 1994), and this species demonstrates area sensitivity. In Illinois, the Swainson's warbler is not observed on tracts smaller than 350 ha (Eddleman and others 1980).

This species does not use canopy height, basal area, successional age class, or species composition as habitat cues (Eddleman and others 1980, Graves 2002), but selects habitat based on understory characteristics. Dense thickets are required, and stem densities of about 35,000 stems per ha are optimal (Graves 2002). Canopy gaps are important for encouraging this dense growth, and canopy cover typically is high (70 to 80 percent) but rarely closed (> 90 percent) (Eddleman and others 1980, Graves 2001, Somershoe and others 2003). Understory vegetation is primarily woody; herbaceous cover is typically sparse (< 25 percent) (Eddleman and others 1980, Brown and Dickson 1994). Leaf litter is abundant and provides an important foraging substrate (Graves 2001, Somershoe and others 2003).

Hydrology is a critical factor influencing the habitat suitability for this warbler. In bottomland and floodplain habitats, birds select areas that typically are drier than surrounding sites (Graves 2001, Somershoe and others 2003). Inundation of otherwise suitable habitat from March - September negatively affects the quality of an otherwise suitable site (Graves 2002). This species occasionally breeds in xeric uplands with appropriate understory characteristics (Carrie 1996).

Model Description

The HSI model for the Swainson's warbler includes six variables: landform, landcover, successional age class, forest patch size, proportion of forest in a 1-km radius, and small stem (< 2.5 cm d.b.h.) density.

Table 128.—Relationship of landform, landcover type, and successional age class to suitability index scores for Swainson's warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.400	0.000	0.000
	Deciduous	0.000	0.000	0.400	0.900	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.400	0.900	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.200	0.000	0.000
	Deciduous	0.000	0.000	0.200	0.500	0.600
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.400	0.800	0.800
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.200	0.000	0.000
	Deciduous	0.000	0.000	0.200	0.500	0.600
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.400	0.800	0.800

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 128). We adjusted the relative habitat quality rankings of Hamel (1992) for Swainson's warbler vegetation and successional age class associations to maximize habitat suitability in woody wetland habitats along floodplains, and to ensure that transitional sapling stands that may be used in the WGCP were assigned SI scores (Carrie 1996).

We included forest patch size (SI2) in the model because of the preference of the Swainson's warbler for interior sites within large forest tracts. We assumed that the minimum patch size in which Eddleman and others (1980) observed this species (350 ha) represented optimal habitat. Because this study was at the northern limit of the range of the Swainson's warbler, we assumed that birds would occupy significantly smaller tracts (Table 129). We based a logistic function on these assumptions to predict the impact of forest patch size on habitat suitability (Fig. 77). Nevertheless, the suitability of a specific patch size also is influenced by its landscape context (SI3). In predominantly forested landscapes, small forest patches that otherwise may not be suitable may be occupied due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 78) to data (Table 130) derived from Donovan and others (1997), who observed differences

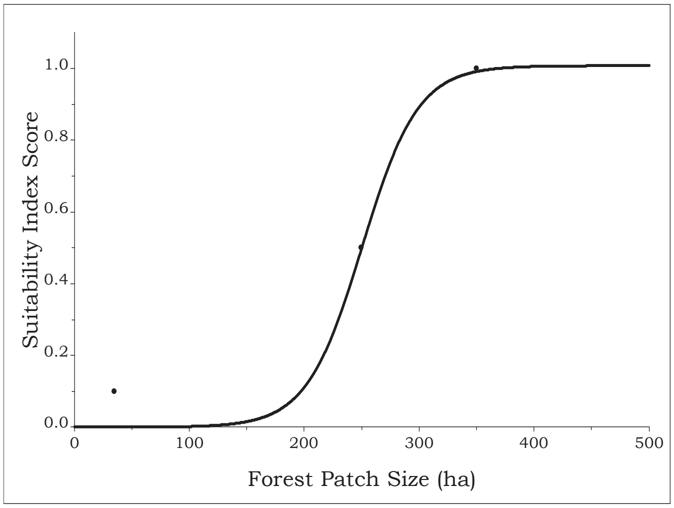


Figure 77.— Relationship between forest patch size and suitability index (SI) scores for Swainson's warbler habitat. Equation: SI score = (1.001 / (1 + (31096.960 * e $^{-0.041 * (\text{forest patch size})}$))).

Table 129.—Influence of forest patch size on suitability index (SI) score for Swainson's warbler habitat

Forest patch size (ha)	SI score
0[a]	0.00
35[a]	0.01
250[a]	0.50
350[b]	1.00
500[a]	1.00

[a]Assumed value.
[b]Eddleman and others (1980).

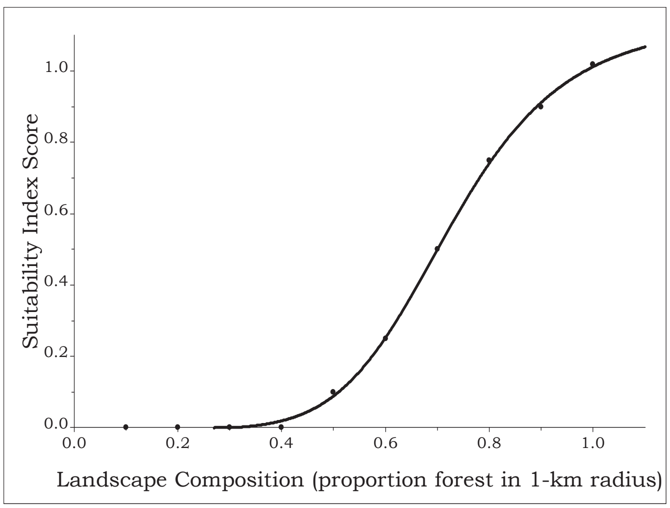


Figure 78.—Relationship between landscape composition and suitability index (SI) scores for Swainson's warbler habitat. Equation: SI score = 1.047 / (1.000 + (1991.516 * e $^{-10.673 * \text{landscape composition}}$)).

Table 130.—Relationship between landscape composition (proportion forest in 1-km radius) and suitability index (SI) scores for Swainson's warbler habitat

Landscape composition	SI score
0.00[a]	0.00
0.10[a]	0.00
0.20[a]	0.00
0.30[a]	0.00
0.40[a]	0.00
0.50[a]	0.10
0.60[a]	0.25
0.70[b]	0.50
0.80[a]	0.75
0.90[a]	0.90
1.00[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoint between moderately and lightly fragmented forest defined the specific cutoff for average (SI score = 0.500) habitat. We used the maximum score from SI2 or SI3 to account for the higher suitability of small patches in predominantly forested landscapes relative to their size alone.

The Swainson's warbler breeds in dense thickets and stem densities of approximately 35,000 stems per ha are optimal (SI score = 1.000) (Graves 2002). Stem densities can be even higher in early-successional bottomland hardwoods (> 200,000/ha), but we assumed habitat

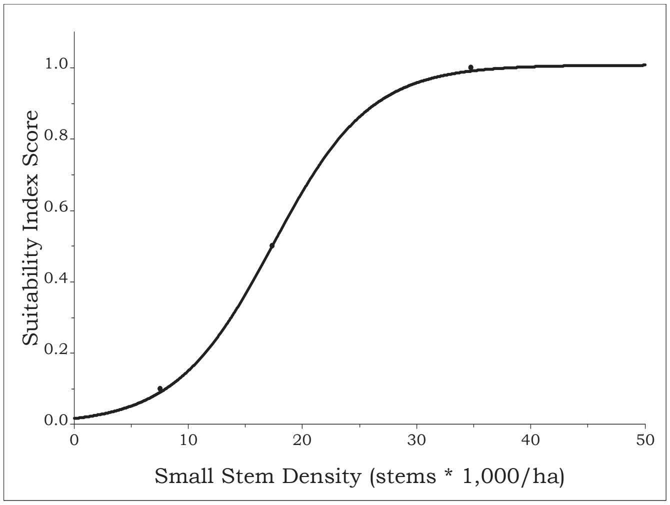


Figure 79.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for Swainson's warbler habitat. Equation: SI score = 1.008 / (1.000 + (59.233 * $e^{-0.235 * (\text{small stem density} / 1000)}$)).

Table 131.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for Swainson's warbler habitat

Small stem density	SI score
0.000[a]	0.0
7.550[b]	0.1
17.365[b]	0.5
34.773[b]	1.0
72.999[b]	1.0

[a]Assumed value.
[b]Graves (2002).

suitability was not negatively affected by stem density. Therefore, we fit a logistic function (Fig. 79) to data from Graves (2002) that captured the effect of varying stem density on habitat suitability (Table 131).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI4) and multiplied that by the maximum SI score for forest patch size (SI2) or percent forest in the 1-km landscape (SI3) and finally calculated the geometric mean of that product.

Overall HSI = $((\text{SI1} * \text{SI4})^{0.500} * \text{Max}(\text{SI2 or SI3}))^{0.500}$

Verification and Validation

The Swainson's warbler was found only in 31 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.010$) positive relationship ($r_s = 0.31$) between average HSI score and mean BBS route abundance across all subsections. However, when subsections where this species was not found were removed from the analysis, the relationship was not significant ($P = 0.893$; $r_s = -0.03$). Thus, the HSI model better predicts the absence of the Swainson's warbler than its abundance in subsections where this species is found. The generalized linear model predicting BBS abundance from BCR and HSI for the Swainson's warbler was significant ($P \leq 0.001$; $R^2 = 0.260$); however, the coefficient on the HSI predictor variable was negative ($\beta = -0.298$). Therefore, we considered the HSI model for the Swainson's warbler verified but not validated (Tirpak and others 2009a).

Swallow-tailed Kite

D.A. Rintoul, Patuxent Bird Identification InfoCenter
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Status

The swallow-tailed kite (*Elanoides forficatus*) is a neotropical raptor that reaches the northern limit of its distribution in the Unites States. Once ranging throughout the Mississippi River drainage as far north as Minnesota, this species now is restricted to seven states in the Southeast. There are too few swallow-tailed kites detected on BBS routes in the WGCP to estimate a population trend; however, this species is a Bird of Conservation Concern and immediate management attention priority in this BCR (regional combined score = 18; Table 1). The swallow-tailed kite no longer breeds in the CH and this species warrants critical recovery efforts in this region (regional combined score = 19).

Natural History

The swallow-tailed kite is a rare breeder in the continental United States. The current restriction of this species to seven southern states (with limited distributions in all but Florida) represents a significant contraction of its former range. Most of the information on this bird in the United States is from Florida (Meyer 1995).

The swallow-tailed kite has a large home range (500 to 1800 ha) that increases substantially (> 20,000 ha) when the long but regular foraging forays characteristic of this species are included. With such a large home range, the important role of landscape structure on habitat suitability is not surprising. Critical habitat elements are large, tall trees for nesting and open habitats containing prey (Meyer 1995, Sykes and others 1999). Any interspersion of these features is useable (e.g., trees adjacent to prairie, wetlands, or marsh). Landscapes containing bottomland hardwood forest interspersed with scattered openings are particularly attractive. The edges of pine forests along swamps and riparian zones also are commonly used along the Coastal Plains. The Mississippi kite typically occupies habitats that are drier and contain more contiguous forest than the habitats of the swallow-tailed kite.

Model Description

The HSI model for the swallow-tailed kite includes six variables: landform, landcover, successional age class, forest patch size, landscape composition, and dominant tree density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 132). We then directly assigned SI scores to these combinations on the basis of relative habitat quality rankings from Hamel (1992) for the swallow-tailed kite. However, we assumed that only stands in the sawtimber successional age class provided suitable habitat for this species

We also included forest patch size (SI2) as a variable because of this bird's large home range and association with large blocks of forested wetlands. We fit a logarithmic function (Fig. 80)

Table 132.—Relationship of landform, landcover type, and successional age class to SI scores for swallow-tailed kite habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.500
	Mixed	0.000	0.000	0.000	0.000	0.500
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.800
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.800

to data (Table 133) from Zimmerman (2004) on the mean value of forest in 5-km buffers around swallow-tailed kite nest sites and the maximum home range size reported by Cely and Sorrow (1990) to assess the impact of forest patch size on habitat suitability scores for the swallow-tailed kite.

Like the Mississippi kite, the swallow-tailed kite forages aerially in open habitats, so it requires both forested sites for nesting and open areas for foraging (SI3). We based the ideal composition of vegetation types in the landscape on data from Sykes and others (1999), who observed 20 percent open habitat within 200-ha core areas in Florida. We maximized habitat suitability at this threshold and reduced SI scores in landscapes containing greater or lower proportions of open habitat (Table 134, Fig. 81).

The swallow-tailed kite nests in dominant trees (SI4) that extend above the canopy. We assumed that trees with a d.b.h. greater than 76.2 cm would extend above the canopy in the sawtimber stands that provide the exclusive habitat for this species. We assumed that one dominant tree per ha would satisfy this requirement and that the swallow-tailed kite would be absent from stands with a uniform canopy (zero dominant trees/ha). We fit an exponential function (Fig. 82) to the values between these data points and assumed that

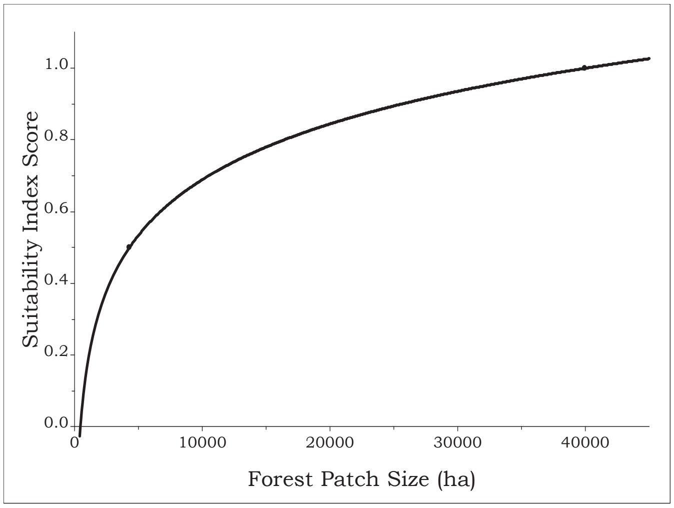

Figure 80.—Relationship between forest patch size and suitability index (SI) scores for swallow-tailed kite habitat. Equation: SI score = 0.224 * ln(forest patch size) – 1.376.

Table 133.—Influence of forest patch size on suitability index (SI) scores for swallow-tailed kite habitat

Forest patch size (ha)	SI score
4,300[a]	0.5
40,000[b]	1.0

[a]Zimmerman (2004).
[b]Cely and Sorrow (1990).

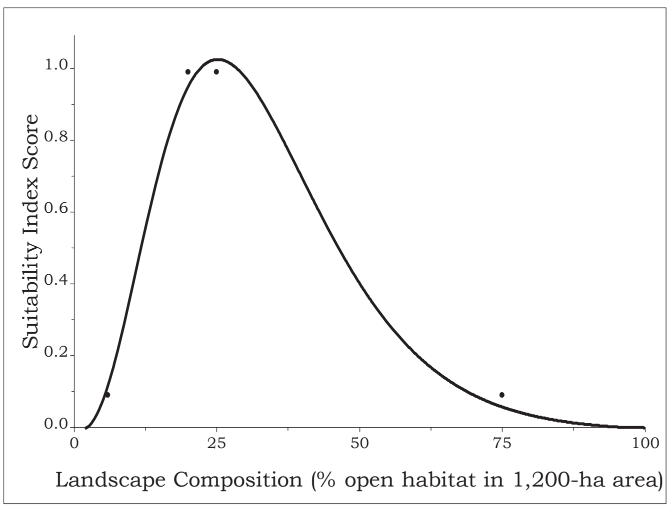

Figure 81.—Relationship between landscape composition and suitability index (SI) scores for swallow-tailed kite habitat. Equation: SI score = $(0.001 * 0.885^{(\text{percent open habitat})}) * (\text{percent open habitat})^{3.065}$.

Table 134.—Suitability index scores for swallow-tailed kite habitat based on landscape composition (percent of open habitat) within 1,200-ha landscape

Landscape composition[a]	SI score
6[b]	0.1
20[c]	1.0
25[b]	1.0
75[b]	0.1

[a]Water, grasslands, cultivated lands, and emergent wetlands.
[b]Assumed value.
[c]Sykes and others (1999).

stands with 14 dominant trees per ha (the maximum value from the WGCP during the FIA surveys of the 1990s) were associated with maximum habitat suitability (Table 135).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI4) and landscape composition (SI2 and SI3) separately and then the geometric mean of these means together.

$$\text{Overall HSI} = ((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$$

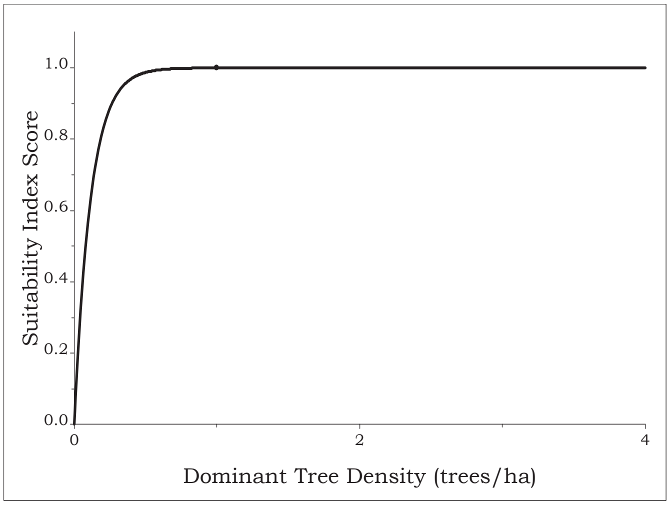

Figure 82.—Relationship between dominant tree density and (SI) scores for swallow-tailed kite habitat. Equation: SI score = $1 - e^{-8.734 * \text{dominant tree density}}$.

Table 135.—Influence of dominant tree (> 76.2 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for swallow-tailed kite habitat

Dominant tree density[a]	SI score
0	0.0
1	1.0
14	1.0

[a]Assumed value.

Verification and Validation

The swallow-tailed kite was found in 8 of the 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.73$) between average HSI score and mean BBS route abundance across all subsections. However, when subsections where this species was not found were removed from the analysis, the relationship was not significant ($P = 0.432$; $r_s = 0.33$). Thus, the HSI model better predicts the absence of the swallow-tailed kite than its abundance in subsections where this species is found. The generalized linear model predicting BBS abundance from BCR and HSI for the swallow-tailed kite was significant ($P \leq 0.001$; $R^2 = 0.522$), and the coefficient on the HSI predictor variable was both positive ($\beta = 0.725$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the swallow-tailed kite both verified and validated (Tirpak and others 2009a).

Whip-poor-will

Chandler S. Robbins,
Patuxent Bird Identification InfoCenter
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Status

The whip-poor-will (*Caprimulgus vociferus*) is a neotropical migrant with a more northerly range than the chuck-will's-widow, though the ranges of the two are not exclusive and overlap broadly across the CH. The whip-poor-will has declined by 1.8 percent per year since 1967 in the CH (Sauer and others 2005) (Table 5), where this species is a Bird of Conservation Concern and has a regional combined score of 17 (Table 1). A large proportion of the continental population (35.5 percent) breeds in the CH (Panjabi and others 2001). This species is a rare breeder in the WGCP (regional combined score = 13).

Natural History

Owing to its cryptic coloration and crepuscular activity pattern, the whip-poor-will is one of the least studied birds in North America (Cink 2002). Breeding habitat in the CH and WGCP consists of xeric deciduous and mixed forests with a sparse understory. This species also is associated with open areas, such as rural farmland, powerline and roadway rights-of-way, clearcuts and selectively logged forest, old fields, and reclaimed surface mines. Shaded forest stands with limited ground cover adjacent to open areas for foraging provide ideal whip-poor-will habitat. This species usually is absent from extensive areas of closed canopy forest, but there are no data on minimum or maximum thresholds for forest patch size. Small, isolated woodlots in a Maryland agricultural landscape are not used (Reese 1996, cited in Cink 2002). In Massachusetts, Grand and Cushman (2003) found that the whip-poor-will is strongly associated with complex patch shapes and high contrast edges. This species nests on the forest floor and hatching is synchronized with the full moon to optimize the foraging time of adults. Whip-poor-wills are not strongly territorial; home range varies from 2.8 to 11.1 ha.

Model Description

The HSI model for whip-poor-will includes four variables: landform, landcover, successional age class, and the relative composition of forest and open habitats in the landscape.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 136). We directly assigned SI scores to these combinations on the basis of relative habitat rankings for vegetation and successional age class associations of the whip-poor-will reported by Hamel (1992).

The whip-poor-will nests in forest and forages in openings. As a result, it requires landscapes with an interspersion (SI2) of these landcover types. We assumed that a landscape with 70 percent forest and 30 percent open habitat was optimal (Michael Wilson, 2006, College of William & Mary, pers. commun.) and that landscapes with a greater proportion of forest

Table 136.—Relationship of landform, landcover type, and successional age class to suitability index scores for whip-poor-will habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.667	0.667
	Deciduous	0.000	0.000	0.334	0.667	0.667
	Evergreen	0.000	0.000	0.334	0.667	0.667
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.333	0.333
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.334	0.667	0.667
	Evergreen	0.000	0.000	0.334	0.667	0.667
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.333	0.333
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.334	0.667	0.667
	Evergreen	0.000	0.000	0.334	0.667	0.667
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.333	0.333

were more suitable than those with less forest cover so long as some openings were present (Table 137; sensu Cooper 1981).

We calculated the overall HSI score as the geometric mean of the two component variables.

Overall HSI = $(SI1 * SI2)^{0.500}$

Verification and Validation

The whip-poor-will was found in 76 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant (P = 0.005) positive relationship (r_s = 0.30) between average HSI score and mean BBS route abundance across subsections. This relationship was even stronger (r_s = 0.47) when subsections in which the whip-poor-will was not detected were removed from the analysis. The generalized linear model predicting BBS abundance from BCR and HSI for the whip-poor-will was significant (P = 0.002; R^2 = 0.139), and the coefficient on the HSI predictor variable was positive (β = 1.270) but not significantly different from zero (P = 0.229). Therefore, we considered the HSI model for the whip-poor-will verified but not validated (Tirpak and others 2009a).

Table 137.—Suitability index scores for whip-poor-will habitat based on the relative proportion of cells providing open and forest landcover within 500-m radius

Proportion forest[b]	Proportion open[a]										
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
0.3	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10			
0.4	0.00	0.25	0.25	0.25	0.25	0.25	0.25				
0.5	0.00	0.50	0.50	0.50	0.50	0.50					
0.6	0.00	0.70	0.90	0.90	0.90						
0.7	0.00	0.80	0.90	1.00							
0.8	0.00	0.80	0.90								
0.9	0.00	0.80									
1.0	0.00										

[a]Open = pasture/hay, recreational grasses, grasslands/herbaceous, and emergent herbaceous wetland landcovers or grass-forb and shrub-seedling successional age class stands.

[b]Forest = any habitats with positive SI1 values (Table 136).

White-eyed Vireo


David Arbour, U.S. Forest Service

Status

The white-eyed vireo (*Vireo griseus*) is a neotropical migrant that breeds throughout the southeastern United States. Populations have been stable in both the CH and WGCP over the last 40 years, but have been increasing in the WGCP by 1.6 percent annually since 1980 (Sauer and others 2005; Table 5). This species requires management attention in both the CH and WGCP (regional combined score = 15 and 16, respectively) but is not a Bird of Conservation Concern in either BCR (Table 1).

Natural History

A small secretive songbird, the white-eyed vireo is associated with dense vegetation in secondary deciduous scrub-shrub, wood margins, overgrown pastures, abandoned farmlands, streamside thickets, and even mid- to late successional forests (Hopp and others 1995). This species shares habitats with the blue-gray gnatcatcher, Carolina wren, gray catbird, and brown thrasher, but prefers later successional forest than the yellow-breasted chat, prairie warbler, and Bell's vireo.

In Texas, the white-eyed vireo breeds in areas of shrubby vegetation (0 to 1 m) with dense foliage (Conner and Dickson 1997). Similarly, in Virginia, it prefers habitats with an extensive undergrowth of shrubs, brambles, and saplings interspersed with taller trees (10 to 20 percent of area). Vireo densities are higher in glade and regenerating forest habitat than edges in Missouri (Fink and others 2006). Densities also are inversely related to vegetation height, foliage density at 12 to 15 m, density of pole trees, and percent canopy closure (Conner and others 1983). Prather and Smith (2003) found that this species was more abundant in tornado-damaged forest in Arkansas than in undamaged areas. In South Carolina, abundance was positively related to gap size in bottomland forest that had been harvested by group-selection (Moorman and Guynn 2001). Territory size (0.1 to 1.8 ha) and population density vary with habitat quality. Brood parasitism affects nearly half of all nests and may significantly reduce productivity. The white-eyed vireo is more abundant in wide riparian strips of bottomland hardwood forest than in narrow strips (Kilgo and others 1998).

Model Description

The HSI model for the white-eyed vireo includes six variables: landform, landcover, successional age class, edge occurrence, canopy cover, and small stem (< 2.5 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 138). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the habitat associations of the white-eyed vireo in the Southeast.

Table 138.—Relationship of landform, landcover type, and successional age class to suitability index (SI) scores for white-eyed vireo habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000	0.834	0.500	0.333
	Deciduous	0.000	1.000	0.834	0.500	0.333
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	1.000	0.834	0.500	0.333
	Woody wetlands	0.000	1.000	0.834	0.500	0.333
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.667	0.500	0.333	0.167
	Deciduous	0.000	0.667	0.500	0.333	0.167
	Evergreen	0.000	0.667	0.500	0.333	0.167
	Mixed	0.000	0.667	0.500	0.333	0.167
	Orchard-vineyard	0.000	0.667	0.500	0.333	0.167
	Woody wetlands	0.000	1.000	0.834	0.500	0.333
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.667	0.500	0.333	0.167
	Deciduous	0.000	0.667	0.500	0.333	0.167
	Evergreen	0.000	0.667	0.500	0.333	0.167
	Mixed	0.000	0.667	0.500	0.333	0.167
	Orchard-vineyard	0.000	0.667	0.500	0.333	0.167
	Woody wetlands	0.000	1.000	0.834	0.500	0.333

Table 139.—Influence of edge on suitability index (SI) scores for white-eyed vireo habitat

3 × 3 pixel window around forest pixel includes field? [a]	SI score
Yes[b]	1.00
No	0.01

[a]Field defined as any sapling, shrub-seedling, or grass-forb age class pixel, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high-intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any pole or sawtimber age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands.

[b]Seedling-shrub and sapling habitats used regardless of edge.

In older forest stands, the white-eyed vireo concentrates on edges (SI2) and other areas with dense vegetation (Conner and Dickson 1997). We used a 3 × 3 pixel window (90 x 90 m) to identify the interfaces between pole and sawtimber successional age class forest and herbaceous and nonforest landcovers (hard edge) or shrub-seedling, grass-forb, and sapling successional age class forest (soft edge). We assumed that pole and sawtimber stands adjacent to these edges would have the highest SI score but applied a residual suitability value (0.01) to areas not identified as edge habitats to compensate for small forest gaps and openings that may be used. Shrub-seedling and sapling stands were suitable habitat regardless of edge (Table 139).

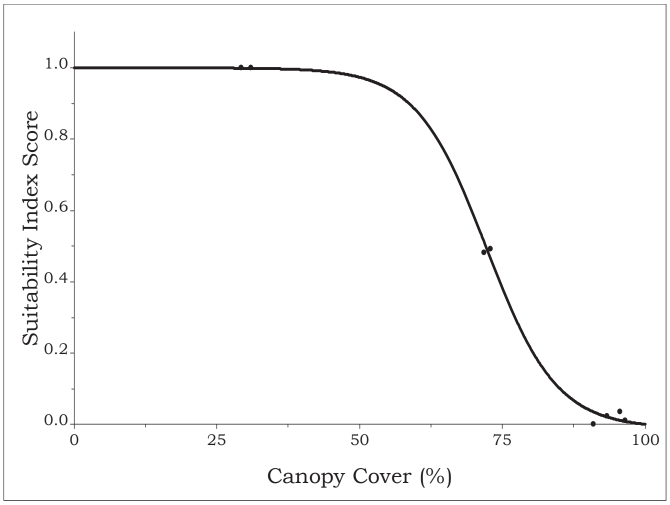

Figure 83.—Relationship between canopy cover and suitability index (SI) scores for white-eyed vireo habitat. Equation: SI score = 1 - (1.0101 / (1 + (127952.58 * e $^{-0.1629 * \text{canopy cover}}$))).

Table 140.—Influence of canopy cover on suitability index (SI) scores for white-eyed vireo habitat

Canopy cover (percent)	SI score
29.26[a]	1.000
31.00[b]	1.000
71.86[a]	0.482
73.00[b]	0.493
91.00[b]	0.000
93.38[a]	0.024
95.58[a]	0.036
96.59[b]	0.012

[a]Annand and Thompson (1997).
[b]Prather and Smith (2003).

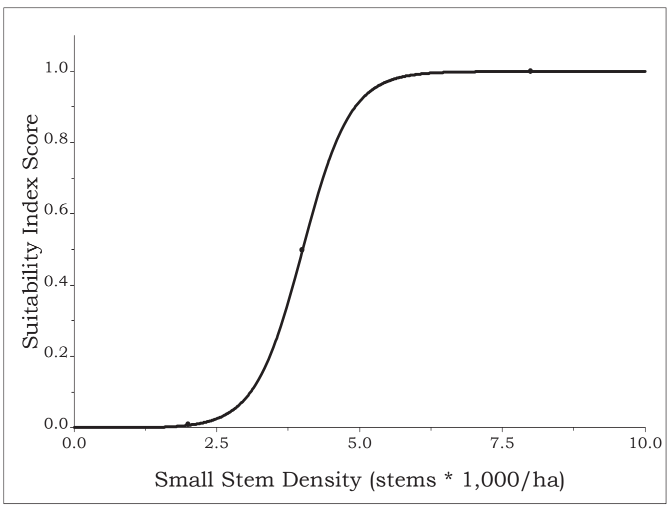

Figure 84.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for white-eyed vireo habitat. Equation: SI score = (1.000 / (1 + (14512.121 * e $^{-2.396 * (\text{small stem density} / 1000)}$))).

Table 141.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for white-eyed vireo habitat

Small stem density[a]	SI score
2	0.01
4	0.50
8	1.00

[a]Annand and Thompson (1997).

To refine the association of the white-eyed vireo with canopy gaps, we modeled the effect of canopy cover (SI3) on SI scores as an inverse logistic function (Fig. 83) that captured the absence of this species in closed-canopy forests (Table 140).

Finally, we fit a logistic function (Fig. 84) to data from Annand and Thompson (1997) (Table 141) on the influence of small stem (< 2.5 cm d.b.h.) density (SI4) on the relative density of the white-eyed vireo to quantify the relationship between SI scores and this habitat feature.

Assuming that this species uses edge as a surrogate to its preferred shrub-seedling and sapling habitats, we calculated HSI scores separately for shrub-seedling-sapling and pole-sawtimber forest stands. In the former, the geometric mean of forest structure variables alone defines the suitability score. For the latter, landscape composition (edge occurrence) also was a factor in the calculation.

Shrub-seedling and sapling (young) successional age classes:

HSI_{Young}: $(SI1 * SI3 * SI4)^{0.333}$

Pole and sawtimber (old) successional age classes:

HSI_{Old}: $((SI1 * SI3 * SI4)^{0.333} * SI2)^{0.500}$

To determine the overall HSI score, we summed the age class specific HSIs:

Overall HSI = $HSI_{Young} + HSI_{Old}$

Verification and Validation

The white-eyed vireo was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P = 0.002$) positive association ($r_s = 0.33$) between average HSI score and mean BBS route abundance across all subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the white-eyed vireo was significant ($P \leq 0.001$; $R^2 = 0.529$); however, the coefficient on the HSI predictor variable was negative ($\beta = -9.070$). Therefore, we considered the HSI model for the white-eyed vireo verified but not validated (Tirpak and others 2009a).

Wood Thrush


Steve Maslowski, U.S. Fish & Wildlife Service

Status

The wood thrush (*Hylocichla mustelina*) is a familiar woodland migrant to the forests of the eastern and central United States. Population declines for this species in the Midwest are linked to higher predation and parasitism rates in fragmented landscapes (Robinson and others 1995, Sauer and others 2005) (Table 5). The wood thrush is both a Bird of Conservation Concern and a management attention priority in the CH and WGCP (regional combined score = 16 and 15, respectively; Table 1).

Natural History

The wood thrush is a long-distance neotropical migrant that exemplifies the decline in songbirds due to forest fragmentation. Due to its general abundance, ease of nest location and monitoring, and area sensitivity, the wood thrush is easy to study and there is a large body of knowledge on this bird (Roth and others 1996). This species is common in deciduous and mixed forests but rare in pure evergreen stands (Roth and others 1996). Mesic, upland forests with a moderate density of midcanopy trees and shrubs for nesting and an open understory with abundant leaf litter for foraging are optimal (Roth and others 1996). Closed overstory canopies are commonly used (Roth and others 1996, Bell and Whitmore 2000).

The wood thrush displays area sensitivity in productivity but not in its occupancy of habitats. It nests in forest fragments as small as 0.3 ha, albeit at low densities (Tilghman 1987, Weinberg and Roth 1998), and in narrow (< 150 m wide) riparian strips (Sargent and others 2003). However, nest predation and parasitism rates are extremely high in fragments of less than 80 ha and in riparian buffers less than 530 m wide (Donovan and others 1995, Hoover and others 1995, Peak and others 2004). Landscapes with greater amounts of forest cover (particularly unfragmented forest) mitigate some of these effects in small woodlots (Donovan and others 1997, Driscoll and Donovan 2004, Driscoll and others 2005). Nest success is predicted better by the amount of forest in the landscape than by the structural characteristics of microhabitat around nests (Hoover and Brittingham 1998, Driscoll and others 2005).

Model Description

The HSI model for the wood thrush includes seven variables: landform, landcover, successional age class, forest patch size, percent forest in the local (1-km radius) landscape, small stem (< 2.5 cm d.b.h.) density, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 142). We directly assigned SI scores to these combinations on the basis of habitat associations reported by Hamel (1992) but made minor adjustments to increase SI scores for sapling stands on the basis of data from Thompson and others (1992).

Table 142.—Relationship of landform, landcover type, and successional age class to suitability index scores for wood thrush habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.250	0.750	0.750	1.000
	Transitional-shrubland	0.000	0.250	0.750	0.750	1.000
	Deciduous	0.000	0.250	0.750	0.750	1.000
	Evergreen	0.000	0.167	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.667
	Orchard-vineyard	0.000	0.250	0.333	0.333	0.667
	Woody wetlands	0.000	0.250	0.500	0.500	1.000
Terrace-mesic	Low-density residential	0.000	0.250	0.500	0.500	0.834
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.667 (0.000)
	Deciduous	0.000	0.250	0.500	0.500	0.834
	Evergreen	0.000	0.167	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.667
	Orchard-vineyard	0.000	0.250	0.333	0.333	0.667
	Woody wetlands	0.000	0.334	0.667	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.334	0.667	0.667	1.000
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.667 (0.000)
	Deciduous	0.000	0.334	0.667	0.500	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.667
	Orchard-vineyard	0.000	0.334	0.333	0.333	0.667
	Woody wetlands	0.000	0.334	0.667	0.667	1.000

Although the wood thrush will occupy small forest fragments, its density may be lower within them. Therefore, we included forest patch size (SI2) in the HSI model. We fit an exponential function (Fig. 85) to data from Robbins and others (1989) and Kilgo and others (1998) (riparian strips in this study were assumed to be 10 km long) that documented changes in relative occurrence with changes in patch size (Table 143). Nevertheless, the suitability of a forest patch is influenced not only by its size but also by its landscape context (SI3). To capture this relationship, we fit a logistic function (Fig. 86) to data (Table 144) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from SI2 or SI3 to increase the suitability of small patches in heavily forested landscapes.

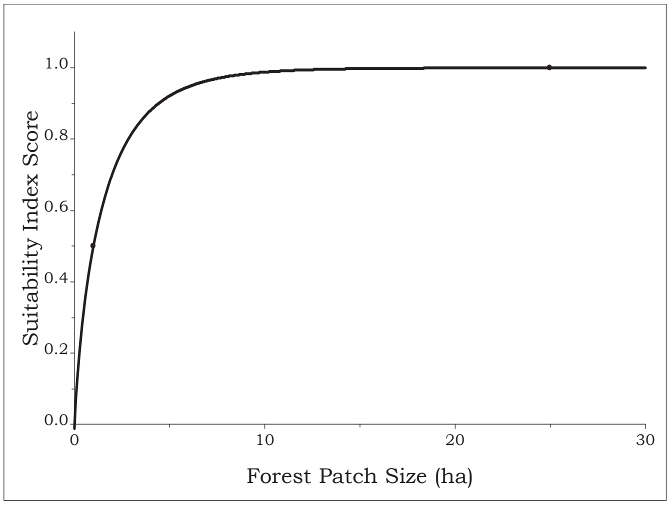

Figure 85.—Relationship between forest patch size and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1.000 – (1.017 * e $^{-0.710\ *\ (\text{forest patch size}\ \wedge\ 0.797)}$).

Table 143.—Influence of forest patch size on suitability index (SI) scores for wood thrush habitat

Forest patch size (ha)	SI score
0[a]	0.0
1[a]	0.5
25[b]	1.0
500[a]	1.0

[a]Robbins and others (1989).
[b]Kilgo and others (1998).

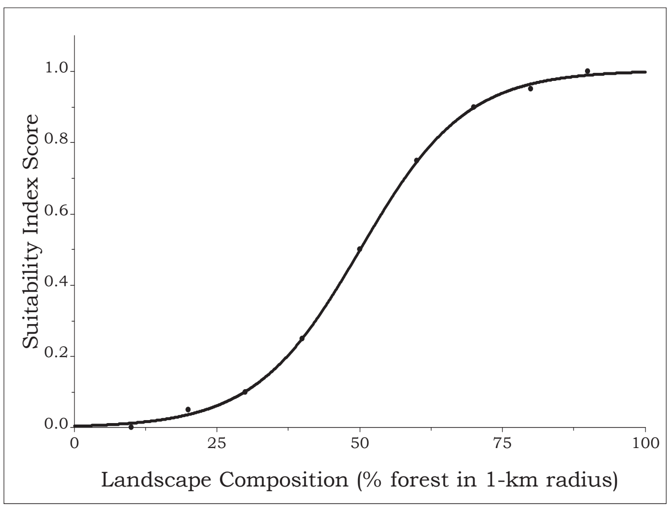

Figure 86.—Relationship between landscape composition and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108\ *\ \text{landscape composition}}$)).

Table 144.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for wood thrush habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

The wood thrush forages in leaf litter on the forest floor and is most common in stands with an open understory. We included small stem density (SI4) in the model as a proxy to understory cover. Although some researchers suggest that the wood thrush selects habitats with higher stem densities than generally are available, the controls in these studies typically are in mature forest and the wood thrush may simply be selecting habitats with locally high stem densities (Artman and Downhower 2003). We assumed that the average stem density (1,988 stems/ha) observed by Hoover and Brittingham (1998) around wood thrush nests was representative of optimal habitat. We discounted habitat suitability as small stem density increased due to presumed reductions in leaf litter, the preferred foraging substrate (Roth and others 1996). Nonetheless, Hoover and Brittingham (1998) observed wood thrush

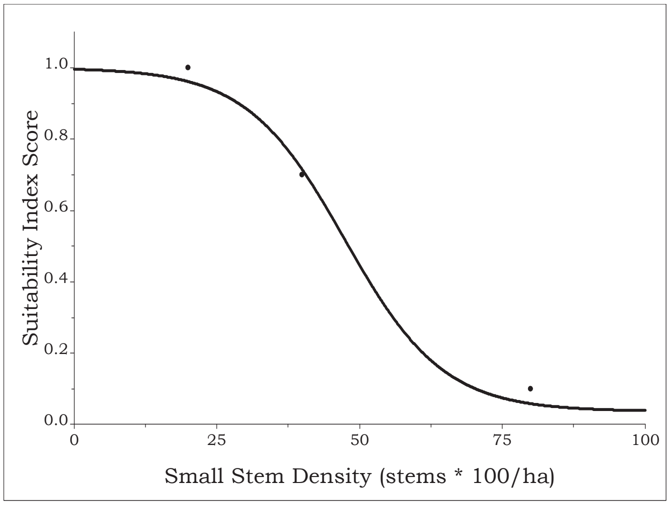

Figure 87.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 100/ha) and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1 - (0.963 / (1 + (243.780 * e $^{-0.116 * (small\ stem\ density / 100)}$)).

Table 145.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 100/ha) on suitability index (SI) scores for wood thrush habitat

Small stem density[a]	SI score
0	1.0
20	1.0
40	0.7
80	0.1
100	0.0

[a]Assumed value.

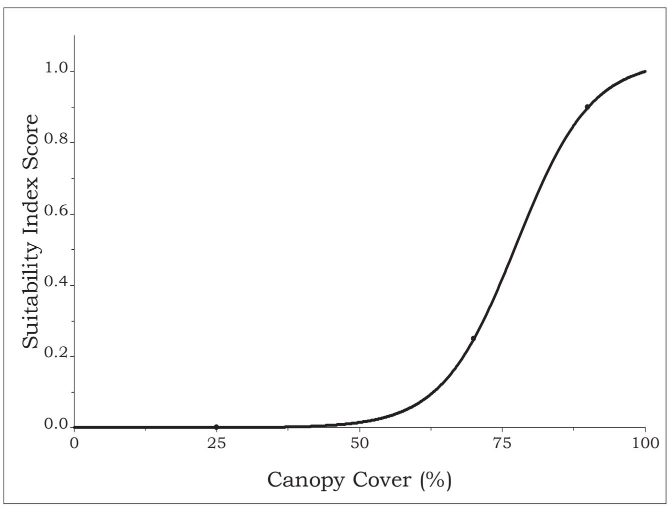

Figure 88.—Relationship between canopy cover and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1.032 / (1 + (141241.64 * e $^{-0.153 * canopy\ cover}$)).

Table 146.—Influence of canopy cover (percent) on suitability index (SI) scores for wood thrush habitat

Canopy cover (percent)	SI score
25[a]	0.00
70[b]	0.25
90[b]	0.90
100[b]	1.00

[a]Hoover and Brittingham (1998).
[b]Annand and Thompson (1997).

utilizing sites with extraordinarily high small stem densities (58,500 stems/ha, no doubt localized). Therefore, we assigned residual SI scores to sites with these characteristics. We fit an inverse logistic function (Fig. 87) to small stem density numbers that reflected this relationship (Table 145).

The wood thrush also is associated with closed-canopied forests, so we included canopy cover (SI5) as a variable and fit a logistic function (Fig. 88) to data from Annand and Thompson (1997) and Hoover and Brittingham (1998) to predict SI scores from canopy cover values (Table 146).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1, SI4, and SI5) and then calculated the geometric mean of this value and the maximum of SI scores from forest patch size or percent forest in the landscape (Max(SI2 or SI3)).

$$\text{Overall HSI} = ((\text{SI1} * \text{SI4} * \text{SI5})^{0.333} * \text{Max(SI2 or SI3)})^{0.500}$$

Verification and Validation

The wood thrush was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.52$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the wood thrush was significant ($P \leq 0.001$; $R^2 = 0.311$), and the coefficient on the HSI predictor variable was both positive ($\beta = 9.992$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the wood thrush both verified and validated (Tirpak and others 2009a).

Worm-eating Warbler

Charles H. Warren, images.nbii.gov

Status

The worm-eating warbler (*Helmitheros vermivorus*) breeds on forested slopes of the eastern deciduous forest. It is notably absent from the Mississippi floodplain and the relatively flat forest-prairie ecotone immediately east of the Great Plains. Its preference for rugged terrain and its high-pitched, insect-like song result in underestimations of its density from roadside surveys. As a result, there are no credible trends from BBS data for this species (Table 5). Nevertheless, this species is a Bird of Conservation Concern in both BCRs. However, PIF designates the worm-eating warbler as a management attention priority in the CH (regional combined score = 18) and a planning and responsibility species in the WGCP (regional combined score = 15; Table 1).

Natural History

The worm-eating warbler is a neotropical migrant that breeds in forest interiors of the Eastern United States (Hanners and Patton 1998). Minimum area requirements range from 21 ha in the mid-Atlantic (Robbins and others 1989) to more than 800 ha in Missouri (Wenny and others 1993). This species nests on the ground along moderate to steep slopes (≥ 20 percent) with dense (≥ 48 percent) shrub understories in mature deciduous and mixed deciduous-coniferous forests (Gale and others 1997). Both Artman and others (2001) and Blake (2005) found that the worm-eating warbler was less abundant in recently burned stands due to the loss of leaf litter, a preferred nesting and foraging substrate. Canopy closure exceeded 95 percent in both Missouri (Wenny and others 1993) and Connecticut (Gale and others 1997).

Model Description

The HSI model for the worm-eating warbler includes seven variables: landform, landcover, successional age class, slope, forest patch size, percent forest in the landscape, and small stem (< 2.5 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 147). We directly assigned SI scores to these combinations on the basis of habitat associations reported by Hamel (1992).

We included slope (SI2) in our model because of the prevalence of steep slopes in the territories of the worm-eating warbler. We defined slope classes on the basis of data from Gale and others (1997) who identified the relative preference of various slopes for this species (Table 148).

We also included forest patch size (SI3) as a variable to account for the preference of the worm-eating warbler for forest interiors. We fit a modified exponential function (Fig. 89) to data from Robbins and others (1989) to quantify the relationship between patch size

Table 147.—Relationship of landform, landcover type, and successional age class to suitability index scores for worm-eating warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.300	0.700	0.800
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.500	0.600
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.300	0.800	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.400	0.400
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.200	0.600	0.800
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.400	0.400

and habitat suitability (Table 149). The suitability of a forest patch is influenced by its size and landscape context (SI4). To capture this relationship, we fit a logistic function (Fig. 90) to data (Table 150) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We assigned the maximum SI score of SI3 or SI4 to each site to account for the higher suitability of small forest patches in heavily forested landscapes.

We relied on data from Wenny and others (1993) and Annand and Thompson (1997) (Table 151) to quantify the relationship between SI scores and small stem density (SI5; Fig. 91). We assumed that the worm-eating warbler occupied forests with low stem densities, but these sites had lower suitability scores than sites with well developed understories characterized by dense stems.

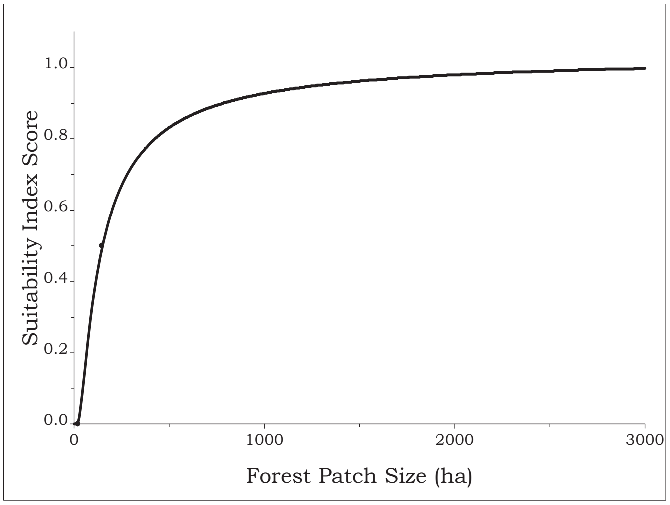

Figure 89.—Relationship between forest patch size and suitability index (SI) scores for worm-eating warbler habitat. Equation: SI score = 1.035 * $e^{-109.238 / (\text{forest patch size})}$.

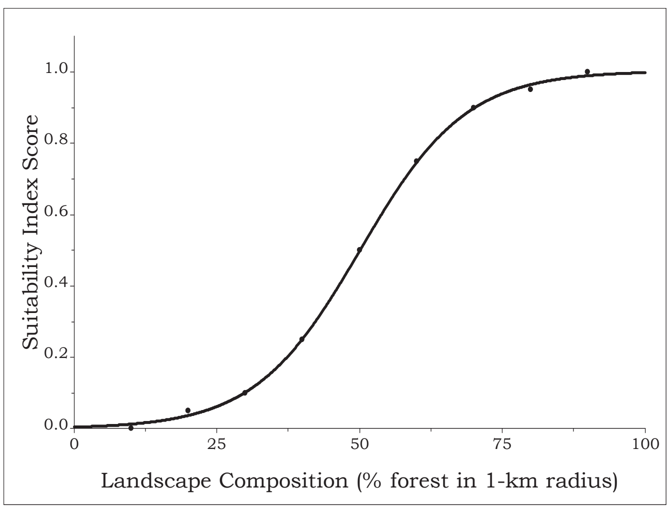

Figure 90.—Relationship between landscape composition and suitability index (SI) scores for worm-eating warbler habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * $e^{-0.108 * (\text{landscape composition})}$)).

Table 148.—Influence of slope on suitability index (SI) scores for worm-eating warbler habitat

Slope (percent)[a]	SI score
< 5	0.0
5-20	0.5
21	1.0

[a]Gale and others (1997).

Table 149.—Influence of forest patch size on suitability index (SI) scores for worm-eating warbler habitat

Forest patch size (ha)	SI score
21[a]	0.0
120[b]	0.5
3,200[a]	1.0

[a]Robbins and others (1989).
[b]Assumed value.

Table 150.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for worm-eating warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

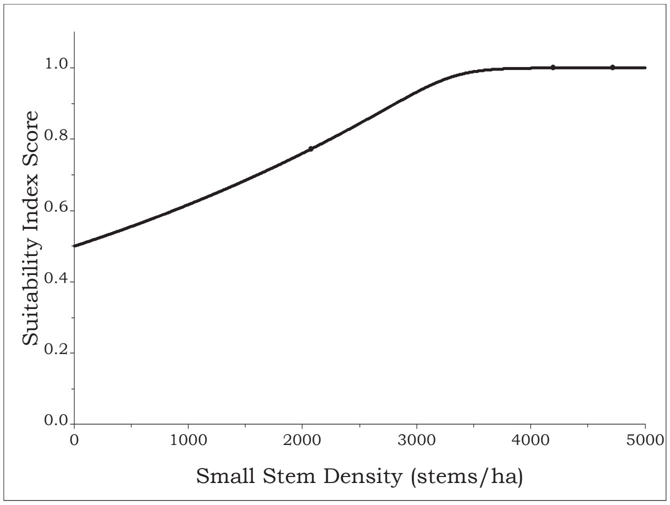

Figure 91.—Relationship between small stem (< 2.5 cm d.b.h.) density and suitability index (SI) scores for worm-eating warbler habitat.
Equation: SI score = 1.000 / (1 + e $^{18.707 - 0.006 * \text{(small stem density)}}$) ^ 1 / 26.989
Equation takes the general form: $y = a/(1 + e^{b-cx})^{1/d}$.

Table 151.—Influence of small stem (< 2.5 cm d.b.h.) density (stems/ha) on suitability index (SI) scores for worm-eating warbler habitat

Small stem density	SI score
0[a]	0.500
2,077[b]	0.773
4,200[c]	1.000
4,717[b]	1.000

[a]Assumed value.
[b]Annand and Thompson (1997).
[c]Wenny and others (1993).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI5) and landscape composition (Max(SI3 or SI4) and SI2) separately and then the geometric mean of these means together.

Overall HSI = $((\text{SI1} * \text{SI5})^{0.500} * (\text{Max(SI3 or SI4)} * \text{SI2})^{0.500})^{0.500}$

Verification and Validation

The worm-eating warbler was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.66$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the worm-eating warbler was significant ($P \leq 0.001$; $R^2 = 0.408$), and the coefficient on the HSI predictor variable was both positive (β = 1.798) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the worm-eating warbler both verified and validated (Tirpak and others 2009a).

Yellow-billed Cuckoo


U.S. Forest Service

Status

The yellow-billed cuckoo (*Coccyzus americanus*) is a neotropical migrant that breeds throughout North America east of the Rocky Mountains. The yellow-billed cuckoo is abundant in the CH and WGCP (10.43 and 12.93 birds/route, respectively), but populations in these BCRs have declinded slightly (Table 5). Although the yellow-billed cuckoo is not a Bird of Conservation Concern in either BCR, it is a management attention priority in both due to the importance of these regions (the core of this bird's range) for the sustainability of the continental population (Table 1).

Natural History

A long-distance migrant, the yellow-billed cuckoo breeds in low, dense scrub near streams, marshes, and wetlands within otherwise open woodlands (Hughes 1999). It is among the most common birds in floodplain habitats along the Mississippi River and occupies both young cottonwood-willow stands and mature silver maple forests (Knutson and others 2005). This species exhibits some area sensitivity. Conner and others (2004) found that the yellow-billed cuckoo was most abundant in riparian strips more than 70 m wide, and Aquilani and Brewer (2004) recorded highest abundances in forest tracts larger than 55 ha.

Breeding success is correlated with insect outbreaks, particularly those of hairy caterpillars, and population densities vary greatly with food supply. Nests are located in dense, broad-leaved, deciduous shrubs or trees within 10 m of the ground. Twedt and others (2001) reported no difference in nest success between bottomland hardwoods and cottonwood plantations, nor did Wilson (1999) report a difference in nest success among stands subject to alternative thinning rates in Arkansas. On the basis of anticipated harvest scenarios, Klaus and others (2005) predicted that populations of the yellow-billed cuckoo would decline by approximately 37 percent on the Cherokee National Forest over the next 60 years.

Model Description

The HSI model for the yellow-billed cuckoo includes seven variables: landform, landcover, successional age class, edge occurrence, midstory tree (11 to 25 cm d.b.h.) density, percent forest in the landscape (10-km radius), and forest patch size.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 152). We directly assigned SI scores to these combinations on the basis of habitat associations of the yellow-billed cuckoo reported by Hamel (1992). We increased SI scores within floodplain-valley and terrace-mesic landforms to account for the higher abundance of the yellow-billed cuckoo on these sites in the CH and WGCP.

Table 152.—Relationship of landform, landcover type, and successional age class to suitability index scores for yellow-billed cuckoo habitat. Values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.500	0.667	1.000
	Transitional-shrubland	0.000	0.000	0.500	0.667	1.000
	Deciduous	0.000	0.000	0.500	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.500	0.667	1.000
	Woody wetlands	0.000	0.000	0.333	0.667	0.667
Terrace-mesic	Low-density residential	0.000	0.000	0.500	0.667	1.000
	Transitional-shrubland	0.000	0.000	0.500 (0.000)	0.667 (0.000)	1.000 (0.000)
	Deciduous	0.000	0.000	0.500	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.500	0.667	1.000
	Woody wetlands	0.000	0.000	0.333	0.667	0.667
Xeric-ridge	Low-density residential	0.000	0.000	0.250	0.333	0.500
	Transitional-shrubland	0.000	0.000	0.250 (0.000)	0.333 (0.000)	0.500 (0.000)
	Deciduous	0.000	0.000	0.250	0.333	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.083	0.167	0.167
	Orchard-vineyard	0.000	0.000	0.250	0.333	0.500
	Woody wetlands	0.000	0.000	0.167	0.333	0.333

This species is more abundant within edge (SI2) habitats than within forest interiors (Kroodsma 1984). We used a 9 × 9 pixel moving window (270 x 270 m) to identify habitat edges and assumed that these locations represented optimal habitat. Nevertheless, nonedge habitats also are used by the yellow-billed cuckoo so we assigned to these sites only a slightly lower SI score (0.667; Table 153).

The yellow-billed cuckoo breeds in forest stands with well-developed midstories (SI3). We fit a quadratic function (Fig. 92) to data from Annand and Thompson (1997) on the relative densities of this species in stands with different midstory tree densities (Table 154) to predict how SI scores responded to changes in this habitat variable.

Table 153.—Influence of edge on suitability index (SI) scores for yellow-billed cuckoo habitat

9 × 9 pixel window around forest pixel includes field[a]	SI score
Yes	1.000
No	0.667

[a]Field defined as any shrub-seedling or grass-forb age class pixel, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high-intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any used sapling, pole, or sawtimber age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands.

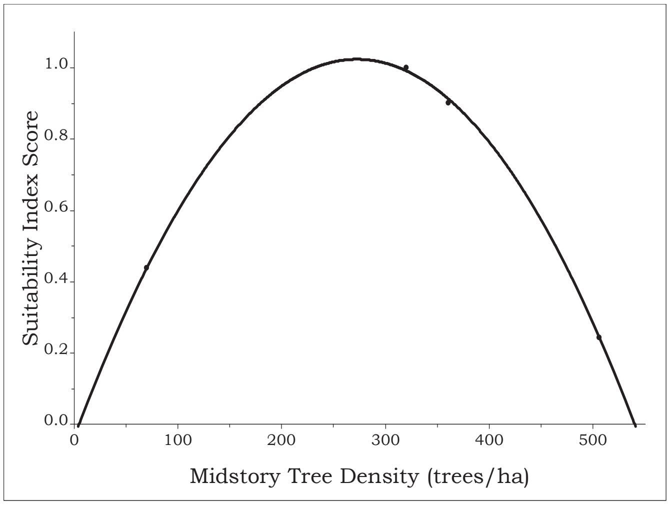

Figure 92.—Relationship between midstory tree (11–25 cm d.b.h.) density and suitability index (SI) scores for yellow-billed cuckoo habitat. Equation: SI score = 0.0078 * (midstory tree density) – 0.00001 * (midstory tree density)^2 – 0.0355.

Table 154.—Influence of midstory tree (11–25 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for yellow-billed cuckoo habitat

Midstory tree density[a]	SI score
70	0.439
320	1.000
361	0.902
506	0.244

[a]Annand and Thompson (1997).

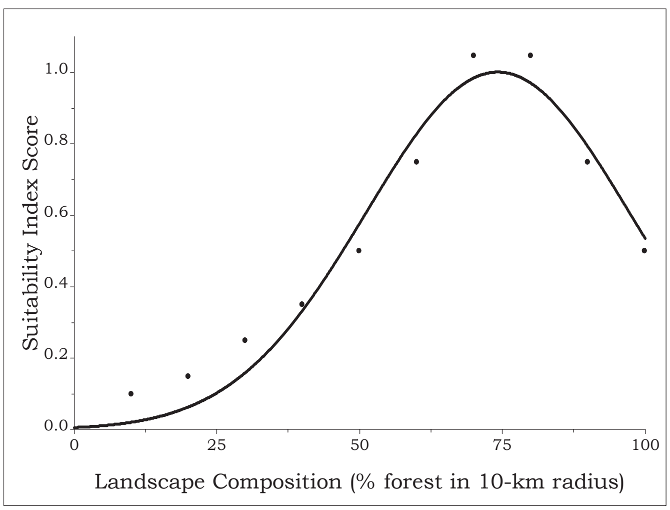

Figure 93.—Relationship between landscape composition and suitability index (SI) scores for yellow-billed cuckoo habitat. Equation: SI score = 1.002 * $e^{((0 – ((\text{landscape forest composition} * 100) – 74.165) \wedge 2) / 1064.634)}$.

Table 155.—Relationship between landscape composition (percent forest in 10-km radius) and suitability index (SI) scores for yellow-billed cuckoo habitat

Landscape composition[a]	SI score
0	0.00
10	0.10
20	0.20
30	0.30
40	0.40
50	0.50
60	0.75
70	1.00
80	1.00
90	0.75
100	0.50

[a]Assumed value.

Although a forest-breeding species, the yellow-billed cuckoo is associated with fragmented landscapes (Robbins and others 1989, Hughes 1999). We assumed that 70 to 80 percent forest in a 10-km landscape (SI4) was characteristic of ideal habitat (Table 155) and fit a function that reduced SI scores symmetrically as forest compositions departed from these ideal proportions (Fig. 93). Nevertheless, the cuckoo exhibits area sensitivity and may be absent or at low densities in small fragments (Robbins and others 1989, Bancroft and others 1995, Hughes 1999). Therefore, we used data from these sources to derive a logistic function (Fig. 94) that quantified the relationship between habitat suitability and forest patch size (SI5; Table 156).

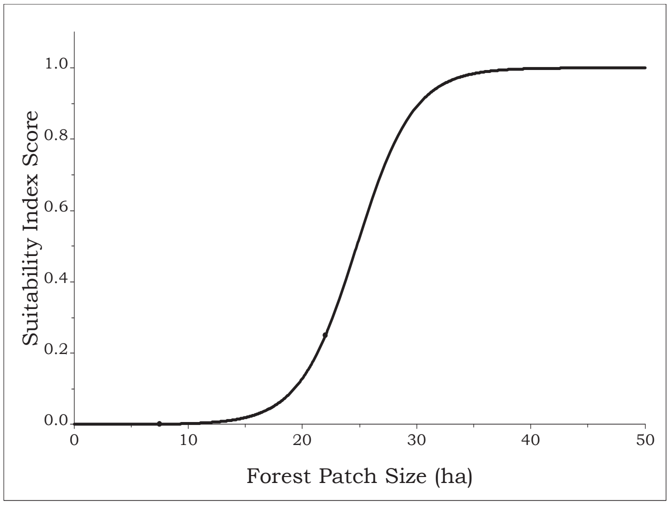

Figure 94.—Relationship between forest patch size and suitability index (SI) scores for yellow-billed cuckoo habitat. Equation: SI score = 1.000 / (1.000 + (20350.850 * e $^{-0.401 * \text{forest patch size}}$)).

Table 156.—Influence of forest patch size on suitability index (SI) scores for yellow-billed cuckoo habitat

Forest patch size (ha)	SI score
0[a]	0.00
7.5[b]	0.00
22[c]	0.25
50[d]	1.00

[a]Assumed value.
[b]Bancroft and others (1995).
[c]Hughes (1999).
[d]Robbins and others (1989).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI3) and landscape composition (SI2, SI4, and SI5) separately and then the geometric mean of these means together.

Overall HSI = $((\text{SI1} * \text{SI3})^{0.500} * (\text{SI2} * \text{SI4} * \text{SI5})^{0.333})^{0.500}$

Verification and Validation

The yellow-billed cuckoo was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant (P = 0.024) positive relationship (r_s = 0.24) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the yellow-billed cuckoo was significant ($P \leq 0.001$; R^2 = 0.190), and the coefficient on the HSI predictor variable was positive (β = 5.265) but not significantly different from zero (P = 0.302). Therefore, we considered the HSI model for the yellow-billed cuckoo verified but not validated (Tirpak and others 2009a).

Yellow-breasted Chat

Chandler S. Robbins, Patuxent Bird Identification InfoCenter
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Status

The yellow-breasted chat (*Icteria virens*) is a neotropical migrant that breeds in early successional habitats across the eastern United States. The distribution of this species in the West is patchy. Populations have responded to the loss of early successional habitat and have declined sharply across the northern edge of this bird's distribution (Sauer and others 2005). Within the CH, where this species has a regional combined score of 16 and is a management attention priority, populations have declined by approximately 2 percent per year during the last 40 years (Table 5). Conversely, at the southern limit of their range, populations have increased (1.3 percent annual increases in the WGCP from 1966 to 2005; Table 5).

Natural History

The yellow-breasted chat breeds in low, dense, deciduous and evergreen vegetation within forests lacking a closed canopy (Eckerle and Thompson 2001). Habitat associations include forest edges and openings, regenerating forest, powerline rights-of-way, fencerows, upland thickets, abandoned farms, and shrubby areas along streams, swamps, and ponds. Chats are most abundant in 6- to 9-year-old cottonwood plantations in the Mississippi Alluvial Valley (Twedt and others 1999). However, Annand and Thompson (1997) observed similar abundance across stands subject to alternative forest management prescriptions. In east Texas, density is positively correlated with foliage density at 0 to 3 m, the percentage of saplings that are pine, and the number of shrub species. Densities are negatively affected by increasing vegetation height, percent canopy cover, foliage density at 12 to 15 m, and density of pole trees (Conner and others 1983).

In Missouri, the yellow-breasted chat nests more than 20 m from the edge of large early successional patches characterized by high densities of small stems (Burhans and Thompson 1999). Nest success increases with patch size; territories range from 0.5 to 1.6 ha.

Model Description

The HSI model for the yellow-breasted chat includes six variables: landform, landcover, successional age class, edge, early successional patch size, and small stem (< 2.5 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 157). We directly assigned SI scores to these combinations based on data from Hamel (1992). However, we assumed that shrub-seedling habitats were optimal and that pole stands were nonhabitat. We ignored landform effects in assessing habitat suitability for this species.

Chats prefer to nest more than 20 m from the edge of mature forest (SI2) (Woodward and others 2001). Thus, we used a 3 × 3 pixel window (90 x 90 m) to identify suitable early

Table 157.—Relationship of landform, landcover type, and successional age class to suitability index scores for yellow-breasted chat habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000	0.500	0.000	0.000
	Deciduous	0.000	1.000	0.500	0.000	0.000
	Evergreen	0.333	0.667	0.500	0.000	0.000
	Mixed	0.333	0.667	0.334	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.667	0.334	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.333	1.000	0.500	0.000	0.000
	Deciduous	0.167	1.000	0.500	0.000	0.000
	Evergreen	0.333	0.667	0.500	0.000	0.000
	Mixed	0.333	0.667	0.334	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.667	0.334	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.333	1.000	0.500	0.000	0.000
	Deciduous	0.333	1.000	0.500	0.000	0.000
	Evergreen	0.333	0.667	0.500	0.000	0.000
	Mixed	0.333	0.667	0.334	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.667	0.334	0.000	0.000

successional forest sites immediately adjacent to pole or sawtimber successional age class forest. We reduced the suitability of these sites by half (SI score = 0.500; Table 158).

Table 158.—Influence of edge on suitability index (SI) scores for yellow-breasted chat habitat

3 × 3 pixel window around early successional pixel includes mature forest[a]	SI score
Yes	0.5
No	1.0

[a]Early successional = grass-forb, shrub-seedling, and sapling successional age classes; mature forest = pole or sawtimber successional age classes.

The yellow-breasted chat is associated with large patches of early successional forest (SI3). We aggregated all grass-forb, shrub-seedling, and sapling successional age class sites to calculate patch sizes for this species. We fit a logarithmic function (Fig. 95) to data from Rodewald and Vitz (2005) on the relative abundance of the yellow-breasted chat in early successional patches of various sizes to quantify the relationship between patch size and habitat suitability (Table 159).

This species occupies sites with high small stem densities (SI4). Therefore, we fit a logistic function (Fig. 96) to data from Annand and Thompson (1997) relating the relative density of the yellow-breasted chat to small stem densities (Table 160) to predict the effect of this habitat characteristic on habitat suitability.

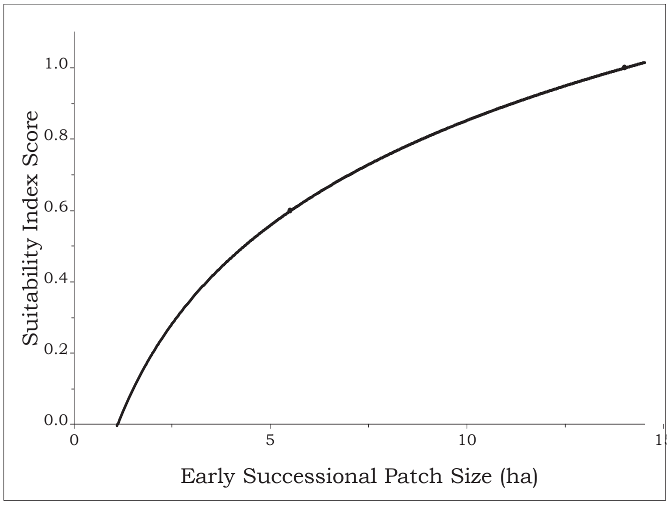

Figure 95.—Relationship between early successional patch size and suitability index (SI) scores for yellow-breasted chat habitat. Equation: SI score = -0.212 + 0.453 * ln(forest patch size).

Table 159.—Influence of early successional patch size on suitability index (SI) scores for yellow-breasted chat habitat; early successional patches only include grass-forb, shrub-seedling, and sapling successional age classes

Early successional patch size (ha)[a]	SI score
6	0.6
14.5	1.0

[a]Rodewald and Vitz (2005).

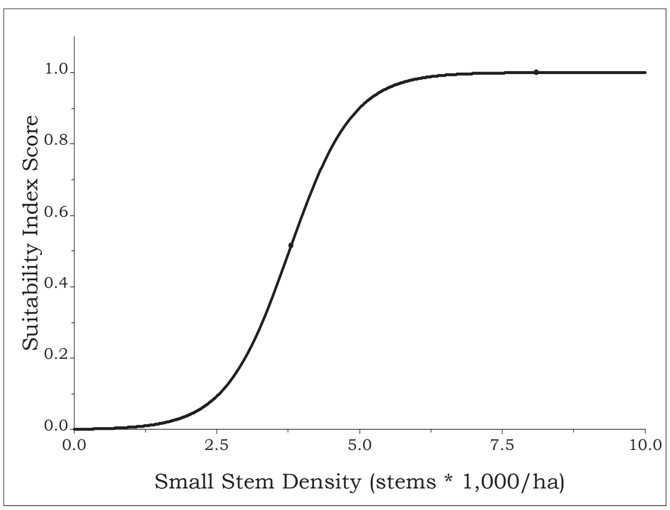

Figure 96.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for yellow-breasted chat habitat. Equation: SI score = (1.000 / (1 + (1148216.200 * e $^{-3.689 * (\text{small stem density / 1000})}$))).

Table 160.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for yellow-breasted chat habitat

Small stem density[a]	SI score
0.0	0.000
3.8	0.516
8.1	1.000

[a]Annand and Thompson (1997).

To calculate the overall HSI score for the yellow-breasted chat, we determined the geometric mean of the SI scores for forest structure attributes (SI1 and SI4) and the SI score for landscape composition (SI2 and SI3) separately and then the geometric mean of these values together.

Overall HSI = $((\text{SI1} * \text{SI4})^{0.500} * (\text{SI2} * \text{SI3})^{0.500})^{0.500}$

Verification and Validation

The yellow-breasted chat was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.40$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the yellow-breasted chat was significant ($P \leq 0.001$; $R^2 = 0.379$), and the coefficient on the HSI predictor variable was both positive ($\beta = 93.367$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the yellow-breasted chat both verified and validated (Tirpak and others 2009a).

Yellow-throated Vireo

Chandler S. Robbins,
Patuxent Bird Identification InfoCenter
Photo used with permission

Status

The yellow-throated vireo (*Vireo flavifrons*) is a neotropical migrant found throughout North America east of the Great Plains. Populations in both the CH and WGCP are stable (Sauer and others 2005) (Table 5). This species is not a Bird of Conservation Concern in either region (Table 1) but is a planning and responsibility species in both the CH (regional combined score = 16) and WGCP (regional combined score = 15). Approximately 20 percent of the continental population breeds in these two BCRs (Panjabi and others 2001).

Natural History

The yellow-throated vireo breeds along the edges of mature forest stands; its abundance may even decline within forest interiors (Rodewald and James 1996). Appropriate edges include streams, rivers, swamps, and roads. Parks, orchards, and suburban habitats also may be used (Rodewald and James 1996). This species uses both bottomland and upland sites but is restricted to deciduous and mixed-forest habitats. As a forest edge species, it is not area sensitive and may benefit from canopy gaps. However, Robbins and others (1989) observed a positive relationship between the abundance of the yellow-throated vireo and forest cover within a 2-km buffer. Similarly, this bird did not use riparian forests strips that were less than 70 m wide in east Texas (Conner and others 2004). Thus, the yellow-throated vireo prefers canopy gaps within forested landscapes. The key component of its habitat is canopy structure, and this species selects taller trees (> 20 m) than other vireos (James 1976). Robbins and others (1989) also noted a positive relationship between abundance and canopy height. Specific tree species do not affect selection (Gabbe and others 2002).

Model Description

Our HSI model for the yellow-throated vireo includes six variables: landform, landcover, successional age class, forest patch size, percent forest in the landscape (1-km radius), and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 161). We directly assigned SI scores to these combinations on the basis of relative rankings of habitat associations for the yellow-throated vireo described in Hamel (1992).

Although a forest edge species, the yellow-throated vireo is affected by forest area (SI2) and the percentage of forest in the landscape (SI3). We fit a logarithmic function (Fig. 97) to data from Blake and Karr (1987) and Kilgo and others (1998) to describe the relationship between forest patch size and habitat suitability (Table 162). Similarly, we used a logistic function to predict habitat suitability from percent forest cover in a 1-km radius landscape (Fig. 98) based on data (Table 163) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15

Table 161.—Relationship of landform, landcover type, and successional age class to SI scores for yellow-throated vireo habitat

Landform	Landcover type	Successional age class				
		Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.333	0.667
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.333	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.333	0.667
	Woody wetlands	0.000	0.000	0.000	0.417	0.834
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.250	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.250	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.250	0.500
	Woody wetlands	0.000	0.000	0.000	0.500	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.334	0.667
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.334	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.334	0.667
	Woody wetlands	0.000	0.000	0.000	0.500	1.000

percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively.

The affinity of the yellow-throated vireo for canopy gaps led us to incorporate canopy cover in the HSI model for this species (SI4). We fit a smoothed quadratic function (Fig. 99) to data from Kahl and others (1985) (Table 164) on the relative density of this species at varying canopy closures, and assumed that Kahl's optimal designation of canopy cover (80 to 90 percent) was associated with maximum SI scores. Further, we assumed that habitat suitability declined symmetrically as canopy cover departed from this optimum.

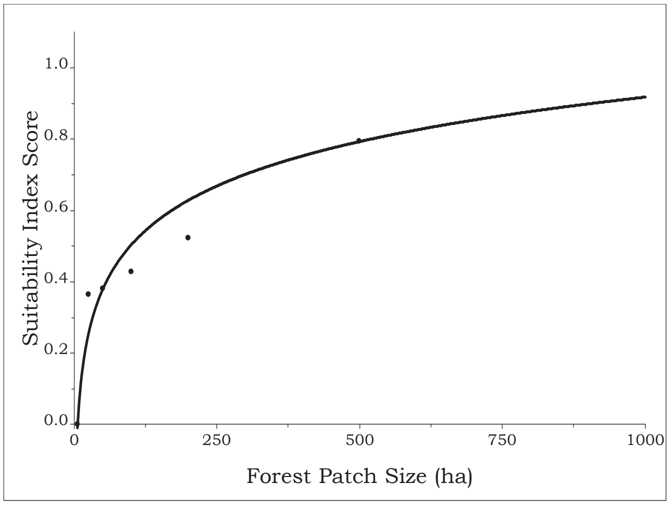

Figure 97.—Relationship between forest patch size and suitability index (SI) scores for yellow-throated vireo habitat. Equation: SI score = 0.180 * ln(forest patch size) – 0.323.

Table 162.—Influence of forest patch size on suitability index (SI) scores for yellow-throated vireo habitat

Forest patch size (ha)	SI score
6.5[a]	0.000
25[b]	0.365
50[b]	0.381
100[b]	0.429
200[b]	0.524
500[b]	0.794
1000[b]	1.000

[a]Blake and Karr (1987).

[b]Kilgo and others (1998).

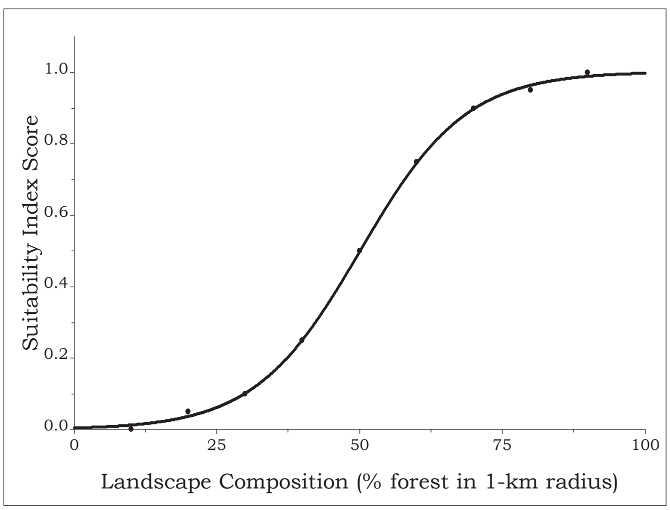

Figure 98.—Relationship between landscape composition and suitability index (SI) scores for yellow-throated vireo habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * $e^{-0.108 \text{ * (landscape composition)}}$)).

Table 163.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for yellow-throated vireo habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.

[b]Donovan and others (1997).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI4) and landscape composition attributes (SI2 and SI3) separately and then the geometric mean of these means together.

Overall HSI = $((\text{SI1} * \text{SI4})^{0.500} * (\text{SI2} * \text{SI3})^{0.500})^{0.500}$

Canopy cover (percent)	SI score
0[a]	0.00
70[b]	0.75
80[b]	1.00
90[a]	0.90

[a]Assumed value.
[b]Kahl and others (1985).

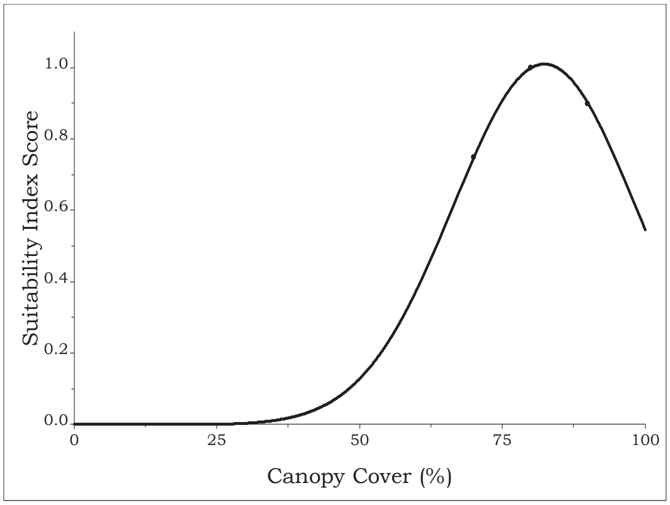

Figure 99.—Relationship between canopy cover and suitability index (SI) scores for yellow-throated vireo habitat. Equation: SI score = 1.011 * $e^{(0-((\text{canopy cover} - 82.319)\wedge 2 / 508.869))}$.

Verification and Validation

The yellow-throated vireo was found in all 88 subsections of the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance per subsection identified a significant ($P \leq 0.001$) positive association ($r_s = 0.51$) between these two variables. The generalized linear model predicting BBS abundance from BCR and HSI for the yellow-throated vireo was significant ($P = 0.002$; $R^2 = 0.133$), and the coefficient on the HSI predictor variable was both positive ($\beta = 2.811$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the yellow-throated vireo both verified and validated (Tirpak and others 2009a).

Yellow-throated Warbler


Deanna K. Dawson, Patuxent Bird Identification InfoCenter
Photo used with permission

Status

The yellow-throated warbler (*Dendroica dominica*) is a neotropical migrant that breeds in the southeastern United States and reaches its highest densities in the Ohio River Valley. This species has remained relatively stable in the WGCP over the past 40 years but has increased considerably in the CH (3.8 percent per year since 1967; Table 5). The yellow-throated warbler is not a Bird of Conservation Concern in either BCR but is a planning and responsibility species in the CH (regional combined score = 15; Table 1).

Natural History

The yellow-throated warbler breeds in two distinct habitat types: mature bottomland hardwood forest and dry, upland oak-pine forest (Hall 1996). It is more common in the former. This species shows a strong affinity for cypress along the Coastal Plains, but prefers sycamore along inland rivers (Hall 1996, Gabbe and others 2002). Where Spanish moss is found, it is used for both foraging and nesting (Hall 1996). Elsewhere, the warbler forages by creeping along limbs and probing leaf clusters and pinecones. This bird is both an interior and edge species and may occupy woodlots as small as 6 ha (Blake and Karr 1987). Robbins and others (1989) associated this species with large tree (> 38 cm d.b.h.) density, forest in a 2-km buffer, and coniferous canopy cover.

Model Description

Our HSI model for the yellow-throated warbler includes six variables: landform, landcover, successional age class, large tree (> 50 cm d.b.h.) density, distance to water, and percent forest in the landscape (1-km radius).

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 165). We directly assigned SI scores to these combinations on the basis of habitat associations outlined by Hamel (1992) for the yellow-throated warbler in the Southeast.

We also incorporated large tree density (SI2) into the HSI model for the yellow-throated warbler because of its affinity for nesting and foraging in large trees (Hamel 1992, Robbins and others 1989). Lacking data points from the literature to fit a curve, we assumed that SI scores were logistically related to large tree density up to 50 trees per ha and remained optimal above this threshold (Fig. 100, Table 166).

The yellow-throated warbler typically nests near water (Hall 1996, Hamel 1992). Thus, we included distance to water (SI3) in the HSI model. We assumed that sites closer to water had a higher suitability. Lacking quantitative data on the potential effect of water on habitat suitability, we assumed that the size of the yellow-throated warbler's territory is similar to that of the Acadian flycatcher but that the warbler is not as dependent on water as the

Table 165.—Relationship of landform, landcover type, and successional age class to suitability index (SI) scores for yellow-throated warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.250	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.250	0.500
	Evergreen	0.000	0.000	0.000	0.333	0.667
	Mixed	0.000	0.000	0.000	0.333	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.834	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.167	0.167
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.167	0.167
	Evergreen	0.000	0.000	0.000	0.333	0.667
	Mixed	0.000	0.000	0.000	0.333	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.500	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.167	0.333
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.167	0.333
	Evergreen	0.000	0.000	0.000	0.333 (0.167)	0.667 (0.334)
	Mixed	0.000	0.000	0.000	0.333	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.500	1.000

flycatcher. Therefore, we assumed that all sites less than 100 m from water were optimal but reduced SI more slowly for the yellow-throated warbler than the Acadian flycatcher as distance to water increased (Fig. 101; Table 167).

The yellow-throated warbler responds to the percentage of forest in the landscape (SI4). To capture this relationship, we fit a logistic function (Fig. 102) to data (Table 168) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively.

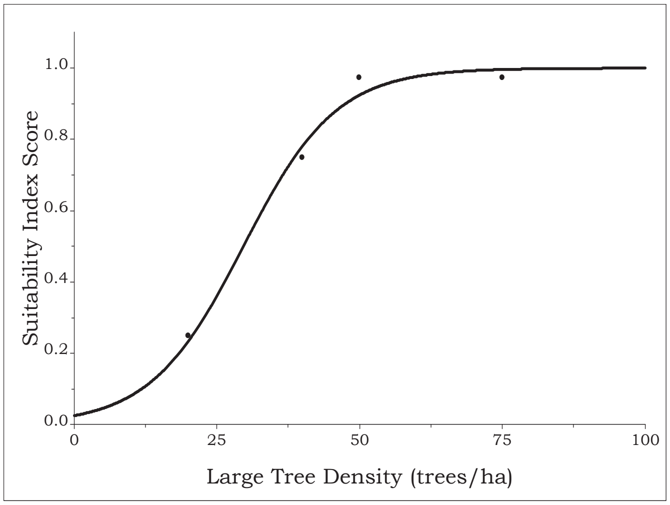

Figure 100.—Relationship between large tree (> 50 cm d.b.h.) density and suitability index (SI) scores for yellow-throated warbler habitat. Equation: SI score = 1.000 / (1.0000 + (38.185 * e $^{-0.123 * \text{large tree density}}$)).

Table 166.—Influence of large tree (> 50 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for yellow-throated warbler habitat

Large tree density[a]	SI score
0	0.00
20	0.25
40	0.75
50	1.00
75	1.00

[a]Assumed value.

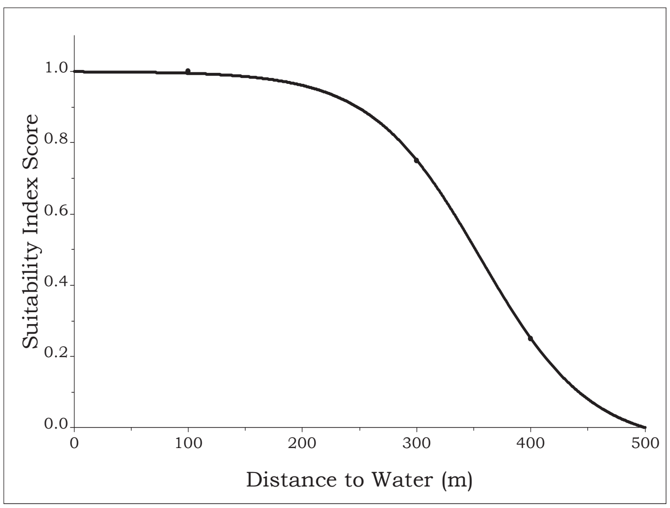

Figure 101.—Relationship between distance to water and suitability index (SI) scores for yellow-throated warbler habitat. Equation: SI score = 1 - (1.050 / (1 + (1661.322 * e $^{-0.021 * \text{distance to water}}$))).

Table 167.—Relationship between distance to water and suitability index (SI) scores for yellow-throated warbler habitat

Distance to water (m)[a]	SI score
100[b]	1.00
300[b]	0.75
400[b]	0.25
500[b]	0.00

[a]Water defined as NHD streams or NLCD water, woody wetlands, and emergent herbaceous wetlands classes.
[b]Assumed value.

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI2) and landscape composition attributes (SI3 and SI4) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI2)^{0.500} * (SI3 * SI4)^{0.500})^{0.500}$

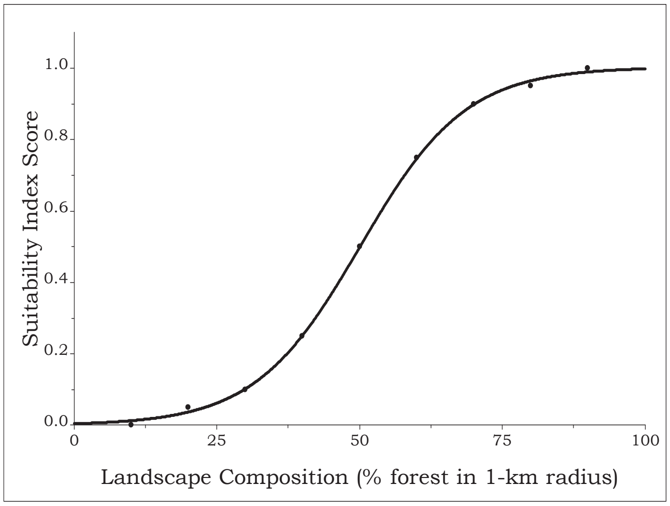

Figure 102.—Relationship between landscape composition and suitability index (SI) scores for yellow-throated warbler habitat. Equation: SI score= 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 168.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for yellow-throated warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.

[b]Donovan and others (1997).

Verification and Validation

The yellow-throated warbler was found in 87 of the 88 subsections within the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance identified a significant ($P \leq 0.001$) positive association ($r_s = 0.48$) between these two variables within subsections where this species was detected. The generalized linear model predicting BBS abundance from BCR and HSI for the yellow-throated warbler was significant ($P = 0.003$; $R^2 = 0.125$), and the coefficient on the HSI predictor variable was both positive (β = 2.870) and significantly different from zero ($P = 0.020$). Therefore, we considered the HSI model for the yellow-throated warbler both verified and validated (Tirpak and others 2009a).

CURRENT MODEL USE AND FUTURE DIRECTIONS

For species with verified and validated models, we developed geospatial datasets that summarize the habitat suitability and estimated population size of these species within each subsection for two periods (1992 and 2001). These datasets are being used to assess changes in habitats through time and identify which model variables are associated with these changes. We also are using these datasets as conservation design tools to identify the specific location and type of management practice that may most effectively increase the habitat quality and population size of target species. Population estimates explicitly tied to habitat suitability are allowing the refinement of landbird population objectives and spatial depiction of these objectives at the ecological subsection scale. We are developing a decision-support tool based on these model outputs that will estimate the magnitude of management that may be required to achieve population objectives for a particular species and will assess the simultaneous impacts of different management options on populations of multiple species.

With conservation informed by these models in both the CH and WGCP, these models are informing the status at the continental scale of species with a significant portion of their populations in these BCRs (e.g., Kentucky warbler; Panjabi and others 2005). Adoption and application of these models in other BCRs (the East Gulf Coastal Plain Joint Venture references the use of these models in its Implementation Plan [East Gulf Coastal Plain Joint Venture 2008]) may provide a framework for assessing the status of additional species at the continental scale. However, the use of these models outside the CH and WGCP will require careful scrutiny and additional testing to ensure that the habitat associations remain valid as differences in forest types among regions (particularly outside the Southeast) likely will affect the SI scores in the landform, forest type, and successional age class matrix derived from Hamel (1992).

ACKNOWLEDGMENTS

We thank the following reviewers who provided invaluable feedback for improving our HSI models: Eric Baka, Laurel Moore Barnhill, Charles Baxter, Michelle Beck, Jim Bednarz, Jeff Buler, Wes Burger, Dirk Burhans, Bob Cooper, Dean Demarest, Randy Dettmers, Jim Dickson, Therese Donovan, Rob Doster, John Dunning, Jane Fitzgerald, Jim Giocomo, Bill Giuliano, Gypsy Gooding, Fred Guthery, Carola Haas, Tom Haggerty, Paul Hamel, Kirsten Hazler, Larry Hedrick, Mark Howery, Pamela Hunt, Chuck Hunter, James Ingold, Brad Jacobs, Christopher Kellner, Eric Kershner, John Kilgo, Melinda Knutson, Jeff Kopachena, David Krementz, Scott Lanyon, Chester Martin, Dan McAuley, Joe Meyers, Warren Montague, Christopher Moorman, Rua Mordecai, Allan Mueller, Wayne Norling, Brainard Palmer-Ball, David Pashley, Bruce Reid, Rochelle Renken, Amanda Rodewald, Scott Rush, Kristin Schaumburg, Brian Smith, Phil Stauffer, Jeffrey Stratford, Wayne Thogmartin, Bill Vermillion, Shawchyi Vorisek, R. Montague Whiting, Jr., Mike Wilson, Randy Wilson, and Doug Zollner.

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Habitat Suitability Index (HSI) models were developed to assess habitat quality for 40 priority bird species in the Central Hardwoods and West Gulf Coastal Plain/ Ouachitas Bird Conservation Regions. The models incorporated both site and landscape environmental variables from one of six nationally consistent datasets. Potential habitat was first defined from unique landform, landcover, and successional age class combinations. Species-specific environmental variables identified from the literature were used to refine initial habitat estimates. Models were verified by comparing subsection-level HSI scores and Breeding Bird Survey (BBS) abundance via Spearman rank correlation. Generalized linear models that predicted BBS abundance as a function of HSI were used to validate models.

KEY WORDS: Conservation planning, ecoregion, forest, Forest Inventory and Analysis, National Landcover Dataset, validation.

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Subject: Red Cockaded Woodpecker Habitat Suitability Index Model Geographical Range of Applicability for US Army Corps of Engineers Civil Works Projects.

Date: 10 May 2023

Point of Contact: Patrick W. Smith, PhD, Biologist, Regional Planning and Environment Division, South
Patrick.W.Smith@usace.army.mil
504-862-1583

1.0 Purpose

The purpose is to document the geographical range of applicability of Tirpak and others (2009; Attachment 1) Red Cockaded Woodpecker (RCW) Habitat Suitability Index (HSI) model for US Army Corps of Engineers (USACE) Civil Works (CW) Projects.

2.0 Background Information

2.1 Red Cockaded Woodpecker HSI Development

Tirpak and others (2009; Attachment 1) developed HSI models to assess habitat quality for 40 priority bird species in the Central Hardwoods (CH) and West Gulf Coast Plain (WGCP) Bird Conservation Regions (BCR; Figure 1). The WGCP consists primarily of pine forests and thusly contains large populations of pine specialists (e.g., RCW). The WGCP also contains broad swaths of bottomland hardwood forests.

This RCW HSI was developed using key habitat factors by compiling data from pertinent literature sources. Habitat suitability was assumed to be a function of both composition and structure at the site and landscape scales. Six Suitability Indices are combined to calculate the overall HSI score.

1. Landform, landcover, and successional age class matrix
2. Forest patch size
3. Pine basal area
4. Hardwood basal area
5. Distance to nearest patch
6. Large pine density

2.2 Rapid Assessment Metrics to Enhance Wildlife Habitat and Biodiversity within Southern Open Pine Ecosystems

Nordman and others (2016) developed a rapid assessment tool for forest condition meters for southern open pine ecosystems (Attachment 2). This work focuses on open pine ecosystems and has a large geographic area of interest that somewhat overlaps with the WGCP called of the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCP&O LCC).

Part of the development of this tool included identifying priority species (e.g., RCW) and assessing their habitat relationships across different pine ecosystems within the GCP&O LCC. The RCW is found in all project states except Missouri (extirpated) and across all open pine ecosystem groupings.

3.0 Geographical Range of Applicability

3.1 Description of Geographical Range of Applicability

The geographical range of applicability of the RCW HSI for CW Projects includes all open pine habitats within the WGCP and CH BCRs, the GCP&O LCC, and the southeastern United States (Figure 1). A description of the WGCP and CH BCRs is included in Attachment 1, and a description of the GCP&O LCC is included in Attachment 2. Little's (1971) representation of the native range of longleaf pine is shown here as an approximation of where open pine forests could be found and/or restored in the coastal plain of the southeastern United States (Attachment 3). The RCW HSI was initially developed for the WGCP and CH BCRs, but for USACE CW Planning purposes the geographical range of applicability has been extended to include other open pine habitats shown in Figure 1.

Site investigations should be performed to determine if the area of interest is open pine habitat prior to implementing the RCW HSI. There are many sources of information describing and delineating open pine ecosystems that could be used to help determine if this model is appropriate. For instance, White et. al (2016; Attachment 4) includes information and a key on delineating open pine ecosystems that could be used by model users.

3.2 Justification of Geographical Range of Applicability

Extension of the geographical range of applicability to include open pine habitats within the GCP&O LCC and other open pine ecosystems throughout the southeastern United States is justified, because Nordman and others' (2016) found RCW habitat relationships to be robust across all open pine ecosystems within the GCP&O LCC (Attachment 2), and John Tirpak, the primary author of the RCW HSI, agreed with this determination via email on 8 AUG 2022 stating that the RCW HSI as shown could be applied to all coastal plain open pine ecosystems (Attachment 5).

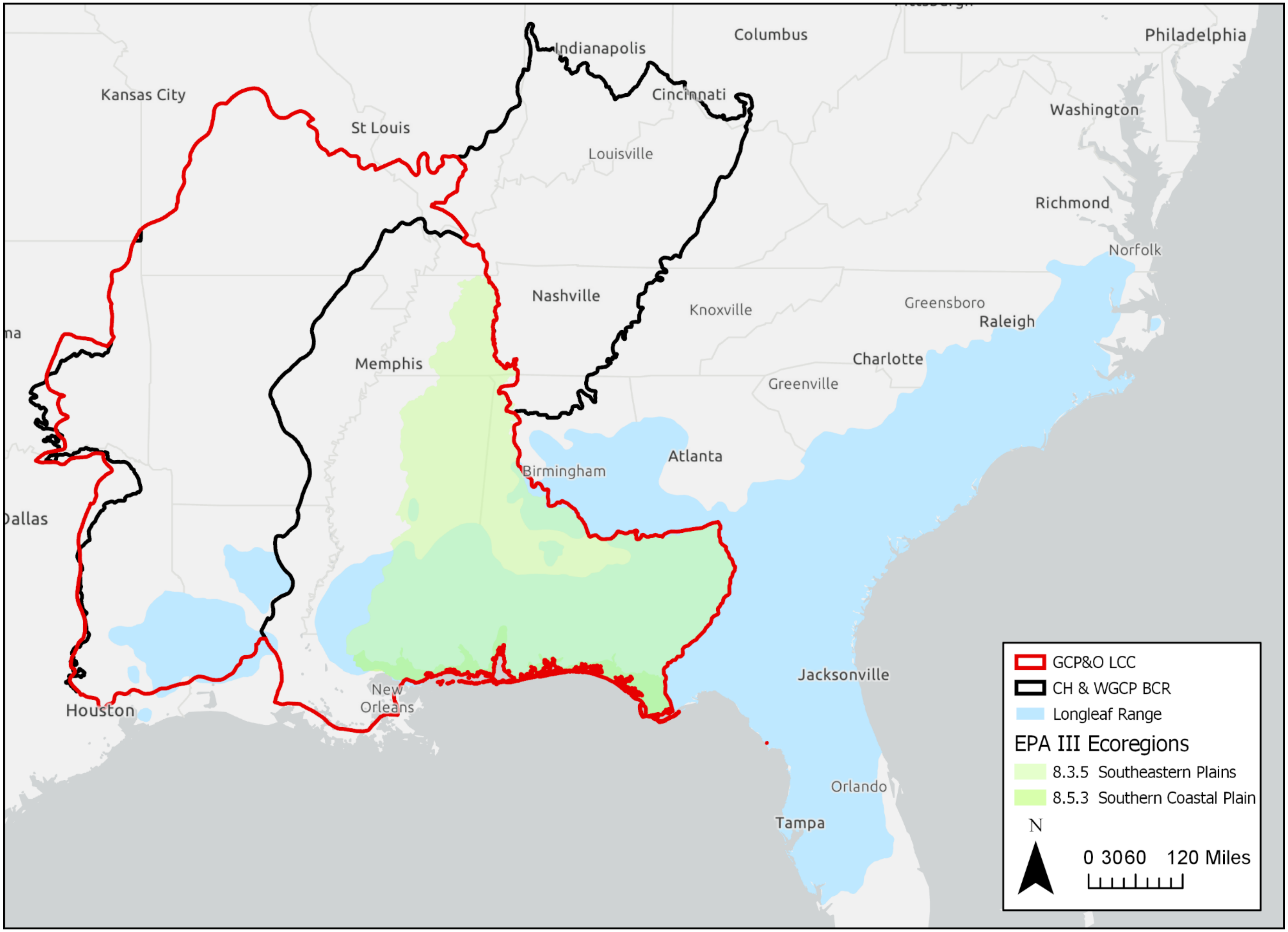

Figure 1: The black polygon shows the Central Hardwoods (CH) and West Gulf Coast Plain (WGCP) Bird Conservation Regions (BCR). The red polygon shows the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative (GCP&O LCC). Environmental Protection Agency Level III Ecoregions Southern Plains and Southern Coastal Plains within the GCP&O LCC are shown as green polygons. Little's (1971) approximation of the historic extent of longleaf pine savannahs are shown as a visual approximation of where open pine ecosystems may occur within the coastal plain of the southeastern US.

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Report NRS-49

Multiscale Habitat Suitability Index Models for Priority Landbirds in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions

John M. Tirpak
D. Todd Jones-Farrand
Frank R. Thompson, III
Daniel J. Twedt
William B. Uihlein, III






Abstract

Ecoregional conservation planning for priority landbirds requires methods that explicitly link populations to habitat conditions at multiple scales. We developed Habitat Suitability Index (HSI) models to assess habitat quality for 40 priority bird species in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions. The models incorporated both site and landscape environmental variables derived from one of six nationally consistent datasets: ecological subsections from the National Ecological Unit Hierarchy, National Land Cover Dataset, National Elevation Dataset, National Hydrography Dataset, State Soil Geographic Database, and Forest Inventory and Analysis data. We initially defined potential habitat for each species from unique landform, landcover, and successional age class combinations. Species-specific environmental variables identified from the literature were used to refine initial habitat estimates. We verified models by comparing subsection-level HSI scores and Breeding Bird Survey (BBS) abundance via Spearman rank correlation. To validate models, we developed generalized linear models that predicted BBS abundance as a function of HSI score and Bird Conservation Region. We considered models that included a significant ($P \leq 0.100$) positive coefficient on the BBS predictor to be valid and useful for conservation planning.

The Authors

JOHN M. TIRPAK is science coordinator for the Lower Mississippi Valley Joint Venture, Vicksburg, MS.

D. TODD JONES-FARRAND is a postdoctoral fellow with the Department of Fisheries and Wildlife Sciences, University of Missouri, Columbia, MO.

FRANK R. THOMPSON, III is a research wildlife biologist and Project Leader with the Northern Research Station, Columbia, MO.

DANIEL J. TWEDT is a research wildlife biologist with the U.S. Geological Survey Patuxent Wildlife Research Center, Vicksburg, MS.

WILLIAM B. UIHLEIN, III is coordinator for the Lower Mississippi Valley Joint Venture, Vicksburg, MS.

Cover Photos

Clockwise from top left:
Cerulean warbler, U.S. Forest Service; Wood thrush, Steve Maslowski, U.S. Fish & Wildlife Service; Pileated woodpecker, U.S Forest Service; Painted bunting, Deanna K. Dawson, Patuxent Bird Identification InfoCenter, Photo used with permission; Kentucky warbler, U.S. Fish & Wildlife Service; Bewick's wren, Dave Menke, U.S. Fish & Wildlife Service.

Manuscript received for publication 27 August 2008

Published by:
U.S. FOREST SERVICE
11 CAMPUS BLVD SUITE 200
NEWTOWN SQUARE PA 19073-3294

July 2009

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CONTENTS

INTRODUCTION

The primary goal of the North American Landbird Conservation Plan (Rich and others 2004) is to create landscapes that can sustain populations of the 448 native landbird species that breed in the United States and Canada. To attain this goal, the Plan advocates a three-phase approach:

1. Establish population objectives at the continental scale.
2. Allocate these population objectives to specific Bird Conservation Regions (BCRs).
3. Translate the regional population objectives to habitat goals within each BCR.

The first two steps of this process have been completed (Panjabi and others 2001, Rosenberg and Blancher 2005), and it is at this third step where the conservation community stands today.

Translating target population numbers into concrete habitat goals requires both knowledge of how landbird populations respond to changing habitat conditions and a method for quantifying this relationship. However, there are few data explicitly linking landbird abundance to specific habitat conditions, nor is there consensus on the optimal methodology to achieve this linkage. The goal of our research is to develop a comprehensive, replicable approach to ecoregional habitat assessment that links habitat conditions to the density of priority bird species. Specific objectives are to:

1. Assess the ability of landscapes to sustain priority species at prescribed population levels based on the extent and distribution of available habitats.
2. Monitor changes in the ability of landscapes to sustain species.
3. Predict how landscape suitability changes under alternative succession and disturbance patterns, land use, conservation strategies, management practices, and development pressures.

To create a replicable and transferable methodology, we selected a Habitat Suitability Index (HSI) modeling approach. HSI models were initially developed by the U.S. Department of the Interior (USDI) Fish and Wildlife Service (FWS) to evaluate habitat quality for a variety of species (Schamberger and others 1982). These models identify and quantify the relationship between key environmental variables and habitat suitability on a scale from 0 to 1. HSI scores are calculated independently for each environmental factor and an appropriate weighting scheme is used to combine individual variables and determine a composite suitability index (SI) score for a particular location. Although the FWS developed HSI models solely with site-specific habitat variables (e.g., canopy cover) for assessing stand-level habitat suitability, researchers are increasingly developing HSI models that incorporate broad-scale metrics (e.g., percent forest in a 1-km radius) for application to large landscapes (Larson and others 2003). The continued use of the HSI approach by both researchers and managers likely is a result of the intuitive nature of these models as well as their scalability and portability to novel situations. HSI models easily incorporate existing information via a priori hypotheses but also allow generalization of habitat relationships across areas and species where empirical data are limited. Currently, few HSI models include environmental variables at both the site and landscape scale due to the limited site-specific data across areas that are large enough to exhibit strong differences in landscape structure or composition. Nevertheless, habitat selection by birds is a multiscale process (Villard and others 1998) and habitat models should reflect conditions at multiple scales. This report begins filling this gap by documenting multiscale HSI models for 40 priority landbird species (Table 1).

Table 1.—Partners in Flight regional combined score and USDI Fish and Wildlife Service Bird of Conservation Concern status for 40 priority landbird species in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions

		Central Hardwoods		West Gulf Coastal Plain/Ouachitas	
Species	Alpha code[a]	Regional combined score	Bird of Conservation Concern	Regional combined score	Bird of Conservation Concern
Acadian flycatcher	ACFL	16	No	17	Yes
American woodcock	AMWO	--	No	--	No
Bachman's sparrow	BACS	20	Yes	20	Yes
Bell's vireo	BEVI	15	Yes	16	Yes
Bewick's wren	BEWR	15	Yes	16	Yes
Black-and-white warbler	BAWW	13	No	16	No
Blue-gray gnatcatcher	BGGN	14	No	13	No
Blue-winged warbler	BWWA	19	Yes	--	No
Brown thrasher	BRTH	15	No	13	No
Brown-headed nuthatch	BHNU	19	No	19	Yes
Carolina chickadee	CACH	15	No	16	No
Cerulean warbler	CERW	19	Yes	19	Yes
Chimney swift	CHSW	16	No	14	No
Chuck-will's-widow	CWWI	14	No	16	Yes
Eastern wood-pewee	EAWP	15	No	16	No
Field sparrow	FISP	17	No	15	No
Great crested flycatcher	GCFL	13	No	13	No
Hooded warbler	HOWA	13	No	16	No
Kentucky warbler	KEWA	18	No	19	Yes
Louisiana waterthrush	LOWA	15	Yes	18	Yes
Mississippi kite	MIKI	14	No	16	No
Northern bobwhite	NOBO	16	No	15	No
Northern parula	NOPA	12	No	13	No
Orchard oriole	OROR	17	No	18	Yes
Painted bunting	PABU	16	No	17	No
Pileated woodpecker	PIWO	13	No	16	No
Prairie warbler	PRAW	18	Yes	18	Yes
Prothonotary warbler	PROW	14	No	17	Yes
Red-cockaded woodpecker	RCWO	21	No	21	No
Red-headed woodpecker	RHWO	16	Yes	17	Yes
Swainson's warbler	SWWA	20	Yes	20	Yes
Swallow-tailed kite	STKI	19	No	18	Yes
Whip-poor-will	WPWI	17	Yes	13	No
White-eyed vireo	WEVI	15	No	16	No
Wood thrush	WOTH	16	Yes	15	Yes
Worm-eating warbler	WEWA	18	Yes	15	Yes
Yellow-billed cuckoo	YBCU	13	No	15	No
Yellow-breasted chat	YBCH	16	No	13	No
Yellow-throated vireo	YTVI	16	No	15	No
Yellow-throated warbler	YTWA	15	No	16	No

[a]Pyle and DeSante (2003).

STUDY AREAS

We developed HSI models for landbirds identified as priorities in the Central Hardwoods (CH) and West Gulf Coastal Plain/Ouachitas (WGCP) BCRs (Fig. 1). The CH, approximately 33 million ha straddling the Mississippi River, is dominated by deciduous hardwood forest. This region is bordered to the north and west by the tallgrass prairie ecosystem, to the east by the Appalachian Mountains, and to the south by the southern pine belt along the Coastal Plain. The vast forests of the CH make it an important breeding area for many area-sensitive species,

Figure 1.—Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions.

including the cerulean warbler, Kentucky warbler, Louisiana waterthrush, and worm-eating warbler (Panjabi and others 2001). The WGCP also is predominantly forested but consists primarily of pine: longleaf pine in the south transitioning to loblolly and shortleaf pine in the north. As a result, this region contains large populations of pine specialists (e.g., red-cockaded woodpecker, brown-headed nuthatch, and pine warbler). The WGCP also contains broad swaths of bottomland hardwood forest, particularly along the Arkansas, Ouachita, and Sabine Rivers, which support substantial populations of the hooded warbler, Kentucky warbler, and Swainson's warbler (Conner and Dickson 1997).

METHODS

Priority Bird Species

We selected priority bird species for modeling by identifying a subset of the forest-breeding landbirds in the CH or WGCP with a Partners in Flight (PIF) regional combined score of at least 15 (Panjabi and others 2005) or an FWS designation as a Bird of Conservation Concern (USDI Fish and Wildl. Serv. 2002) (Table 1). Forty-nine species initially met these criteria. We eliminated Bachman's warbler and the ivory-billed woodpecker from consideration due to limited habitat and validation data available within the CH and WGCP for these species. Also, we did not model habitat suitability for the ruffed grouse, broad-winged hawk, eastern kingbird, scissor-tailed flycatcher, loggerhead shrike, summer tanager, or eastern towhee. We added American woodcock, blue-gray gnatcatcher, great crested flycatcher, and northern parula to ensure the species modeled were representative of a cross section of habitat associations (e.g., early successional forest, pine savanna, bottomland hardwoods) and conservation priorities (e.g., critical recovery, management attention, planning and responsibility) within these BCRs.

HSI Model Development

In our adaptation of the HSI approach, we assume that habitat suitability is a function of both composition and structure at the site and landscape scales. To characterize environmental variables at each of these scales, we relied on six nationally consistent datasets:

1. Ecological subsections from the National Ecological Unit Hierarchy.
2. National Landcover Dataset (NLCD) (30-m pixels).
3. National Elevation Dataset (NED) (30-m pixels).
4. National Hydrography Dataset (NHD).
5. State Soil Geographic Database (STATSGO).
6. Forest Inventory and Analysis (FIA) data.

The first five datasets are widely available and commonly used to characterize landscape composition and structure. The sixth, FIA, provides information on the composition and structure of vegetation within forest patches (i.e., site scale) from a national field survey of forest lands undertaken by the USDA Forest Service. A description of the methodology used to integrate these datasets in a spatially explicit framework is available in Tirpak and others (2009b).

Table 2.—Parameters and data sources for inputs in priority forest-breeding landbird Habitat Suitability Index models, Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions; numbers correspond to Suitability Index (SI) functions in text

	Species code[a]					
Data source	ACFL	AMWO	BACS	BEVI	BEWR	BAWW
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)						
NLCD and NHD						
Occurrence of water						
Distance (m) to water	2					
NLCD						
Forest patch size (ha)	4		2			2
Landscape composition (percent forest in 1-km radius)	5					3
Landscape composition (percent forest in 10-km radius)						
Occurrence of edge				3		
Distance (m) to edge						
Interspersion – 1 landcover class						
Interspersion – 2 landcover classes		3		2	2	
Connectivity (km)			4			
Grass-open landcover						
FIA						
Basal area (m^2/ha)						
Hardwood basal area (m^2/ha)						
Pine basal area (m^2/ha)						
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)						
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)					3	
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)	3		3			4
Small stem (< 2.5 cm d.b.h.) density (stems/ha)		2		4		
DEM						
Slope						
NHD						
Distance (m) to stream						
STATSGO						
Soil texture		4				
Soil moisture		5				

continued

As a first step in developing HSI models, we identified key habitat factors for each species from the literature and compiled all pertinent data from these sources. In the interests of parsimony and processing time, we generally limited our HSI models to five or fewer suitability indices (Table 2). The first SI in all models (with the exception of chimney swift) was a function that assigned SI scores to unique combinations of landform, landcover, and successional age classes. Landform comprised three classes (floodplain-valley, terrace-mesic, and xeric-ridge) developed from the digital elevation model-derived metrics of aspect, slope, topographic position (the difference between the elevation value of an individual pixel and the average elevation in a 500- and 1,500-m-radius window around it), and relief. Landcover was classified to seven forest types derived from the NLCD: low-density residential, transitional-shrubland, deciduous, evergreen,

Table 2.—continued

Data source	Species code[a]					
	BGGN	BWWA	BRTH	BHNU	CACH	CERW
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)		2				
NLCD and NHD						
Occurrence of water						
Distance (m) to water						
NLCD						
Forest patch size (ha)	2					2
Landscape composition (percent forest in 1-km radius)						3
Landscape composition (percent forest in 10-km radius)	3		4			
Occurrence of edge	4		2			
Distance (m) to edge						
Interspersion – 1 landcover class						
Interspersion – 2 landcover classes						
Connectivity (km)						
Grass-open landcover						
FIA						
Basal area (m^2/ha)	5					
Hardwood basal area (m^2/ha)				4		
Pine basal area (m^2/ha)						
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)						4
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)				2	2	
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)		3				5
Small stem (< 2.5 cm d.b.h.) density (stems/ha)			3	3		
DEM						
Slope						
NHD						
Distance (m) to stream						
STATSGO						
Soil texture						
Soil moisture						

continued

mixed, orchard-vineyard, and woody wetlands. Finally, successional age class was delineated into five classes based on the average diameter at breast height (d.b.h.) of dominant trees in each stand, ultimately derived from FIA data: grass-forb (trees < 2.5 cm d.b.h.), shrub-seedling (2.5 to 7.5 cm), sapling (7.5 to 12.5 cm), pole (12.5 to 37.5 cm), and sawtimber (> 37.5 cm).

We assigned to each of the 105 unique landform, landcover, and successional age class combinations (three landform classes × seven forest type classes × five successional age classes) an SI value based on the relative habitat suitability rankings reported in the bird habitat matrices in Hamel (1992). These matrices qualitatively assess habitat suitability (marginal, suitable, optimal) for each bird species based on seral stage (4 classes) and forest type (23 classes). To adapt these matrices to our purposes, we crosswalked these forest types to our

Table 2.—continued

Data source	CHSW	CWWI	EAWP	FISP	GCFL	HOWA
	Species code[a]					
DEM, NLCD, and FIA						
Landform, landcover, and successional age class		1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)						
NLCD and NHD						
Occurrence of water						
Distance (m) to water						
NLCD						
Forest patch size (ha)						4
Landscape composition (percent forest in 1-km radius)			2			5
Landscape composition (percent forest in 10-km radius)						
Occurrence of edge						
Distance (m) to edge					3	
Interspersion – 1 landcover class	1					
Interspersion – 2 landcover classes		2				
Connectivity (km)						
Grass-open landcover				4		
FIA						
Basal area (m^2/ha)						
Hardwood basal area (m^2/ha)						
Pine basal area (m^2/ha)						
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)			3			
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)						
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)					2	
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)				2		3
Small stem (< 2.5 cm d.b.h.) density (stems/ha)				3		2
DEM						
Slope						
NHD						
Distance (m) to stream						
STATSGO						
Soil texture						
Soil moisture						

continued

landform-landcover classes and adapted the four seral stages to our five successional age classes (Table 3). First, we identified which of the 23 forest types occurred in the CH or WGCP (seven types: Sandhills longleaf pine, oak-gum-cypress, elm-ash-cottonwood, loblolly pine-shortleaf pine, mixed pine-hardwood, oak-hickory, and cove hardwoods). We then assigned these forest types to specific landform and landcover combinations based on the physiography associated with these forest communities.

However, not all NLCD landcovers have an analogous forest types in the Hamel classification. For example, orchards-vineyards, low-density residential, and transitional-shrubland landcover types provide habitat for many priority species but do not have a specific forest type association. Therefore, we assigned to orchards-vineyards and low-density residential sites the same SI scores

Table 2.—continued

Data source	KEWA	LOWA	MIKI	NOBO	NOPA	OROR
	Species code[a]					
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)						
NLCD and NHD						
Occurrence of water						
Distance (m) to water						
NLCD						
Forest patch size (ha)	3	5	2		2	
Landscape composition (percent forest in 1-km radius)		6			3	2
Landscape composition (percent forest in 10-km radius)	4					
Occurrence of edge						
Distance (m) to edge						
Interspersion – 1 landcover class						
Interspersion – 2 landcover classes			3	5		
Connectivity (km)						
Grass-open landcover				4		
FIA						
Basal area (m^2/ha)						3
Hardwood basal area (m^2/ha)				2		
Pine basal area (m^2/ha)				3		
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)			4			
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)						
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)		3			4	
Small stem (< 2.5 cm d.b.h.) density (stems/ha)	2	4				
DEM						
Slope						
NHD						
Distance (m) to stream		2				
STATSGO						
Soil texture						
Soil moisture						

continued

as those for deciduous landcovers on the assumption that orchards are composed primarily of deciduous species and low-density residential sites typically are planted with deciduous shade trees. Similarly, we assumed that transitional-shrubland sites are regenerating forests. Where there were transitional-shrubland pixels in floodplain-valley landforms, we assumed that they were hardwood forest regeneration. Thus, we assigned to them the same SI scores associated with deciduous habitats. On the higher and drier landforms, transitional-shrubland sites likely are dominated by oak and redcedar in the CH and pine in the WGCP, so we assigned to these sites the same SI scores as those for mixed and evergreen forest in each BCR, respectively (Table 3).

To assign SI scores to specific age classes, we used the relative habitat quality values reported in Hamel (1992) for grass-forb, shrub-seedling, and sawtimber seral stages. However, Hamel

Table 2.—continued

Data source	Species code[a]					
	PABU	PIWO	PRAW	PROW	RCWO	RHWO
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)			3			
NLCD and NHD						
Occurrence of water				2		
Distance (m) to water						
NLCD						
Forest patch size (ha)		3		3	2	
Landscape composition (percent forest in 1-km radius)		4		4		
Landscape composition (percent forest in 10-km radius)						
Occurrence of edge			2			5
Distance (m) to edge	2					
Interspersion – 1 landcover class						
Interspersion – 2 landcover classes	3					
Connectivity (km)					5	
Grass-open landcover						
FIA						
Basal area (m^2/ha)						
Hardwood basal area (m^2/ha)					4	
Pine basal area (m^2/ha)					3	
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						4
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)					6	
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)						
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)				5		2
Large (> 30 cm d.b.h.) snag density (snags/ha)		2				3
Canopy cover (percent)			5			
Small stem (< 2.5 cm d.b.h.) density (stems/ha)	4		4			
DEM						
Slope						
NHD						
Distance (m) to stream						
STATSGO						
Soil texture						
Soil moisture						

continued

combined sapling- and pole-size trees into a single class, whereas we separated these two successional age classes (a segregation we believed was more appropriate for many of our species). To tease apart the SI scores for sapling and pole age classes, we averaged the value for sapling-pole with shrub-seedling (for sapling) or sawtimber (for pole). This approach assumes that sapling and pole stands have an equal weighting by Hamel in assessing the relative habitat quality for the aggregate age class, and that there is a linear relationship across age classes that allows us to discern the relative influence of each by simple averaging.

After crosswalking Hamel's forest types and seral stages to our landform-landcover-successional age class matrix, we assigned SI scores to each unique combination based on Hamel's qualitative assessments. Combinations considered optimal (Hamel 1992) were assigned a value of 1.000;

Table 2.—continued

Data source	Species code[a]					
	SWWA	STKI	WPWI	WEVI	WOTH	WEWA
DEM, NLCD, and FIA						
Landform, landcover, and successional age class	1	1	1	1	1	1
NLCD and FIA						
Early successional patch size (ha)						
NLCD and NHD						
Occurrence of water						
Distance (m) to water						
NLCD						
Forest patch size (ha)	2	2			2	3
Landscape composition (percent forest in 1-km radius)	3				3	4
Landscape composition (percent forest in 10-km radius)						
Occurrence of edge				2		
Distance (m) to edge						
Interspersion – 1 landcover class		3				
Interspersion – 2 landcover classes			2			
Connectivity (km)						
Grass-open landcover						
FIA						
Basal area (m^2/ha)						
Hardwood basal area (m^2/ha)						
Pine basal area (m^2/ha)						
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)						
Large (> 50 cm d.b.h) tree density (trees/ha)						
Large (> 35 cm d.b.h) pine density (trees/ha)						
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)		4				
Midstory (11–25 cm d.b.h.) density (trees/ha)						
Snag density (snags/ha)						
Large (> 30 cm d.b.h.) snag density (snags/ha)						
Canopy cover (percent)				3	5	
Small stem (< 2.5 cm d.b.h.) density (stems/ha)	4			4	4	5
DEM						
Slope						2
NHD						
Distance (m) to stream						
STATSGO						
Soil texture						
Soil moisture						

continued

those considered suitable were assizned a value of 0.667; and those considered marginal had a value of 0333. We assumed that forest types and age classes not assigned a qualitative habitat ranking were not used and assigned to these combinations an SI score of zero. Where a landform-landcover type was represented by more than one of Hamel's forest types, SI values for the forest types were averaged. For example, deciduous landcover on floodplain-valley landforms are associated with cove hardwood and elm-ash-cottonwood forest communities. Cove hardwood is suitable (SI = 0.667) for the Acadian flycatcher but elm-ash-cottonwood is optimal (SI = 1.000). Thus, this landform-landcover type combination is assigned a base SI score of 0.834 (i.e., 1.667/2) prior to adjusting for successional age class (Table 4). Finally, we standardized all SI scores in the matrix to ensure that the maximum value was 1.000.

Table 2.—continued

Data source	Species code[a]			
	YBCU	YBCH	YTVI	YTWA
DEM, NLCD, and FIA				
Landform, landcover, and successional age class	1	1	1	1
NLCD and FIA				
Early successional patch size (ha)		3		
NLCD and NHD				
Occurrence of water				
Distance (m) to water				3
NLCD				
Forest patch size (ha)	5		2	
Landscape composition (percent forest in 1-km radius)			3	4
Landscape composition (percent forest in 10-km radius)	4			
Occurrence of edge	2	2		
Distance (m) to edge				
Interspersion – 1 landcover class				
Interspersion – 2 landcover classes				
Connectivity (km)				
Grass-open landcover				
FIA				
Basal area (m^2/ha)				
Hardwood basal area (m^2/ha)				
Pine basal area (m^2/ha)				
Sawtimber (> 28 cm d.b.h.) tree density (trees/ha)				
Large (> 50 cm d.b.h) tree density (trees/ha)				2
Large (> 35 cm d.b.h) pine density (trees/ha)				
Dominant (> 76.2 cm d.b.h.) tree density (trees/ha)				
Midstory (11–25 cm d.b.h.) density (trees/ha)	3			
Snag density (snags/ha)				
Large (> 30 cm d.b.h.) snag density (snags/ha)				
Canopy cover (percent)			4	
Small stem (< 2.5 cm d.b.h.) density (stems/ha)		4		
DEM				
Slope				
NHD				
Distance (m) to stream				
STATSGO				
Soil texture				
Soil moisture				

[a]Pyle and DeSante 2003; see Table 1.

Similarly, we directly assigned SI scores to individual classes for other discrete environmental variables (e.g., occurrence of water). For continuous environmental variables (e.g., canopy cover), we used CurveExpert 1.38 software (Hyams 2001)[1] to fit smoothed functions through known data points derived from the literature that quantify the relationship between each specific environmental factor and HSI scores for particular species. Information sources, assumptions, and functions (type and equation) are detailed in the model accounts.

[1]The use of trade, firm, or corporation names in this publication is for the information and convenience of the reader. Such use does not constitute an official endorsement or approval by the U.S. Department of Agriculture or Forest Service of any product or service to the exclusion of others that may be suitable.

Table 3.—Crosswalk between landform-landcover class combinations and vegetation types defined in Hamel (1992)

Landform	Landcover type	Hamel vegetation type[a]
Floodplain-valley	Low-density residential	Same as deciduous
	Transitional-shrubland	Same as deciduous
	Deciduous	Cove hardwoods Elm-ash-cottonwood
	Evergreen	Loblolly pine-shortleaf pine
	Mixed	Mixed pine-hardwood
	Orchards-vineyards	Same as deciduous
	Woody wetlands	Oak-gum-cypress Elm-ash-cottonwood
Terrace-mesic	Low-density residential	Same as deciduous
	Transitional-shrubland	Same as mixed in Central Hardwoods, same as evergreen in West Gulf Coastal Plain/Ouachitas
	Deciduous	Oak-hickory Cove hardwoods
	Evergreen	Loblolly pine-shortleaf pine
	Mixed	Mixed pine-hardwood
	Orchards-vineyards	Same as deciduous
	Woody wetlands	Elm-ash-cottonwood
Xeric-ridge	Low-density residential	Same as deciduous
	Transitional-shrubland	Same as Mixed in Central Hardwoods, same as evergreen in West Gulf Coastal Plain/Ouachitas
	Deciduous	Oak-hickory
	Evergreen	Loblolly pine-shortleaf pine. Also includes Sandhills longleaf pine in West Gulf Coastal Plain/Ouachitas
	Mixed	Mixed pine-hardwood
	Orchards-vineyards	Same as deciduous
	Woody wetlands	Elm-ash-cottonwood

[a]Hamel (1992).

To calculate the overall HSI score, we determined the geometric mean of SI scores for site-scale and landscape-scale variables separately and then the geometric mean of these means together. Use of the geometric mean follows recommendations from the published standards for development of HSI models (USDI Fish and Wildl. Serv. 1981). The equal weighting of individual functions within a spatial scale assumes that all variables are required for a habitat to be suitable and that all variables are nonsubstitutable. Further, the equal weighting of functions across scales assumes that site and landscape variables are equally important. The notable exception to use of the geometric mean was for species where both forest patch size and percent forest in the landscape are included as model parameters. In these cases, we used the maximum SI score from these two variables to account for the use of small forest patches by area-sensitive species when small patches are embedded in predominantly forested landscapes (Rosenberg and others 1999). For each species, we solicited at least five reviewers with an intimate knowledge of the habitat requirements of at least one species. Each reviewer received a standard questionnaire requesting feedback on the appropriateness of the functions included in the model. We revised models based on reviewers' comments.

Model Testing

To test the HSI models for reliability, we followed the three-stage framework (calibration, verification, and validation) outlined by Brooks (1997). We first ensured that the equations

Table 4.—Initial assignment of suitability index scores for Acadian flycatcher habitat to landform, landcover type, and successional age classes based on Hamel (1992)

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.834	0.834	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	1.000	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.667	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.834	0.834	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.333	0.333	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.834	0.834	1.000

used to predict SI scores resulted in the full potential range of SI scores given the habitat conditions within each BCR (i.e., calibration). We then used Spearman rank correlation to compare HSI scores to abundance estimates from Breeding Bird Survey (BBS) data summarized by ecological subsection (i.e., verification). We ranked subsections by HSI score and BBS abundance for each species and within each BCR independently to compensate for geographical differences in these regions not explicitly incorporated in the HSI models. We assessed correlations between these variables based on all subsections and based solely on subsections within which each species was detected. The former analysis provides insight into the overall model performance; the latter addresses the potential bias associated with correctly predicting the absence of a rare species in many subsections.

Following verification, we validated HSI models by developing species-specific generalized linear models that predicted abundance (as indexed by BBS data) from HSI and BCR predictor variables. We considered HSI models validated if the general linear model was significant ($P < 0.100$) and the coefficient on the HSI predictor variable was both significant ($P < 0.100$) and positive. Detailed results of these analyses are documented in Tirpak and others (2009a).

MODEL ACCOUNTS

Acadian Flycatcher

John J. Mosesso, images.nbii.gov

Status

The Acadian flycatcher (*Empidonax virescens*) is a long-distance migrant found throughout most of the eastern United States. While populations have declined in the northern portion of its range (particularly the Appalachians) over the last 40 years, populations in the South, particularly along the Atlantic and East Gulf Coastal Plains, have increased (Sauer and others 2005). However, the Acadian flycatcher has declined in the WGCP (Table 5), and the FWS classifies this species as a Bird of Conservation Concern in the WGCP (Table 1). Similarly, PIF considers the Acadian flycatcher as a planning and responsibility species in the CH (regional combined score of 16). In the WGCP, the flycatcher has a regional combined score of 17, warranting management attention (Table 1).

Natural History

The Acadian flycatcher is a forest-interior species associated with water throughout most of its range: bottomland hardwood and cypress forests in the Southeast and riparian forests and ravines in the deciduous forests of the Midwest and Northeast (Whitehead and Taylor 2002). This species is found in numerous forest types and uses a variety of tree species for nesting. However, this bird typically is associated with mesic forest stands and avoids upland oak-hickory sites (Klaus and others 2005). Breeding territories are small and average 1 ha (Woolfenden and others 2005). The Acadian flycatcher typically nests in midstory trees and large shrubs in mature forests. Canopy cover typically is dense (> 95 percent; Wilson and Cooper 1998), and the understory usually is sparse (Bell and Whitmore 2000, Wood and others 2004).

The Acadian flycatcher is particularly susceptible to forest fragmentation. Aquilani and Brewer (2004) found this species only in forest tracts larger than 55 ha in north-central Mississippi. Blake and Karr (1987) did not observe the Acadian flycatcher in woodlots smaller than 24 ha. In east Texas, the Acadian flycatcher was absent from riparian buffer strips less than 70 m wide (Conner and others 2004). Results were similar in Missouri (Peak and others 2004) and Indiana (Ford and others 2001).

Even in large forested tracts (> 600 ha), nest predation and parasitism rates may be 10 to 20 percent higher if the surrounding landscape is highly fragmented. Nevertheless, Fauth and Cabe (2005) did not observe significant effects of parasitism on a Blue Ridge study site where 75 percent of the landscape was forested, including 45 percent more than 250 m from an edge. Disturbance, whether natural (e.g., tornado or pest outbreak) or anthropogenic (e.g., silvicultural treatments—thinning, selective harvesting, clearcutting, and prescribed burning) reduced the abundance and productivity of the Acadian flycatcher in most landscapes (Artman and others 2001, Duguay and others 2001, Robinson and Robinson 2001, Twedt and others 2001, Prather and Smith 2003, Blake 2005).

Table 5.—Trend estimates (percent change per year) for 40 priority landbird species in the Central Hardwoods and West Gulf Coastal Plain/Ouachitas Bird Conservation Regions, 1967 to 2004 (Sauer and others 2005)

	Central Hardwoods			West Gulf Coastal Plain/Ouachitas		
Species	Trend	*P*	*n*[a]	Trend	*P*	*n*
Acadian flycatcher	-0.3	0.56	107	-2.0	0.05	67
American woodcock	-9.1	0.35	3	--[b]	--	--
Bachman's sparrow	--	--	--	-7.8	0.00	27
Bell's vireo	-3.2	0.49	18	-4.7	0.03	14
Bewick's wren	-6.5	0.00	61	0.8	0.88	11
Black-and-white warbler	2.3	0.21	50	-2.9	0.01	60
Blue-gray gnatcatcher	-1.0	0.26	118	-0.9	0.36	75
Blue-winged warbler	-4.0	0.01	62	--	--	--
Brown thrasher	-1.4	0.00	125	-1.4	0.01	64
Brown-headed nuthatch	--	--	--	-1.4	0.18	52
Carolina chickadee	0.2	0.70	123	-2.0	0.00	77
Cerulean warbler	-6.3	0.00	34	-9.5	0.00	5
Chimney swift	-2.6	0.00	124	-1.1	0.15	76
Chuck-will's-widow	-0.9	0.19	64	-1.3	0.04	60
Eastern wood-pewee	-1.4	0.00	124	-4.9	0.00	75
Field sparrow	-3.2	0.00	125	-3.7	0.01	45
Great crested flycatcher	-0.8	0.09	123	-1.3	0.04	77
Hooded warbler	2.7	0.08	31	-3.1	0.35	60
Kentucky warbler	-0.4	0.32	108	-2.2	0.00	73
Louisiana waterthrush	2.6	0.02	66	-1.3	0.49	28
Mississippi kite	16.3	0.16	2	6.4	0.21	16
Northern bobwhite	-3.1	0.00	125	-4.4	0.00	75
Northern parula	3.7	0.00	95	-2.5	0.17	53
Orchard oriole	-0.9	0.01	124	-3.0	0.01	75
Painted bunting	19.8	0.61	5	-0.6	0.48	63
Pileated woodpecker	1.8	0.01	112	-0.9	0.14	72
Prairie warbler	-2.6	0.00	94	-4.4	0.00	60
Prothonotary warbler	0.0	0.98	52	-5.8	0.00	53
Red-cockaded woodpecker	--	--	--	9.0	0.00	6
Red-headed woodpecker	-1.0	0.09	115	-3.2	0.00	68
Swainson's warbler	--	--	--	23.5	0.23	26
Swallow-tailed kite	--	--	--	--	--	--
Whip-poor-will	-1.8	0.05	71	6.6	0.22	11
White-eyed vireo	-0.4	0.20	120	-0.8	0.19	76
Wood thrush	-0.7	0.05	118	-1.4	0.05	67
Worm-eating warbler	0.4	0.77	44	-2.3	0.51	28
Yellow-billed cuckoo	-1.9	0.00	125	-1.1	0.00	77
Yellow-breasted chat	-1.9	0.00	125	1.3	0.01	75
Yellow-throated vireo	0.9	0.25	99	1.1	0.38	62
Yellow-throated warbler	3.8	0.00	76	-0.9	0.65	43

[a]Number of Breeding Bird Survey routes on which trend estimate is based.
[b]No trend estimate available.

Table 6.—Relationship of landform, landcover type, and successional age class to suitability index scores for Acadian flycatcher habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.050	0.917	1.000
	Deciduous	0.000	0.000	0.050	0.917	1.000
	Evergreen	0.000	0.000	0.017	0.167	0.333
	Mixed	0.000	0.000	0.017	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.050	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.017	0.333	0.333
	Deciduous	0.000	0.000	0.042	0.667	0.834
	Evergreen	0.000	0.000	0.017	0.167	0.333
	Mixed	0.000	0.000	0.017	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.050	1.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.017	0.333	0.333
	Deciduous	0.000	0.000	0.033	0.500	0.667
	Evergreen	0.000	0.000	0.017	0.167	0.333
	Mixed	0.000	0.000	0.017	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.050	1.000	1.000

Model Description

Our Acadian flycatcher model includes seven variables related to density: landform, landcover type, successional age class, distance to water, canopy cover, forest patch size, and percent forest in a 1-km radius window.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 6). We directly assigned SI scores to these combinations on the basis of habitat suitability data from Hamel (1992) on the relative quality of different vegetation types and successional stages for the Acadian flycatcher. However, we reduced SI scores for sapling and evergreen habitats on the basis of data from Hazler (1999).

Because the Acadian flycatcher typically is found near water (Whitehead and Taylor 2002), we fit an inverse logistic function to describe the relationship between SI scores for this species and increasing distance to water (SI2; Fig 2). The flycatcher often aligns at least one edge of its 1-ha territory along a stream or wetland (Woolfenden and others 2005).

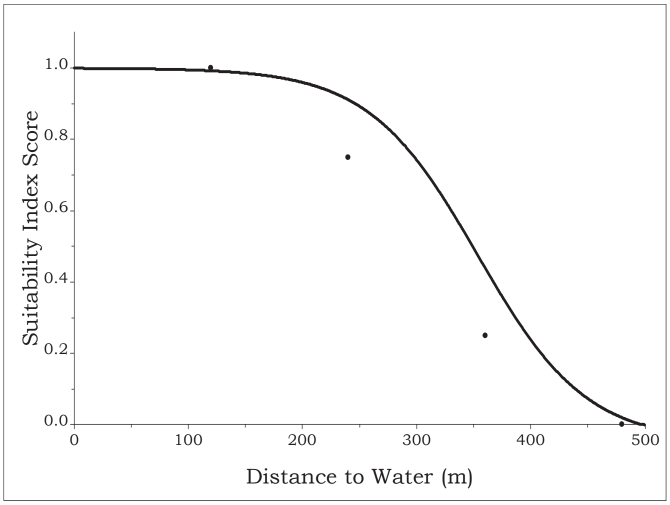


Figure 2.—Relationship between distance to water and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 1 - (1.049 / (1 + (1664.953 * e $^{-0.021 \text{ * distance to water}}$))).

Table 7.—Relationship between distance to water and suitability index (SI) scores for Acadian flycatcher habitat

Distance to water (m)[a]	SI score
0[b]	1.00
120[c]	1.00
240[b]	0.75
360[b]	0.25
480[b]	0.00

[a]Water defined as streams from the National Hydrography Dataset (medium resolution) or classified as water, woody wetlands, or emergent herbaceous wetlands in the National Land Cover Dataset.

[b]Assumed value.

[c]Woolfenden and others (2005).

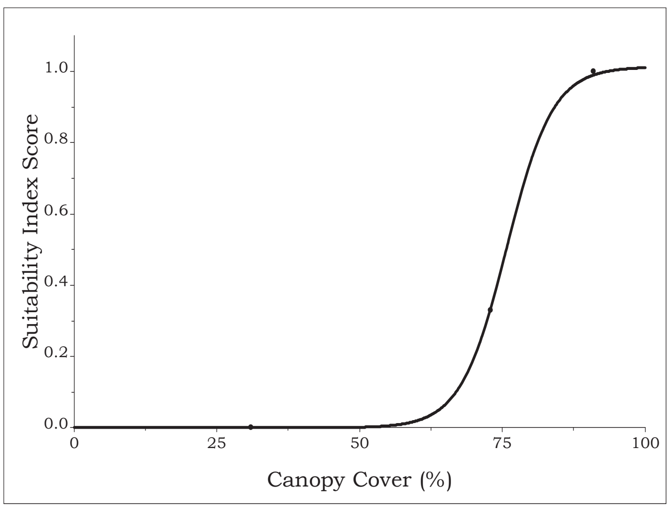


Figure 3.—Relationship between canopy cover and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 1.013 / (1.000 + (144082770 * e $^{-0.248 \text{ * canopy cover}}$)).

Table 8.—Relationship between canopy cover and suitability index (SI) scores for Acadian flycatcher habitat

Canopy cover (percent)	SI score
0[a]	0.00
31[b]	0.00
73[b]	0.33
91[b]	1.00
100[a]	1.00

[a]Assumed value.

[b]Prather and Smith (2003).

Assuming a circular home range, the diameter of the home range (112.8 m) represents the farthest distance from water a bird could be within the home range. On the basis of this assumption, we assigned all locations less than 120 m from water SI scores of 1.000 (Table 7). The Acadian flycatcher also uses sites that are more than 120 m from water but generally are found at lower densities there. Thus, we considered areas 360 m from water (a distance of three home range diameters) as having an SI score that is one-quarter of the optimal value (0.250) and sites at least 480 m from water as nonhabitat (SI score of zero).

The habitat suitability model for the Acadian flycatcher also included canopy closure (SI3) as a variable because of the strong affinity of this species for closed-canopy forests (Prather and Smith 2003). For this variable, we used a logistic function (Fig. 3) to extrapolate between known break points in the canopy cover-relative density relationship (Table 8).

We also included forest patch size (SI4) as a variable because of the sensitivity of the Acadian flycatcher to fragmentation (Robbins and others 1989) and increasing edge density (Parker and others 2005). We used a logarithmic function (Fig. 4) to describe the relatively quick increase in suitability of a forest patch with increasing area (Robbins and others 1989) (Table 9). We assumed that 312 ha, the minimum forest patch size on which Wallendorf and others (2007) always observed the Acadian flycatcher, was representative of optimal habitat (SI score = 1.000). Nevertheless, the effects of forest patch size on suitability are influenced by the percentage of forest in the landscape. In predominantly forested landscapes, small forest patches that may not be used in predominantly nonforested landscapes may provide habitat due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 5) to data (Table 10) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum value of SI4 or SI5 to assess area sensitivity and to account for small patches in predominantly forested landscapes and large patches in predominantly non-forested landscapes.

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI3) and landscape attributes (maximum value of SI4 or SI5 and SI2) separately and then the geometric mean of these means together.

$$\text{Overall HSI} = ((SI1 * SI3)^{0.500} * (\text{Max}(SI4 \text{ or } SI5) * SI2)^{0.500})^{0.500}$$

Verification and Validation

The Acadian flycatcher was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.47$) between average HSI score and mean BBS abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the Acadian flycatcher was significant ($P = 0.095$; $R^2 = 0.054$), and the coefficient on the HSI predictor variable was both positive ($\beta = 4.250$) and significantly different from zero ($P = 0.043$). Therefore, we considered the HSI model for the Acadian flycatcher both verified and validated (Tirpak and others 2009a).

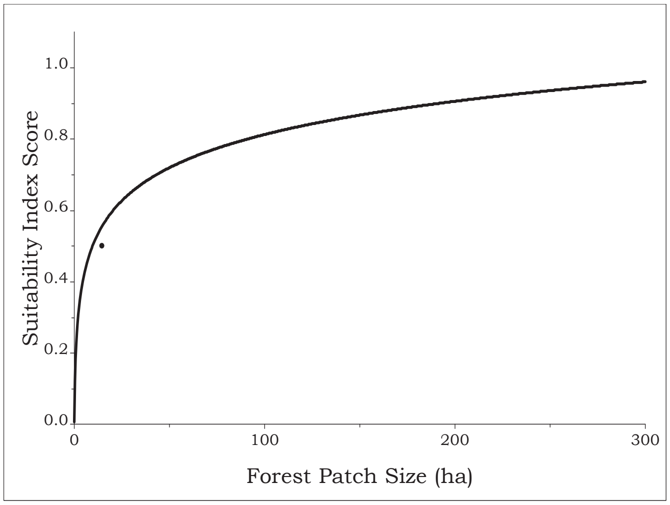


Figure 4.—Relationship between forest patch size and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 0.174 * ln(forest patch size) + 0.010.

Table 9.—Relationship between forest patch size and suitability index (SI) scores for Acadian flycatcher habitat

Forest patch size (ha)	SI score
0.2[a]	0.0
15[a]	0.5
312[b]	1.0

[a]Robbins and others (1989).
[b]Wallendorf and others (2007).

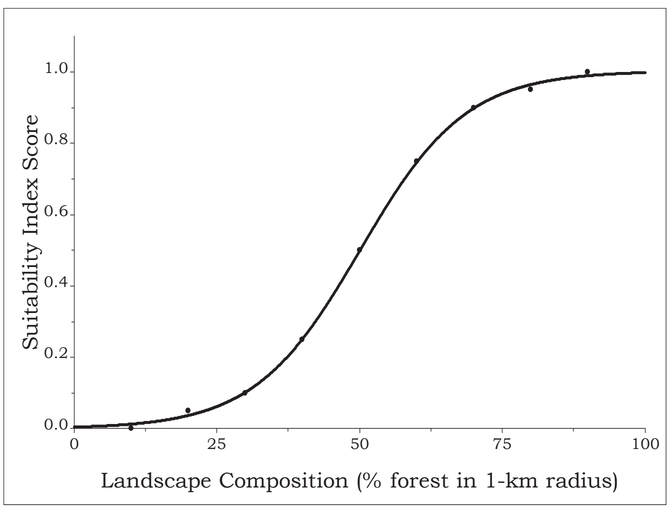


Figure 5.—Relationship between landscape composition and suitability index (SI) scores for Acadian flycatcher habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 10.—Relationship between local landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for Acadian flycatcher habitat

Local landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed that value.
[b]Dononvan and others (1997).

American Woodcock


U.S. Fish & Wildlife Service

Status

The American woodcock (*Scolopax minor*) is a popular gamebird found throughout the eastern United States and southeastern Canada. Although this species breeds primarily in the northern portion of its continental range, small numbers breed regularly throughout the wintering range in the Southeast. Singing ground surveys and wing collections from northern latitudes in the Central United States document annual 1.8 percent declines in woodcock since 1968 (Kelley 2003). The status of the relatively small breeding population in the Southeast is unknown.

Natural History

The American woodcock breeds in early successional habitat throughout its range (Keppie and Whiting 1994). Typically, these young forest stands are on moist, uncompacted soils that allow the woodcock to probe for earthworms, the bird's preferred food (Steketee 2000). Equally important is an interspersion of the forest with openings that provide sites for both courtship displays and roosting (Sepik and Derleth 1993). Openings used by woodcock in Maine generally were at least 1.2 ha (Dunford and Owen 1973). Given the affinity of the woodcock for openings and early successional habitat, Sprankle and others (2000) recommended even-age forest management in rotational blocks to ensure that both habitat requirements are met.

Most of the available quantitative information on breeding habitat for the American woodcock is from the Northeast, particularly Maine and Pennsylvania (Straw and others 1986, McAuley and others 1996). Shrub cover generally is high (75 to 87 percent; Morgenweck 1977), while overstory cover typically is moderate (50 to 64 percent; Dunford and Owen 1973, Gregg and others 2000). Nests are in young forest stands (Morgenweck 1977). McAuley and others (1996) compared nest sites to random sites and found lower basal area and fewer coniferous saplings, but higher densities of deciduous saplings and shrub stems around nests sites. Young broods inhabit young to mid-age forest interspersed with openings; older broods occupy sites with greater basal area but fewer mature trees (Morgenweck 1977).

Many habitat variables have been associated with the presence of woodcock (Storm and others 1995; Klute and others 2002). Landcover variables were the best predictors at fine scales whereas indices of landscape heterogeneity were the most important predictors at large spatial scales (Klute and others 2000). Murphy and Thompson (1993) developed a model to predict the density of males on singing grounds in central Missouri that contained small stem density (≤ 2.5 cm d.b.h.), tree density (> 2.5 cm d.b.h.), and field size as predictor variables.

Table 11.—Relationship of landform, landcover type, and successional age class to suitability index scores for American woodcock habitat

Landform	Landcover type	Successional age class: Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	1.000	0.667	0.333
	Deciduous	0.000	0.000	1.000	0.667	0.333
	Evergreen	0.000	0.000	0.500	0.250	0.125
	Mixed	0.000	0.000	0.667	0.333	0.167
	Orchard-vineyard	0.000	0.000	0.667	0.333	0.167
	Woody wetlands	0.000	0.000	1.000	0.667	0.333
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.834	0.500	0.250
	Deciduous	0.000	0.000	0.834	0.500	0.250
	Evergreen	0.000	0.000	0.400	0.200	0.100
	Mixed	0.000	0.000	0.500	0.250	0.125
	Orchard-vineyard	0.000	0.000	0.500	0.250	0.125
	Woody wetlands	0.000	0.000	0.834	0.500	0.250
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.750	0.400	0.167
	Deciduous	0.000	0.000	0.750	0.400	0.167
	Evergreen	0.000	0.000	0.333	0.167	0.083
	Mixed	0.000	0.000	0.400	0.200	0.100
	Orchard-vineyard	0.000	0.000	0.500	0.417	0.000
	Woody wetlands	0.000	0.000	0.750	0.400	0.167

Model Description

The American woodcock HSI model includes seven variables: landform, landcover, successional age class, small stem density (< 2.5 cm d.b.h.), composition of appropriately sized foraging-nesting and courtship-roosting habitat patches in the landscape, soil moisture, and soil texture.

The first suitability function combines landform, landcover type, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 11). Because the woodcock prefers moist habitats with high deciduous stem densities, we assigned the highest SI scores to sapling-aged transitional, deciduous, and woody wetland cover types in floodplain-valley landforms. We considered mixed and evergreen forests as well as xeric-ridge landforms as poor habitat for the American woodcock.

We included small stem density (SI2) as a model function because the woodcock relies on vertical structure to provide security from predators as it forages, nests, and loafs during the day. McAuley and others (1996) summarized habitat attributes around woodcock nest sites from seven studies in which stem density ranged from 5,051 to 49,250 stems per ha. Due to the relatively small sample size and the lack of geographic representation within the samples

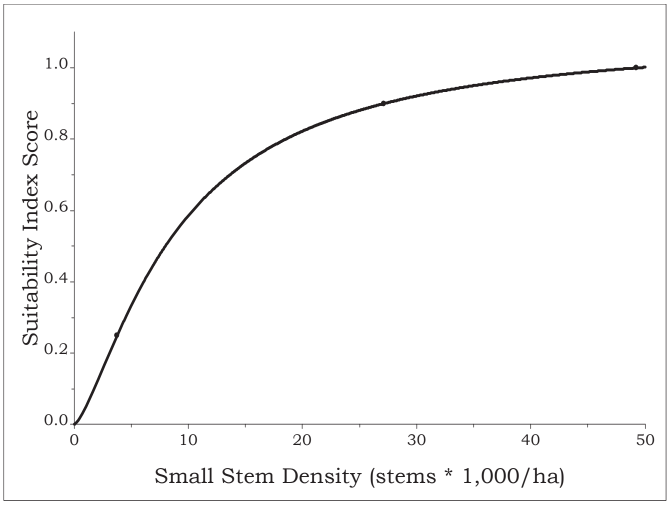


Figure 6.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems*1000/ha) and suitability index (SI) scores for American woodcock habitat. Equation: SI score = 1.029 * (0.998 – $e^{-0.076 * (\text{small stem density} / 1000)}$).

Table 12.—Influence of small stem (< 2.5 cm d.b.h.) density (stems*1,000/ha) on suitability index (SI) scores for American woodcock habitat

Small stem density	SI score
0[accc]	0.00
3.767[b]	0.25
27.125[c]	0.90
49.250[d]	1.00

[a]Assumed value.
[b]Murphy and Thompson (1993).
[c]McAuley and others (1996).
[d]Coon and others (1982).

(both New York and Pennsylvania are represented twice), we used the midpoint of this range rather than the average to summarize these data. With three of the studies observing stem densities of at least 44,000 and three observing densities of approximately 14,000 stems per ha (+/- 600 stems/ha), we believed there was adequate evidence to assign to the midpoint of this range (27,125 stems/ha) a higher SI score than average (0.500). Therefore, we assigned 27,125 stems per ha an SI score of 0.900, the maximum stem density (49,250) an SI score of 1.000 and the minimum density (3,767 stems/ha, as reported by Murphy and Thompson [1993]) an SI score of 0.250 (Table 12). We fit a logistic function through these data points to quantify the small stem density-SI score relationship (Fig. 6).

The next two variables relate to the minimum size of habitat patches used by the American woodcock. Movement rates within diurnal foraging and nesting habitats often are low, resulting in small diurnal home ranges (≤ 0.3 ha; Hudgins and others 1985). Conversely, the woodcock displays and roosts in relatively large openings at night (≥ 1.6 ha; Keppie and Whiting 1994). We used these data to establish minimum area thresholds for forests and openings, respectively. Nevertheless, the ultimate suitability of either of these habitat types is related to their interspersion with one another, as the woodcock requires both. Ideally, these habitats should be separated by less than 400 m (Hudgins and others 1985) even though the average home range may be at least 74 ha (485-m radius; Keppie and Whiting 1994). Because home ranges may encompass areas of nonhabitat, the American woodcock sometimes is found where the proportion of these habitat types within a typical home range is relatively small (e.g., 0.1; Table 13). We assumed that the woodcock derives greater benefit from increasing proportions of early successional forest habitat than field habitat within its home ranges due to greater foraging opportunities and increased protection from predators. Thus, our table defining the relationship between landscape composition (SI3)

Table 13.—Suitability index scores for American woodcock habitat based on composition of open and forest habitat within 500-m radius

	Proportion open[a]										
Proportion forest[b]	0.00	0.10	0.20	0.30	0.40	0.50	0.60	0.70	0.80	0.90	1.00
0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.10	0.05	0.05	0.05	0.05	0.05	0.00	0.00	0.00	0.00	0.00	
0.20	0.10	0.10	0.10	0.10	0.10	0.05	0.05	0.05	0.00		
0.30	0.20	0.20	0.20	0.20	0.20	0.10	0.10	0.05			
0.40	0.40	0.40	0.40	0.40	0.40	0.20	0.10				
0.50	0.60	0.60	0.60	0.60	0.60	0.40					
0.60	0.80	0.80	0.80	0.80	0.80						
0.70	1.00	1.00	1.00	1.00							
0.80	1.00	1.00	1.00								
0.90	1.00	1.00									
1.00	1.00										

[a]Merged grasslands, pasture/hay, fallow, urban/recreational grasses, emergent herbaceous wetlands, grass-forb, and shrub-seedling forests ≥1.6 ha.

[b]Sites with a positive SI1 score (Table 11) and ≥ 0.3 ha.

and SI scores shows greater increases in suitability with relatively modest increases in diurnal habitat compared to the increases in suitability associated with similar proportional increases in openings.

Soil properties also influence American woodcock habitat suitability. This species feeds nearly exclusively on earthworms, which it probes for preferentially in moist loamy soils (Rabe and others 1983). Because soils with excessive clay or sand contain insufficient, accessible earthworms with which to support a foraging woodcock, we included both soil texture (SI4) and soil drainage (SI5) as variables in the habitat suitability model. We used the STATSGO database to define soil characteristics. Soil texture classes from STATSGO were crosswalked to soil texture classes from the soil triangle (Table 14) and then assigned SI scores on the basis of texture descriptions in Rabe and others (1983) (Table 15). We also assumed that soil drainage class was associated with soil moisture content and similarly assigned SI scores to these drainage classes (Table 16) based on observations from Rabe and others (1983), who documented higher probing rates in soils with greater moisture contents.

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI2) and landscape factors (SI3, SI4 and SI5) separately and then the geometric mean of these means together.

$$\text{Overall HSI} = ((SI1 * SI2)^{0.500} * (SI3 * SI4 * SI5)^{0.333})^{0.500}$$

Table 14.—Crosswalk of soil texture classes defined in STATSGO soil database to soil texture triangle classes

STATSGO soil texture class	Soil texture triangle class
Clayey	Clay
Clayey over loamy	Clay
Clayey-skeletal	Clay
Coarse-loamy	Sandy loam
Coarse-silty	Sandy loam
Fine	Silt
Fine-loamy	Silt loam
Fine-loamy over clayey	Silty clay loam
Fine-loamy over sandy or sandy-skeletal	Silt loam
Fine-silty	Silt
Fine-silty over clayey	Silt
Loamy	Loam
Loamy-skeletal	Loam
Loamy-skeletal over clayey	Loam
Not used	None
Sandy	Sand
Very-fine	Silty clay
All others	None

Table 15.—Suitability index (SI) scores for American woodcock habitat based on soil texture triangle classes

Soil texture triangle class	SI score
Clay	0.0[a]
Silty clay	0.0[a]
Silty clay loam	0.2[a]
Silt loam	0.4[a]
Silt	0.0[a]
Loam	1.0[b]
Sandy loam	0.8[b]
Loamy sands	0.0[a]
Sands	0.0[b]
Sandy clay loam	0.4[a]
Sandy clay	0.0[a]
Clay loam	0.1[b]
None	0.0[a]

[a]Assumed value.
[b]Rabe and others (1983).

Table 16.—Suitability index (SI) scores for American woodcock habitat based on soil moisture, as defined by drainage class in the STATSGO soil database

Soil moisture	SI score
Very poorly	1.0[a]
Poorly	1.0[a]
Somewhat poorly	0.5[a]
Moderately well	0.1[a]
Well	0.0[a]
Somewhat excessively	0.0[a]
Excessively	0.0[a]

[a]Rabe and others (1983).

Verification and Validation

The American woodcock was observed only in 50 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.36$) between average HSI score and mean BBS route abundance across all subsections. When the 38 subsections in which the American woodcock was not found were removed from the analysis, the correlation not only remained significant ($P \leq 0.001$) but also was more strongly positive ($r_s = 0.68$). Thus, the HSI model is predicting habitat for this species in subsections where it was not detected on BBS routes. The generalized linear model predicting BBS abundance from BCR and HSI for the American woodcock was significant ($P \leq 0.001$; $R^2 = 0.218$), and the coefficient on the HSI predictor variable was both positive ($\beta = 0.090$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the American woodcock both verified and validated (Tirpak and others 2009a).

Bachman's Sparrow

U.S. Forest Service

Status

Bachman's sparrow (*Aimophila aestivalis*) is a resident bird associated with pine savannas and other open habitats throughout the Southeastern United States. Although its range expanded north to include Illinois, Indiana, and Ohio at the turn of the 20th century (likely in response to widespread land clearing), the range of this species has contracted steadily over the last 100 years. Today, the Bachman's sparrow is restricted to the extreme Southeast. BBS data from the central United States indicates significant annual declines (8.1 percent) over the past 40 years; declines have been particularly steep since 1980 (20.8 percent/year). This species is a Bird of Conservation Concern in both the CH and WGCP (Table 1). Similarly, this bird has a regional combined score of 20 in both regions, and PIF considers this species in need of critical recovery in the CH and immediate management in the WGCP (Table 1).

Natural History

Bachman's sparrow occupies two primary habitats in the Southeast: mature (> 80 year old) pine stands that are frequently burned (< 3-year burn interval) and recently cutover areas (< 5 year old; Dunning and Watts 1990). However, productivity is lower in these latter habitats (one vs. three offspring/pair/year; Liu and others 1995, Perkins and others 2003a). On the basis of this lower productivity and the poor colonizing ability of this species—suitable clearcut habitats more than 3 km from a source population generally remained unoccupied in South Carolina (Dunning and others 1995)—Tucker and others (2004) considered Bachman's sparrow as endemic to mature longleaf pine stands.

In all studies of Bachman's sparrow habitat, two features are identified repeatedly: a dense grass understory and an open overstory, both of which are maintained through frequent fires (Haggerty 1998, Plentovich and others 1998, Tucker and others 2004, Wood and others 2004). Stands managed for the red-cockaded woodpecker via prescribed burning typically provide excellent habitat for the Bachman's sparrow as well because the fires are frequent enough to suppress dense woody understories and maintain sparse canopies (Wilson and others 1995, Plentovich and others 1998, Provencher and others 2002, Wood and others 2004).

Model Description

Our habitat suitability model for the Bachman's sparrow includes six variables: landform, landcover type, successional age class, forest patch size, canopy cover, and connectivity.

The first suitability function combines landform, landcover type, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 17). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the relative quality of different vegetation types in different successional stages for this species.

Table 17.—Relationship of landform, landcover type, and successional age class to suitability index scores for Bachman's sparrow habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	1.000	0.333	0.000	0.000	1.000
	Deciduous	1.000	0.333	0.000	0.000	0.000
	Evergreen	1.000	0.333	0.000	0.000	1.000
	Mixed	1.000	0.333	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	1.000	0.333	0.000	0.000	1.000
	Deciduous	1.000	0.333	0.000	0.000	0.000
	Evergreen	1.000	0.333	0.000	0.000	1.000
	Mixed	1.000	0.333	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	1.000	0.333	0.000	0.000	1.000
	Deciduous	1.000	0.333	0.000	0.000	0.000
	Evergreen	1.000	0.333	0.000	0.000	1.000
	Mixed	1.000	0.333	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

We also included forest patch size (SI2) as a variable because of the relatively large home range for this species (mean = 2.5 ha; Haggerty 1998). Home ranges varied among regions and habitat types (reviewed in Mitchell 1998). They were slightly larger in evergreen stands (4.8 ha) than in ephemeral, early successional habitats (2.2 ha). We fit a logistic function (Fig. 7) through these data points, assuming that the former represented a stand area that would be occupied reliably and that the latter value was a minimum below which the sparrow would be absent (Table 18).

We included canopy cover (SI3) as a third suitability function to satisfy the two-fold requirement for open canopies and dense understories, two habitat components often well correlated (Table 19). Haggerty (1998) observed an average canopy cover of 9.5 percent at sites occupied by the Bachman's sparrow and 40 percent canopy cover at unoccupied sites. Wood and others (2004) observed 20 times more Bachman's sparrows in habitats with 25 to 50 percent canopy cover than sites with 50 to 75 percent cover. We fit an inverse logistic function to these data to extrapolate values between these known points (Fig. 8).

Because this resident species is restricted to a specialized habitat, occupancy of a site by the Bachman's sparrow is affected by the ability of dispersers to colonize it. This ability is

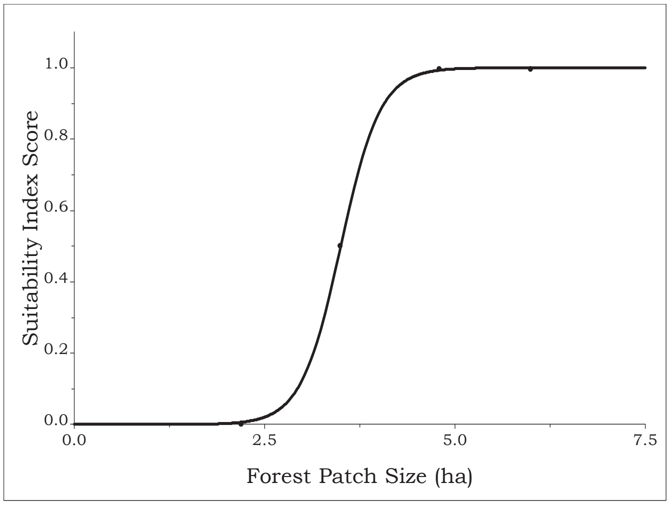


Figure 7.—Relationship between forest patch size and suitability index (SI) scores for Bachman's sparrow habitat. Equation: SI score = 1.000 / (1 + (699817.120 * e $^{-3.845 \text{ * forest patch size}}$)).

Table 18.—Relationship between forest patch size and suitability index (SI) scores for Bachman's sparrow habitat

Forest patch size (ha)	SI score
0.0[a]	0.0
2.2[b]	0.0
3.5[b]	0.5
4.8[b]	1.0
6.0[a]	1.0

[a]Assumed value.
[b]Stober (1996), reviewed in Mitchell (1998).

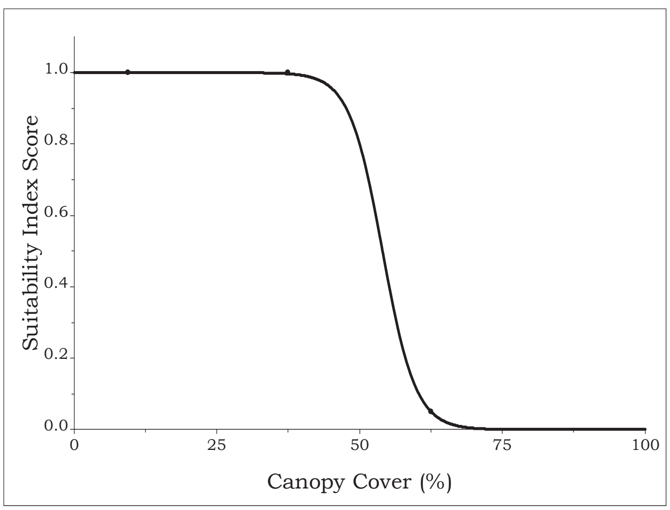


Figure 8.—Relationship between canopy cover and suitability index (SI) scores for Bachman's sparrow habitat. Equation: SI score = 1 - (1.000 / (1 + (126024970 * e $^{-0.3455 \text{ * canopy cover}}$))).

Table 19.—Relationship between canopy cover and suitability index (SI) scores for Bachman's sparrow habitat

Canopy cover (percent)	SI score
0.0[a]	1.00
9.5[b]	1.00
37.5[c]	1.00
62.5[c]	0.05
100.0[a]	0.00

[a]Assumed value.
[b]Haggerty (1998).
[c]Wood and others (2004).

directly affected by the connectivity (or conversely the isolation) of habitat patches (SI4). Birds are unable to colonize clearcuts more than 3 km distant before succession renders habitat conditions within them unsuitable (Dunning and others 1995). Although isolation also may affect the occupancy of mature evergreen stands, habitat conditions within them are less ephemeral. Thus, the Bachman's sparrow has a potentially longer time to colonize these stands. To compensate for this differential temporal window in accessibility, we used a 15-km distance threshold to fit a longer tail to the function relating connectivity of patches to their suitability as Bachman's sparrow habitat (Table 20, Fig. 9). We also assumed that source populations were restricted to mature evergreen forest stands with a preliminary overall SI score (calculated from SI1, SI2, and SI3) that was greater than 0.8.

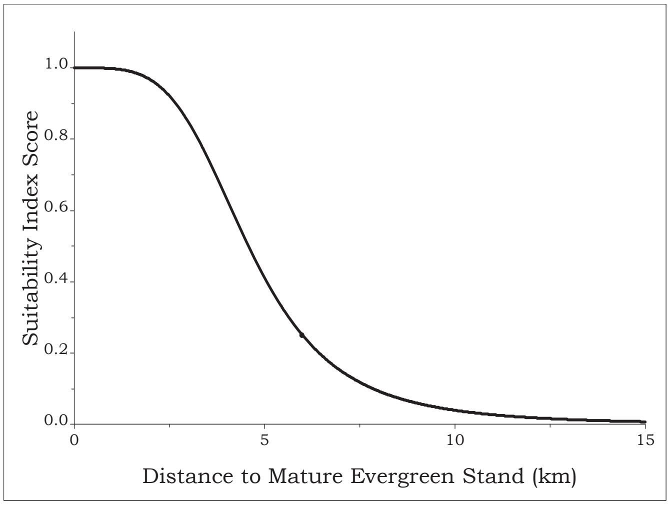


Figure 9.—Relationship between distance to nearest evergreen sawtimber habitat with initial suitability index (SI) score >0.8 and SI scores for Bachman's sparrow habitat. Equation: SI score = 1 / (1.000 + (0.002 * (distance to evergreen sawtimber habitat with initial SI score >0.8)$^{4.066}$)).

Table 20.—Relationship between distance to nearest evergreen sawtimber habitat with initial suitability index (SI) score > 0.8 and SI scores for Bachman's sparrow habitat

Habitat connectivity (km)	SI score
0[a]	1.00
6[b]	0.25
15[b]	0.00

[a]Dunning and others (1995).
[b]Assumed value.

To calculate the overall HSI score, we calculated the geometric mean of the two SIs related to forest structure (SI1 and SI3) and landscape attributes (SI2 and SI4) separately and then the geometric mean of these values together.

Overall HSI = $((SI1 * SI3)^{0.500} * (SI2 * SI4)^{0.500})^{0.500}$

Verification and Validation

Bachman's sparrow was found only in 29 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.62$) between average HSI score and mean BBS route abundance across all subsections. However, when subsections where the Bachman's sparrow was not found were removed from the analysis, the relationship was not significant ($r_s = 0.24$; P = 0.208). Thus, the HSI model predicts the absence of the Bachman's sparrow better than its abundance in subsections where it is found. The generalized linear model predicting BBS abundance from BCR and HSI for the Bachman's sparrow was significant ($P \leq 0.001$; $R^2 = 0.567$), and the coefficient on the HSI predictor variable was both positive (ß = 0.908) and significantly different from zero ($P = 0.079$). Therefore, we considered the HSI model for the Bachman's sparrow both verified and validated (Tirpak and others 2009a).

Bell's Vireo


Steve Maslowski, U.S. Fish & Wildlife Service

Status

Bell's vireo (*Vireo bellii*) is a scrubland specialist that reaches the eastern limit of its range in the CH and WGCP. Throughout both regions this species has declined over the past 40 years, with the most severe declines in the southern portion of the eastern range (-4.7, -6.6, and -10.1 percent annually in Missouri, Oklahoma, and the Ozark-Ouachita Plateau, respectively; Sauer and others 2005). Bell's vireo has a regional combined score of 15 in the CH and 16 in the WGCP, and PIF considers the species as requiring management attention in both regions (Table 1). The FWS also recognizes Bell's vireo as a Bird of Conservation Concern in both BCRs (Table 1).

Natural History

Bell's vireo is a small, Neotropical migrant associated with dense, low, shrubby vegetation (Brown 1993). It uses a variety of early successional scrubland habitats that meet these requirements (e.g., riparian woods, brushy fields, and regenerating forest). Most of the research on this species was conducted in the West, where Bell's vireo is alternately described as a riparian specialist (particularly the federally endangered subpopulation of least Bell's vireo in California) or a scrub-shrub generalist. This bird nests in dense shrub or understory vegetation 0.5 to 1.5 m above the ground, making its nests susceptible to both terrestrial and avian predators. Predation and brood parasitism are the primary causes of nest failure (Budnik and others 2000, 2002; Powell and Steidl 2000). Increasing the density of large shrub patches may improve Bell's vireo habitat in Missouri (Budnik and others 2002).

Model Description

The model for Bell's vireo includes six variables: landform, landcover, successional age class, interspersion of forest and open areas, edge, and small stem density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 21). We directly assigned SI values to these combinations on the basis of data from Hamel (1992) relating vegetation types and successional age class to habitat suitability estimates for Bell's vireo.

Both landcover and age class data were used to identify upland shrublands in grassland landscapes, the preferred habitat for this species in its eastern range (Budnik and others 2000). We used a 10-ha moving window (an average home range; Budnik and others 2000) to assess the interspersion of shrubland and grassland habitats (SI2). We assumed that an area containing 50 percent of each habitat type was ideal (Table 22). To extrapolate from this point we used broad incremental changes in habitat suitability (20 percent) and applied these symmetrically to 10-percent incremental changes in the proportion of scrubland or grassland. Landscapes lacking shrublands or grasslands were unsuitable and assigned an SI score of zero.

Table 21.—Relationship of landform, landcover type, and successional age class to suitability index scores for Bell's vireo habitat

Landform	Landcover type	Successional age class				
		Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.500	0.250	0.125	0.000	0.000
	Deciduous	0.500	0.250	0.125	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.500	0.250	0.125	0.000	0.000
	Woody wetlands	0.500	0.500	0.250	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.500	1.000	0.750	0.000	0.000
	Deciduous	0.250	0.500	0.375	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.250	0.500	0.375	0.000	0.000
	Woody wetlands	1.000	0.500	0.250	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.500	1.000	0.750	0.000	0.000
	Deciduous	0.500	1.000	0.750	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.500	1.000	0.750	0.000	0.000
	Woody wetlands	1.000	0.500	0.250	0.000	0.000

Table 22.—Relative composition of scrubland and grassland within 10-ha moving window on suitability index scores for Bell's vireo habitat

Proportion scrubland[b]	Proportion grassland[a]										
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	
0.2	0.0	0.0	0.1	0.2	0.4	0.4	0.4	0.4	0.4		
0.3	0.0	0.1	0.2	0.4	0.6	0.6	0.6	0.6			
0.4	0.0	0.2	0.4	0.6	0.8	0.8	0.8				
0.5	0.0	0.2	0.4	0.6	0.8	1.0[c]					
0.6	0.0	0.2	0.4	0.6	0.8						
0.7	0.0	0.2	0.4	0.6							
0.8	0.0	0.2	0.4								
0.9	0.0	0.2									
1.0	0.0										

[a]Grasslands/herbaceous, pasture/hay, and grass-forb successional age class.
[b]Shrub-seedling and sapling successional age classes.
[c]Budnik and others (2000); all other values assumed.

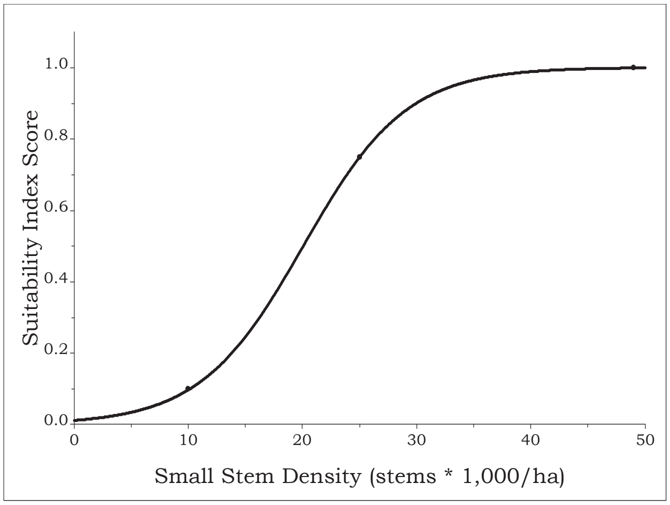


Figure 10.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for Bell's vireo habitat. Equation: SI score = 1.001 / (1.000 + (85.005 * $e^{-0.222 * (\text{small stem density} / 1000)}$)).

Table 23.—Influence of edge occurrence on suitability index (SI) scores for Bell's vireo habitat

3 × 3 pixel window around forest pixel includes field[a]	SI score
Yes[b]	1.0
No	0.0

[a]Field defined as any shrub-seedling or grass-forb age class pixel, natural grasslands/herbaceous, or pasture/hay. Forest defined as any used sapling age class pixel of transitional, shrublands, deciduous, orchard, or woody wetlands.

[b]Grass-forb and seedling-shrub habitats used regardless of edge.

Table 24.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) and suitability index (SI) scores for Bell's vireo habitat

Small stem density	SI score
0[a]	0.00
10[a]	0.10
25[a]	0.75
49[b]	1.00

[a]Assumed value.
[b]Farley (1987).

Bell's vireo uses a variety of young woody habitats (Brown 1993); however, birds also nest along the edges of sapling stands and in hedgerows (Budnik and others 2002). Therefore, we included edge (SI3) as a parameter in the Bell's vireo HSI model. To identify edges, we examined the eight pixels surrounding each sapling age class pixel to determine whether any were classified as shrub-seedling or grass-forb age class forest or as a nonforest landcover class. If so, the central pixel in the 3 × 3 pixel window (90 x 90 m) was assigned an SI score of 1.000; if not, it was assigned a zero. We assigned to grass-forb and shrub-seedling pixels an SI score of 1.000 regardless of edge (Table 23). Similarly, we always assigned to pole and sawtimber pixels an SI score of zero regardless of edge.

We also included small stem density (SI4) as a component of the overall Bell's vireo HSI model because of the importance of dense woody shrub cover for this species. Farley (1987) measured an average of 9.8 stems greater than 2 mm per 1-m diameter plot (approximately 392,000 stems/ha) in Bell's vireo territories. This relatively high stem value included woody and nonwoody stems of all sizes greater than 2 mm; therefore, we assumed that that only one-eighth of these stems (49,000 = ⅛ * 392,000) were woody and less than 2.5 cm d.b.h. and that this value represented optimal habitat (Table 24, Fig. 10).

To calculate the overall HSI score for Bell's vireo, we first determined the geometric mean of the suitability indices related to forest structure (SI1 and SI4) and landscape attributes (SI2 and SI3) separately and then determined the geometric mean of these values together. Because SI3 applies only to sapling habitats, HSI scores were calculated differently for sapling successional age class stands than for grass-forb or shrub-seedling successional age class stands. To determine the overall SI score across the entire BCR, we added suitability scores from individual age classes across the entire landscape.

For grass-forb and shrub-seedling habitats:

$$HSI_{GF\ and\ SS} = (((SI1 * SI4)^{0.500}) * (SI2))^{0.500}$$

For sapling habitats:

$$HSI_{Sap} = ((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$$

$$Overall\ HSI = HSI_{GF\ and\ SS} + HSI_{Sap}$$

Verification and Validation

Bell's vireo was found in 54 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.44$) between average HSI score and mean BBS route abundance across all subsections. Removing subsections in which Bell's vireo was not observed had a minimal effect on these results ($r_s = 0.46$; $P \leq 0.001$). The generalized linear model predicting BBS abundance from BCR and HSI for the Bell's vireo was significant ($P = 0.042$; $R^2 = 0.072$); however, the coefficient on the HSI predictor variable was negative ($\beta = -19.906$) and not significantly different from zero ($P = 0.544$). Therefore, we considered the HSI model for the Bell's vireo verified but not validated (Tirpak and others 2009a).

Bewick's Wren

Dave Menke, U.S. Fish & Wildlife Service

Status

Bewick's wren (*Thryomanes bewickii*) was once a common resident throughout the Southeast and mid-Atlantic. However, its range has contracted steadily over the last century and today this species is virtually absent east of the Mississippi River (Kennedy and White 1997). BBS data from FWS Region 4 indicates that populations have declined by 12.8 percent per year over the last 40 years (Sauer and others 2005). The decline of this species coincided with the range expansion of the house wren, which often destroys Bewick's wren nests in areas where the species' ranges overlap (Kennedy and White 1996). Bewick's wren is a Bird of Conservation Concern in both the CH and WGCP (Table 1). PIF identifies the species as requiring both critical recovery in the WGCP (regional combined score = 16) and immediate management attention in the CH (regional combined score = 15).

Natural History

Bewick's wren is a small resident passerine that breeds in a variety of vegetation types, including brushy areas, scrub and thickets in open country, and open and riparian woodlands (Kennedy and White 1997). This plasticity has produced conflicting reports of habitat associations in the literature (e.g., dry vs. riparian, open woodlands vs. shrub thickets). However, this species likely responds most strongly to the availability of nest sites. Bewick's wren nests in cavities or opportunistically in crevices up to 10 m high. In the eastern portion of its range, this bird often lives near human habitation, particularly farmland. As mentioned, population declines of this species may be partly the result of competition with the house wren (Kennedy and White 1996). Bewick's wren is found primarily in grassland scrub while the house wren occurs primarily in secondary growth on abandoned agricultural land and in residential areas. Both species exploit the full range of these habitat types, and populations of both expanded as these latter types increased. However, as scrub habitats declined, Bewick's wren may have declined because its primary source habitat no longer was abundant.

Model Description

Our model for Bewick's wren includes five variables: landform, landcover, successional age class, interspersion of forest and open habitats, and snag density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 25). We then directly assigned an SI score to these combinations on the basis of data from Hamel (1992) on the relative quality of Bewick's wren habitat based on vegetation type and successional age class.

We also considered as important for this species the interspersion of forest and grassland habitats (SI2), as Bewick's wren is most abundant in semi-open areas containing about 40 percent woodland (Pogue and Schnell 1994; Table 26). We relied on data from Pogue and Schnell to define SI values along the diagonal axis of our interspersion table (where forest and grassland totaled 100 percent) and completed the table from these values.

Table 25.—Relationship of landform, landcover type, and successional age class to suitability index scores for Bewick's wren habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	1.000	1.000	0.500	0.000	0.000
	Transitional-shrubland	1.000	1.000	0.500	0.000	0.000
	Deciduous	0.500	0.500	0.250	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	1.000	1.000	0.500	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	1.000	1.000	0.500	0.000	0.000
	Transitional-shrubland	1.000	1.000	0.500	0.000	0.000
	Deciduous	0.500	0.500	0.250	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	1.000	1.000	0.500	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	1.000	1.000	0.500	0.000	0.000
	Transitional-shrubland	1.000	1.000	0.500	0.000	0.000
	Deciduous	0.500	0.500	0.250	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	1.000	1.000	0.500	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

Table 26.—Influence of interspersion between forest and open habitats (as indexed by relative composition within 10-ha moving window) on suitability index scores for Bewick's wren habitat

	Proportion open[a]										
Proportion forest[b]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00[c]
0.1	0.00	0.00	0.05	0.10	0.10	0.20	0.20	0.20	0.20	0.20[c]	
0.2	0.00	0.05	0.10	0.15	0.20	0.25	0.40	0.40	0.40[c]		
0.3	0.00	0.05	0.20	0.25	0.60	0.80	0.80	0.80[c]			
0.4	0.00	0.05	0.20	0.40	0.80	1.00	1.00[c]				
0.5	0.00	0.05	0.20	0.40	0.80	1.00[c]					
0.6	0.00	0.10	0.20	0.40	0.80[c]						
0.7	0.00	0.10	0.20	0.40[c]							
0.8	0.00	0.10	0.20[c]								
0.9	0.00	0.10[c]									
1.0	0.00[c]										

[a]Open = grasslands, herbaceous planted (pasture-hay, fallow, and urban-recreational grasses), emergent herbaceous wetlands.
[b]Forest = forested upland, low-density residential, shrubland, transitional, and woody wetlands.
[c]Pogue and Schnell (1994); all other values assumed.

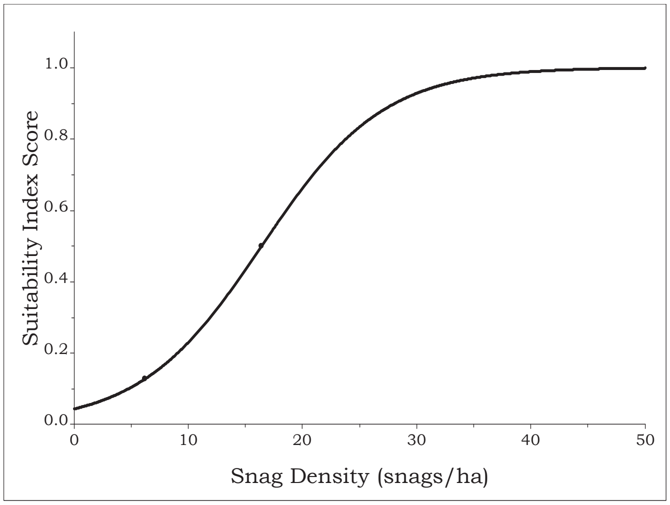


Figure 11.—Relationship between snag density and suitability index (SI) score for Bewick's wren habitat. Equation: SI score = 1.0011 / (1 + (21.9129 * $e^{-0.1881 * \text{snag density}}$)).

Table 27.—Influence of snag density on suitability index scores for Bewick's wren habitat

Snag density (snags/ha)	SI score
6.2[a]	0.128
16.4[b]	0.500
52.8[a]	1.000

[a]Rumble and Gobeille (2004).
[b]Sedgwick and Knopf (1990).

We also included snag density (SI3) in our model of Bewick's wren habitat because as a secondary cavity nester, this species responds strongly to nest-site availability. We assumed that higher snag densities would decrease competition with other cavity nesters, improving habitat quality. Specific data relating snag density to Bewick's wren habitat suitability were not available, so we assumed that the average snag density observed by Sedgwick and Knopf (1990) (16.4 snags/ha) within home ranges of the house wren, a secondary cavity nester of similar size, represented average habitat suitability (SI score = 0.500) for the Bewick's wren. We coupled this information with data from Rumble and Gobeille (2004) (Table 27) on the relative density of the house wren in habitats with different snag densities to build a logistic function quantifying the relationship between habitat suitability and snag density (Fig. 11).

To calculate the overall HSI score, we first calculated the geometric mean of the two suitability indices related to forest structure attributes (SI1 and SI3), and then the geometric mean of this result and the SI related to interspersion (SI2).

Overall HSI = $((\text{SI1} * \text{SI3})^{0.500} * \text{SI2})^{0.500}$

Verification and Validation

Bewick's wren was found in 74 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.40$) between average HSI score and mean BBS route abundance across subsections. However, this relationship was weaker ($r_s = 0.35$; $P = 0.002$) when subsections in which the Bewick's wren was not detected were removed from the analysis. The generalized linear model predicting BBS abundance from BCR and HSI for the Bewick's wren was not significant ($P = 0.517$; $R^2 = 0.015$), and the coefficient on the HSI predictor variable was negative (ß = -3.193) and not significantly different from zero ($P = 0.857$). Therefore, we considered the HSI model for the Bewick's wren verified but not validated (Tirpak and others 2009a).

Black-and-white Warbler

Charles H. Warren, images.nbii.gov

Status

The black-and-white warbler (*Mniotilta varia*) is a neotropical migrant found throughout the eastern United States and southern Canada. This is a forest-interior species and the annual declines of 1.2 percent observed in the United States over the last 40 years likely are the result of increasing forest fragmentation (Sauer and others 2005). This species has a regional combined score of 16 in the WGCP, where it is a species requiring management attention (Table 1). The black-and-white warbler has a regional combined score of only 13 in the CH. The FWS does not recognize the black-and-white warbler as a Bird of Conservation Concern in either BCR (Table 1).

Natural History

As a forest-interior specialist, the black-and-white warbler is found in the mature deciduous hardwood forests of the eastern United States and Canada (Kricher 1995). It is highly sensitive to fragmentation in the landscape (Robbins and others 1989) and typically is absent from small woodlots (< 7.5 ha; Galli and others 1976). Hamel (1992) suggested that 550 ha was the minimum tract size for this species in the Southeast.

Few studies have focused exclusively on the habitat ecology of this bird, though Conner and others (1983) found that the black-and-white warbler is associated with mature forest stands with high densities of large (> 32 cm d.b.h.) trees. Although a ground-nesting bird, this species is associated with high densities of hardwood saplings. Conversely, pine saplings negatively affect both the presence and abundance of the black-and-white warbler.

This bird occupies upland and bottomland forests but reaches greater densities in the former, with oak-hickory and cove forests considered optimal (Hamel 1992). Nevertheless, successional age may be the most critical habitat factor affecting the black-and-white warbler. Dettmers and others (2002) validated Hamel's (1992) habitat suitability model for the black-and-white warbler, finding the model performed well due to the restriction of the black-and-white warbler to older age class forests. However, Thompson and others (1992) and Annand and Thompson (1997) observed the black-and-white warbler in sapling and clearcut stands in Missouri.

Model Description

Our HSI model for the black-and-white warbler includes six variables: landform, landcover, successional age class, forest patch size, percent forest in a 1-km radius, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 28). We directly assigned SI scores to these combinations based on vegetation type and age class associations of the black-and-white warbler reported by Hamel (1992). However, we assigned higher values to shrub-seedling stands based on data from Thompson and others (1992) and Annand and Thompson (1997).

Table 28.—Relationship between landform, landcover type, age class, and suitability index scores for black-and-white warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.167	0.333	0.333	0.667
	Deciduous	0.000	0.167	0.333	0.333	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	0.333
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.333 (0.000)
	Deciduous	0.000	0.167	0.333	0.333	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	0.333
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.333 (0.000)
	Deciduous	0.000	0.167	0.333	0.333	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	0.333

Forest patch size (SI2) affects occurrence of this species as it is notably absent from small forest blocks. Therefore, we fit a logarithmic function (Fig. 12) relating forest patch size to SI scores derived from probability of occurrence data from Robbins and others (1989) (Table 29). The relative value of a forest block of a specific size is influenced by its landscape context. In predominantly forested landscapes, small forest patches that may not be used in predominantly nonforested landscapes may provide habitat due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 13) to data (Table 30) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. Because of the extreme sensitivity of the black-and-white warbler to fragmented landscapes, we assumed that the midpoint between moderately and lightly fragmented forest defined the specific cutoff for average (SI score = 0.500) hatitat. We used the maximum value of SI2 or SI3 to account for small patches in predominantly forested landscapes and large patches in predominantly nonforested landscapes.

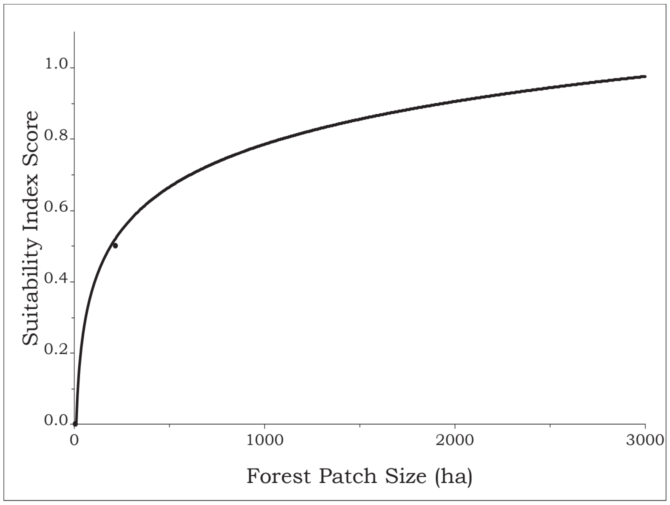


Figure 12.—Relationship between forest patch size and suitability index (SI) scores for black-and-white warbler habitat. Equation: SI score = 0.1731 * ln(forest patch size) – 0.4096.

Table 29.—Influence of forest patch size on suitability index (SI) scores for black-and-white warbler habitat

Forest patch size (ha)	SI score
10[a]	0.0
220[b]	0.5
3,200[b]	1.0

[a]Assumed value.
[b]Robbins and others (1989).

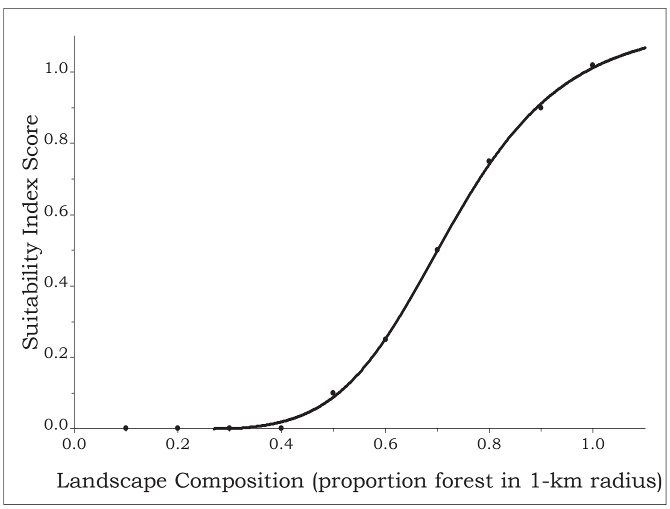


Figure 13.—Relationship between landscape composition and suitability index (SI) scores for black-and-white warbler habitat. Equation: SI score = 1.047 / (1.000 + (1991.516 * e $^{-10.673 * \text{landscape composition}}$)).

Table 30.—Relationship between landscape composition (proportion forest in 1-km radius) and suitability index (SI) scores for black-and-white warbler habitat

Landscape composition[a]	SI score
0.00[a]	0.00
0.10[a]	0.00
0.20[a]	0.00
0.30[a]	0.00
0.40[a]	0.00
0.50[a]	0.10
0.60[a]	0.25
0.70[b]	0.50
0.80[a]	0.75
0.90[a]	0.90
1.00[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

Canopy cover (SI4) also may affect the quality of black-and-white warbler habitat. Thus, we included it as a factor in our HSI model. Prather and Smith (2003) reported higher densities of the black-and-white warbler in forests with relatively open canopies, so we used their data (Table 31) to derive an inverse logistic function (Fig. 14) that quantified the relationship between canopy cover and SI scores.

We calculated the overall HSI score as the geometric mean of the geometric mean of individual SI functions related to forest structure (SI1 and SI4) multiplied by the maximum SI score for forest patch size or percent forest in the 1-km radius landscape.

Overall HSI = $((SI1 * SI4)^{0.500} * Max(SI2 \text{ or } SI3))^{0.500}$

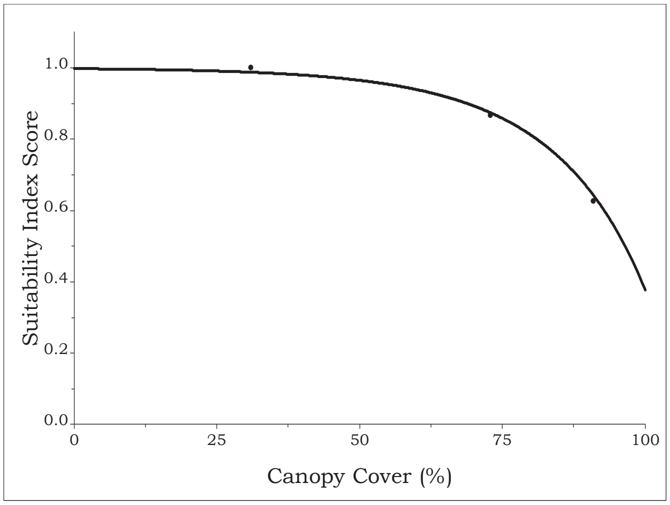


Figure 14.—Relationship between canopy cover and suitability index (SI) scores for black-and-white warbler habitat. Equation: SI score = 1 - (-4.190 / (1 + (-1890.213 * e $^{-0.055 * \text{canopy cover}}$))).

Table 31.—Influence of canopy cover on suitability index (SI) scores for black-and-white warbler habitat.

Canopy cover (percent)[a]	SI score
31	1.000
73	0.866
91	0.627

[a]Prather and Smith (2003).

Verification and Validation

The black-and-white warbler was found in 85 of the 88 subsections within the CH and WGCP. Not surprisingly, Spearman rank correlations based on all subsections and only subsections in which this species was found produced similar results: significant ($P \leq 0.001$ for both analyses) positive relationships (r_s = 0.54 and 0.53, respectively) between average HSI score and mean BBS route abundance. The generalized linear model predicting BBS abundance from BCR and HSI for the black-and-white warbler was significant ($P \leq 0.001$; R^2 = 0.380), and the coefficient on the HSI predictor variable was both positive (β = 3.194) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the black-and-white warbler both verified and validated (Tirpak and others 2009a).

Blue-gray Gnatcatcher

Charles H. Warren, images.nbii.gov

Status

The blue-gray gnatcatcher (*Polioptila caerulea*) is a short-distance migrant found throughout eastern North America and the Southwest. Populations are relatively stable in both the CH and WGCP (Table 5). The FWS does not recognize this species as a Bird of Conservation Concern in either region (Table 1). This bird requires management attention in the CH (regional combined score = 14) but does not have any special designation in the WGCP (regional combined score =13; Table 1).

Natural History

The blue-gray gnatcatcher is a small passerine that inhabits woodland types ranging from shrubland to mature forest (Ellison 1992). It prefers deciduous habitats and is rare or absent in evergreen forests. This species attains its highest numbers in mesic and low-lying areas, but is also found in xeric forests and along ridges.

Kershner and others (2001) did not identify specific microhabitat requirements for this species in Illinois, and considerable variation in nest height (0.8 to 24.4 m) and territory size (0.5 to 8 ha) has been documented across the range.

Although often associated with edges, this bird may be area sensitive (Knutson 1995, Kilgo and others 1998). Nest success was greater for nests placed higher and farther from an edge in Illinois (Kershner and others 2001) but did not differ between bottomland hardwood stands and cottonwood plantations in the Mississippi Alluvial Valley (Twedt and others 2001). The abundance of the blue-gray gnatcatcher was higher in bottomland hardwood stands surrounded by fields than those surrounded by pine forest (Kilgo and others 1998).

Model Description

The HSI model for the blue-gray gnatcatcher includes seven variables in five functions: landform, landcover, successional age class, forest patch size, percent forest in a 1-km radius landscape, edge, and basal area.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 32). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the relative quality of vegetation associations and successional age classes for this species. We adjusted Hamel's values for shrub-seedling and sapling-aged stands to account for the higher densities observed in young forests by Thompson and others (1992) and Annand and Thompson (1997).

We included forest patch size (SI2) as a variable to account for the area sensitivity of the blue-gray gnatcatcher. We fit a logarithmic function (Fig. 15) to data from Robbins and others (1989) on the probability of occurrence for this bird in stands of various sizes (Table 33). Nevertheless, the actual use of a forest patch reflects both its area and its landscape

Table 32.—Relationship of landform, landcover type, and successional age class to suitability index scores for blue-gray gnatcatcher habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.333	0.667	0.667	1.000
	Transitional-shrubland	0.000	0.333	0.667	0.667	1.000
	Deciduous	0.000	0.333	0.667	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.083	0.167	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	1.000
Terrace-mesic	Low-density residential	0.000	0.333	0.667	0.667	1.000
	Transitional-shrubland	0.000	0.333 (0.000)	0.667 (0.000)	0.667 (0.000)	1.000 (0.000)
	Deciduous	0.000	0.333	0.667	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.083	0.167	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	1.000
Xeric-ridge	Low-density residential	0.000	0.333	0.667	0.667	1.000
	Transitional-shrubland	0.000	0.333 (0.000)	0.667 (0.000)	0.667 (0.000)	1.000 (0.000)
	Deciduous	0.000	0.333	0.667	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.083	0.167	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.333	0.333	1.000

context (SI3). In predominantly forested landscapes, a small forest patch that otherwise may not be suitable may be occupied due to its proximity to a larger forest block (Rosenberg and others 1999). Because the gnatcatcher also is associated with edges, it may not be as abundant in predominantly forested landscapes that lack significant edge habitat. Thus, we assumed that the relationship between habitat suitability of the blue gray gnatcatcher and the amount of forest in the landscape followed a Gaussian function (Fig. 16), with landscapes containing 70 to 80 percent forest as optimal and suitability declining as the proportion of forest in the landscape moved from this ideal (Table 34). We used the maximum suitability score of SI2 or SI3 to simultaneously account for patch area and landscape composition.

We also included edge (SI4) in our HSI model because of the association of the blue-gray gnatcatcher with edges within large forest blocks. This species nests along both hard and soft edges (typically within 30 m; Kershner and others 2001). Therefore, we defined edge as the interface among sapling, pole, and sawtimber stands and herbaceous and nonforest landcovers (hard edge) or seedling and grass-forb stands (soft edge). We used a 7 × 7 pixel moving window (210 x 210 m) to identify where these adjacencies occurred but recognized that the blue-gray gnatcatcher is not restricted to edge habitats and applied a residual SI score (0.010) to sites that did not meet this criterion (Table 35).

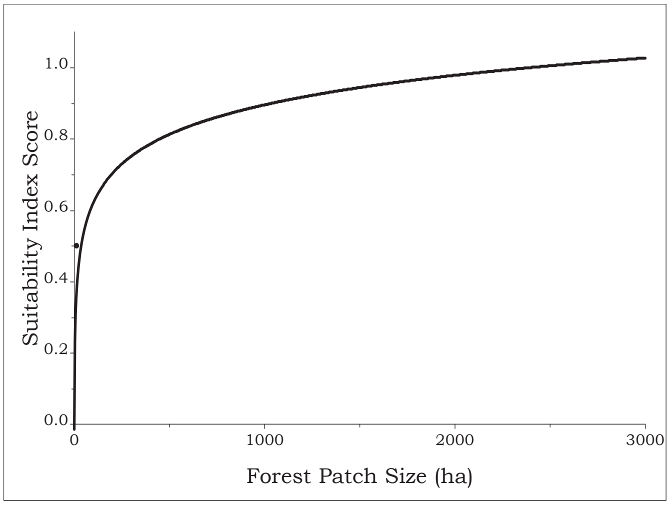


Figure 15.—Relationship between forest patch size and suitability index (SI) scores for blue-gray gnatcatcher habitat. Equation: SI score = 0.137 * ln(forest patch size) + 0.186.

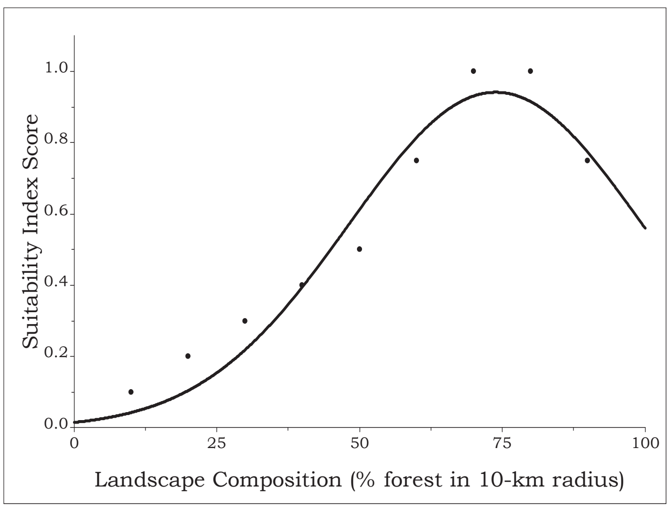


Figure 16.—Relationship between landscape composition and suitability index (SI) scores for blue-gray gnatcatcher habitat. Equation: SI score = 1.002 * $e^{((0 – ((\text{landscape composition}) – 74.165) ^ 2) / 1064.634)}$.

Table 33.—Influence of forest patch size on suitability index (SI) scores for blue-gray gnatcatcher habitat

Forest patch size (ha)[a]	SI score
6.8	0.0
15	0.5
3,200	1.0

[a]Robbins and others (1989).

Table 34.—Relationship between landscape composition (percent forest in 10-km radius) and suitability index (SI) scores for blue-gray gnatcatcher habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.10
20[a]	0.20
30[b]	0.30
40[a]	0.40
50[b]	0.50
60[a]	0.75
70[b]	1.00
80[a]	1.00
90[b]	0.75
100[a]	0.50

[a]Assumed value.
[b]Dononvan and others (1997).

Table 35.—Influence of edge on suitability index (SI) scores for blue-gray gnatcatcher habitat

7 × 7 pixel window around forest pixel includes field[a]	SI score
Yes	1.00
No	0.01

[a]Field defined as any shrub-seedling or grass-forb age class forest, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any used sapling, pole, or sawtimber age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands (i.e., SI1 > 0).

We fit a quadratic function to data from Annand and Thompson (1997) on the response of the blue-gray gnatcatcher to basal area (SI5; Table 36, Fig. 17), reflecting the preference of this species for open forest conditions.

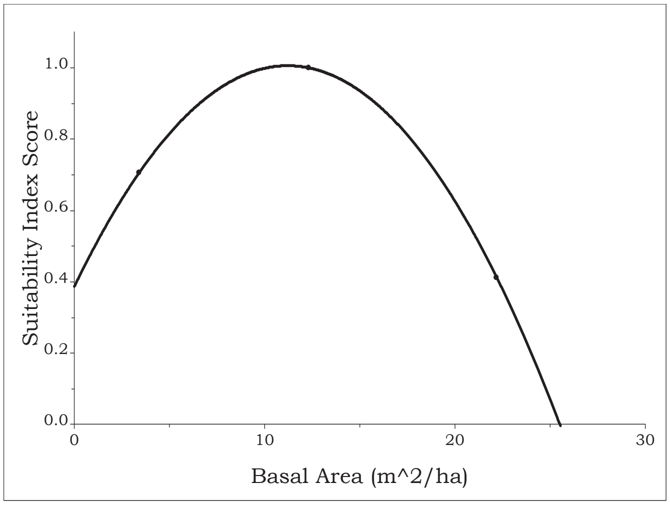


Figure 17.—Relationship between basal area and suitability index (SI) scores for blue-gray gnatcatcher habitat. Equation: SI score = 0.3863 + 0.1105 * (basal area) – 0.0049 * (basal area)^2.

Table 36.—Influence of basal area (m^2/ha) on suitability index (SI) scores for blue-gray gnatcatcher habitat

Basal area[a]	SI score
3.41	0.706
12.33	1.000
22.20	0.412

[a]Annand and Thompson (1997).

To calculate the HSI score for sapling, pole, and sawtimber age classes, we determined the geometric mean of SI scores for forest structure (SI1 and SI5) and landscape composition attributes (Max(SI2 or SI3) and SI4) separately and then the geometric mean of these means together. Because edge occurrence (SI4) was not applicable to the shrub-seedling age class, we calculated HSI scores separately for this age class and summed across age classes to determine the overall HSI score for the landscape.

Sapling, pole, and sawtimber successional age classes:

$$HSI_{Old} = (((SI1 * SI5)^{0.500}) * ((Max\ (SI2\ or\ SI3)) * SI4)^{0.500})^{0.500}$$

Shrub-seedling successional age classes:

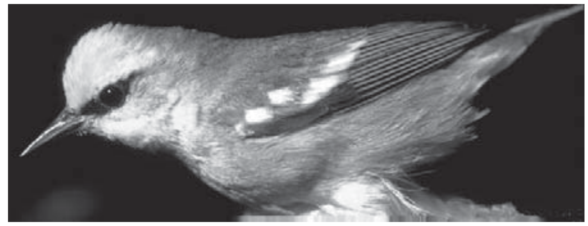
$$HSI_{Shrub} = ((SI1 * SI5)^{0.500} * (Max\ (SI2\ or\ SI3)))^{0.500}$$

$$Overall\ HSI = HSI_{Old} + HSI_{Shrub}$$

Verification and Validation

The blue-gray gnatcatcher was found in all 88 subsections of the CH and WGCP. Spearman rank correlation analysis on average HSI score and mean BBS route abundance across subsections resulted in a significant ($P \leq 0.001$) positive relationship ($r_s = 0.58$) between these variables. The generalized linear model predicting BBS abundance from BCR and HSI for the blue-gray gnatcatcher was significant ($P \leq 0.001$; $R^2 = 0.210$), and the coefficient on the HSI predictor variable was both positive ($\beta = 19.625$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the blue-gray gnatcatcher both verified and validated (Tirpak and others 2009a).

Blue-winged Warbler



Chandler S. Robbins, Patuxent Bird Identification InfoCenter
Photo used with permission

Status

The blue-winged warbler (*Vermivora pinus*) is a neotropical migrant found from southern New England west to the Lake States and south through the southern Appalachians and Ozarks. Across most of its range, this species has been stable and has even increased in some areas (possibly to the detriment of the golden-winged warbler, with which it sometimes interbreeds; Gill 1980). Once limited to a mostly Midwestern range, this bird expanded into southern New England as forests were cleared and farms were abandoned. However, as the forest has matured in this region, the blue-winged warbler has experienced declines (3.3 and 5.3 percent annually from 1966 to 2004 in the increasingly residential Connecticut and New Jersey, respectively). A similar phenomenon has occurred in the Southeast and BBS data indicate a 3.7 percent decline in FWS Region 4 during this same period (Sauer and others 2005). This species is designated a Bird of Conservation Concern in the CH but not in the WGCP (Table 1), where it rarely breeds. It has a regional combined score of 19 in the CH and requires management attention in that region (Table 1).

Natural History

The blue-winged warbler is an early successional species (Gill and others 2001) that benefited from European settlement by expanding its range following the initial clearing of forests for agriculture and the subsequent abandonment of farms. Breeding habitat includes early to midsuccessional forest containing dense low growth (shrubs, young trees, thickets). This species makes use of a variety of landform conditions from wetland edges to dry uplands, though mated males have more xeric territories than unmated males. Territories range from 0.2 to 5 ha, with boundaries often aligned along edges. Nests typically are within 30 m of a forest edge in grassy areas with high numbers of small (< 10 cm d.b.h.) trees. Density is inversely related to successional age class, fragmentation, and the abundance of the golden-winged warbler and brown-headed cowbird.

Model Description

The blue-winged warbler model includes five variables: landform, landcover, successional age class, early successional patch size, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 37). We directly assigned SI scores to these combinations based on habitat associations reported in Hamel (1992) for the blue-winged warbler. We modified Hamel's data to maximize SI scores in the transitional-shrubland landcover class in the xeric landform.

We also included early successional patch size (SI2) in our model on the basis of data from Rodewald and Vitz (2005) on the relative abundance of the blue-winged warbler in small and large clearcuts (Table 38; Fig. 18). We defined early successional forest by age class and included only grass-forb, shrub-seedling, and sapling age classes in the calculation of patch area.

Table 37.—Relationship of landform, landcover type, and successional age class to suitability index scores for blue-winged warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333	0.167	0.000	0.000
	Deciduous	0.000	0.333	0.167	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.083	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.667	0.333	0.000	0.000
	Deciduous	0.000	0.667	0.333	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000	0.500	0.000	0.000
	Deciduous	0.000	1.000	0.500	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000

Table 38.—Influence of early successional patch size on suitability index scores for blue-winged warbler habitat; early successional patches include all adjacent grass-forb, shrub-seedling, and sapling successional age class forest

Early successional patch size (ha)	SI score
0[a]	0.000
4[b]	0.786
13[b]	1.000

[a]Assumed value.
[b]Rodewald and Vitz (2005).

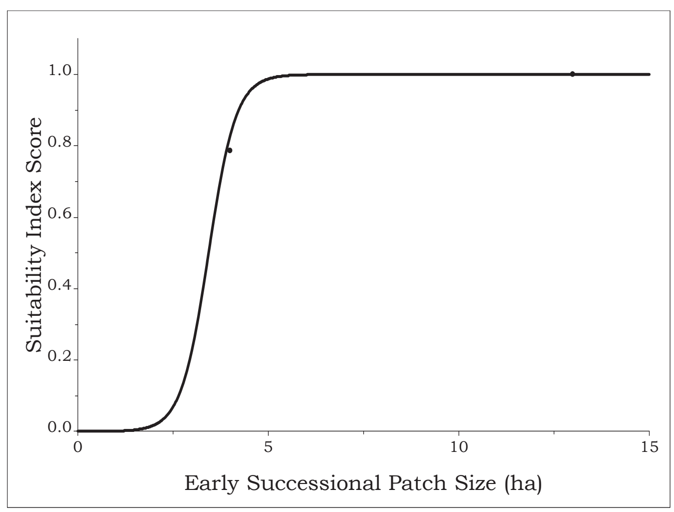


Figure 18.—Relationship between early successional patch size and suitability index (SI) scores for blue-winged warbler habitat. Equation: SI score = 1.000 / (1 + (14353.617 * e $^{-2.788 \text{ * forest patch size}}$)).

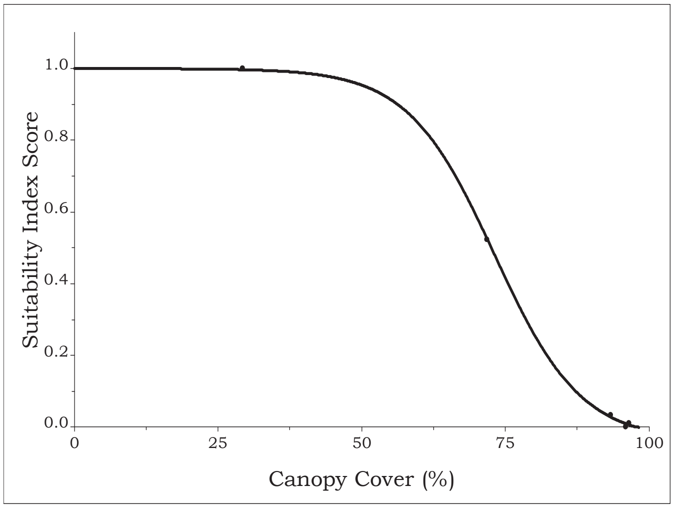


Figure 19.—Relationship between canopy cover and suitability index (SI) scores for blue-winged warbler habitat. Equation: SI score = 1 - (1.0381 / (1 + (16277.383 * e $^{-0.1327 * \text{canopy cover}}$))).

Table 39.—Influence of canopy cover on suitability index (SI) scores for blue-winged warbler habitat

Canopy cover (percent)[a]	SI score
29.26	1.000
71.86	0.523
93.38	0.034
95.58	0.000
96.59	0.011

[a]Annand and Thompson (1997).

We used an inverse logistic function (Fig. 19) to quantify the relationship between canopy cover (SI3) and SI scores to reflect the lower densities of the blue-winged warbler in forests with increasingly closed canopies. We defined this function by fitting a curve to data from Annand and Thompson (1997) on the relative density of this bird in forest stands with different estimates of canopy cover (Table 39).

To calculate the overall HSI score for this species , we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI3) and then calculated the geometric mean of this value and early successional patch size (SI2).

Overall HSI = $((\text{SI1} * \text{SI3})^{0.500} * \text{SI2})^{0.500}$

Verification and Validation

The blue-winged warbler was found in 64 of the 88 subsections within the CH and WGCP. We used Spearman rank correlations between average HSI score and mean BBS route abundance at the subsection scale to verify this model. We observed significant positive relationships when analyses included all subsections (r_s = 0.26; P = 0.014) or only those subsections where this species was detected (r_s = 0.28; P = 0.026). The generalized linear model predicting BBS abundance from BCR and HSI for the blue-winged warbler was significant ($P \leq 0.001$; R^2 = 0.232), and the coefficient on the HSI predictor variable was positive (β = 1.717) but not significantly different from zero (P = 0.334). Therefore, we considered the HSI model for the blue-winged warbler verified but not validated (Tirpak and others 2009a).

Brown Thrasher

Jeffrey A Spendelow, Patuxent Bird Identification InfoCenter
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Status

The brown thrasher (*Toxostoma rufum*) is a short-distance migrant found throughout eastern North America. Although populations in the CH and WGCP declined by 1.4 percent per year between 1966 and 2004 (Table 5), this species is not considered a Bird of Conservation Concern in either BCR (Table 1). The brown thrasher has a regional combined score of 13 and 15 in the WGCP and CH, respectively, and is a species warranting management attention in the CH (Table 1).

Natural History

A ground-foraging passerine, the brown thrasher is associated with edge habitats throughout the eastern United States and Canada (Cavitt and Haas 2000). Breeding habitat includes a variety of vegetation types, but this species reaches its highest densities in shrublands and midsuccessional forests. Grand and Cushman (2003) found that thrashers in Massachusetts were associated predominately with the amount of scrub oak in the landscape. Rumble and Gobeille (2004) found no significant difference in brown thrasher occurrence among seral stages of cottonwood floodplains in South Dakota, though this bird was detected most often in younger forest classes. Savanna restoration efforts increase thrasher abundance by reducing tree density (Davis and others 2000).

Nests are typically low in a tree or shrub but some may be on the ground. Territory size and thrasher density vary according to habitat quality (0.5 to 1.1 ha and 0.1 to 0.4/ha, respectively). The FWS (Cade 1986) developed an HSI model for this species that included three site-specific variables: density of woody stems, canopy cover, and litter cover.

Model Description

Our brown thrasher model includes six variables: landform, landcover, successional age class, edge occurrence, small stem density (<2.5 cm d.b.h.), and forest composition in a 10-km radius.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 40). We directly assigned SI scores to these combinations on the basis of habitat associations reported by Hamel (1992) for the brown thrasher in the Southeast.

This edge species inhabits thickets and hedgerows in deciduous forests. Because the brown thrasher uses both hard and soft edges, we defined edge (SI2) as the interface between pole age forest and herbaceous or non-forest landcovers (hard edge) and seedling or grass-forb age forest (soft edge). To be suitable, we required pole age forest sites to be adjacent to an edge (Table 41). However, we relaxed this requirement for seedling-shrub and sapling stands, which we considered suitable regardless of edge.

Table 40.—Relationship of landform, landcover type, and successional age class to suitability index scores for brown thrasher habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.500	0.333	0.083	0.000
	Transitional-shrubland	0.000	0.500	0.333	0.083	0.000
	Deciduous	0.000	0.500	0.333	0.083	0.000
	Evergreen	0.000	0.667	0.500	0.167	0.000
	Mixed	0.000	1.000	0.667	0.167	0.000
	Orchard-vineyard	0.000	0.500	0.333	0.083	0.000
	Woody wetlands	0.000	0.667	0.417	0.083	0.000
Terrace-mesic	Low-density residential	0.000	0.667	0.417	0.083	0.000
	Transitional-shrubland	0.000	1.000 (0.667)	0.667 (0.500)	0.167	0.000
	Deciduous	0.000	0.667	0.417	0.083	0.000
	Evergreen	0.000	0.667	0.500	0.167	0.000
	Mixed	0.000	1.000	0.667	0.167	0.000
	Orchard-vineyard	0.000	0.667	0.417	0.083	0.000
	Woody wetlands	0.000	0.667	0.500	0.167	0.000
Xeric-ridge	Low-density residential	0.000	1.000	0.667	0.167	0.000
	Transitional-shrubland	0.000	1.000 (0.334)	0.667 (0.250)	0.167 (0.083)	0.000
	Deciduous	0.000	1.000	0.667	0.167	0.000
	Evergreen	0.000	0.667 (0.334)	0.500 (0.250)	0.167 (0.083)	0.000
	Mixed	0.000	1.000	0.667	0.167	0.000
	Orchard-vineyard	0.000	1.000	0.667	0.167	0.000
	Woody wetlands	0.000	0.667	0.500	0.167	0.000

Table 41.—Influence of edge on suitability index (SI) scores for brown thrasher habitat

3 × 3 pixel window around forest pixel includes field[a]	SI score
Yes[b]	1.0
No	0.0

[a]Field defined as any shrub-seedling or grass-forb age class pixel, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any used pole age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands.

[b]Seedling-shrub and sapling habitats used regardless of edge.

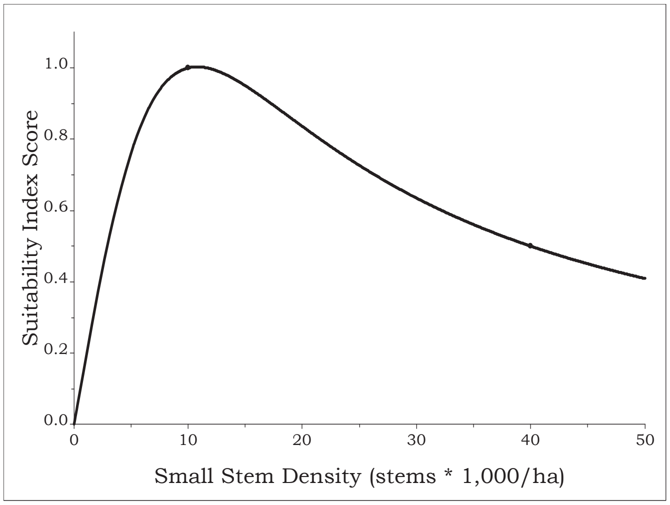


Figure 20.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for brown thrasher habitat. Equation: SI score = (0.1 + (0.165 * (small stem density / 1000))) / (1 + (-0.003 * (small stem density / 1000)) + (0.0078 * ((small stem density / 1000))^2)).

Table 42.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for brown thrasher habitat

Small stem density[a]	SI score
0	0.1
10	1.0
40	0.5

[a]Cade (1986).

The brown thrasher occupies habitats with numerous small stems (SI3). We fit a smoothed quadratic function (Fig. 20) to HSI cutoff values from the FWS HSI model for this species (Cade 1986; Table 42) to quantify the relationship between small stem density and habitat suitability.

Although the brown thrasher is associated with edges, it prefers modestly forested landscapes (Haas 1997). We included forest composition (SI4) in our model, assuming that habitat suitability would be low if there were no woodland (i.e., 0 percent forest, the left side of the function; Fig. 21) or no edges (i.e., 100 percent forest, the right side of the function). Haas (1997) observed higher reproductive success for birds in more isolated shelterbelts and Robbins and others (1989) observed negative relationships between the occurrence of the gray catbird and American robin (species that share similar habitat preferences to those of the brown thrasher) and forest patch size. Further, Perkins and others (2003b) observed an increase in abundance of edge-associated birds as the total amount of woody cover decreased. However, the brown thrasher responded positively to the amount of forest cover in the study area. We interpreted these observations as evidence that this species would exhibit a preference for landscapes with moderate forest landcover. We fit a Gaussian function to landscape proportions reflecting this pattern and assumed that landscapes that were 70 percent forested were associated with the maximum SI score (Table 43).

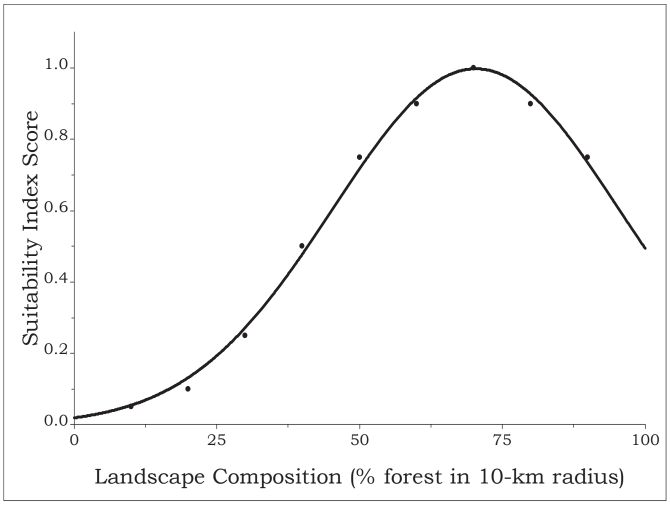


Figure 21.—Relationship between landscape composition and suitability index (SI) scores for brown thrasher habitat. Equation: SI score = 0.998 * e $^{((0 - ((\text{landscape composition}) - 70.304) \wedge 2) / 1253.402)}$.

Table 43.—Relationship between landscape composition (percent forest in 10-km radius) and suitability index (SI) scores for brown thrasher habitat

Landscape composition[a]	SI score
0	0.00
10	0.05
20	0.10
30	0.25
40	0.50
50	0.75
60	0.90
70	1.00
80	0.90
90	0.75
100	0.50

[a]Assumed value.

We assumed that the brown thrasher used edge as a surrogate to early successional habitat, so we calculated HSI scores separately for young (seedling-shrub and sapling) and old (pole) age class forests. In the former, the geometric mean of forest structure and landscape composition variables defines the suitability score. For the latter, we included edge occurrence in the calculation. We summed the age class-specific HSI scores to determine the overall HSI score for all sites.

Seedling-shrub and sapling successional age classes:

HSI_{Young}: $((SI1 * SI3)^{0.500} * SI4)^{0.500}$

Pole successional age class:

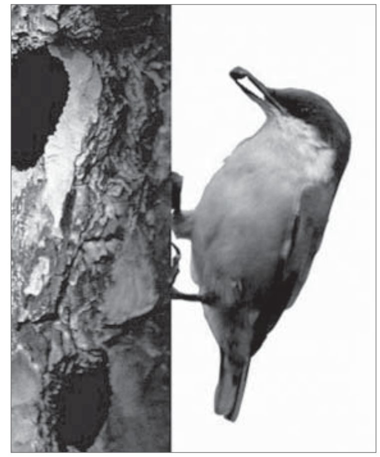
HSI_{Pole}: $((SI1 * SI3)^{0.500} * SI4)^{0.500} * SI2$

Overall SI = $HSI_{Young} + HSI_{Pole}$

Verification and Validation

The brown thrasher was found in all 88 subsections of the CH and WGCP. Spearman rank correlation did not identify a positive relationship between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the brown thrasher was significant ($P \leq 0.001$; $R^2 = 0.719$); however, the coefficient on the HSI predictor variable was negative ($\beta = -7.087$). Therefore, we considered the HSI model for the brown thrasher neither verified nor validated (Tirpak and others 2009a).

Brown-headed Nuthatch



Fernbank Science Center
Photo used with permission

Status

The brown-headed nuthatch (*Sitta pusilla*) is a resident species of mature pine forests along the Piedmont and Coastal Plains of the southeastern United States. Although this species has experienced modest declines throughout most of its range over the last 40 years (1.2 percent per year), only in Florida has the decline been significant (4.2 percent annually from 1966 to 2004; Sauer and others 2005). This species is an FWS Bird of Conservation Concern in the WGCP (Table 1), where it has a regional combined score of 19. The brown-headed nuthatch is a rare breeder in the CH (regional combined score = 19), and PIF considers this species one that warrants critical recovery in that region.

Natural History

The brown-headed nuthatch is closely associated with pine: it breeds in mature pine forests and forages almost exclusively in pine trees (> 98 percent of observations; Withgott and Smith 1998). Although often associated with the longleaf pine savanna characteristic of the habitat for red-cockaded woodpecker and Bachman's sparrow, the brown-headed nuthatch has a broader niche than these species (Hamel 1992, Dornak and others 2004). The habitat of this species is defined by two habitat elements: mature pines for foraging and cavities for nesting (Wilson and Watts 1999, Dornak and others 2004). Specific composition of pine species is not as critical as d.b.h., with an average d.b.h. of 25.6 cm considered optimal (O'Halloran and Conner 1987 cited in Dornak and others 2004). The brown-headed nuthatch nests primarily in large-diameter snags < 3 m tall and may require seven to eight snags per ha to ensure adequate nest and roost sites, particularly in the presence of interspecific competition for cavities. In urban areas, the brown-headed nuthatch readily adopts nest boxes and may use other manmade cavities, such as streetlights.

This species prefers open pine stands with few hardwoods (≤ 17.4 stems/ha and basal area ≤ 5 m^2/ha) and an open midstory (Wilson and Watts 1999). Optimal canopy cover is highly variable (15 to 85 percent) but stands with closed canopies are not preferred (O'Halloran and Conner 1987, Wilson and Watts 1999). Undergrowth typically is sparse (roughly 35 percent; Dornak and others 2004). The nuthatch regularly breeds at low densities in suboptimal habitats, including stands with small pines, a large fraction of hardwoods, and dense understories (Withgott and Smith 1998). Area sensitivity apparently is not an issue for this species, which is not an acceptable host for the brown-headed cowbird (Withgott and Smith 1998).

Model Description

The HSI model for the brown-headed nuthatch includes six variables: landform, landcover, successional age class, snag density, small stem (< 2.5 cm d.b.h.) density, and hardwood basal area.

Table 44.—Relationship of landform, landcover type, and successional age class to suitability index scores for brown-headed nuthatch habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 44). We directly assigned SI scores to these combinations on the basis of habitat associations of the brown-headed nuthatch described by Hamel (1992).

We included snag density (SI2) in our HSI model because of the importance of cavities to this species. We assumed that the SI score was zero when eight or fewer snags of any size were present (Dornak and others 2004). We fit a logistic function (Fig. 22) to data from Wilson and Watts (1999) (Table 45) to quantify the relationship between snag density and SI scores.

We also used small stem density as a function (SI3) in the HSI model to account for the preference of the brown-headed nuthatch for open understories. We fit an inverse logistic function (Fig. 23) to hypothetical data reflecting this preference (Table 46). The shape of this function is supported by observations from Wilson and others (1995), who observed a higher abundance of the brown-headed nuthatch in stands immediately following wildlife stand improvements and prescribed burns (when stem density was lowest) with subsequent declines in abundance as stem density increased through time.

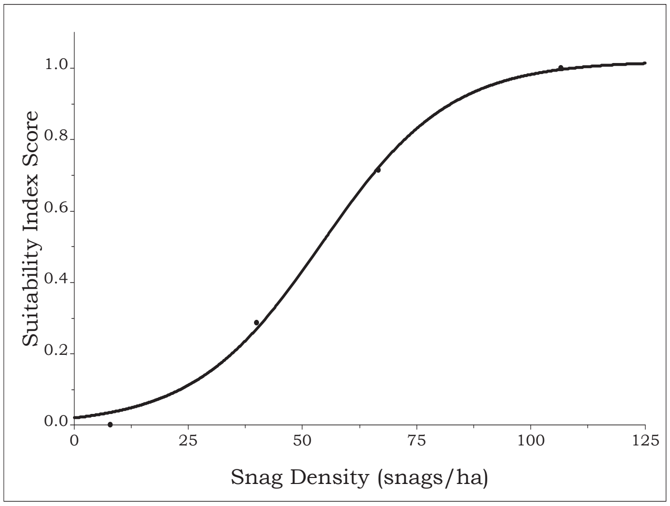


Figure 22.—Relationship between snag density and suitability index (SI) scores for brown-headed nuthatch habitat. Equation: SI score = 1.000 / (1 + (49.165 * e $^{(-0.073 * \text{snag density})}$)).

Table 45.—Influence of snag density on suitability index (SI) scores for brown-headed nuthatch habitat

Snag density (snags/ha)	SI score
8[a]	0.000
40[b]	0.286
66.67[b]	0.715
106.67[b]	1.000

[a]Dornak and others (2004).
[b]Wilson and Watts (1999).

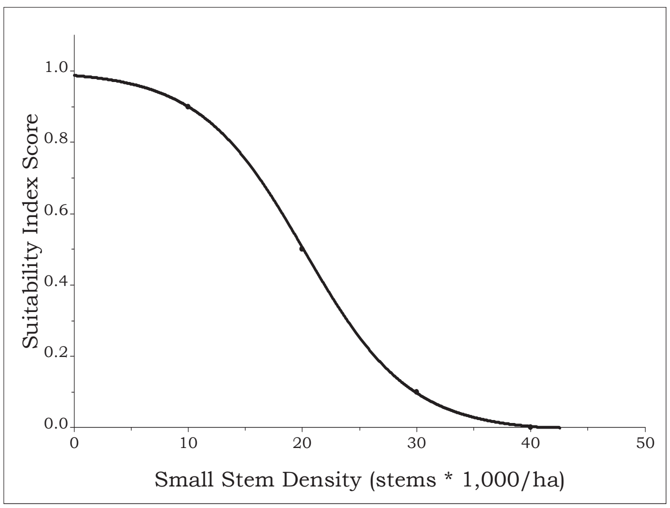


Figure 23.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for brown-headed nuthatch habitat. Equation: SI score = 1 - (1.010 / (1 + (79.565 * e $^{(-0.217 * (\text{small stem density} / 1000))}$))).

Table 46.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for brown-headed nuthatch habitat

Small stem density[a]	SI score
0[1]	1.0
10[1]	0.9
20[1]	0.5
30[1]	0.1
40[1]	0.0

[a]Assumed value.

Finally, we incorporated hardwood basal area (SI4) as a model variable as birds are less abundant in habitats with a greater hardwood component (Wilson and others 1995, Withgott and Smith 1998, Wilson and Watts 1999). Again, we relied on data from Wilson and Watts (1999) (Table 47) to develop an inverse logistic function to describe the relationship between hardwood basal area and SI score (Fig. 24).

To determine the overall HSI score for the brown-headed nuthatch, we calculated the geometric mean of the four individual functions related to forest structure attributes.

Overall HSI = (SI1 * SI2 * SI3 * SI4)$^{0.250}$

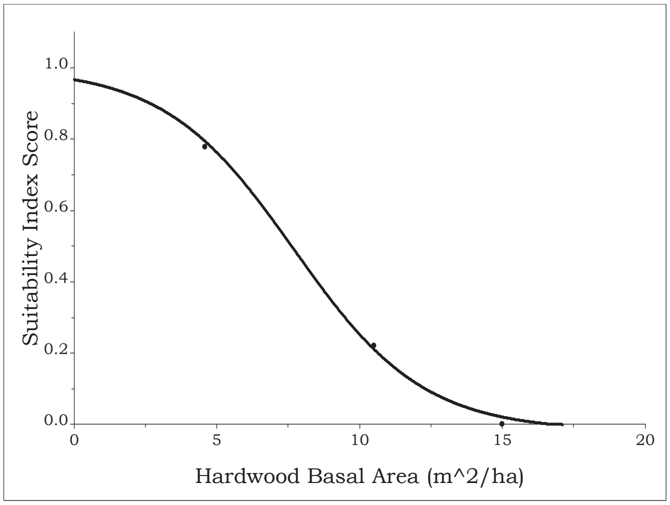


Figure 24.—Relationship between hardwood basal area and suitability index (SI) scores for brown-headed nuthatch habitat. Equation: SI score = 1 - (1.018 / (1 + (29.747 * e $^{(-0.441 * \text{hardwood basal area})}$))).

Table 47.—Influence of hardwood basal area on suitability index (SI) scores for brown-headed nuthatch habitat

Hardwood basal area (m^2/ha)	SI score
0.0[a]	1.000
4.6[a]	0.778
10.5[a]	0.222
15.0[b]	0.000
20.0[b]	0.000

[a]Wilson and Watts (1999).
[b]Assumed value.

Verification and Validation

The brown-headed nuthatch was found in 37 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.58$) between average HSI score and mean BBS route abundance across subsections. This relationship was even stronger ($r_s = 0.80$) when subsections in which the brown-headed nuthatch was not detected were removed from the analysis. The generalized linear model predicting BBS abundance from BCR and HSI for the brown-headed nuthatch was significant ($P \leq 0.001$; $R^2 = 0.738$), and the coefficient on the HSI predictor variable was both positive (ß = 4.712) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the brown-headed nuthatch both verified and validated (Tirpak and others 2009a).

Carolina Chickadee


Charles H. Warren, images.nbii.gov

Status

The Carolina chickadee (*Parus carolinensis*) is a resident species of the southeastern United States. Although populations have been stable in the CH, this species has declined by about 2 percent annually over the last 40 years in the WGCP (Table 5). This bird is a planning and responsibility species in both the CH (regional combined score = 15) and WGCP (regional combined score = 16; Table 1).

Natural History

The Carolina chickadee is a generalist species that breeds in a variety of forest types across a broad spectrum of landforms (Mostrom and others 2002). It nests in cavities of live and dead trees within multilayered forests containing well developed shrub, midstory, and overstory canopies (Hamel 1992). Abundance declines following reduction of hardwoods in pine stands, likely as a result of the loss of midstory trees (Provencher and others 2002). Nest success and adult survival is positively correlated with woodlot area but is lower on edges regardless of patch size (Doherty and Grubb 2002). Nest destruction by the house wren is a major cause of nest failure in areas where the ranges of these species overlap. Territory size ranges from 1.6 to 2.4 ha.

Model Description

The Carolina chickadee model includes four variables: landform, landcover, successional age class, and snag density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 48). We directly assigned SI scores to these combinations on the basis of vegetation and successional age class associations of the Carolina chickadee reported in Hamel (1992).

We included snag density (SI2) as a variable because of the importance of nest and roost cavities for the chickadee, a secondary cavity nester. Data for the Carolina chickadee were not available but Rumble and Gobeille (2004) and Sedgwick and Knopf (1990) observed the black-capped chickadee in habitats with six snags per hectare (Table 49). Therefore, we assumed that stands with six or more snags per ha were representative of optimal habitat. Because the chickadee can use cavities in live trees, we assumed that stands with no snags were not necessarily nonhabitat and assigned to them a small but non-zero SI score (0.03). We fit a logistic function through these data points to quantify the relationship between snag density and habitat suitability (Fig. 25).

We calculated the overall HSI score as the geometric mean of the two individual functions:

Overall HSI = $(SI1 * SI2)^{0.500}$

Table 48.—Relationship of landform, landcover type, and successional age class to SI scores for Carolina chickadee habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.167	0.500	0.667
	Transitional-shrubland	0.000	0.000	0.167	0.500	0.667
	Deciduous	0.000	0.000	0.167	0.500	0.667
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.500	0.667
	Woody wetlands	0.000	0.000	0.167	0.500	0.667
Terrace-mesic	Low-density residential	0.000	0.000	0.167	0.500	0.667
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.167	0.500	0.667
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.500	0.667
	Woody wetlands	0.000	0.000	0.167	0.500	0.667
Xeric-ridge	Low-density residential	0.000	0.000	0.167	0.500	0.667
	Transitional-shrubland	0.000	0.000	0.334 (0.250)	0.834 (0.667)	1.000 (0.834)
	Deciduous	0.000	0.000	0.167	0.500	0.667
	Evergreen	0.000	0.000	0.334 (0.250)	0.834 (0.667)	1.000 (0.834)
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.500	0.667
	Woody wetlands	0.000	0.000	0.167	0.500	0.667

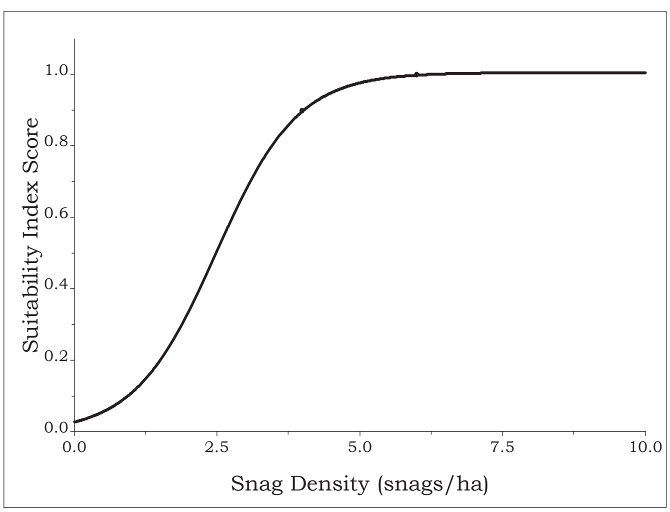


Figure 25.—Relationship between snag density and suitability index (SI) scores for Carolina chickadee habitat. Equation: SI score = 1.007 / (1.000 + (32.567 * $e^{(-1.403 * \text{snag density})}$)).

Table 49.—Influence of snag density on suitability index (SI) scores for Carolina chickadee habitat

Snag density (snags/ha)	SI score
0[a]	0.03
4[b]	0.90
6[a, c]	1.00

[a]Rumble and Gobeille (2004).
[b]Assumed value.
[c]Sedgwick and Knopf (1990).

Verification and Validation

The Carolina chickadee was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.55$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the Carolina chickadee was significant ($P \leq 0.001$; $R^2 = 0.473$), and the coefficient on the HSI predictor variable was both positive ($\beta = 5.142$) and significantly different from zero ($P = 0.038$). Therefore, we considered the HSI model for the Carolina chickadee both verified and validated (Tirpak and others 2009a).

Cerulean Warbler


U.S. Forest Service

Status

The cerulean warbler (*Dendroica cerulea*) is a long-distance migrant to the eastern United States. Densities are highest in the Ohio River Valley and along the Cumberland Plateau. This species has declined across most of its range, including the CH and WGCP (6.3 and 9.5 percent per year from 1966 to 2004, respectively; Table 5). The cerulean warbler is classified as a Bird of Conservation Concern requiring critical recovery in the WGCP (regional combined score = 19) and immediate management in the CH (regional combined score = 19) (Table 1). Concern for this species culminated in a petition to the FWS to list the cerulean warbler as threatened. However, this action was deemed unwarranted on the basis of current scientific information (Federal Register 71:234 [6 December 2006] p. 70717).

Natural History

A forest interior specialist, the cerulean warbler has experienced some of the most dramatic declines of any songbird over the last 30 years (Hamel 2000). This species has a broad geographic range but is abundant only locally. It may nest semi-colonially, with territories in good habitat highly clumped. The cerulean warbler seems to be highly sensitive to forest fragmentation. Robbins and others (1989) found a 50 percent reduction in observations of this species as forest patch size declined from 3,000 to 700 ha. No birds were detected on forest patches less than 138 ha. Estimates from other researchers suggest that forest tracts as large as 8,000 ha may be required to ensure sustainable populations in the Mississippi Alluvial Valley (summarized in Hamel [2000]).

Although it requires large forest tracts, the cerulean warbler establishes territories near interior forest gaps. Weakland and Wood (2005) observed a positive association between this species and forest roads or snags that created small canopy openings. Aside from canopy gaps (a measure of horizontal canopy structure), the cerulean warbler also may respond to the vertical canopy profile. Canopy cover of 6 to 12 m and more than 24 m was preferred in West Virginia (Weakland and Wood 2005). In Ontario, canopy cover of 12 to 18 m and more than 18 m was preferred (Jones and Robertson 2001). The difference in preferred canopy heights between these studies likely reflects differences in local vegetation structure rather than an absolute difference in preferred canopy height. The key habitat feature in both is the multilayered character of the overstory canopy.

Closed-canopy stands with large trees (both in height and d.b.h.) are commonly associated with the cerulean warbler but likely are a crude proxy for the aforementioned canopy features that provide the true selection criteria for this bird (Hamel 2000). This species is associated with bottomland hardwoods in the Southeast and ridges in West Virginia (Hamel 2000, Weakland and Wood 2005). Again, specific landforms probably are not directly selected for but are correlated with the location of large tracts of deciduous forest containing large trees and favorable canopy conditions in these landscapes.

Table 50.—Relationship of landform, landcover type, and successional age class to suitability index scores for cerulean warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.400	0.800
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.400	0.800
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.400	0.800
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.400	0.800

In “Birds of North America,” Hamel (2000) stated: “Important habitat elements for this species thus appear to be large tracts with big deciduous trees in mature to old-growth forest with horizontal heterogeneity of the canopy. The pattern of vertical distribution of foliage in the canopy is also important.”

Model Description

The HSI model for the cerulean warbler includes seven variables: landform, landcover, successional age class, forest patch size, percent forest in a 1-km radius, dominant tree density, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 50). We directly assigned SI scores to these combinations on the basis of habitat associations of the cerulean warbler outlined in Hamel (1992).

We derived the suitability function for forest patch size (SI2) by fitting a logistic curve (Fig. 26) to data from Robbins and others (1989) and Rosenberg and others (2000), who

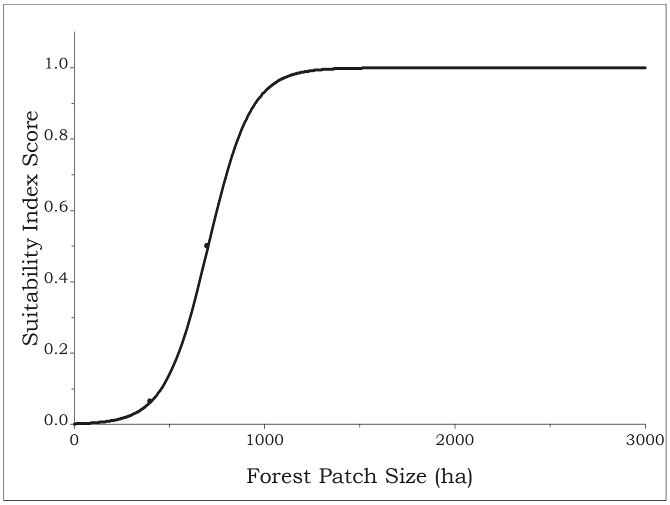


Figure 26.—Relationship between forest patch size and suitability index (SI) scores for cerulean warbler habitat. Equation: SI score = 1.000 / (1.000 + (524.457 * e $^{-0.0089 * \text{forest patch size}}$)).

Table 51.—Influence of forest patch size on suitability index (SI) scores for cerulean warbler habitat

Forest patch size (ha)	SI score
400[a]	0.064
700[b]	0.500
3,000[b]	1.000
5,000[c]	1.000

[a]Rosenberg and others (2000).
[b]Robbins and others (1989).
[c]Assumed value.

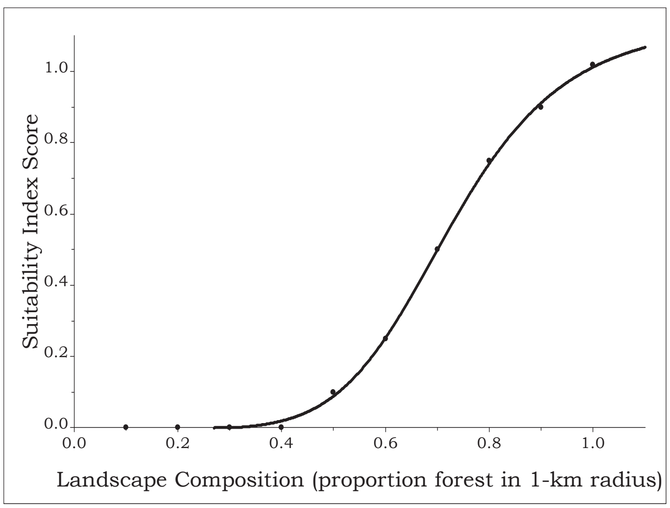


Figure 27.—Relationship between landscape composition and suitability index (SI) scores for cerulean warbler habitat. Equation: SI score = 1.047 / (1.000 + (1991.516 * e $^{-10.673 * \text{landscape composition}}$)).

Table 52.—Relationship between landscape composition and suitability index (SI) scores for cerulean warbler habitat

Landscape composition	SI score
0.00[a]	0.00
0.10[a]	0.00
0.20[a]	0.00
0.30[a]	0.00
0.40[a]	0.00
0.50[a]	0.10
0.60[a]	0.25
0.70[b]	0.50
0.80[a]	0.75
0.90[a]	0.90
1.00[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

observed that about 95 percent of all birds in FWS Region 4 were on tracts of at least 400 ha (Table 51). Recognizing the suitability of a forest patch is affected by its landscape context (Rosenberg and others 1999), we fit a logistic function (Fig. 27) to data (Table 52) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoint between moderately and lightly fragmented forest defined the specific cutoff for average (SI score = 0.500) habitat. We used the maximum value from SI2 or SI3 to account for the suitability of small patches in predominantly forested landscapes.

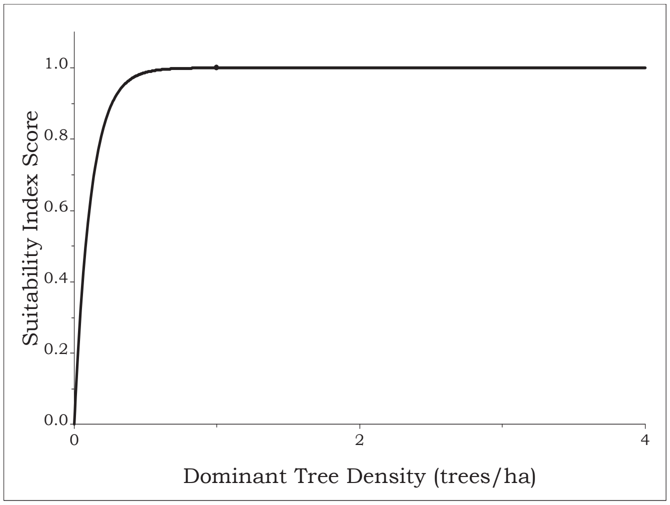


Figure 28.—Relationship between dominant tree density and suitability index (SI) scores for cerulean warbler habitat. Equation: SI score = 1 – $e^{-8.734 * \text{dominant tree density}}$.

Table 53.—Influence of dominant tree density on suitability index (SI) scores for cerulean warbler habitat

Dominant tree density (trees/ha)[a]	SI score
0	0.0
1	1.0
14	1.0

[a]Assumed value.

We used the density of dominant trees (SI4) in the HSI model and assumed that trees with a d.b.h. greater than 76.2 cm would produce the heterogeneous vertical canopy structure preferred by the cerulean warbler. On the basis of qualitative habitat descriptions by Rosenberg and others (2000), we assumed that the cerulean warbler reached its highest density in stands containing at least one dominant tree per ha. Because this bird nests almost exclusively in these trees (Weakland and Wood 2005), we also assumed that it would be absent from stands with a uniform canopy height (i.e., no dominant trees). We fit an exponential function (Fig. 28) to these data points and assumed that stands with at least 14 dominant trees per ha (the maximum number observed in the WGCP during the FIA surveys of the 1990s) were associated with maximum habitat suitability (Table 53).

We used data from Rosenberg and others (2000), Jones and others (2001), and Weakland and Wood (2005) to derive an inverse quadratic function (Fig. 29) that predicted habitat suitability for the cerulean warbler from canopy cover (SI5; Table 54). Canopy cover of 50 percent or less is associated with failed reproduction by this species (Jones and others 2001), so we considered these values as nonhabitat (SI score = 0.000). Rosenberg and others (2000) identified “a tall, but broken, canopy” as one of the few common denominators of cerulean warbler habitat rangewide, and we maximized the SI score at 90 percent canopy closure. However, Weakland and Wood (2005) observed the cerulean warbler selecting internal edges, so we also discounted habitat suitability for closed canopies. Nonetheless, we recognize that a dense upper canopy is needed by this species (Hamel 2000) and assigned to sites with 80 and 100 percent canopy cover an average SI score (0.500).

To calculate overall HSI scores for cerulean warbler habitat, we calculated the geometric mean of the three suitability indices related to forest structure (SI1, SI4, and SI5) and the maximum value for the two suitability indices related to landscape composition (SI2 and SI3) separately and then the geometric mean of these values together.

Overall SI = $((\text{SI1} * \text{SI4} * \text{SI5})^{0.333} * \text{Max}(\text{SI2 or SI3}))^{0.500}$

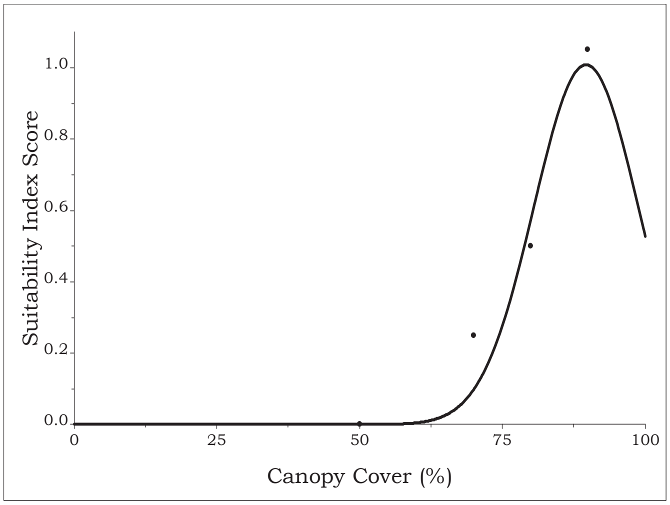


Figure 29.—Relationship between canopy cover and suitability index (SI) scores for cerulean warbler habitat. Equation: SI score = 1 / (62.548 – (1.369 * canopy cover) + (0.007612 * (canopy cover)^2)).

Table 54.—Influence of canopy cover on suitability index (SI) scores for cerulean warbler habitat

Canopy cover (percent)	SI score
50[a]	0.00
70[b]	0.25
80[b]	0.50
90[c]	1.00
100[d]	0.50

[a]Jones and others (2001).
[b]Hamel (2000).
[c]Rosenberg and others (2000).
[d]Weakland and Wood (2005).

Verification and Validation

The cerulean warbler was found in 60 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant positive relationship between average HSI score and mean BBS route abundance across all subsections ($P \leq 0.001$; $r_s = 0.44$) and those in which this species was detected ($P \leq 0.001$; $r_s = 0.42$). The generalized linear model predicting BBS abundance from BCR and HSI for the cerulean warbler was significant ($P \leq 0.001$; $R^2 = 0.205$), and the coefficient on the HSI predictor variable was both positive ($\beta = 0.627$) and significantly different from zero ($P = 0.023$). Therefore, we considered the HSI model for the cerulean warbler both verified and validated (Tirpak and others 2009a).

Chimney Swift


Ron Austing, used with permission

Status

The chimney swift (*Chaetura pelagica*) is a familiar bird found across most of North America east of the Rocky Mountains. Populations have declined in both the CH and WGCP over the last 40 years (2.6 and 1.1 percent per year). However, the high annual variability in abundance for this species prevents the identification of significant trends (Sauer and others 2005; Table 5). This bird has a regional combined score of 16 and requires management attention in the CH. However, in the WGCP, the chimney swift is only a planning and responsibility species with a regional combined score of 14 (Table 1).

Natural History

The range of the chimney swift, a small, long-distance migrant, expanded dramatically with European settlement and the increase in artificial nest structures (e.g., chimneys) that followed (Cink and Collins 2002). Prior to European settlement, this species probably was distributed thinly and relied on tree cavities for nesting. Nesting in trees is now rare (Graves 2004) and most nests and roosts are concentrated in urban areas (Cink and Collins 2002). This species is weakly territorial (typically one nest per cavity), and population declines may be due to the loss of nest sites as large, open chimneys become scarce. Home ranges are largely unknown.

Model Description

For a bird that occurs in such close association with humans, few data are available on the habitat preferences of the chimney swift. We assumed that habitat suitability for this species was primarily a function of the availability of nest and roost sites within the proper landscape context (i.e., open chimneys near foraging areas). To identify these locations, we estimated the proportion of foraging habitats in a 1-km buffer around each pixel of developed landcover. We assumed that this bird could travel 1 km from nesting-roosting areas to foraging habitats (defined as water, grassland, pasture-hay, recreational grasses, or forest landcover classes) and that these habitats had to be more than 1 ha to accommodate the aerial foraging maneuvers of this species. Because the chimney swift is semi-colonial, we also assumed that that as foraging habitat increased in the 1-km buffer, developed pixels were increasingly isolated and would be of lower suitability (Table 55). We used a quadratic curve (Fig. 30) to quantify the relationship between landscape composition and habitat suitability for this species.

Verification and Validation

The chimney swift occurred in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.50$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the chimney swift was significant ($P \leq 0.001$; $R^2 = 0.208$), and the coefficient on the HSI predictor variable was positive ($\beta = 5.043$) but not significantly different from zero ($P = 0.524$). Therefore, we considered the HSI model for the chimney swift verified but not validated (Tirpak and others 2009a).

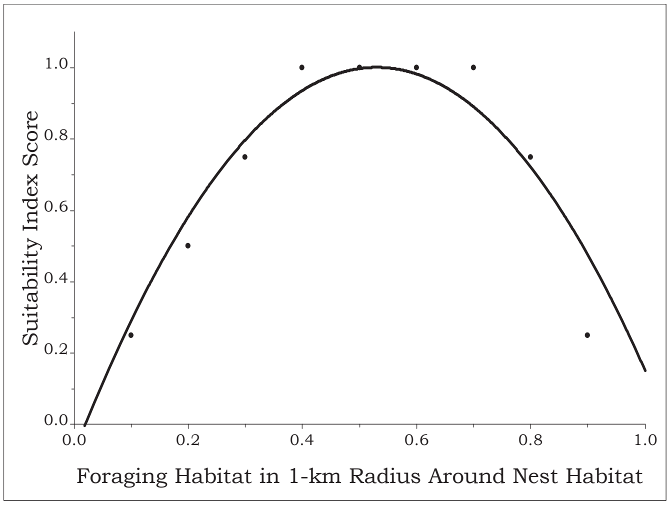


Figure 30.—Relationship between proportion of foraging habitat within 1-km buffer around potential nesting/roosting sites on suitability index (SI) scores for chimney swift habitat. Equation: SI score = (-0.0769 + (4.0734 * proportion foraging cover) - (3.8462 * (proportion foraging cover^2))).

Table 55.—Influence of proportion of foraging habitat[a] within 1-km buffer around potential nesting-roosting sites[b] on suitability index (SI) scores for chimney swift habitat

Proportion[c] of foraging habitat around potential nesting-roosting sites	SI score
0.0	0.00
0.1	0.25
0.2	0.50
0.3	0.75
0.4	1.00
0.5	1.00
0.6	1.00
0.7	1.00
0.8	0.75
0.9	0.25
1.0	0.25

[a]Foraging habitat = water, grassland, pasture-hay, recreational grasses, forest > 1 ha.

[b]Nesting-roosting site = any developed landcover.

[c]Assumed value.

Chuck-will's-widow


Chandler S. Robbins, Patuxent Bird Identification InfoCenter
Photo used with permission

Status

The chuck-will's-widow (*Caprimulgus carolinensis*) is a neotropical migrant that breeds in the southeastern United States. It has experienced small yet significant declines in the WGCP over the last 40 years (1.3 percent per year; Sauer and others 2005). Populations in the CH have remained relatively stable during the same period (Table 5). Chuck-will's-widow is as Bird of Conservation Concern and a PIF species in need of management attention in the WGCP (regional combined score = 16). This species has no special conservation status in the CH (regional combined score = 14; Table 1).

Natural History

The chuck-will's-widow, like all nightjars, is nocturnal and most active on moonlit nights. Because of this behavior and its cryptic coloration, this species is difficult to study and few systematic investigations of its habitat, demography, or population status have been conducted. Most of the information on chuck-will's-widow is anecdotal and coincident to studies of other species (Straight and Cooper 2000).

The chuck-will's-widow occupies woodland habitats interspersed with large openings in which the bird forages at night. Calling males are equally abundant among suburban, pasture, and forested landscapes (Cooper 1981). Urban habitats are unsuitable (Straight and Cooper 2000). The chuck-will's-widow prefers more open habitats than the whip-poor-will (Cooper 1981) and is unaffected by forest fragmentation (it may even benefit from it). Drier sites also are preferred.

Model Description

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 56). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the habitat associations of the chuck-will's-widow in the Southeast.

The realized suitability of the sites identified in SI1 depends largely on landscape context. Cooper (1981) found that the abundance of chuck-will's-widow was highest in areas with equal amounts of forest and agriculture. Therefore, we used the proportion of these two habitats in a 500-m radius window (SI2) in the HSI model. We assigned the maximum SI score to landscapes characterized by 50 percent forest and 50 percent agriculture. We reduced these scores as landscapes varied from this optimal configuration towards a more open or a more forested composition with a stronger reduction in suitability for increasingly forested landscapes (Table 57).

The overall HSI score for chuck-will's-widow is based solely on SI2, which incorporates the results from SI1.

Overall HSI = SI2

Table 56.—Relationship of landform, landcover type, and successional age class to suitability index scores for chuck-will's-widow habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.083	0.167	0.167
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.083	0.167	0.167
	Evergreen	0.000	0.000	0.334	0.834	1.000
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334 (0.250)	0.834 (0.583)	1.000 (0.667)
	Deciduous	0.000	0.000	0.167	0.333	0.333
	Evergreen	0.000	0.000	0.334 (0.250)	0.834 (0.583)	1.000 (0.667)
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

Verification and Validation

The chuck-will's-widow was found in 86 of the 88 subsections within the CH and WGCP. Spearman rank correlations yielded similar results when analysis included all subsections and only those subsections in which this species was detected: significant ($P \leq 0.001$ and 0.003, respectively) positive associations (r_s = 0.34 and 0.32, respectively) between average HSI score and mean BBS route abundance. The generalized linear model predicting BBS abundance from BCR and HSI for the chuck-will's-widow was significant ($P \leq 0.001$; R^2 = 0.312), and the coefficient on the HSI predictor variable was positive (β = 0.569) but not significantly different from zero (P = 0.415). Therefore, we considered the HSI model for the chuck-will's-widow verified but not validated (Tirpak and others 2009a).

Table 57.—Suitability index scores for chuck-will's-widow habitat based on proportion of nesting-roosting and foraging habitat within 500-m radius landscape

	Proportion foraging[a]										
Proportion nest and roost[b]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.1	0.2	0.2	0.2	0.2	0.2	0.2	
0.2	0.0	0.0	0.1	0.2	0.4	0.6	0.6	0.6	0.5		
0.3	0.0	0.1	0.2	0.4	0.6	0.6	0.8	0.8			
0.4	0.0	0.2	0.4	0.6	0.8	0.8	1.0				
0.5	0.0	0.2	0.4	0.6	0.8	1.0[c]					
0.6	0.0	0.2	0.4	0.6	0.8						
0.7	0.0	0.2	0.4	0.6							
0.8	0.0	0.2	0.4								
0.9	0.0	0.2									
1.0	0.0										

[a]Foraging = pasture-hay, recreational grasses, grasslands, and emergent herbaceous wetland landcovers or grass-forb and shrub-seedling successional age classes.

[b]Nest and roost = habitats identified in SI1 (Table 56).

[c]Cooper (1981).

Eastern Wood-pewee

Jeffrey A Spendelow, Patuxent Bird Identification InfoCenter
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Status

The eastern wood-pewee (*Contopus virens*) is a long-distance neotropical migrant that breeds throughout the temperate regions of eastern North America (McCarty 1996). This species reaches its highest densities in the Ozark Mountain region of the CH, where it has a regional combined score of 15 (Table 1). In the WGCP, the eastern wood-pewee has a regional combined score of 16. This bird is one requiring management attention in both BCRs, with declining populations in both regions (Sauer and others 2005) (Table 5).

Natural History

The eastern wood-pewee is a common species in woodlands of all types (deciduous, mixed, and evergreen). However, this species consistently selects open park-like conditions on xeric sites with limited canopy cover and low shrub densities (Robbins and others 1989; McCarty 1996). The eastern wood-pewee is positively associated with increasing density of sawtimber trees, reaching a threshold at 100 trees per ha where a negative relationship develops (Best and Stauffer 1986, Robbins and others 1989).

The eastern wood-pewee, common in both forest interiors and edges, generally is area-insensitive, and may occupy fragments as small as 0.3 ha (Blake and Karr 1987, Robbins and others 1989). Its cryptic nests high in the canopy may limit predation and parasitism, allowing the pewee to occupy small fragments without the adverse effects on reproduction common to other open-cup nesters (McCarty 1996, Knutson and others 2004, Underwood and others 2004). This species is not found in riparian corridors with less than 24 percent forest cover in the landscape (Perkins and others 2003b).

Model Description

The HSI model for the eastern wood-pewee includes five variables: landform, landcover, successional age class, percent forest in a 1-km radius, and density of sawtimber trees (> 28 cm d.b.h.).

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 58). We directly assigned SI scores to these combinations on the basis of habitat associations of the eastern wood-pewee reported by Hamel (1992).

This species can occupy small forest fragments but may require a minimum amount of forest in the landscape. Therefore, our model did not include a forest patch size function but relied solely on landscape composition (SI2). We used a logistic function (Fig. 31) to predict SI scores from the percentage of forest in the landscape (Table 59).

Table 58.—Relationship of landform, landcover type, and successional age class to suitability index scores for eastern wood-pewee habitat. Values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.167	0.250	0.500	0.667
	Transitional-shrubland	0.000	0.167	0.250	0.500	0.667
	Deciduous	0.000	0.167	0.250	0.500	0.667
	Evergreen	0.000	0.250	0.333	0.667	1.000
	Mixed	0.000	0.000	0.167	0.667	1.000
	Orchard-vineyard	0.000	0.167	0.250	0.500	0.667
	Woody wetlands	0.000	0.250	0.333	0.417	0.500
Terrace-mesic	Low-density residential	0.000	0.000	0.167	0.583	0.834
	Transitional-shrubland	0.000	0.000 (0.333)	0.167 (0.333)	0.667	1.000
	Deciduous	0.000	0.000	0.167	0.583	0.834
	Evergreen	0.000	0.250	0.333	0.667	1.000
	Mixed	0.000	0.000	0.167	0.667	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.583	0.834
	Woody wetlands	0.000	0.250	0.333	0.500	0.667
Xeric-ridge	Low-density residential	0.000	0.000	0.167	0.667	1.000
	Transitional-shrubland	0.000	0.000 (0.167)	0.167 (0.250)	0.667	1.000
	Deciduous	0.000	0.000	0.167	0.667	1.000
	Evergreen	0.000	0.250 (0.167)	0.333 (0.250)	0.667	1.000
	Mixed	0.000	0.000	0.167	0.667	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.667	1.000
	Woody wetlands	0.000	0.250	0.333	0.500	0.667

We included density of sawtimber trees in the HSI model and used the threshold of 100 trees per ha observed by Best and Stauffer (1986) as the optimal value in a quadratic function (Fig. 32) that links density of sawtimber trees (SI3) to habitat suitability. Because Best and Stauffer (1986) observed a reduction in wood-pewee abundance at sawtimber tree densities less than 100 trees per ha and Robbins and others (1989) observed a negative relationship between occurrence and tree density, we assumed a symmetrical decline in habitat quality as sawtimber tree density increased or decreased above or below the optimum (Table 60).

To calculate the overall HSI score, we determined the geometric mean of individual SI functions relating to forest structure (SI1 and SI3) and then calculated the geometric mean of this value and landscape composition (SI2).

Overall HSI = $((SI1 * SI3)^{0.500} * SI2)^{0.500}$

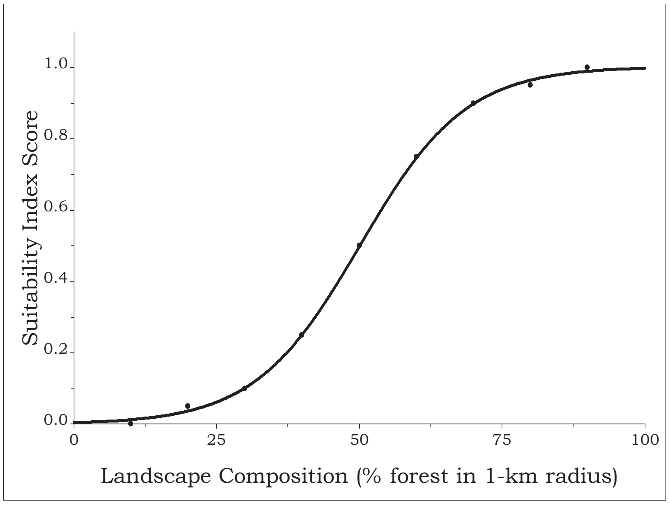

Figure 31.—Relationship between landscape composition and suitability index (SI) scores for eastern wood-pewee habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 59.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for eastern wood-pewee habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Dononvan and others (1997).

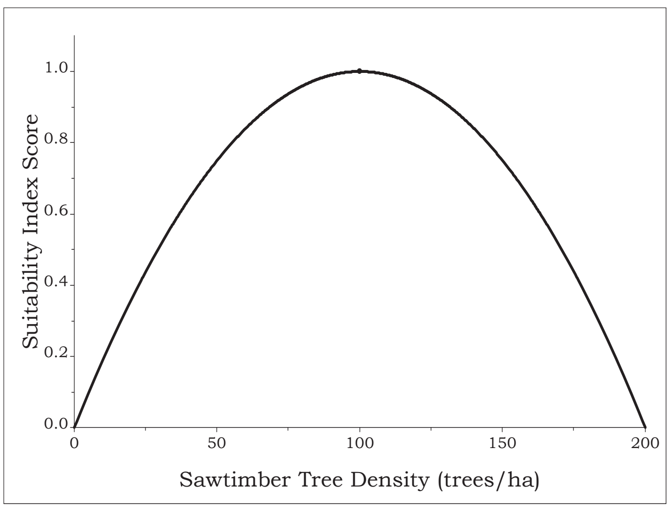

Figure 32.—Relationship between sawtimber tree (≥ 28 cm d.b.h.) density and suitability index (SI) scores for eastern wood-pewee habitat. Equation: SI score = (0.0200 * sawtimber tree density) - (0.0001 * (sawtimber tree density^2)).

Table 60.—Influence of sawtimber tree (≥ 28 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for eastern wood-pewee habitat

Sawtimber tree density	SI score
0[a]	0.0
100[b]	1.0
200[a]	0.0

[a]Assumed value.
[b]Best and Stauffer (1986).

Verification and Validation

The eastern wood-pewee was found in all 88 subsections of the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance identified a significant ($P \leq 0.001$) positive association ($r_s = 0.46$) between these two variables at the subsection scale. The generalized linear model predicting BBS abundance from BCR and HSI for the eastern wood-pewee was significant ($P \leq 0.001$; $R^2 = 0.472$), and the coefficient on the HSI predictor variable was both positive (ß = 5.183) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the eastern wood-pewee both verified and validated (Tirpak and others 2009a).

Field Sparrow


Deanna K. Dawson, Patuxent Bird Identification InfoCenter
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Status

The field sparrow (*Spizella pusilla*) is a short-distance migrant found throughout North America east of the Rocky Mountains. Associated with early successional habitats, this species has experienced the sharp declines typical of many scrub-shrub and grassland species in the East. BBS data indicate declines in populations of the field sparrow in both the CH and WGCP (Sauer and others 2005; Table 5). The field sparrow has a regional combined score of 17 and 15 in the CH and WGCP, respectively, but is not a Bird of Conservation Concern in either BCR (Table 1). About 20 percent of the continental population occurs in the CH (Panjabi and others 2001).

Natural History

The field sparrow breeds in a variety of vegetation types, including brushy pastures, second-growth scrub, forest openings and edges, Christmas tree farms, orchards, nurseries, and roadsides and railroads near open fields (Carey and others 1994). Abundance increases in forested landscapes managed for early successional habitat (Yahner 2003), and this bird commonly occupies reclaimed mines (DeVault and others 2002) and savanna restoration sites (Davis and others 2000). Abundance is positively related to the size of old fields in Arkansas (Bay 1994). The field sparrow nests on or near the ground in early spring but may nest in saplings or shrubs later in the year. Brood parasitism rates vary geographically but the field sparrow generally is a poor cowbird host. Parasitism rates are higher in thinned forest stands than in regenerating plantations (Barber and others 2001).

This species also uses grasslands, though at lower densities than in shrub-scrub habitats (Horn and others 2002). Grass type affects habitat suitability, with warm-season grasses supporting higher abundance (Giuliano and Daves 2002, Walk and Warner 2000), nest density (Farrand 2005), and productivity than cool-season grasses (Giuliano and Daves 2002). Conservation Reserve Program fields serve as source habitat for the field sparrow in Missouri (McCoy and others 1999).

Model Description

The model predicting habitat suitability for the field sparrow includes six variables: landform, land cover, successional age class, canopy cover, density of small stems (< 2.5 cm d.b.h.), and the presence of grassy landcover.

The first suitability function of the field sparrow HSI model combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 61). We used habitat associations of the field sparrow reported by Hamel (1992) to assign SI scores to these combinations.

Table 61.—Relationship of landform, landcover type, and successional age class to suitability index scores for field sparrow habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333	0.000	0.000	0.000
	Deciduous	0.000	0.333	0.000	0.000	0.000
	Evergreen	0.667	1.000	0.000	0.000	0.000
	Mixed	0.667	1.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.333	0.000	0.000	0.000
	Woody wetlands	0.000	0.167	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.667	1.000	0.000	0.000	0.000
	Deciduous	0.000	0.667	0.000	0.000	0.000
	Evergreen	0.667	1.000	0.000	0.000	0.000
	Mixed	0.667	1.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.667	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.667	1.000	0.000	0.000	0.000
	Deciduous	0.000	1.000	0.000	0.000	0.000
	Evergreen	0.667	1.000	0.000	0.000	0.000
	Mixed	0.667	1.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	1.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.000	0.000	0.000

We included canopy cover (SI2) and small stem density (SI3) as SIs in our model to account for the absence of the field sparrow from closed-canopy forests or forested sites with an open understory. We used data from Annand and Thompson (1997) (Tables 62 and 63) to fit a quadratic function to canopy cover and a Gaussian function to small stem density for predicting SI scores (Fig. 33 and 34). The negative relationship between the field sparrow and stem density is supported by Carey and others (1994), who observed a reduction in habitat suitability as "thickets of trees spread in the habitat." Sousa (1983) constructed an HSI model that contained a negative relationship between habitat suitability and percent shrub cover. Suitability of habitat for the field sparrow declined from optimal at 50 percent shrub cover (defined as the percentage of ground shaded by a vertical projection of the canopies of woody vegetation less than 5 m) to unsuitable at 75 percent shrub cover. We did not have a quantitative estimate of the relationship between small stem density and shrub cover, so we assumed that 40,000 stems per ha would shade 75 percent of the ground. We were conservative with this estimate; lacking quantitative data, we did not want to exclude stands that might provide habitat for this species.

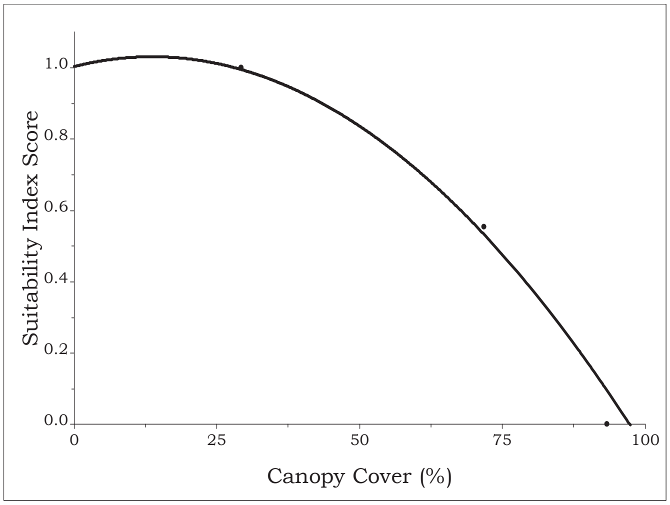

Figure 33.—Relationship between canopy cover and suitability index (SI) scores for field sparrow habitat. Equation: SI score = 1.0038 + 0.0040 * (canopy cover) – 0.0001475 * (canopy cover)^2.

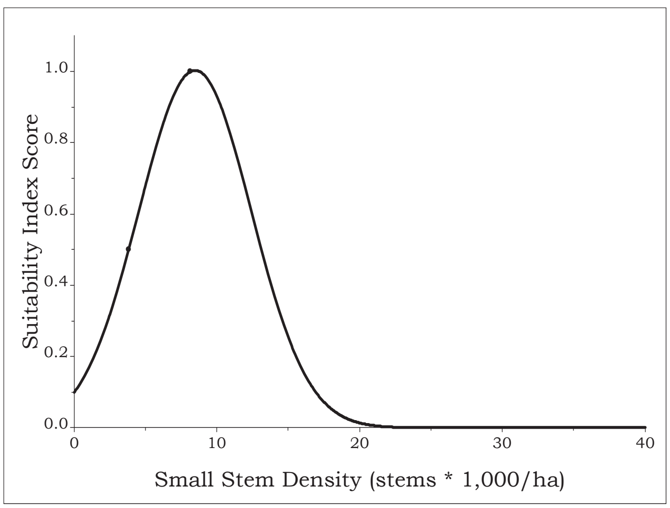

Figure 34.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for field sparrow habitat. Equation: SI score = 1.003 * e ($^{-((\text{small stem density / 1000}) - 8.461)\hat{}2\ )/\ 31.0472}$.

Table 62.—Influence of canopy cover on suitability index (SI) scores for field sparrow habitat

Canopy cover (percent)	SI score
0.00[a]	1.000
29.26[b]	1.000
71.86[b]	0.555
93.38[b]	0.000
100.00[a]	0.000

[1]Assumed value.
[2]Annand and Thompson (1997).

Table 63.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for field sparrow habitat

Small stem density	SI score
0[a]	0.1
3.812[b]	0.5
8.148[b]	1.0
40.000[a]	0.0

[a]Sousa (1983).
[b]Annand and Thompson (1997).

Table 64.—Relationship between grass landcover and suitability index (SI) scores for field sparrow habitat

Landcover	SI score
Grassland-herbaceous[a]	1.0
Pasture-hay[a]	0.5

[a]Must occur ≤ 170 meters from forested landcover.

The field sparrow often is associated with grasslands with sufficient perches (Carey and others 1994, Kahl and others 1985). Therefore, we included an SI function related to grasslands (SI4) in the model. Many useable grassland sites may have insufficient woody cover to be classified as shrublands in the NLCD, so we required all grassland types (natural as well as pasture and hayfields) to be within 170 m of a wooded edge—a distance approximating a large field sparrow territory (Best 1974)—to be considered useable. Natural grasslands also are more likely to contain dense grass nesting sites than pastures and hayfields (Giuliano and Daves 2002, Farrand 2005), so we assigned to useable natural grasslands an SI score of 1.000 and to useable pasture-hayfields a score of 0.500 (Table 64).

To calculate the HSI score for field sparrow habitat in forested landcovers, we calculated the geometric mean of the SI scores relating to forest structure (SI1, SI2, and SI3). We added the SI score for grasslands (SI4) to this value to determine the overall HSI score.

Overall HSI = $((SI1 * SI2 * SI3)^{0.333} + SI4)$

Verification and Validation

The field sparrow was found in 87 of the 88 subsections within the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance identified a significant ($P \leq 0.001$) positive association ($r_s = 0.55$) between these two variables within subsections where this species was detected. The generalized linear model predicting BBS abundance from BCR and HSI for the field sparrow was significant ($P \leq 0.001$; $R^2 = 0.690$), and the coefficient on the HSI predictor variable was both positive ($\beta = 37.060$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the field sparrow both verified and validated (Tirpak and others 2009a).

Great Crested Flycatcher

Deanna K. Dawson,
Patuxent Bird Identification InfoCenter
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Status

The great crested flycatcher (*Myiarchus crinitus*), a neotropical migrant, is found throughout the forests of eastern North America and the riparian habitats of the Mississippi River watershed. Populations have remained relatively stable across most of its range, though in the WGCP they have declined by 1.3 percent per year since 1966 (Sauer and others 2005) (Table 5). This species has a regional combined score of 13 in both the CH and WGCP (Table 1).

Natural History

The great crested flycatcher is an obligate cavity nester in deciduous forest habitats of the eastern United States; it generally is absent in pure evergreen stands (Lanyon 1997). This species is not area sensitive but does require a minimum amount of forested habitat in the landscape. It may nest in patches as small as 0.2 ha and abundance may decline in forest interiors (Robbins and others 1989). The great crested flycatcher does not occupy riparian corridors surrounded by less than 14.7 percent forest (Perkins and others 2003b), and detection probabilities steadily increase with increasing corridor width (Groom and Grubb 2002).

The great crested flycatcher forages by sallying from exposed perches (Lanyon 1997), so open forest stands are preferred. Holmes and others (2004) found that abundance was highest in heavily cut stands where one-third or more of the basal area was removed. Similarly, Moorman and Guynn (2001) found that the great crested flycatcher was associated with large (0.5 ha) canopy gaps in bottomland hardwood forest in South Carolina. Snags not only provide exposed perches for foraging but also cavities for nesting, and the great crested flycatcher is negatively affected by the removal of snags associated with certain forestry practices (Lohr and others 2002). Where snags are lacking, this species will use nest boxes and other artificial cavities; this enables it to occupy cemeteries, suburban parks, and wooded pastures. Wakeley and Roberts (1996) found that this bird is associated with mesic sites, but this may reflect a preference for bottomland hardwoods over evergreen uplands in the Southeast.

Model Description

The HSI model for great crested flycatcher includes five variables: landform, landcover, successional age class, snag density, and distance to edge.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 65). We directly assigned SI scores to these combinations on the basis of relative habitat quality associations reported by Hamel (1992) for the great crested flycatcher.

Table 65.—Relationship of landform, landcover type, and successional age class to suitability index scores for great crested flycatcher habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.167	0.500	0.667
	Transitional-shrubland	0.000	0.000	0.167	0.500	0.667
	Deciduous	0.000	0.333	0.333	0.500	0.667
	Evergreen	0.000	0.333	0.333	0.500	0.667
	Mixed	0.000	0.333	0.333	0.667	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.500	0.667
	Woody wetlands	0.000	0.333	0.333	0.667	1.000
Terrace-mesic	Low-density residential	0.000	0.333	0.333	0.583	0.834
	Transitional-shrubland	0.000	0.333	0.333	0.667 (0.500)	1.000 (0.667)
	Deciduous	0.000	0.333	0.333	0.583	0.834
	Evergreen	0.000	0.333	0.333	0.500	0.667
	Mixed	0.000	0.333	0.333	0.667	1.000
	Orchard-vineyard	0.000	0.000	0.167	0.583	0.834
	Woody wetlands	0.000	0.333	0.333	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.167	0.667	1.000
	Transitional-shrubland	0.000	0.333 (0.250)	0.333 (0.250)	0.667 (0.500)	1.000 (0.667)
	Deciduous	0.000	0.333	0.333	0.667	1.000
	Evergreen	0.000	0.333 (0.250)	0.333 (0.250)	0.500	0.667
	Mixed	0.000	0.333	0.333	0.667	1.000
	Orchard-vineyard	0.000	0.333	0.333	0.667	1.000
	Woody wetlands	0.000	0.333	0.333	0.667	1.000

The great crested flycatcher relies on snags (SI2) for nesting and foraging. We fit a logistic function (Fig. 35) through average snag values (8.5/ha) observed by Lohr and others (2002), assuming that this value represented average habitat suitability (SI score = 0.500) and that a higher abundance of snags would not be detrimental but increase the likelihood that this bird will use a site (Table 66).

This species is associated with edges (Lanyon 1997), and its abundance declines with increasing distance from an edge (SI3). Small and Hunter (1989) found that more than 60 percent of all flycatchers were less than 60 m from an edge. We assumed maximum habitat suitability at the edge and modeled the relationship between distance to edge and SI score as an inverse logistic function through these data points (Fig. 36, Table 67).

To calculate the overall HSI, we determined the geometric mean of SI scores for forest structure (SI1 and SI2) and then calculated the geometric mean of this value with the edge function (SI3).

Overall HSI = $((SI1 * SI2)^{0.500} * SI3)^{0.500}$

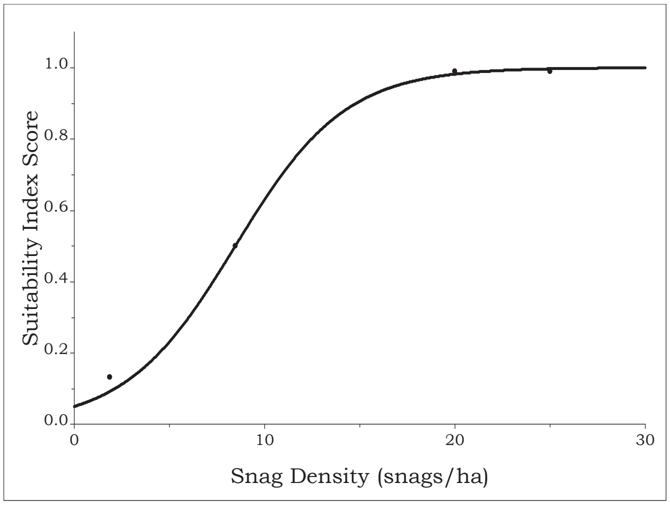


Figure 35.—Relationship between snag density and suitability index (SI) scores for great crested flycatcher habitat. Equation: SI score = 1.001 / (1 + (18.704 * e $^{(-0.346 * \text{snag density})}$)).

Table 66.—Influence of snag density on suitability index (SI) scores for great crested flycatcher habitat

Snag density (snags/ha)	SI score
0.0[a]	0.000
1.9[a]	0.133
8.5[a]	0.500
20.0[b]	1.000
25.0[b]	1.000

[a]Lohr and others (2002).
[b]Assumed value.

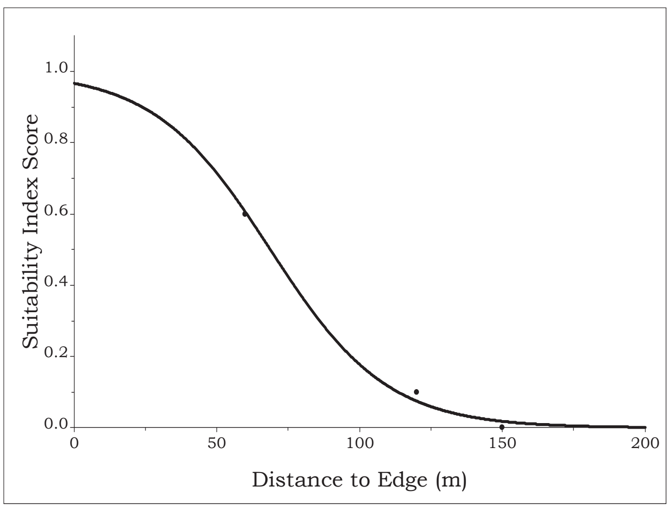


Figure 36.—Relationship between distance to edge and suitability index (SI) scores for great crested flycatcher habitat. Equation: SI score = 1 - (1.000 / (1 + (28.950 * e $^{-0.049 * \text{distance to edge}}$))).

Table 67.—Influence of distance (m) to edge[a] on suitability index (SI) scores for great crested flycatcher habitat

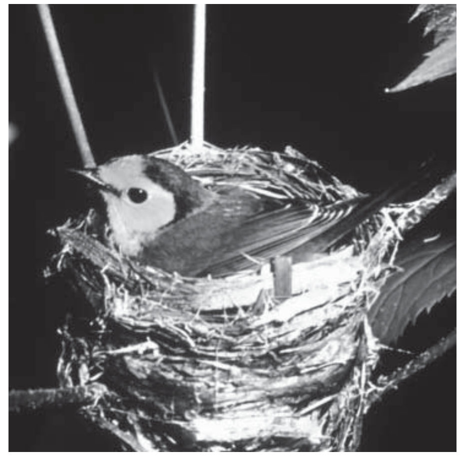
Distance to edge	SI score
0[b]	1.0
60[c]	0.6
120[b]	0.1
150[b]	0.0

[a]Edge defined by nonhabitat pixels adjacent to habitat pixels (defined by SI1).
[b]Assumed value.
[c]Small and Hunter (1989).

Verification and Validation

The great crested flycatcher was found in all 88 subsections within the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance failed to identify a significant ($P \leq 0.001$) association ($r_s = 0.55$) between these two variables. The generalized linear model predicting BBS abundance from BCR and HSI for the great crested flycatcher was not significant ($P = 0.152$; $R^2 = 0.043$), and the coefficient on the HSI predictor variable was negative (β = -2.740) and not significantly different from zero ($P = 0.151$). Therefore, we considered the HSI model for the great crested flycatcher neither verified nor validated (Tirpak and others 2009a).

Hooded Warbler


U.S. Fish & Wildlife Service

Status

The hooded warbler (*Wilsonia citrina*) is a long-distance migrant found throughout the deciduous forests of eastern North America. Because of area sensitivity, it is restricted to forested landscapes and disappears from the forest-prairie ecotone at the western edge of its range faster than other silvicolous species (e.g., eastern wood-pewee). Populations in the WGCP declined prior to 1990 but have since remained stable. Conversely, populations in the CH have increased (Sauer and others 2005) (Table 5). This species is not a Bird of Conservation Concern in either BCR (Table 1) but it is a planning and responsibility species in the WGCP (regional combined score = 16; Table 1). Nearly 30 percent of the continental population of the hooded warbler breeds in the WGCP (Panjabi and others 2001).

Natural History

The hooded warbler breeds in a variety of habitats, from mixed-hardwood forests in the northern portion of its range to cypress-gum swamps in the South. Regardless of forest type, it prefers mesic sites in large forest tracts (> 15 ha; Evans-Ogden and Stutchbury 1994). Although nest success in small forest patches is not significantly lower than in large patches (Buehler and others 2002), females may avoid small fragments and males use edge less than its availability (Norris and Stutchbury 2002, Norris and others 2000). Occupancy of a site by a nesting pair increases with shrub height and the percentage of vegetation between 1 and 2 m.

This species nests in shrubs within small forest clearings or in the dense understories of closed-canopied forests. As a result, territories often include a mix of open and closed canopies. Gaps created by tree fall or selective logging are particularly attractive (≤ 0.5 ha; Annand and Thompson 1997, Moorman and others 2002, Whittam and others 2002), and the hooded warbler colonizes these sites within 1 to 5 years. Nest sites in Canada had denser ground vegetation, fewer tree stems, lower basal area of small trees, and greater basal area of large trees than control sites (Whittam and others 2002). Bisson and Stutchbury (2000) concluded that canopy gaps and density of understory vegetation were the most important factors affecting site selection. Repeated burning, which removed understory vegetation, reduced hooded warbler abundance in Ohio (Artman and others 2001). This species is a common cowbird host, which may explain its sensitivity to fragmentation (Donovan and Flather 2002).

Model Description

The HSI model for the hooded warbler includes seven variables: landform, land cover, successional age class, small stem (< 2.5 cm d.b.h.) density, canopy cover, forest patch size, and percent forest in a 1-km landscape.

Table 68.—Relationship of landform, landcover type, and successional age class to suitability index scores for hooded warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.167	0.667	1.000
	Deciduous	0.000	0.000	0.167	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.334	0.667
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.167 (0.000)	0.500 (0.334)	0.667
	Deciduous	0.000	0.000	0.167	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.334	0.667
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.167 (0.000)	0.500 (0.167)	0.667 (0.334)
	Deciduous	0.000	0.000	0.167	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.334 (0.167)	0.667 (0.334)
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 68). We directly assigned SI scores to these combinations on the basis of relative habitat quality rankings from Hamel (1992) for the hooded warbler in the Southeast.

This species occupies dense understories in mature forested habitats, so we included both small stem density (SI2) and canopy cover (SI3) in our model. We fit a logistic function (Fig. 37) that links small stem density to SI scores on the basis of data from Annand and Thompson (1992) and Moorman and others (2002) (Table 69). We assumed that the average stem density measured at nest sites by Moorman and others (2002) (4,700 stems/ha) was representative of ideal habitat conditions for the hooded warbler and that there was no upper threshold above which habitat suitability declined. We also fit a logistic function (Fig. 38) to data from Annand and Thompson (1997) (Table 70) to link canopy cover values to SI scores.

We included forest patch size (SI4) as a model predictor because of the negative effect of fragmentation on this species. We used an exponential curve (Fig. 39) to predict habitat

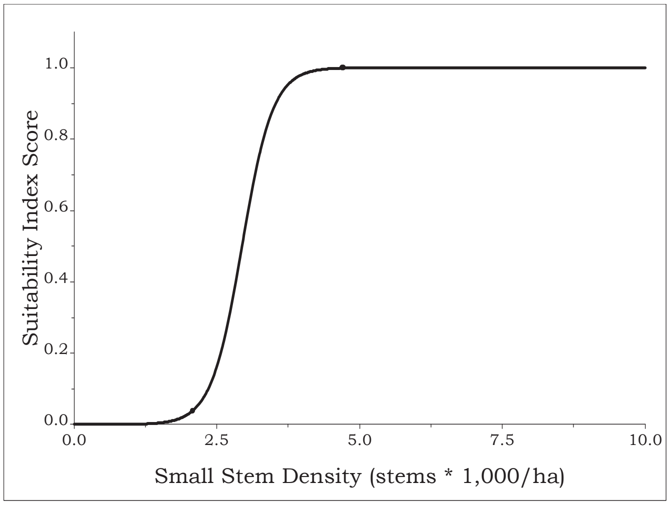


Figure 37.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) on suitability index (SI) scores for hooded warbler habitat. Equation: SI score = 1.000 / (1.000 + (102634.340 * e $^{-4.017 * (\text{small stem density} / 1000)}$)).

Table 69.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for hooded warbler habitat

Small stem density	SI score
0.000[a]	0.000
2.077[b]	0.039
4.700[c]	1.000
4.717[b]	1.000
10.000[a]	1.000

[a]Assumed value.
[b]Annand and Thompson (1992).
[c]Moorman and others (2002).

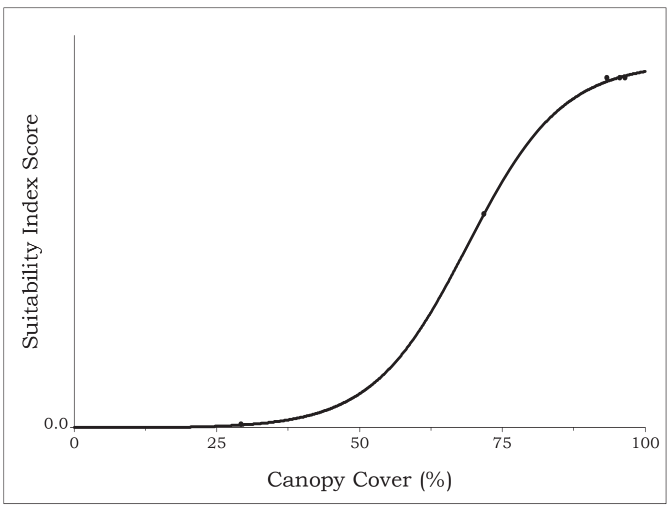


Figure 38.—Relationship between canopy cover on suitability index (SI) scores for hooded warbler habitat. Equation: SI score = 1.024 / (1.000 + (3823.776 * e $^{-0.120 * \text{canopy cover}}$)).

Table 70.—Influence of canopy cover on suitability index (SI) scores for hooded warbler habitat

Canopy cover (percent)	SI score
0.00[a]	0.0
29.26[b]	0.0
71.86[b]	0.6
93.38[b]	1.0
95.58[b]	1.0
96.59[b]	1.0

[a]Assumed value.
[b]Annand and Thompson (1997).

suitability from forest patch size on the basis of data from Evans-Ogden and Stutchbury (1994) and Kilgo and others (1998). To convert riparian widths reported by Kilgo and others (1998) to forest patch sizes, we assumed that all riparian strips were 10 km long (Table 71). The suitability of a specific forest patch is influenced by the percentage of forest in the landscape (SI5). Small patches that otherwise would be unsuitable may be occupied when in close proximity to a large forest block or in a predominantly forested landscape (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 40) to data (Table 72) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent

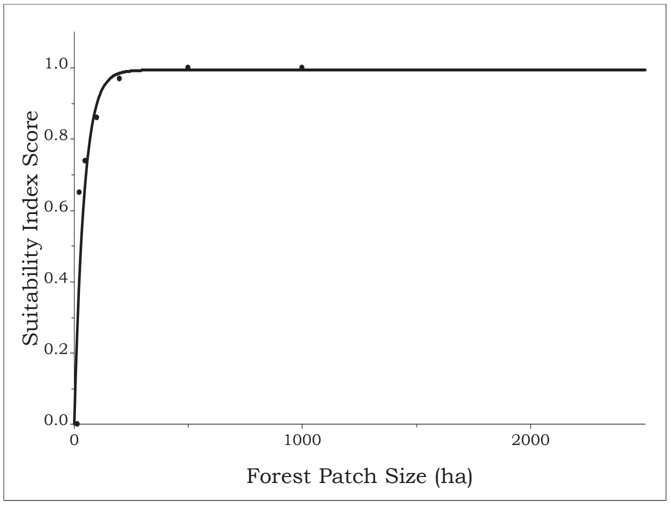


Figure 39.—Relationship between forest patch size and suitability index (SI) scores for hooded warbler habitat. Equation: SI score = 0.994 * (1 - e $^{-0.024 * \text{forest patch size}}$).

Table 71.—Influence of forest patch size on suitability index (SI) scores for hooded warbler habitat

Forest patch size (ha)	SI score
15[a]	0.00
25[b]	0.65
50[b]	0.74
100[b]	0.86
200[b]	0.97
500[b]	1.00
1,000[b]	1.00
2,500[b]	1.00

[a]Evans-Ogden and Stutchbury (1994).
[b]Kilgo and others (1998).

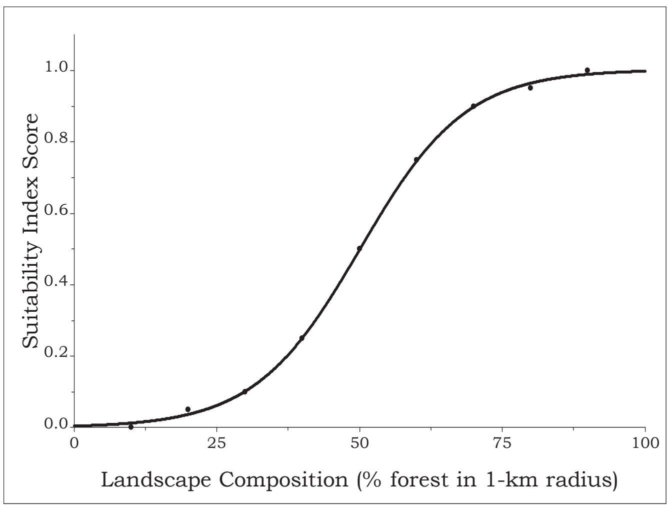


Figure 40.—Relationship between landscape composition and suitability index (SI) scores for hooded warbler habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 72.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for hooded warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Dononvan and others (1997).

forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from SI4 or SI5 to account for the higher suitability of small forest patches in a heavily forested landscape.

The overall HSI score was calculated as the geometric mean of the geometric mean of the SI values from the landform, landcover, and successional age class matrix, small stem density, and canopy cover functions (SI1, SI2, and SI3) multiplied by the maximum value of either the forest patch size or percent forest in the 1-km radius landscape functions (SI4 and SI5).

Overall HSI = $((\text{SI1} * \text{SI2} * \text{SI3})^{0.333} * \text{Max}(\text{SI4 or SI5}))^{0.500}$

Verification and Validation

The hooded warbler was found in 84 of the 88 subsections within the CH and WGCP. Spearman rank correlations identified significant positive associations between average HSI score and mean BBS route abundance across all subsections ($P \leq 0.001$; $r_s = 0.49$) and subsections within which this species was detected ($P \leq 0.001$; $r_s = 0.42$). The generalized linear model predicting BBS abundance from BCR and HSI for the hooded warbler was significant ($P \leq 0.001$; $R^2 = 0.551$), and the coefficient on the HSI predictor variable was both positive ($\beta = 8.190$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the hooded warbler both verified and validated (Tirpak and others 2009a).

Kentucky Warbler


U.S. Fish & Wildlife Service

Status

The Kentucky warbler (*Oporornis formosus*) breeds throughout the southeastern United States; densities are highest west of the Appalachian front. Populations have been stable in the CH over the last 40 years, but have declined in the WGCP by 2.2 percent per year during this period (Table 5). This species requires management attention in both regions (regional combined score = 18 and 19 in the CH and WGCP, respectively). A high percentage of the continental population breeds in both BCRs (28 and 22 percent, respectively; Panjabi and others 2001). The species is an FWS Bird of Conservation Concern in the WGCP (Table 1).

Natural History

The Kentucky warbler, a long-distance migrant, breeds in mature moist deciduous forests of the Southeast. It is a forest-interior specialist, primarily because of low productivity and survival in edge and early successional habitats (Morse and Robinson 1999; Robinson and Robinson 2001). The Kentucky warbler occupies fragments as small as 2.4 ha (Blake and Karr 1987) but tracts larger than 500 ha are considered the minimum size necessary to support sustainable populations (McDonald 1998). A dense understory is a common feature of nesting sites. Ground cover averaged 46 percent in Kentucky warbler territories in Missouri (Wenny and others 1993), and vegetation of less than 1.5 m was denser around nests than random sites in South Carolina (Kilgo and others 1996). Dense vegetation (0.3 to 1 m) was also associated with higher numbers of the Kentucky warbler in Maryland (Robbins and others 1989). Mesic sites are universally selected (McShea and others 1995, McDonald 1998, Gram and others 2003).

Model Description

The habitat suitability model for the Kentucky warbler includes six variables: landform, landcover, successional age class, small stem (< 2.5 cm d.b.h.) density, forest patch size, and percent forest in the landscape.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 73). We relied on relative habitat quality associations reported by Hamel (1992) to assign SI scores to these combinations. However, we increased SI scores for shrub-seedling stands on the basis of data from Thompson and others (1992).

The Kentucky warbler nests at the base of shrubs and occupies habitats containing high densities of small stems (SI2). We used data on the relative abundance of this species from Wenny and others (1993), Kilgo and others (1996), and Annand and Thompson (1997) to derive a logistic function (Fig. 41) that predicts habitat suitability from small stem density (Table 74).

Table 73.—Relationship of landform, landcover type, and successional age class to suitability index scores for Kentucky warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.667	0.417	0.667	0.667
	Deciduous	0.000	0.667	0.417	0.667	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	1.000	0.667	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333 (0.000)	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)
	Deciduous	0.000	0.667	0.334	0.667	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	1.000	0.667	1.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333 (0.000)	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)
	Deciduous	0.000	0.500	0.250	0.500	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.333	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	1.000	0.667	1.000	1.000

We used a logarithmic function (Fig. 42) to quantify the relationship between forest patch size (SI3) and habitat suitability on the basis of minimum patch size observations by Hayden and others (1985) and occupancy rates in different patch sizes reported by Robbins and others (1989) (Table 75). However, the suitability of a specific forest patch is influenced by its landscape context (SI4). Because the Kentucky warbler is particularly sensitive to fragmentation (Lynch and Whigham 1984), we used a 10-km window to characterize the landscape. We fit a logistic function (Fig. 43) to data (Table 76) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively.

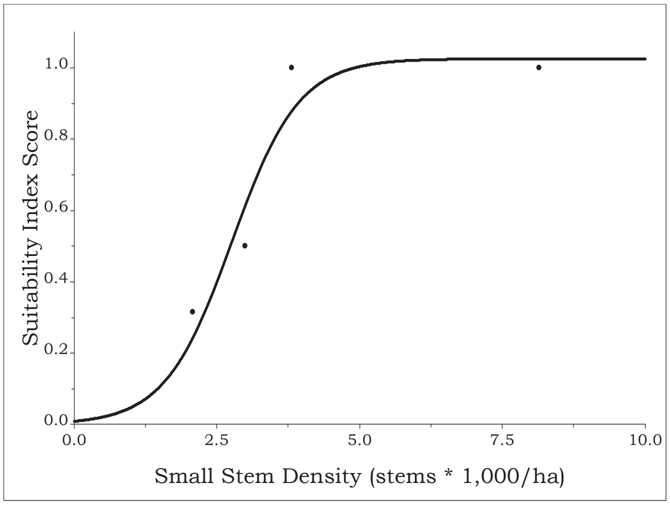


Figure 41.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for Kentucky warbler habitat. Equation: SI score = 1.026 / (1.000 + (111.558 * e -1.707 * $^{(\text{small stem density / 1000})}$)).

Table 74.—Influence of small stem (< 2.5 cm d.b.h.) density (stems/ha) on suitability index (SI) scores for Kentucky warbler habitat

Small stem density	SI score
0.000[a]	0.000
2.077[b]	0.316
3.000[c]	0.500
3.812[b]	1.000
8.148[b]	1.000
47.600[d]	1.000

[a]Assumed value.
[b]Annand and Thompson (1997).
[c]Wenny and others (1993).
[d]Kilgo and others (1996).

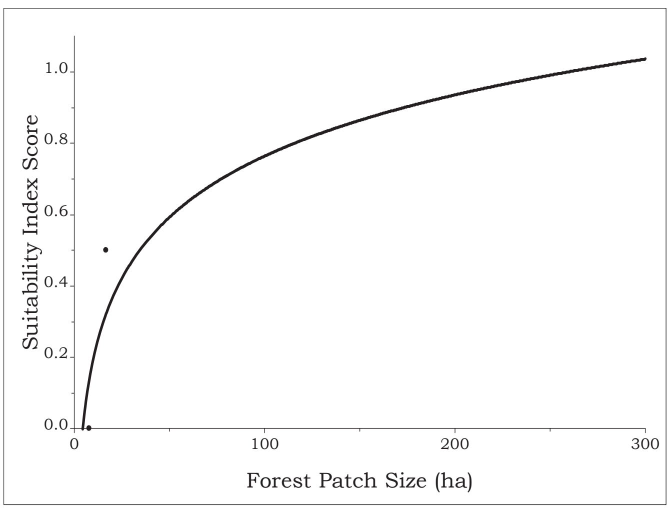


Figure 42.—Relationship between forest patch size and suitability (SI) scores for Kentucky warbler habitat. Equation: SI score = 0.248 * ln(forest patch size) – 0.377.

Table 75.—Influence of forest patch size on suitability index (SI) scores for Kentucky warbler habitat

Forest patch size (ha)	SI score
8[a]	0.0
17[b]	0.5
300[b]	1.0

[a]Hayden and others (1985).
[b]Robbins and others (1989).

To calculate the overall HSI score, we determined the geometric mean of SI scores for functions relating to forest structure (SI1 and SI2) and landscape composition (SI3 and SI4) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI2)^{0.500} * (SI3 * SI4)^{0.500})^{0.500}$

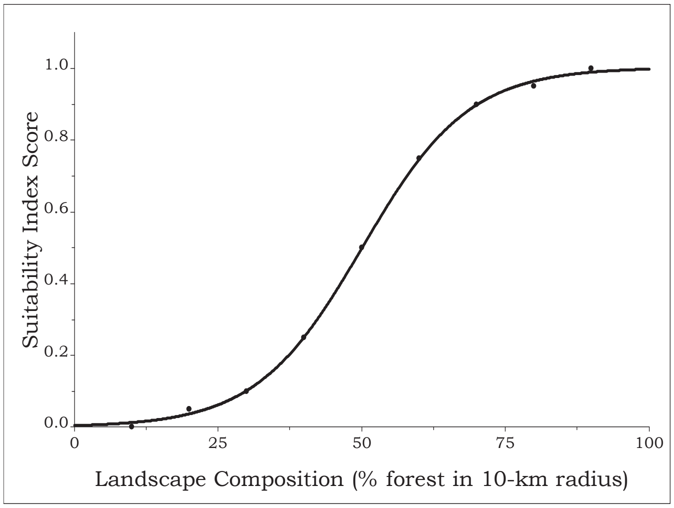


Figure 43.—Relationship between landscape composition and suitability index (SI) scores for Kentucky warbler habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (landscape\ composition)}$)).

Table 76.—Relationship between landscape composition (percent forest in 10-km radius) and suitability index (SI) scores for Kentucky warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Dononvan and others (1997).

Verification and Validation

The Kentucky warbler was found in all 88 subsections of the CH and WGCP. Spearman rank correlations identified a significant positive association between average HSI score and mean BBS route abundance across all subsections ($P \leq 0.001$; $r_s = 0.71$). The generalized linear model predicting BBS abundance from BCR and HSI for the Kentucky warbler was significant ($P \leq 0.001$; $R^2 = 0.346$), and the coefficient on the HSI predictor variable was both positive (β = 6.351) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the Kentucky warbler both verified and validated (Tirpak and others 2009a).

Louisiana Waterthrush


Charles H. Warren, images.nbii.gov

Status

The Louisiana waterthrush (*Seirus motacilla*) is a long-distance neotropical migrant found throughout the deciduous forests of the eastern and central United States. The small population in the WGCP has remained relatively stable since 1966 while the larger population in the CH has increased by 2.6 percent annually (Sauer and others 2005) (Table 5). This species is a Bird of Conservation Concern in both regions (Table 1). However, PIF differentiates the priority for this species in the CH (planning and responsibility, regional combined score = 15) and WGCP (management attention, regional combined score = 18; Table 1).

Natural History

As its name implies, the Louisiana waterthrush is associated with water throughout its range (Robinson 1995). Densities are highest along gravel-bottomed, first- and second-order streams flowing through large (> 350 ha) tracts of mature deciduous forest (Robbins and others 1989, Robinson 1995). Birds also breed at lower densities along mud-bottomed streams in cypress swamps and bottomland hardwood forests (Hamel 1992, Robinson 1995).

Prosser and Brooks (1998) developed and validated an HSI model for the Louisiana waterthrush in central Pennsylvania that included eight variables: canopy cover (> 80 percent considered ideal), shrub cover (< 25 percent), ratio of deciduous to conifer cover (30 to 69 percent, mostly reflecting hemlock dominance along streams in the Northeast), herbaceous cover (< 25 percent), stream order (first- or second-order with well developed pools and riffles), water clarity and substrate (clear and rocky or sandy), nesting cover (presence of uprooted trees or creviced, steep banks), and forest area (> 350 ha).

Model Description

Our HSI model for the Louisiana waterthrush included eight variables: landform, landcover, successional age class, distance to stream, canopy cover, small stem (< 2.5 cm d.b.h.) density, forest patch size, and percent forest in a 1-km radius.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 77). We directly assigned SI scores to these combinations on the basis of vegetation and successional age class associations outlined in Hamel (1992).

We included distance to stream (SI2) as a variable because the waterthrush uses streams and creeks for foraging and nesting. The Louisiana waterthrush restricts its foraging to the streambed and bank, so we assumed a sharp decline in suitability with increasing distance to a stream (Table 78). We used an inverse logistic function to characterize this relationship (Fig. 44).

Table 77.—Relationship of landform, landcover type, and successional age class to suitability index (SI) scores for Louisiana waterthrush habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.500	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.500	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.250	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.334	0.667

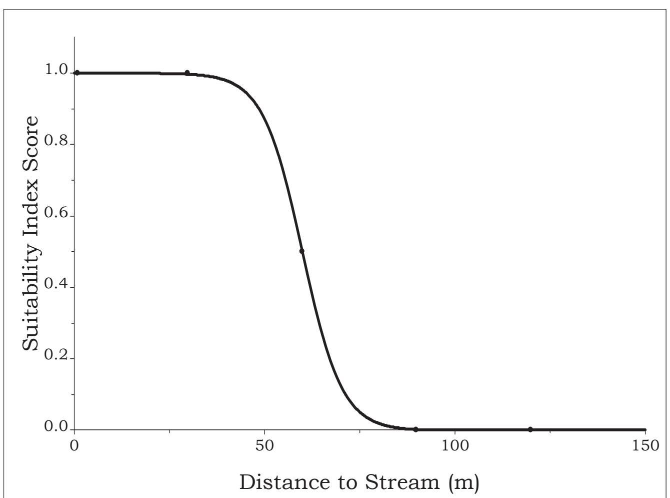


Figure 44.—Relationship between distance to stream and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = 1 - (1.0015 / (1 + (104411.5 * e $^{-0.1926 * \text{distance to stream}}$))).

Table 78.—Relationship between distance to stream and suitability index (SI) scores for Louisiana waterthrush habitat.

Distance to stream (m)[a]	SI score
0	1.0
30	1.0
60	0.5
90	0.0
120	0.0

[a]Assumed value.

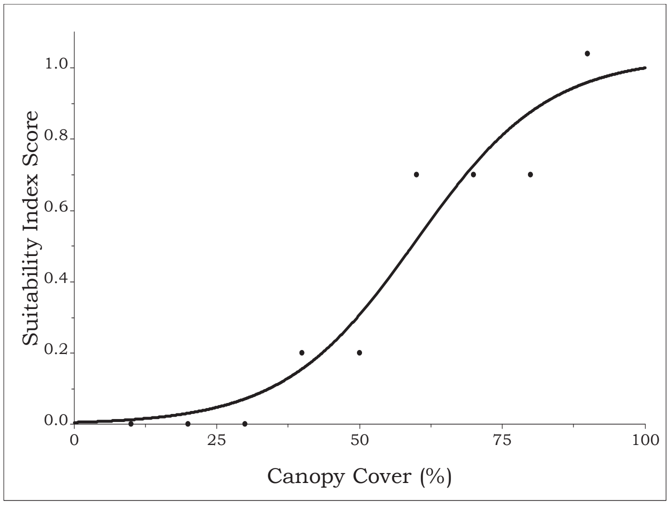


Figure 45.—Relationship between canopy cover and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = (1.0313 / (1 + (175.8083 * e $^{-0.0864 * \text{canopy cover}}$))).

Table 79.—Relationship between canopy cover and suitability index (SI) scores for Louisiana waterthrush habitat

Canopy cover (percent)[a]	SI score
0	0.0
10	0.0
20	0.0
30	0.0
40	0.2
50	0.2
60	0.7
70	0.7
80	0.7
90	1.0

[a]Prosser and Brooks (1998).

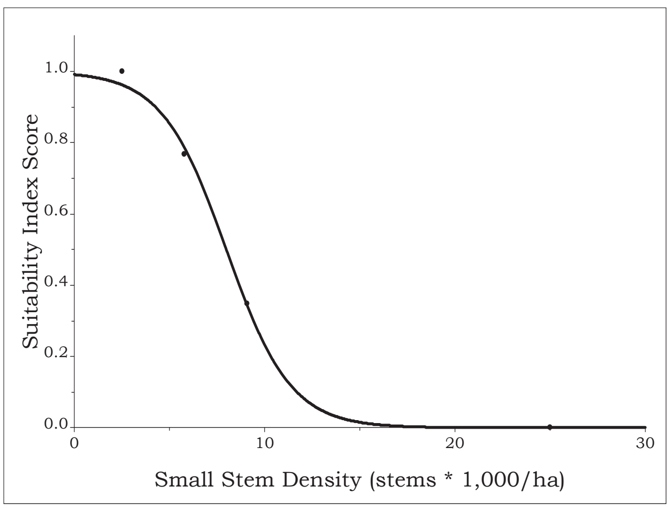


Figure 46.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = 1 - (1.000 / (1 + (113.261 * e $^{-0.592 * (\text{small stem density} / 1000)}$))).

Table 80.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) and suitability index (SI) scores for Louisiana waterthrush habitat

Small stem density	SI score
0[a]	1.000
2.519[a]	1.000
5.803[a]	0.767
9.086[a]	0.349
25.000[b]	0.000

[a]Prosser and Brooks (1998).
[b]Assumed value.

We also included canopy cover (SI3) and small stem density (SI4) as variables based on the preference of this species for mature forested sites with closed canopies and open understories. We fit logistic (Fig. 45) and inverse logistic (Fig. 46) functions to data adapted from the HSI model of Prosser and Brooks (1998) for canopy cover (Table 79) and small stem density (Table 80), respectively.

Forest patch size (SI5) affects the occupancy of habitats by the Louisiana waterthrush. To predict habitat suitability from forest patch size, we fit a logarithmic function (Fig. 47) to data from Hayden and others (1985) and Robbins and others (1989) (Table 81)

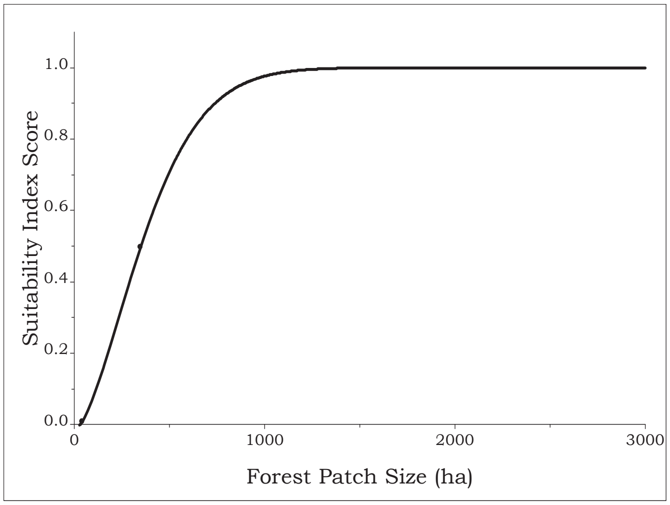


Figure 47.—Relationship between forest patch size and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = 1.000 – (1.010 * e $^{-0.0003 * (\text{forest patch size} \wedge 1.321)}$).

Table 81.—Relationship between forest patch size and suitability index (SI) scores for Louisiana waterthrush habitat

Forest patch size (ha)	SI score
42.2[a]	0.0
350[b]	0.5
3,200[b]	1.0

[a]Hayden and others (1985).
[b]Robbins and others (1989).

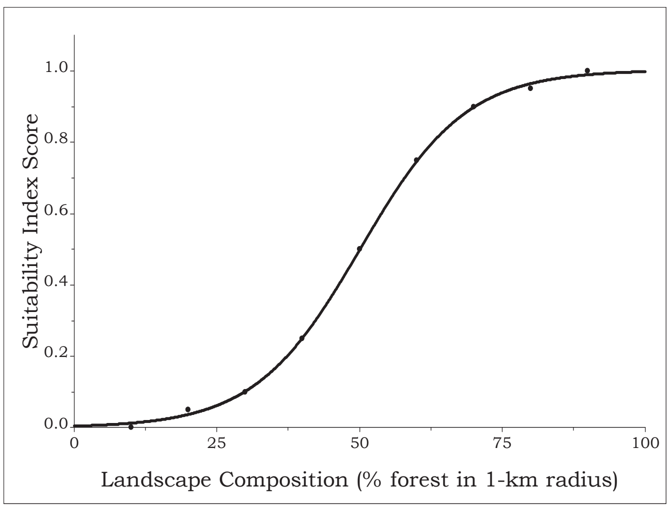


Figure 48.—Relationship between landscape composition and suitability index (SI) scores for Louisiana waterthrush habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 82.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for Louisiana waterthrush habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

on the detection probabilities of the Louisiana waterthrush in patches of varying size. However, forest patch size alone may not be an appropriate measure of a site's suitability. In predominantly forested landscapes, small patches otherwise not suitable may be occupied due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 48) to data (Table 82) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from

SI5 or SI6 to ensure that small forest blocks in predominantly forested landscapes were assigned an appropriate suitability score.

To calculate the overall HSI, we determined the geometric mean of SI scores for forest structure (SI1, SI3, and SI4) and landscape composition (Max (SI5 or SI6) and SI2) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI3 * SI4)^{0.333} * (Max (SI5 \text{ or } SI6) * SI2)^{0.500})^{0.500}$

Verification and Validation

The Louisiana waterthrush was found in all 88 subsections of the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance per subsection identified a significant ($P \leq 0.001$) positive association ($r_s = 0.56$) between these two variables. The generalized linear model predicting BBS abundance from BCR and HSI for the Louisiana waterthrush was significant ($P \leq 0.001$; $R^2 = 0.263$), and the coefficient on the HSI predictor variable was both positive ($\beta = 3.664$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the Louisiana waterthrush both verified and validated (Tirpak and others 2009a).

Mississippi Kite

Peter S. Weber, www.wildbirdphotos.com
Photo used with permission

Status

The Mississippi kite (*Ictinia mississippiensis*), a neotropical migrant raptor, is restricted to the Coastal Plains as well as the lower Mississippi and Red River Valleys. Like many birds of prey, this species has exhibited dramatic recoveries over the last 25 years from historical lows in the 1970s. However, its general scarcity prevents BBS from detecting statistically significant trends (Sauer and others 2005; Table 5). The Mississippi kite is not a Bird of Conservation Concern in the CH or WGCP (Table 1). It has a regional combined score of 14 in the CH and 16 in the WGCP.

Natural history

The Mississippi kite exhibits two breeding strategies within its range. In the southern Great Plains, it is a colonial nester that often inhabits urban areas. In the Mississippi Valley and farther east, this bird is less colonial and nests singly in large trees in bottomland forest and riparian woodlands. Nests from birds within the eastern population generally are located in large (> 22 ha) unfragmented forest near open habitats where birds forage aerially (Parker 1999).

Model Description

The HSI model for the Mississippi kite includes six variables: landform, land cover, successional age class, forest patch size, interspersion of forest and open habitats, and density of dominant trees.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 83). We directly assigned SI scores to these combinations on the basis of relative habitat quality ranks reported by Hamel (1992) for this species. However, we restricted the Mississippi kite to sawtimber stands based on its preference for mature forest stands (Parker 1999).

We also included forest patch size (SI2) in the model and used the range and mean of patch sizes reported by Barber and others (1998) to define the minimum, maximum, and average patch sizes associated with nonhabitat, optimal, and average habitat suitability for this function, respectively (Table 84; Fig. 49).

The Mississippi kite requires large patches of forest and grassland in a specific landscape context (Parker 1999, Coppedge and others 2001). We used the relative amount of these habitats within a 1-km radius as an index to their interspersion at the landscape scale (SI3). We assumed that habitat suitability was optimal in open habitats with few trees (70 to 90 percent agriculture or grassland) or landscapes containing moderate forest cover interspersed with open habitats (60 to 70 percent forest; Table 85).

Table 83.—Relationship of landform, landcover type, and successional age class to suitability index scores for Mississippi kite habitat. Values in parentheses apply to West Gulf Coastal Plain/Ouachitas.

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.500
	Deciduous	0.000	0.000	0.000	0.000	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.333
	Mixed	0.000	0.000	0.000	0.000	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.500
	Woody wetlands	0.000	0.000	0.000	0.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.333
	Deciduous	0.000	0.000	0.000	0.000	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.333
	Mixed	0.000	0.000	0.000	0.000	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.500
	Woody wetlands	0.000	0.000	0.000	0.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.333 (0.167)
	Deciduous	0.000	0.000	0.000	0.000	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.333 (0.167)
	Mixed	0.000	0.000	0.000	0.000	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.500
	Woody wetlands	0.000	0.000	0.000	0.000	1.000

The Mississippi kite nests in dominant trees (SI4) that extend above the canopy. Parker (1999) identified old-growth stands and isolated trees as preferred nesting substrates for this species, and Barber and others (1998) observed the Mississippi kite using nest trees that were higher and larger in d.b.h. than those in the surrounding overstory. We assumed that a tree with a d.b.h. greater than 76.2 cm in a sawtimber stand would extend above the canopy and provide an adequate nest substrate for this species. We further assumed that one dominant tree per ha would satisfy this requirement and that the Mississippi kite would be absent from stands with a uniform canopy (zero dominant trees/ha). We fit an exponential function (Fig. 50) to the values between these data points. Stands with 14 dominant trees per ha (the maximum observed in the WGCP during the FIA surveys of the 1990s) were associated with maximum habitat suitability (Table 86).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI4) and landscape composition (SI2 and SI3) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$

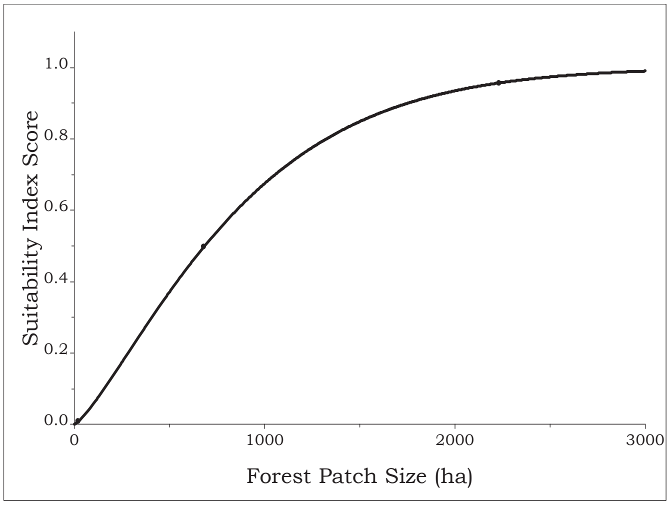


Figure 49.—Relationship between forest patch size and suitability index (SI) scores for Mississippi kite habitat. Equation: SI score = 1.002 – (1.000 * $e^{-0.0002 * (\text{forest patch size} \wedge 1.278)}$).

Table 84.—Influence of forest patch size on suitability index (SI) scores for Mississippi kite habitat

Forest patch size (ha)[a]	SI score
22	0.0
683	0.5
3,000	1.0

[a]Barber and others (1998).

Table 85.—Suitability index scores for Mississippi kite habitat based on proportion of cells providing roosting and nesting habitat within 1-km radius

	Proportion forest[a]										
Proportion agriculture-grassland[b]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.50	0.50	0.50
0.1	0.00	0.00	0.00	0.00	0.20	0.20	0.40	0.60	0.60	0.60	
0.2	0.00	0.00	0.00	0.00	0.40	0.40	0.60	0.80	0.80		
0.3	0.00	0.00	0.00	0.00	0.60	0.60	0.80	1.00			
0.4	0.35	0.40	0.40	0.60	0.80	0.80	1.00				
0.5	0.50	0.50	0.55	0.70	0.70	0.60					
0.6	0.60	0.70	0.75	0.90	0.80						
0.7	0.70	0.75	1.00	1.00							
0.8	0.80	0.90	1.00								
0.9	0.80	1.00									
1.0	0.80										

[a]Woody wetlands, deciduous forest, low-density residential.

[b]Open water, open fields (natural or cultivated), emergent herbaceous wetland.

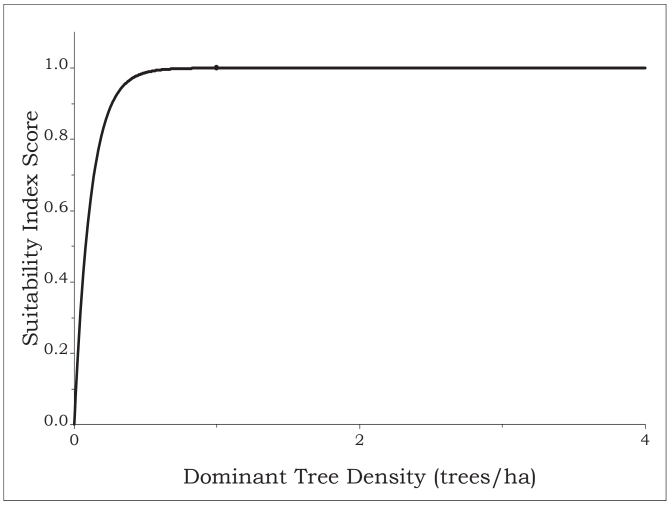


Figure 50.—Relationship between dominant tree (> 76.2 cm d.b.h.) density and suitability index (SI) scores for Mississippi kite habitat. Equation: SI score = 1 – e $^{-8.734\ *\ \text{dominant tree density}}$.

Table 86.—Influence of dominant tree (d.b.h. > 76.2 cm) density (trees/ha) on suitability index (SI) scores for Mississippi kite habitat

Dominant tree density[a]	SI score
0	0.0
1	1.0
14	1.0

[a]Assumed value.

Verification and Validation

The Mississippi kite was found in 49 of the 88 subsections within the CH and WGCP. Spearman rank correlations based on all subsections yielded a significant (P = 0.003) positive association (r_s = 0.31) between average HSI score and mean BBS route abundance. However, this association was not evident when the correlation considered only subsections in which this species was found. The generalized linear model predicting BBS abundance from BCR and HSI for the Mississippi kite was significant ($P \leq 0.001$; R^2 = 0.287); however, the coefficient on the HSI predictor variable was negative (β = -0.176). Therefore, we considered the HSI model for the Mississippi kite verified but not validated (Tirpak and others 2009a).

Northern Bobwhite

U.S. Forest Service

Status

The northern bobwhite (*Colinus virginianus*) is a resident gamebird found throughout the eastern United States and Great Plains. Populations have declined by 3 percent per year since 1966 (Sauer and others 2005). Declines in the CH and WGCP have been equally dramatic (3.1 and 4.4 percent per year, respectively) during this period (Table 5). As a resident gamebird, this species is not afforded special status by the FWS (protection is relegated to state wildlife agencies). Nevertheless, PIF has designated this bird as one requiring management attention in both the CH and WGCP (regional combined scores = 16 and 15, respectively) (Table 1). To address rangewide declines in populations, the Northern Bobwhite Conservation Initiative was established in 2002.

Natural History

The northern bobwhite is an economically important gamebird in the southern and central United States (Brennan 1999). It is associated with early successional vegetation, making use of agricultural fields, grasslands, grass-shrub rangelands, park-like pine forests and mixed pine-hardwood forests. At the county scale in Texas, the area in cultivated land and livestock density show curvilinear relationships to bobwhite population indices (Lusk and others 2002a). In Oklahoma, bobwhite indices decrease with the proportion of the landscape in mature woodland, but increase with the proportion of brushy prairie or early successional habitat (Guthery and others 2001). Guthery and others (2001) found that populations were highest in areas lacking cropland agriculture. However, Williams and others (2000) found that the bobwhite selected cropland when it accounted for a small proportion of the landscape. Patterns of use and survival differ between crop-dominated and rangeland-dominated areas during the hunting season in Kansas (Williams and others 2000). Bobwhite densities vary across the range depending on habitat quality but are highest in areas with small (0.5 to 5.0 ha) interspersed patches of habitat.

Frequency and intensity of disturbance are important for this species, especially in southern pine forests where prescribed burning is a useful management tool. Cram and others (2002) reported higher bobwhite abundance in pine-grassland restoration areas in Arkansas as conifer and hardwood basal area decreased and woody structure less than 2 m tall increased. The bobwhite also occupies cottonwood reforestation plots less than 4 years old in Mississippi and Louisiana (Twedt and others 2002). Most management for this species has been at the local scale, but Guthery (1999) showed that optimal configuration of patch types and sizes has variability (slack), and Williams and others (2004) promoted a regional management strategy that focused on useable space (i.e., more patches of native prairies, savanna, and other favored vegetation types).

Weather affects bobwhite populations, including positive effects of summer temperature and fall precipitation (Lusk and others 2002a) and negative effects of spring flooding and low winter temperatures (Applegate and others 2002). Bridges and others (2001) found a negative correlation between drought indices in dry regions and bobwhite abundance, but this pattern did not hold in wetter regions of Texas. Lusk and others (2002b) also found that climatic variables were more important than landscape variables for predicting bobwhite abundance in Oklahoma.

Nests are constructed of litter (grass or pine needles) in areas of high structural complexity (Townsend and others 2001); brood cover is found in open areas with dense forbs that still permit mobility at ground level. Nevertheless, Taylor and others (1999) did not find any habitat attributes associated with higher probabilities of adult survival or nest success. White and others (2005) examined multiple landscape buffers (radii of 250 to 1,000 m) around nest sites and random points to examine landscape effects on nest site selection. Bobwhite responded to both composition and configuration of landscapes, including proportions of open-canopy planted pine and fallow fields, interspersion-juxtaposition index, and patch density. A model containing all four of these variables applied at the largest landscape had the best predictive ability, but was closely followed by a model containing only proportion of open-canopy planted pine applied at the smallest landscape size. Several other types of habitat models have been developed for the bobwhite: HSI (Schroeder 1985), PATREC (Roseberry and Sudkamp 1998), and logistic regression (Burger and others 2004). Tests of these models showed that they perform poorly (Roseberry and Sudkamp 1998, Burger and others 2004, Jones-Farrand and Millspaugh 2006).

Model Description

Habitat quality for bobwhite is affected by many parameters that are not measured easily at any scale: the proportion of forbs or open areas in grasslands, herbaceous vegetation height, grasslands and crop-field management, and intra- and inter-annual climatic variations. Therefore, we restricted our habitat suitability model to aspects of landscape composition and forest structure that were quantifiable from available datasets. Our final model includes seven variables: landform, landcover, successional age class, hardwood basal area, evergreen basal area, grass landcover, and interspersion of open and forest habitats.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 87). We directly assigned SI scores to these combinations on the basis of habitat associations for the northern bobwhite outlined in Hamel (1992).

Forested sites used by the northern bobwhite typically are woodlands with low hardwood and pine basal area (SI2 and SI3, respectively). We used data from Cram and others (2002) and Palmer and Wellendorf (2006) to inform inverse logistic functions that predict SI scores for the bobwhite at various basal area levels (Tables 88-89; Figs 51-52).

We directly assigned SI scores to grass landcover (SI4) classes based on their potential to provide feeding, nesting, and brood-rearing habitat (Guthery 1997) (Table 90). We assumed that natural grassland-herbaceous landcovers had the greatest potential to provide these habitats, though it is likely that a given patch can satisfy only two of the three requisites

Table 87.—Relationship of landform, landcover type, and successional age class to suitability index (SI) scores for northern bobwhite habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.167	0.167	0.083	0.000	0.000
	Deciduous	0.167	0.167	0.083	0.000	0.000
	Evergreen	1.000	1.000	0.667	0.500	0.667
	Mixed	0.667	1.000	0.667	0.333	0.333
	Orchard-vineyard	0.167	0.167	0.083	0.000	0.000
	Woody wetlands	0.334	0.334	0.250	0.250	0.334
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.667 (1.000)	1.000	0.667	0.333 (0.500)	0.333 (0.667)
	Deciduous	0.333	0.667	0.333	0.000	0.000
	Evergreen	1.000	1.000	0.667	0.500	0.667
	Mixed	0.667	1.000	0.667	0.333	0.333
	Orchard-vineyard	0.333	0.667	0.333	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.667 (0.834)	1.000 (0.834)	0.667	0.333 (0.667)	0.333 (0.667)
	Deciduous	0.333	1.000	0.500	0.000	0.000
	Evergreen	1.000 (0.834)	1.000 (0.834)	0.667	0.500 (0.667)	0.667
	Mixed	0.667	1.000	0.667	0.333	0.333
	Orchard-vineyard	0.333	1.000	0.500	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

at any point in time (Stoddard 1931). We assumed that areas in small grain production provided foraging opportunities but had little residual value for nesting or brood rearing. Similarly, fallow fields provide marginal nest and brood habitat but little forage. Finally, pasture-hay and row crops may provide foraging, nesting, and brood-rearing habitat but their value likely is limited due to management practices that produce unsuitable vegetative structure during most of the breeding season.

The bobwhite relies on landscapes comprised of interspersed vegetation types (White and others 2005, Guthery 2000). We used the composition of open and forest landcovers within a 1-km landscape (SI5) to index the interspersion of these cover types. Guthery (1999, 2000) and others before him (see Schroeder 1985 and references therein) have noted that this species can tolerate a broad range of landscape configurations. On the basis of suggestions from Fred Guthery (2006, Oklahoma State University, pers. commun.), we assumed that high quality habitat was characterized by 10 to 40 percent forest land and 60 to 90 percent open habitat (Table 91).

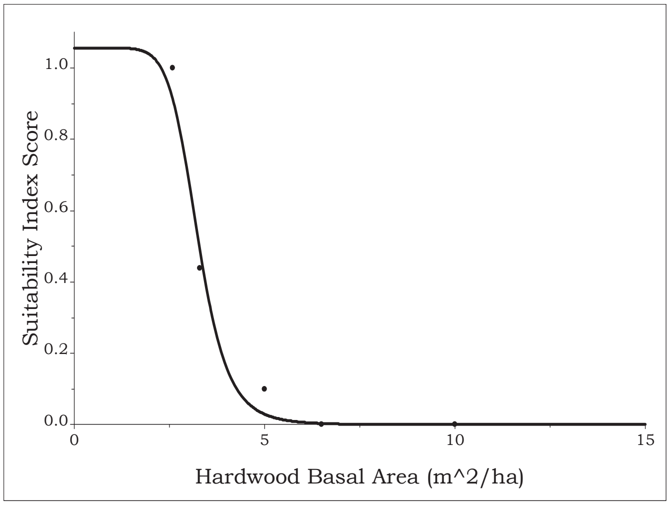


Figure 51.—Relationship between hardwood basal area and suitability index (SI) scores for northern bobwhite habitat. Equation: SI score = 1/ (1.000 + (0.053 * (hardwood basal area)$^{5.068}$)).

Table 88.—Influence of hardwood basal area on suitability index (SI) scores for northern bobwhite habitat

Hardwood basal area (m^2/ha)	SI score
0.0[a]	1.000
2.6[b]	1.000
3.3[b]	0.439
5.0[a]	0.100
6.5[b]	0.000
10.0[a]	0.000

[a]Assumed value.
[b]Cram and others (2002).

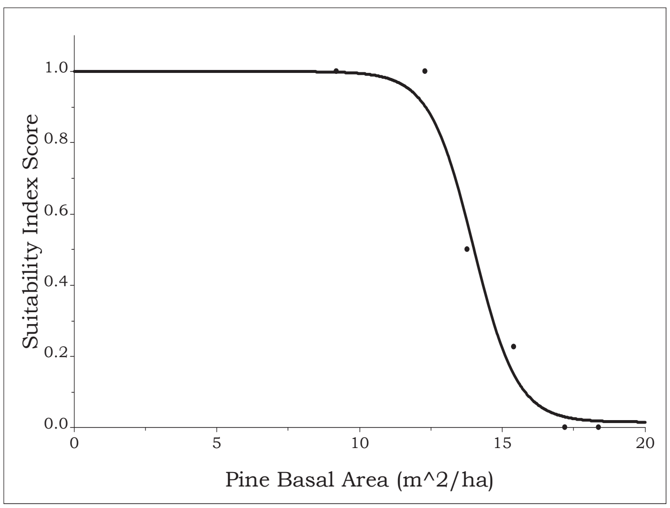


Figure 52.—Relationship between pine basal area and suitability index (SI) scores for northern bobwhite habitat. Equation: SI score = 1 - (0.984 / (1 + (83605490 * e$^{-1.305 * \text{pine basal area}}$))).

Table 89.—Influence of pine basal area on suitability index (SI) scores for northern bobwhite habitat

Pine basal area (m^2/ha)	SI score
0.00[a]	1.000
9.20[b]	1.000
12.30[a]	1.000
13.78[b]	0.500
15.40[c]	0.228
17.20[c]	0.000
18.37[b]	0.000

[a]Assumed value.
[b]Palmer and Wellendorf (2006).
[c]Cram and others (2002).

We calculated the overall HSI score by first determining the geometric mean of SI scores for forest structure attributes (SI1, SI2, and SI3). Open habitats lacking forest structure were assigned SI score independently (SI4). The landscape context of these forest and open habitats were incorporated into the HSI calculation by determining the geometric mean of these site-level and landscape-level variables (SI5) together.

Overall HSI = (((SI1 * SI2 * SI3)$^{0.333}$ + SI4) * SI5)$^{0.500}$

Table 90.—Relationship between open and grassy landcover and suitability index (SI) scores for northern bobwhite habitat

Landcover type[a]	SI score
Grassland-herbaceous	1.0
Pasture-hay	0.1
Row crops	0.1
Small grains	0.4
Fallow	0.2

[a]Assumed value.

Table 91.—Suitability index scores for northern bobwhite habitat based on the proportion of cells providing: 1) good nesting, feeding, and brood-rearing habitat (open landcovers); 2) escape and thermal cover (forest landcovers) within 1-km radius

Proportion	Proportion forest[a]										
open[b]	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0.1	0.00	0.00	0.10	0.15	0.25	0.25	0.25	0.20	0.15	0.10	
0.2	0.00	0.10	0.15	0.25	0.35	0.35	0.30	0.25	0.20		
0.3	0.00	0.30	0.35	0.45	0.45	0.45	0.40	0.30			
0.4	0.00	0.50	0.50	0.50	0.50	0.50	0.50				
0.5	0.00	0.70	0.70	0.70	0.70	0.70					
0.6	0.00	0.90	0.90	0.90	0.90						
0.7	0.00	0.90	1.00	1.00							
0.8	0.00	0.90	1.00								
0.9	0.00	0.90									
1.0	0.00										

[a]Forest = landcovers with positive SI1 score (Table 87).
[b]Open = landcovers identified in SI4 (Table 90).

Verification and Validation

The northern bobwhite was found in all 88 subsections of the CH and WGCP. Spearman rank correlation support a significant ($P = 0.006$) positive association ($r_s = 0.29$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the northern bobwhite was significant ($P \leq 0.001$; $R^2 = 0.440$); however, the coefficient on the HSI predictor variable was negative (β = -37.119). Therefore, we considered the HSI model for the northern bobwhite verified but not validated (Tirpak and others 2009a).

Northern Parula

Chandler S. Robbins, Patuxent Bird Identification InfoCenter
Photo used with permission

Status

The northern parula (*Parula americana*), a long-distance neotropical migrant, breeds in two disjunct zones of eastern North America: New England-southern Canada and the southeastern United States. This species is notably absent from the southern Great Lakes. It depends on epiphytes—Spanish moss in the south and old man's beard in the north—as a nesting substrate. Parula populations have been stable in most regions during the last 40 years and have increased in some areas including the CH (Table 5). This species is not considered a Bird of Conservation Concern in the CH or WGCP (regional combined score = 12 and 13, respectively; Table 1).

Natural History

The northern parula is common in the bottomland hardwood and riverine forests of the Southeastern United States (Moldenhauer and Regelski 1996). It also occupies mixed pine-hardwoods, though at lower densities (Moldenhauer and Regelski 1996). The northern parula has two competing habitat requirements: a preference for canopy gaps and large forest blocks. Moorman and Guynn (2001) found that this species is more abundant near canopy gaps than forest-interior sites with an unbroken canopy in bottomland hardwoods, and Annand and Thompson (1997) observed the highest northern parula densities in forests with canopy gaps resulting from single-tree selection. However, the probability of detecting the northern parula increases with riparian buffer width (Kilgo and others 1998) and forest patch size (Robbins and others 1989).

The northern parula forages in the mid- to upper canopy layers (Moldenhauer and Regelski 1996), so it is not surprising that it prefers microsites with high basal area (Robbins and others 1989), high canopy cover, and tall canopies (James 1971), and avoids areas with dense understories (often associated with open canopies) (Torres and Leberg 1996). In the Southeast, this species nests almost exclusively in Spanish moss (Moldenhauer and Regelski 1996). However, no studies have identified Spanish moss as limiting.

Model Description

The HSI model for the northern parula includes six variables: landform, landcover, successional age class, forest patch size, percent forest in a 1-km radius, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 92). We directly assigned SI scores to these combinations on the basis of habitat associations of northern parulas reported by Hamel (1992) for the Southeast.

We derived a logarithmic function (Fig. 53) from data on the occupancy rate of northern parulas in forest blocks of varying size (SI2; Hayden and others 1985, Robbins and others 1989) (Table 93) to predict habitat suitability from patch area. However, small forest

Table 92.—Relationship of landform, landcover type, and successional age class to suitability index scores for northern parula habitat

Landform	Landcover type	Successional age class				
		Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.083	0.500	0.834
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.250	0.750	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.250	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.167	0.333
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000

patches in predominantly forested landscapes may provide habitat due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 54) to data (Table 94) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from SI2 or SI3 to account for small patches in predominantly forested landscapes.

We included canopy cover (SI4) in our model to capture the preference of the northern parula for interior edges. James (1971), Collins and others (1982), and Morgan and Freedman (1986) found that the northern parula is associated with increased canopy cover. Nonetheless, there seems to be a threshold above which suitability declines. Robbins and others (1989) observed an inverse relationship between canopy cover and northern parula abundance, and Annand and Thompson (1997) observed a threefold increase of parulas in single-tree selection stands characterized by a heterogeneous canopy than in mature forest habitats with closed canopies. On the basis of these studies, we assumed that

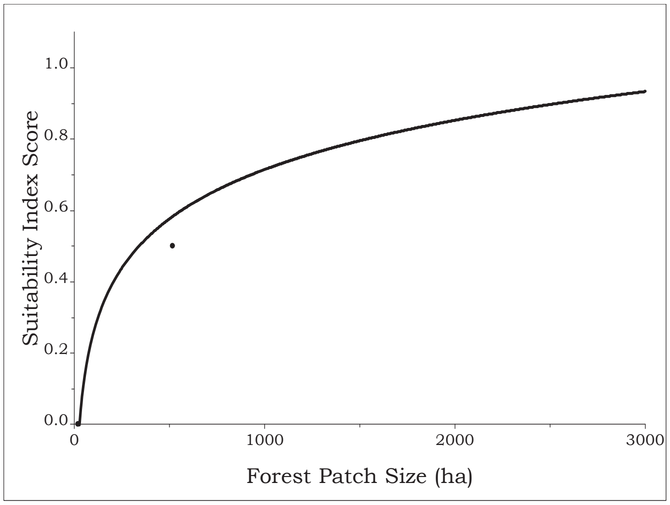


Figure 53.—Relationship between forest patch size and suitability index (SI) scores for northern parula habitat. Equation: SI score = 0.199 * ln(forest patch size) – 0.661.

Table 93.—Influence of forest patch size on suitability index (SI) scores for northern parula habitat

Forest patch size (ha)	SI score
23.6[a]	0.0
520[b]	0.5
3,200[b]	1.0

[a]Hayden and others (1985).

[b]Robbins and others (1989).

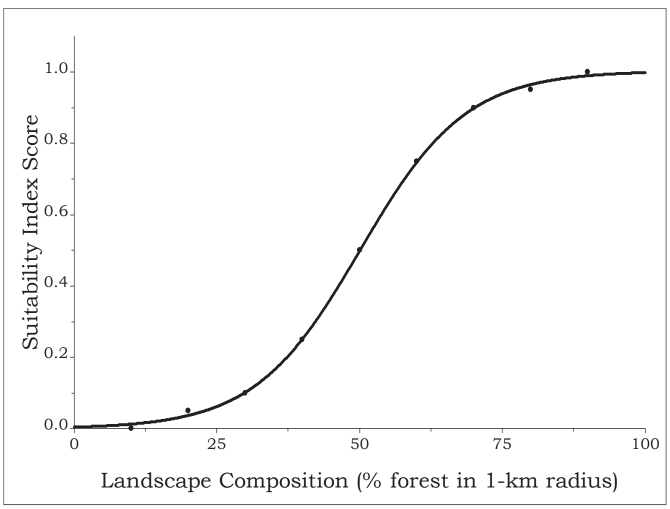


Figure 54.—Relationship between local landscape composition and suitability index (SI) scores for northern parula habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * $e^{-0.108 * (\text{local landscape composition})}$)).

Table 94.—Relationship between local landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for northern parula habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.

[b]Donovan and others (1997).

habitat suitability was optimal at 90 percent canopy cover and decreased as the canopy became increasingly open or closed. We fit an inverse quadratic function (Fig. 55) to data demonstrating this relationship (Table 95).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI4) and then calculated the geometric mean of this value and landscape composition (Max of SI2 or SI3).

Overall HSI = $((\text{SI1} * \text{SI4})^{0.500} * \text{Max(SI2 or SI3)})^{0.500}$

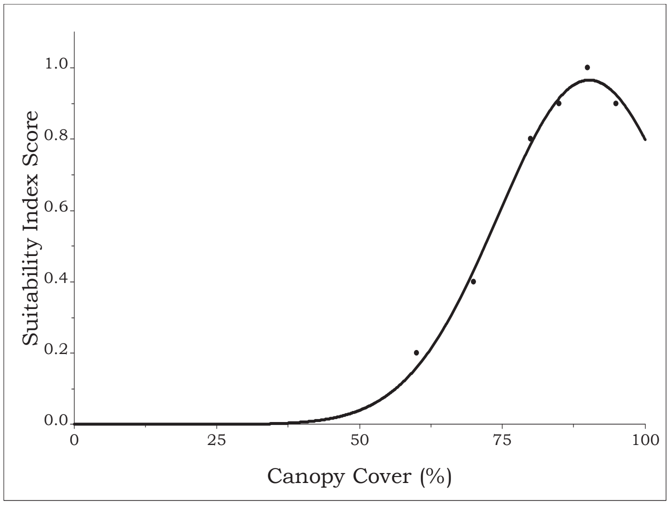


Figure 55.—Relationship between canopy cover and suitability index (SI) scores for northern parula habitat. Equation: SI score = 1 / (37.3645 – (0.8127 * canopy cover) + (0.00454 * (canopy cover^2))).

Table 95.—Influence of canopy cover on suitability index (SI) scores for northern parula habitat

Canopy cover (percent)[a]	SI score
60	0.2
70	0.4
80	0.8
85	0.9
90	1.0
95	0.9
100	0.8

[a]Assumed value.

Verification and Validation

The northern parula was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.51$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the northern parula was significant ($P \leq 0.001$; $R^2 = 0.276$), and the coefficient on the HSI predictor variable was both positive ($\beta = 5.250$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the northern parula both verified and validated (Tirpak and others 2009a).

Orchard Oriole

Deanna K. Dawson,
Patuxent Bird Identification InfoCenter
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Status

The orchard oriole (*Icterus spurius*), a neotropical migrant, is found throughout most of the United States east of the Rocky Mountains except for New England and the northern Great Lakes. Although this species has experienced increases along the edges of its distribution, populations have declined in the core of its range where densities are highest. In the WGCP, populations have declined by 3 percent per year since 1967 (Table 5). Populations in the adjacent Mississippi Alluvial Valley have declined 4 percent. The orchard oriole is a Bird of Conservation Concern in the WGCP and has been identified as a species requiring management attention in both the CH and WGCP (regional combined score = 17 and 18, respectively; Table 1).

Natural History

The orchard oriole breeds in wooded riparian zones, floodplains, marshes, and shorelines (Scharf and Kren 1996) but also in open shrublands and low-density human-dominated areas (e.g., farms and parklands). It is semi-colonial in optimal habitat but relatively solitary in marginal areas. This species is a common host of the brown-headed cowbird.

Model Description

The HSI model for the orchard oriole includes five variables: landform, landcover, successional age class, forest within a 1-km radius, and basal area.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 96). We directly assigned SI scores to these combinations based on vegetation and successional age class associations in Hamel (1992). However, we adjusted Hamel's values to account for the preference of the orchard oriole for mesic habitats (e.g., riparian zones, floodplains, and marshes; Scharf and Kren 1996).

The orchard oriole is not area sensitive but generally is restricted to forested landscapes. Therefore, we included only local forest composition (SI2) in our model to discount forest patches that were isolated within a matrix of nonforest landcover. Conversely, this is an edge species whose abundance declines in heavily forested regions (Scharf and Kren 1996). Therefore, we assumed that landscapes with 70 to 80 percent forest provided optimal habitat suitability and reduced suitability symmetrically as landscape composition shifted from these optima (Table 97, Fig. 56).

This species is most abundant in areas with scattered trees. Heltzel and Leberg (2006) observed significantly fewer orioles in stands with an average basal area of 25 m^2 per ha than in recently harvested stands with an average basal area of 18 m^2 per ha. We assumed that habitat suitability was optimal for the orchard oriole at lower basal areas and modeled

Table 96.—Relationship of landform, landcover type, and successional age class to suitability index scores for orchard oriole habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.500	1.000	1.000
	Transitional-shrubland	0.000	0.000	0.500	1.000	1.000
	Deciduous	0.000	0.000	0.500	1.000	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.500	1.000	1.000
	Woody wetlands	0.000	0.000	0.500	1.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.333	0.667	0.667
	Transitional-shrubland	0.000	0.000	0.250	0.500	0.500
	Deciduous	0.000	0.000	0.250	0.500	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.333	0.667	0.667
	Woody wetlands	0.000	0.000	0.500	1.000	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.333	0.667	0.667
	Transitional-shrubland	0.000	0.000	0.250	0.500	0.500
	Deciduous	0.000	0.000	0.250	0.500	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.333	0.667	0.667
	Woody wetlands	0.000	0.000	0.500	1.000	1.000

the basal area (SI3)-habitat suitability relationship as a quadratic function (Fig. 57) that maximized SI scores at intermediate basal area values (12.5 m^2/ha; Table 98).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure indices (SI1 and SI3) and then determined the geometric mean of this value and landscape composition (SI2).

Overall HSI = $((SI1 * SI3)^{0.500} * SI2)^{0.500}$

Verification and Validation

The orchard oriole was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.34$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the orchard oriole was significant ($P = 0.088$; $R^2 = 0.056$), and the coefficient on the HSI predictor variable was positive ($\beta = 2.442$) but not significantly different from zero ($P = 0.221$). Therefore, we considered the HSI model for the orchard oriole verified but not validated (Tirpak and others 2009a).

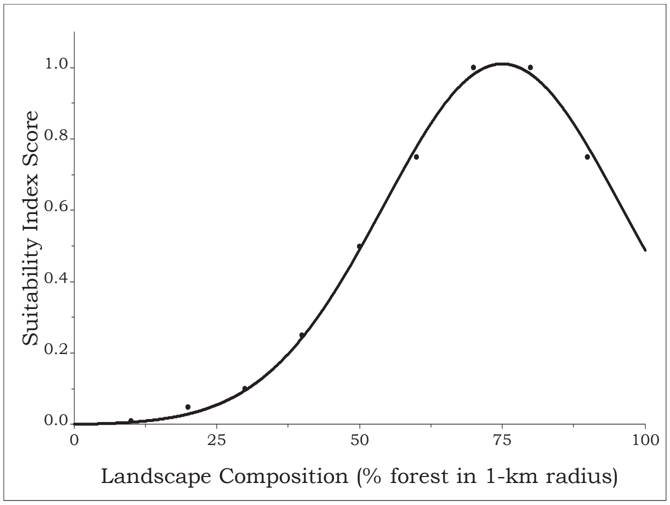

Figure 56.—Relationship between landscape composition and suitability index (SI) scores for orchard oriole habitat. Equation: SI score = 1.011 * e $^{((0 – ((\text{landscape composition} * 100) – 74.945) \wedge 2) / 863.949)}$.

Table 97.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for orchard oriole habitat

Landscape composition[a]	SI score
0	0.00
10	0.00
20	0.05
30	0.10
40	0.25
50	0.50
60	0.75
70	1.00
80	1.00
90	0.75
100	0.50

[a]Assumed value.

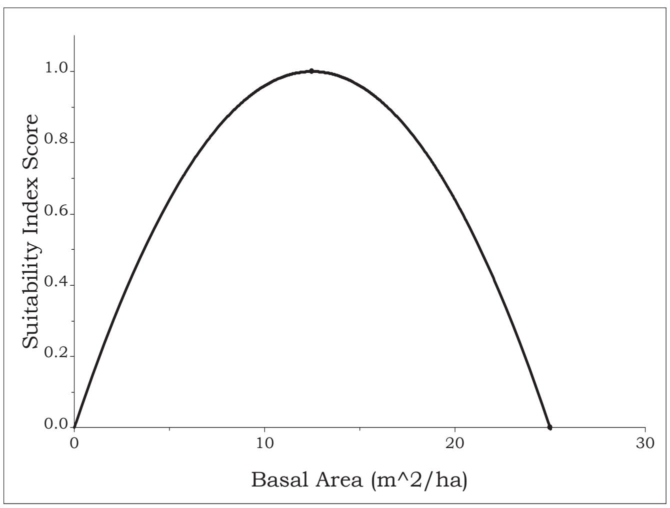

Figure 57.—Relationship between basal area and suitability index (SI) scores for orchard oriole habitat. Equation:
SI score = (0.16 * basal area) - (0.00639 * (basal area^2)).

Table 98.—Influence of basal area (m^2/ha) on suitability index (SI) scores for orchard oriole habitat

Basal area (m^2/ha)	SI score
0.0[a]	0.0
12.5[a]	1.0
25.0[b]	0.0

[a]Assumed value.
[b]Heltzel and Leberg (2006).

Painted Bunting

Deanna K. Dawson,
Patuxent Bird Identification InfoCenter
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Status

The painted bunting (*Passerina cyanea*) occurs as two allopatric populations that may represent separate species (Lowther and others 1999). The western population inhabits the southern Great Plains and the western edges of the CH and WGCP, while the eastern population inhabits the Atlantic Coastal Plain from North Carolina to Florida. Populations have been relatively stable across the WGCP as a whole (Table 5), but populations have declined in Arkansas (5.8 percent per year from 1967 to 2004), Louisiana (3.5 percent), and Texas (2.4 percent) but increased in Oklahoma (1.3 percent; Sauer and others 2005). The painted bunting is not an FWS Bird of Conservation Concern but is a PIF management attention priority in both the CH and WGCP (regional combined score = 16 and 17, respectively; Table 1).

Natural History

The habitat requirements of the painted bunting are poorly understood. This species generally occupies areas of scattered woody vegetation. Kopachena and Crist (2000a) characterized painted bunting habitat in northeast Texas as "wooded areas in otherwise open habitat" as opposed to the indigo bunting, which occurs in "open areas in otherwise wooded habitat." The painted bunting use smaller, more heterogeneous groups of trees than the indigo bunting, but microhabitats differ little between these species (Kopachena and Crist 2000b). The painted bunting occupies narrow riparian strips in eastern Texas and its abundance decreases quickly as widths exceed 70 m (Conner and others 2004).

The painted bunting nests in low, woody vegetation (Lowther and others 1999) and its territory size varies with its population density. In Missouri, territories ranged from 0.64 to 6.66 ha and included 80 percent pasture and 20 percent woodland. This species is a common host of both the brown-headed and bronzed cowbird.

Model Description

The HSI model for the painted bunting includes six variables: landform, landcover, successional age class, distance to edge, interspersion of open and forested lands, and small stem (< 2.5 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 99). We directly assigned SI scores to these combinations on the basis of relative habitat rankings for vegetation and successional age class associations of painted buntings reported by Hamel (1992). We assigned higher values to the shrub-seedling age class than Hamel (1992) on the basis of qualitative descriptions in Lowther and others (1999).

An early-successional species, the painted bunting is associated with edges. We used data on territory density from Lanyon and Thompson (1986; Table 100) to define an inverse logistic function linking SI scores to distance from an edge (SI2; Fig. 58).

Table 99.—Relationship of landform, landcover type, and successional age class to suitability index scores for painted bunting habitat

Landform	Landcover type	Successional age class				
		Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.500	0.500	0.250	0.000
	Deciduous	0.000	0.500	0.500	0.250	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.500	0.500	0.250	0.000
	Woody wetlands	0.000	1.000	0.750	0.500	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.500	0.500	0.250	0.000
	Deciduous	0.000	0.500	0.500	0.250	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.500	0.500	0.250	0.000
	Woody wetlands	0.000	1.000	0.750	0.500	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.500	0.500	0.250	0.000
	Deciduous	0.000	0.500	0.500	0.250	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.500	0.500	0.250	0.000
	Woody wetlands	0.000	1.000	0.750	0.500	0.000

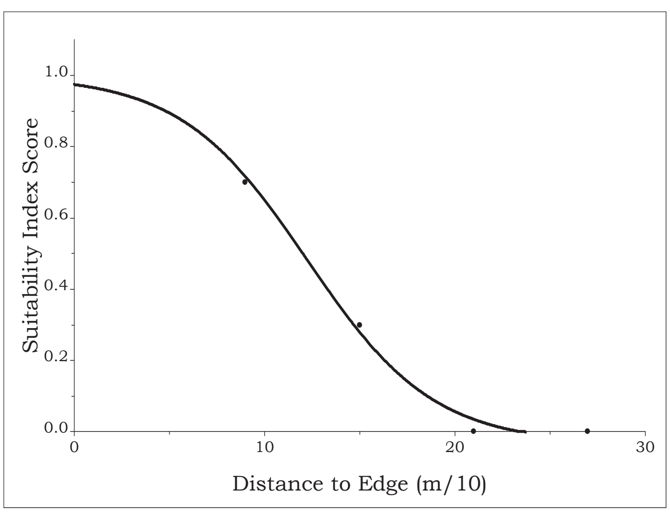


Figure 58.—Relationship between distance to edge and suitability index (SI) scores for painted bunting habitat. Equation: SI score = 1 - (1.034 / (1 + (39.685 * e $^{-0.301 * (\text{distance to edge} / 10 \text{ m})}$))).

Table 100.—Influence of distance to edge on suitability index (SI) scores for painted bunting habitat

Distance to edge (m)	SI score
0[a]	1.0
90[a]	0.7
150[a]	0.3
210[a]	0.0
270[b]	0.0

[a]Lanyon and Thompson (1986).
[b]Assumed value.

Table 101.—Suitability index scores for painted bunting habitat based on the proportion of open and forest landcovers within 5-ha area

Proportion forest[b]	Proportion open[a]										
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
0.2	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5		
0.3	0.0	0.0	0.5	0.7	0.7	0.7	0.7	0.7			
0.4	0.0	0.0	0.5	0.7	0.9	0.9	0.9				
0.5	0.0	0.0	0.5	0.7	0.9	1.0[c]					
0.6	0.0	0.0	0.5	0.7	0.9						
0.7	0.0	0.0	0.5	0.7							
0.8	0.0	0.0	0.5								
0.9	0.0	0.0									
1.0	0.0										

[a]Open = herbaceous natural, cultivated, and emergent herbaceous wetland.

[b]Forest = upland forested, transitional, woody wetland, and orchard/vineyard.

[c]Unpublished data.

The presence of both forest and open landcovers in the landscape (SI3) is perhaps the most important component of painted bunting habitat. We maximized SI scores for this species in landscapes containing 50 percent forest and 50 percent open habitats based on unpublished data (Jeffrey Kopachena, 2006, Texas A&M University—Commerce, pers. commun.). Norris and Elder (1982, cited in Lowther and others 1999) observed the painted bunting in landscapes with forest cover of 20 to 80 percent forest. We used these values as cutoffs for forest cover in our interspersion function for the painted bunting (Table 101).

As an early successional species, the painted bunting occupies habitats containing high densities of small stems (SI4). We assumed that the mean stem density values (6,400 stems/ha) reported by Kopachena and Crist (2000b) were characteristic of average habitat suitability (SI score = 0.500). However, because of the high standard error (6,300 stems/ha) associated with this estimate, we assumed that a stem density that was twice the mean was necessary to ensure optimal habitat (Table 102). We fit a smoothed logistic function through these data points (Fig. 59) to quantify the relationship between small stem density and SI scores for painted bunting habitat.

To calculate the HSI score for sapling and pole successional age class stands, we determined the geometric mean of SI scores for forest structure (SI1 and SI4) and landscape composition (SI2 and SI3) separately and then the geometric mean of these means together.

$$HSI_{Sap\text{-}pole} = ((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$$

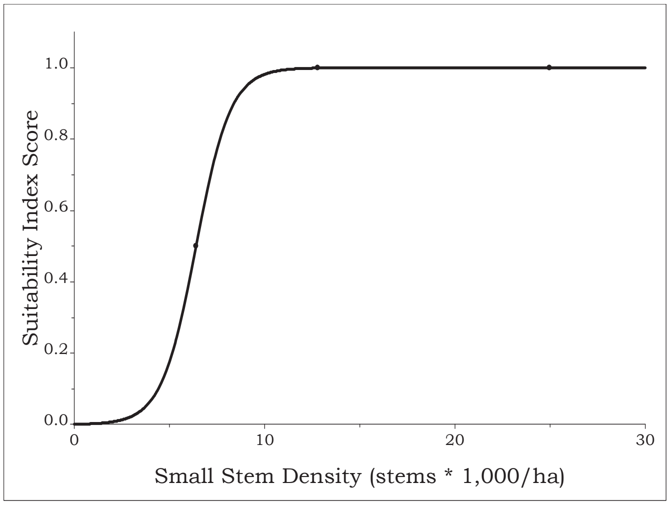


Figure 59.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for painted bunting habitat. Equation: SI score = (1.000 / (1 + (1178.674 * e $^{-1.105 \text{ * (small stem density / 1000)}}$))).

Table 102.—Influence of small stem density (stems * 1,000/ha) on suitability index (SI) scores for painted bunting habitat

Small stem density	SI score
0.0[a]	0.0
6.4[b]	0.5
12.8[a]	1.0
25.0[a]	1.0

[a]Assumed value.
[b]Kopachena and Crist (2000b).

We assumed that shrub-seedling successional age class stands were suitable regardless of edge or landscape composition. Thus, we calculated the HSI score as the geometric mean of forest structure attributes alone (SI1 and SI4).

$HSI_{Shrub} = (SI1 * SI4)^{0.500}$

The overall HSI score is the sum of the two age class specific SIs:

Overall HSI = $SI_{Sap\text{-}pole} + SI_{Shrub}$

Verification and Validation

The painted bunting was found in only 38 of the 88 subsections within the CH and WGCP. Nevertheless, Spearman rank correlations based on either all subsections or only subsections in which the painted bunting occurred produced similar results: significant ($P \leq 0.001$ in both analyses) positive associations (r_s = 0.56 and 0.58, respectively) between average HSI score and mean BBS route abundance at the subsection scale. The generalized linear model predicting BBS abundance from BCR and HSI for the painted bunting was significant ($P \leq$ 0.001; R^2 = 0.480), and the coefficient on the HSI predictor variable was both positive (β = 70.737) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the painted bunting both verified and validated (Tirpak and others 2009a).

Pileated Woodpecker


U.S Forest Service

Status

The pileated woodpecker (*Dryocopus pileatus*) breeds throughout eastern North America, southern Canada, and the montane forests of the West. Populations have been stable across most of its range, including the WGCP, over the last 40 years and have increased along the northern limit of this bird's distribution. In the CH, populations have increased by 1.8 percent per year since 1967 (Sauer and others 2005) (Table 5). This species is a management attention priority in the WGCP (regional combined score = 16) but has no special conservation status in the CH (regional combined score = 13; Table 1).

Natural History

The pileated woodpecker uses a variety of forest types across its range but typically is associated with older successional age classes (Bull and Jackson 1995, Annand and Thompson 1997). The key component to pileated woodpecker habitat is an abundance of large snags—the more the better. Different researchers define "large" differently (Renken and Wiggers 1989, Savignac and others 2000, Showalter and Whitmore 2002) but the pileated woodpecker is invariably associated with the largest available size class. In Missouri, this species is associated with bottomland hardwood forest (Renken and Wiggers 1993); in east Texas, the pileated woodpecker is equally abundant in bottomland hardwoods, longleaf pine savanna, and mixed pine-hardwood stands, so long as suitable snags are available (Shackelford and Conner 1997). Closed canopies (canopy cover of 75 to 96 percent) are the norm (Renken and Wiggers 1989). Because it has a large home range (53 to 160 ha), it is not surprising that the pileated woodpecker is sensitive to forest area. Robbins and others (1989) did not detect this species in woodlots less than 42 ha and larger areas likely are required for breeding pairs. Schroeder (1982) considered 130 ha as the minimum forest patch size for this species.

Model Description

The pileated woodpecker model includes six variables: landform, land cover, successional age class, large snag (> 30 cm d.b.h.) density, forest patch size, and percentage of forest in a 1-km radius.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 103). We used the habitat associations of the pileated woodpecker outlined in Hamel (1992) to assign SI scores to these combinations.

Large snags (SI2) are used for roosting, nesting, and foraging and are an important component of pileated woodpecker habitat. We fit a logistic function (Fig. 60) to data from Renken and Wiggers (1989) on the relative density of this species on sites with varying large snag densities to predict SI scores based on this habitat feature (Table 104).

Table 103.—Relationship of landform, landcover type, and successional age class to suitability index scores for pileated woodpecker habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.042	0.083	0.167
	Transitional-shrubland	0.000	0.000	0.083	0.583	1.000
	Deciduous	0.000	0.000	0.083	0.583	1.000
	Evergreen	0.000	0.000	0.167	0.333	0.333
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.042	0.083	0.167
	Transitional-shrubland	0.000	0.000	0.167	0.500 (0.333)	0.667 (0.333)
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.167	0.333	0.333
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.042	0.083	0.167
	Transitional-shrubland	0.000	0.000	0.167 (0.083)	0.500 (0.167)	0.667 (0.167)
	Deciduous	0.000	0.000	0.000	0.500	1.000
	Evergreen	0.000	0.000	0.167 (0.083)	0.333 (0.167)	0.333 (0.167)
	Mixed	0.000	0.000	0.167	0.500	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.667	1.000

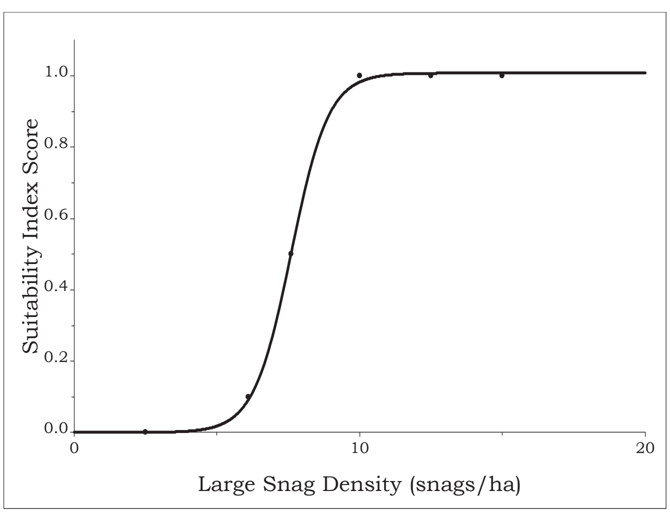


Figure 60.—Relationship between large snag (> 30 cm d.b.h.) density and suitability index (SI) scores for pileated woodpecker habitat. Equation: SI score = (1.0054 / (1 + (747.0936 * e $^{-0.8801 * \text{large snag density}}$))).

Table 104.—Influence of large snag (> 30 cm d.b.h.) density (snags/ha) on suitability index (SI) scores for pileated woodpecker habitat

Large snag density	SI score
0. [a]	0.0
2.5[a]	0.0
6.1[b]	0.1
7.6[b]	0.5
10.0[b]	1.0
15.0[a]	1.0
12.5[a]	1.0

[a]Assumed value.

[b]Renken and Wiggers (1989).

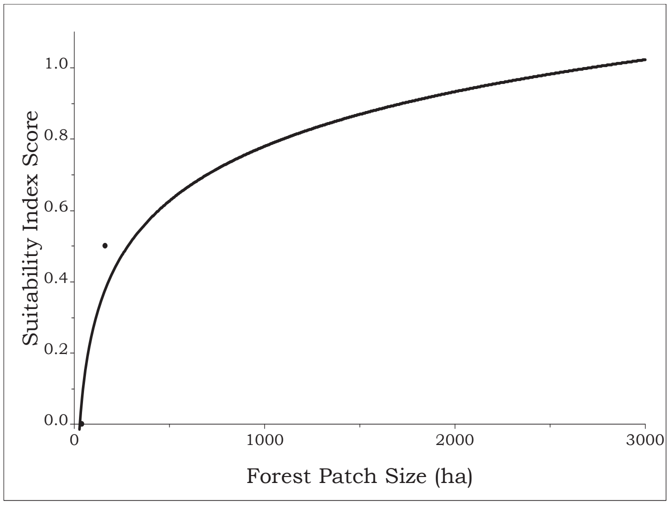


Figure 61.—Relationship between forest patch size and suitability index (SI) scores for pileated woodpecker habitat. Equation: SI score = 0.230 * ln(forest patch size) – 0.877.

Table 105.—Influence of forest patch size on suitability index (SI) scores for pileated woodpecker habitat

Forest patch size (ha)[a]	SI score
42.2	0.0
165	0.5
3,200	1.0

[a]Robbins and others (1989).

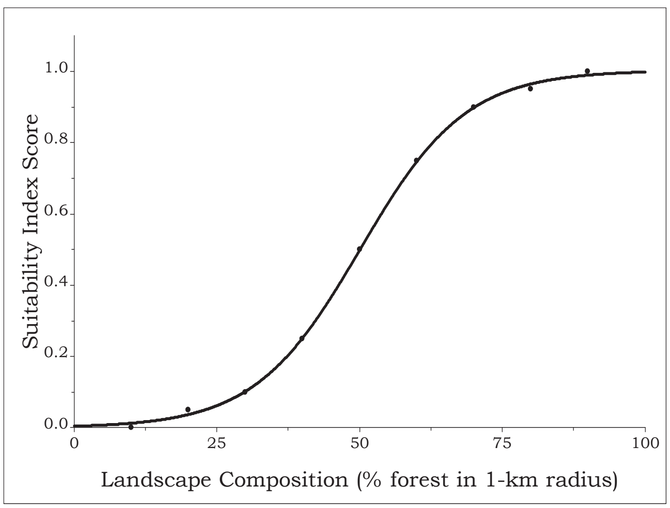


Figure 62.—Relationship between landscape composition and suitability index (SI) scores for pileated woodpecker habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{local landscape composition})}$)).

Table 106.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for pileated woodpecker habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

We incorporated forest patch size (SI3) and percent forest in the local landscape (SI4) as predictors of habitat suitability. Large home ranges for the pileated woodpecker necessitate large forest patches. We fit a logarithmic function (Fig. 61) to data from Robbins and others (1989) on the effect of forest patch size on occupancy rates (Table 105). We also included percent forest in the landscape because small forest patches that may not be used in predominantly nonforested landscapes may provide habitat in predominantly forested landscapes due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 62) to data (Table 106) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from SI3 or SI4 to account for the higher suitability of small forest patches in predominantly forested landscapes.

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI2) and multiplied that by the maximum value of forest patch size (SI3) or percent forest in the 1-km radius landscape (SI4) and calculated the geometric mean of that product.

$$\text{Overall HSI} = ((\text{SI1} * \text{SI2})^{0.500} * \text{Max}(\text{SI3 or SI4}))^{0.500}$$

Verification and Validation

The pileated woodpecker was observed in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.002$) positive association (r_s = 0.33) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the pileated woodpecker was significant ($P \leq 0.001$; $R^2 = 0.313$), and the coefficient on the HSI predictor variable was both positive (ß = 8.852) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the pileated woodpecker both verified and validated (Tirpak and others 2009a).

Prairie Warbler

Deanna K. Dawson,
Patuxent Bird Identification InfoCenter
Photo used with permission

Status

The prairie warbler (*Dendroica discolor*), a neotropical migrant, occupies early successional habitats throughout the eastern United States. Like many early successional species, populations of this bird have declined throughout the eastern and central United States since 1967, including a drop of 2.6 percent per year in the CH and 4.4 percent per year in the WGCP (Table 5). The prairie warbler is an FWS Bird of Conservation Concern and a management attention priority in both BCRs (regional combined score = 18 in the CH and WGCP; Table 1).

Natural History

The prairie warbler breeds in shrubby vegetation under an open canopy (Nolan and others 1999). Typical associations in the CH and WGCP include shrubby southern pine forest, pine barrens, scrub oak barrens, abandoned fields and pastures, regenerating forest, abandoned orchards, grassland-forest edge, Christmas tree farms, and reclaimed strip mine spoils. The prairie warbler uses a variety of landforms from xeric uplands in Arkansas to palustrine swamps in Virginia. In comparison to other early successional warblers, this bird occupies sites with fewer dense shrubs than the blue-winged warbler, more dense vegetation and drier areas than the yellow warbler, and less dense vegetation and higher vegetation strata than the common yellowthroat or yellow-breasted chat (Nolan and others 1999).

The prairie warbler nests in shrubs and small trees that are more than 20 m from a field-forest edge (Nolan and others 1999, Woodward and others 2001). However, in eastern Texas this species typically occurs in narrow riparian zones, with abundance decreasing quickly as widths increase (Conner and others 2004). Mean territory size varies inversely with population density, ranging from 0.2 to 3.5 ha in Indiana (Nolan and others 1999). Territory size also varies with shape of forest patch; it is larger in more linear patches. Although males do not limit movements to their defended territory, a female's home range usually is contained within a male's defended territory. This species is a cowbird host. Although parasitism has little effect on hatching success, it can significantly reduce fledging rates.

Model Description

Our HSI model for the prairie warbler includes seven variables: landform, landcover, successional age class, early-successional patch size, small stem (< 2.5 cm d.b.h.) density, edge occurrence, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 107). We directly assigned SI scores to these combinations on the basis of habitat associations for the prairie warbler documented in Hamel (1992).

Table 107.—Relationship of landform, landcover type, and successional age class to suitability index scores for prairie warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.333	0.167	0.000	0.000
	Deciduous	0.000	0.333	0.167	0.000	0.000
	Evergreen	0.000	0.667	0.334	0.000	0.000
	Mixed	0.000	1.000	0.500	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000 (0.667)	0.500 (0.334)	0.000	0.000
	Deciduous	0.000	0.667	0.333	0.000	0.000
	Evergreen	0.000	0.667	0.334	0.000	0.000
	Mixed	0.000	1.000	0.500	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000 (0.500)	0.500 (0.250)	0.000	0.000
	Deciduous	0.000	1.000	0.500	0.000	0.000
	Evergreen	0.000	0.667 (0.500)	0.334 (0.250)	0.000	0.000
	Mixed	0.000	1.000	0.500	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.333	0.167	0.000	0.000

Both Woodward and others (2001) and Rodewald and Vitz (2005) observed edge avoidance by this species. Thus, we used a 3 × 3 pixel (90 x 90 m) window to identify early successional habitats (i.e., grass-forb, shrub-seedling, or sapling successional age class forest) adjacent to mature forest stands (i.e., pole or sawtimber successional age class) and reduced the suitability of locations adjacent to edges by half (SI2; Table 108).

We also included early successional patch size (SI3) as an explanatory variable because the prairie warbler is absent from small clearings and edge habitats. We used data from Larson and others (2003) (Table 109) to fit a logistic function (Fig. 63) that characterized the relationship between habitat suitability and early successional patch size.

We also included small stem density (SI4) as a variable because the prairie warbler is associated with dense understory vegetation. We used point count and habitat data reported by Annand and Thompson (1997) (Table 110) to derive a logistic function (Fig. 64) that predicted habitat suitability for the prairie warbler from small stem density.

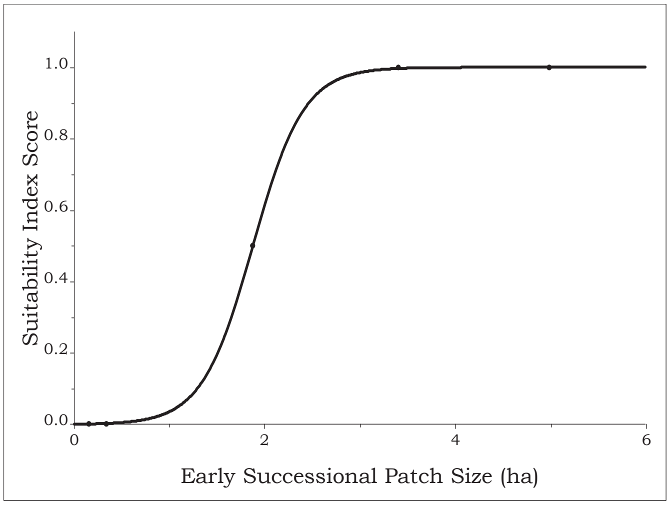


Figure 63.—Relationship between early successional patch size and suitability index (SI) scores for prairie warbler habitat. Equation: SI score = (1.002 / (1 + (1207.332 * e $^{-3.757 \text{ * forest patch size}}$))).

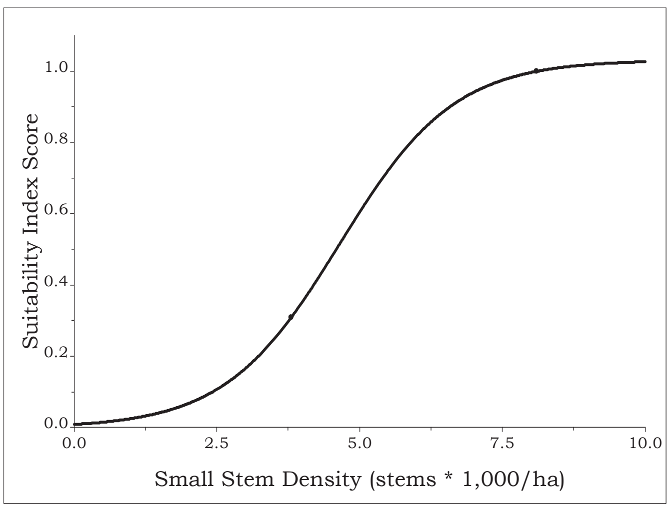


Figure 64.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for prairie warbler habitat. Equation: SI score= (1.000 / (1 + (99.749 * e $^{-1.001 \text{ * (small stem density / 1000)}}$))).

Table 108.—Influence of edge on suitability index (SI) scores for prairie warbler habitat

3 × 3 pixel window around early successional habitat includes mature forest[a]	SI score
Yes	0.5
No	1.0

[a]Early successional = grass-forb, shrub-seedling, and sapling successional age classes; mature forest = pole or sawtimber successional age classes.

Table 109.—Influence of early successional patch size on suitability index (SI) scores for prairie warbler habitat; early successional patches only include grass-forb, shrub-seedling, and sapling successional age classes

Early successional patch size (ha)[a]	SI score
0.18	0.0
0.36	0.0
1.89	0.5
3.42	1.0
5.00	1.0

[a]Larson and others (2003).

Table 110.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for prairie warbler habitat

Small stem density	SI score
0.0[a]	0.00
3.8[b]	0.31
8.1[b]	1.00

[a]Assumed value.
[b]Annand and Thompson (1997).

Finally, we used data from Sheffield (1981) to inform an inverse logistic function (Fig. 65) that discounted SI scores at increasingly high canopy closures (SI5; Table 111).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1, SI4, and SI5) and landscape composition (SI2 and SI3) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI4 * SI5)^{0.333} * (SI2 * SI3)^{0.500})^{0.500}$

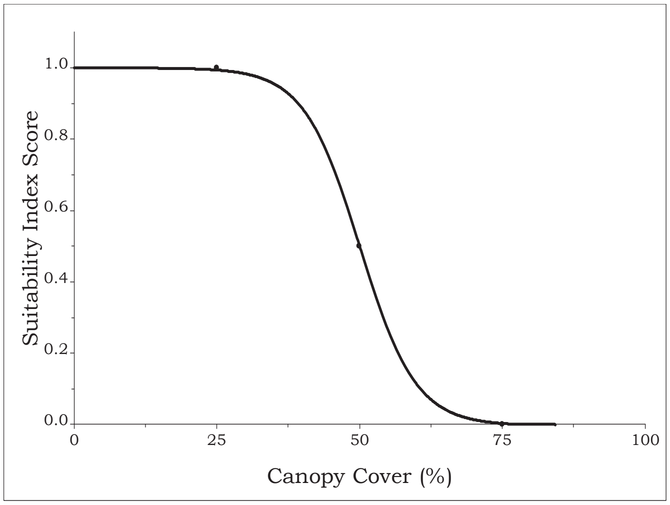


Figure 65.—Relationship between canopy cover and suitability index (SI) scores for prairie warbler habitat. Equation: SI score = 1 - (1.003 / (1 + (26950.420 * e $^{-0.204 * \text{canopy cover}}$))).

Table 111.—Influence of canopy cover on suitability index (SI) scores for prairie warbler habitat

Canopy cover (percent)[a]	SI score
0	1.0
25	1.0
50	0.5
75	0.0
100	0.0

[a]Sheffield (1981).

Verification and Validation

The prairie warbler was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.41$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the prairie warbler was significant ($P = 0.005$; $R^2 = 0.117$), and the coefficient on the HSI predictor variable was both positive ($\beta = 15.317$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the prairie warbler both verified and validated (Tirpak and others 2009a).

Prothonotary Warbler


John and Karen Hollingsworth,
U.S. Fish & Wildlife Service

Status

The prothonotary warbler (*Protonotaria citrea*) is a long-distance neotropical migrant associated with bottomland hardwood and floodplain forests of the Southeast. Densities are highest in the Mississippi Alluvial Valley; this species is notably absent from the central and southern Appalachians. Populations in the CH have remained relatively stable while those in the WGCP, where the prothonotary warbler is a Bird of Conservation Concern (Table 1), have declined by 5.8 percent per year since 1967 (Table 5). This bird is a planning and responsibility species in the CH (regional combined score = 14) and a management attention species in the WGCP (regional combined score = 17).

Natural History

Because it nests in cavities and readily accepts nest boxes, the prothonotary warbler has been well-studied.

Petit (1999) provided an excellent, detailed description of this bird's habitat requirements:

> Key (and nearly universal) features are presence of water near wooded area with suitable cavity nest sites. Nest usually placed over or near large bodies of standing or slow-moving water, including seasonally flooded bottomland hardwood forest, baldcypress swamps, and large rivers or lakes (Walkinshaw 1953, Blem and Blem 1991). Many other forms of water also chosen, such as creeks, streams, backyard ponds, and even swimming pools. Nests located away from permanent water are usually in low-lying, temporarily flooded spots (Walkinshaw 1953).
>
> Other important habitat correlates include low elevation, flat terrain, shaded forest habitats with sparse understory, and in some places, presence of baldcypress (Kahl and others 1985, Robbins and others 1989). Common overstory trees in nesting habitat include willows, maples, sweet gum, willow oak, ashes, elms, river birch, black gum, tupelo, cypress, and other species associated with wetlands. Buttonbush is the most common subcanopy species. Canopy height 12-40 m (usually 16-20), canopy cover usually 50-75 percent; ground vegetation usually very sparse and of low stature (< 0.5 m; Kahl and others 1985).
>
> Exhibits area sensitivity, avoiding forests <100 ha in area and avoiding waterways with wooded borders <30 m wide (Kahl and others 1985).

Model Description

The HSI model for prothonotary warbler includes seven variables: landform, landcover, successional age class, water, forest patch size, percentage of forest in the local (1-km radius) landscape, and snag density.

Table 112.—Relationship of landform, landcover type, and successional age class to suitability index scores for prothonotary warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.100	0.300	0.400
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.100	0.300	0.400
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.300	0.800	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.600	0.800
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.600	0.800

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 112). We directly assigned SI scores to these combinations on the basis of relative rankings of habitat associations reported by Hamel (1992) for the prothonotary warbler in the Southeast.

This species is rarely found more than 200 m from water during the breeding season, so we used a 9 × 9 pixel window (270 x 270 m) to examine whether water was close enough to each site to make it suitable (SI2). If water was present in any of the 81 pixels comprising the window, we assigned the center pixel a value of 1.000. If water was absent, we assigned the center pixel a value of zero (Table 113).

We also included forest patch size (SI3) as a variable in the HSI model because prothonotary warbler abundance is lower in small isolated fragments and thin riparian buffer strips (Table 114; Fig. 66). However, this species occupies small forest fragments within heavily forested landscapes so we included the percentage of forest in the local landscape as a variable (SI4). To capture this relationship, we fit a logistic function (Fig. 67) to data (Table 115) derived

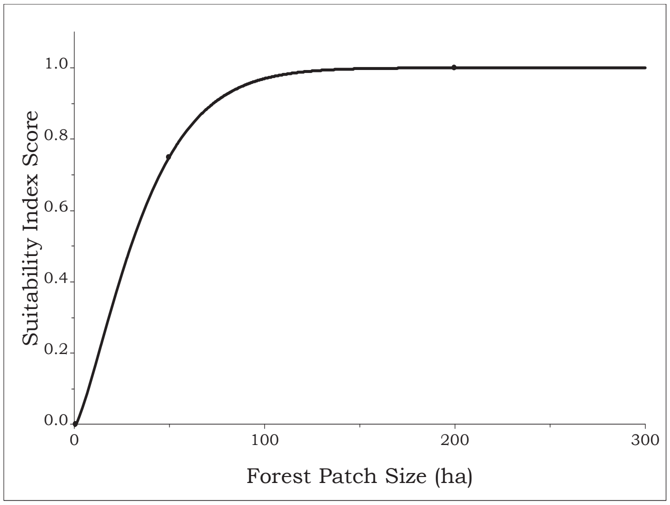


Figure 66.—Relationship between forest patch size and suitability index (SI) scores for prothonotary warbler habitat. Equation: SI score = $1.002 - 1.001 * e^{-0.031 * (\text{forest patch size} \wedge 0.968)}$.

Table 113.—Influence of occurrence of water on suitability index (SI) scores for prothonotary warbler habitat

9 × 9 pixel window contains water	SI score
Yes	1.0
No	0.0

Table 114.—Influence of forest patch size on suitability index (SI) scores for prothonotary warbler habitat

Forest patch area (ha)[a]	SI score
0	0.00
50	0.75
200	1.00
500	1.00

[a]Assumed value.

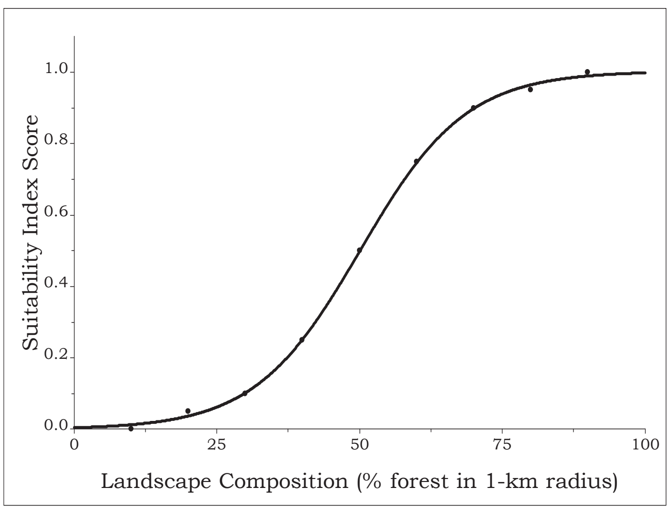


Figure 67.—Relationship between landscape composition and suitability index (SI) scores for prothonotary warbler habitat. Equation: SI score = $1.005 / (1.000 + (221.816 * e^{-0.108 * (\text{landscape composition})}))$.

Table 115.—Relationship between local landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for prothonotary warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We applied the maximum value of SI3 or SI4 to all sites to compensate for the higher suitability of small forest blocks in predominantly forested landscapes.

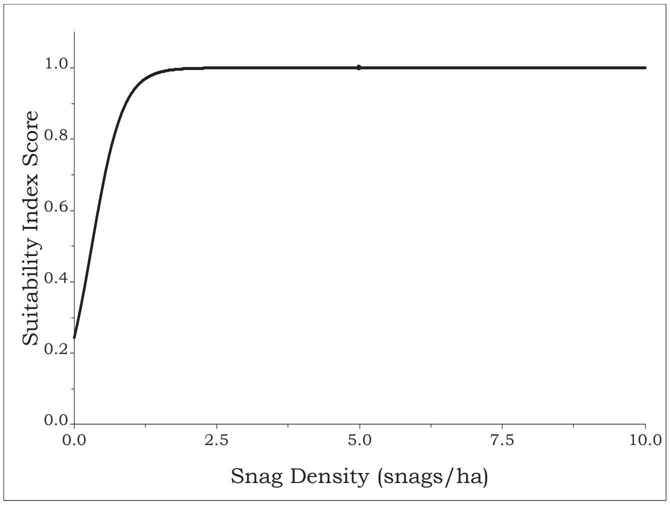


Figure 68.—Relationship between snag density and suitability index (SI) scores for prothonotary warbler habitat. Equation: SI score = 1.000 / (1 + (3.113 * e $^{-3.689 * \text{snag density}}$)).

Table 116.—Influence of snag density on suitability index (SI) scores for prothonotary warbler habitat

Snag density (snags/ha)	SI score
0[a]	0.25
5[b]	1.00
20[a]	1.00

[a]Assumed value.
[b]McComb and others (1986).

The prothonotary warbler is a cavity nester and uses snags (SI5) for nesting. McComb and others (1986) recommended 212 snags per 40 ha to satisfy the requirements of the primary cavity-nesting bird guild. We assumed that five snags per ha (Table 116) was sufficient for this bird (a secondary cavity-nesting species), but we recognized that this species also uses both cavities in live trees and crevices as nest sites. Therefore, we assigned a residual SI score (0.25) to sites lacking snags. We fit a logistic function through these points to quantify the snag density-habitat suitability relationship (Fig. 68).

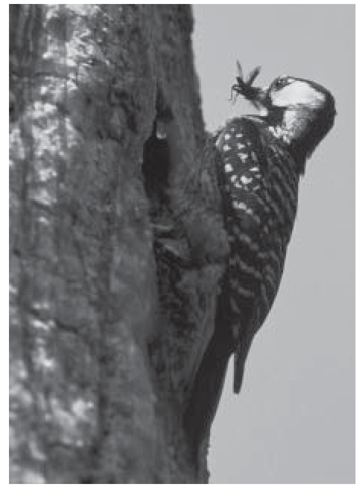
To calculate the overall HSI, we calculated the geometric mean of the two SIs related to forest structure (SI1 and SI5) and the product of the maximum of the two SIs related to landscape composition (SI3 or SI4) and SI2 separately and then the geometric mean of these values together.

Overall HSI = $((SI1 * SI5)^{0.500} * (Max(SI3 \text{ or } SI4) * SI2))^{0.500}$

Verification and Validation

The prothonotary warbler was found in 83 of the 88 subsections within the CH and WGCP. Spearman rank correlations identified significant positive associations between average HSI score and mean BBS route abundance across all subsections ($P \leq 0.001$; r_s = 0.39) and subsections within which the prothonotary warbler were detected ($P \leq 0.001$; r_s = 0.41). The generalized linear model predicting BBS abundance from BCR and HSI for the prothonotary warbler was significant ($P \leq 0.001$; $R^2 = 0.249$), and the coefficient on the HSI predictor variable was both positive (β = 2.271) and significantly different from zero (P = 0.002). Therefore, we considered the HSI model for the prothonotary warbler both verified and validated (Tirpak and others 2009a).

Red-cockaded Woodpecker



John and Karen Hollingsworth, U.S. Fish & Wildlife Service

Status

The red-cockaded woodpecker (*Picoides borealis*) is a federally endangered, nonmigratory resident of old-growth pine forest (particularly longleaf pine) throughout the Southeast (Jackson 1994). Due to the low detection rate for this species (0.05 bird/route in the WGCP), BBS data poorly estimates population trends (Table 5). The red-cockaded woodpecker is designated as a species warranting critical recovery in both the WGCP and CH (regional combined score = 21), though it is extirpated from the latter region.

Natural History

Due to the limited availability of suitable habitat, the red-cockaded woodpecker lives in loose family groups and engages in cooperative breeding (Jackson 1994). Home ranges are large (average = 76.1 ha) but highly variable (17.2 to 159.5 ha; reviewed in Doster and James 1998).

Suitable habitat is defined by two primary habitat components. The first is the presence of large pines. Pines at least 35 cm d.b.h. generally are required for a stand to be occupied by the red-cockaded woodpecker (Davenport and others 2000, James and others 2001, Walters and others 2002). However, once large pine density exceeds 80 per ha, family group size (a demographic parameter related to productivity; Heppell and others 1994) declines (Walters and others 2002). Similarly, as the average d.b.h. of overstory pines increases above 35 cm, habitat quality declines (Davenport and others 2000), though these declines likely are linked to the maturation of the forests rather than to the negative effects of large trees directly. Similar patterns have been observed for overstory pine basal area and small pine tree density in occupied stands, where values for these habitat attributes are lower than local maxima (James and others 2001, Rudolph and others 2002, Walters and others 2002).

Open midstory is the second notable feature of high-quality habitat for the red-cockaded woodpecker. Hardwood midstory trees should be less than 3.26 m tall and ideally less than 1.8 m (Davenport and others 2002, Walters and others 2002). The open midstory typically is maintained through periodic fire (burn interval of 1 to 3 years), which also facilitates a wiregrass understory (James and others 2001). Because this species is nonmigratory and suitable habitat is disjunct, connectivity of patches is critical for the long-term persistence of this species across the landscape.

Model Description

The HSI model for the red-cockaded woodpecker includes eight variables: landform, landcover, successional age class, forest patch size, pine basal area, hardwood basal area, connectivity, and large pine (> 35 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 117).

Table 117.—Relationship between landform, landcover type, age class, and suitability scores for red-cockaded woodpecker habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.200	0.600	0.800
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.200	0.600	0.800
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.200	0.600 (0.700)	0.800 (1.000)
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.000

We directly assigned SI scores to these combinations on the basis of relative rankings of vegetation types and successional age classes for red-cockaded woodpeckers reported by Hamel (1992).

We included forest patch size (SI2) as a variable because of the large home ranges of the red-cockaded woodpecker. We assumed that the minimum and maximum home range sizes reported by Doster and James (1998) represented patch size thresholds for nonsuitable and optimal habitat, respectively. To inform the shape of the curve between these points, we assumed that the minimum area requirement of habitat identified in the red-cockaded woodpecker recovery plan (USDI Fish and Wildl. Serv. 2003) defined average (SI score = 0.500) habitat suitability. We used these data (Table 118) to define a logarithmic function to predict SI scores from forest patch size (Fig. 69).

Pine basal area (SI3) is a key component of red-cockaded woodpecker habitat, and sites with pine basal areas that are too low or too high are of poor quality. We fit a quadratic function (Fig. 70) to data from Conner and others (1995) and Walters and others (2002; Table 119) on the relative abundance of this species in habitats with varying levels of pine basal area.

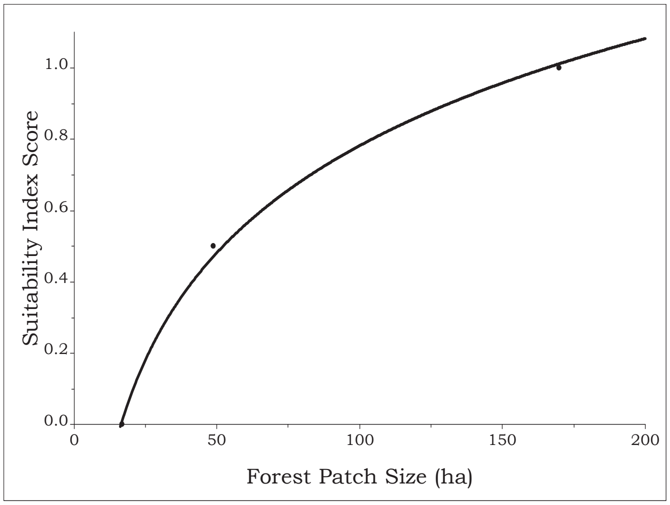


Figure 69.—Relationship between forest patch size and suitability index (SI) scores for red-cockaded woodpecker habitat. Equation: SI score = 0.4334 * ln(forest patch size) – 1.2133.

Table 118.—Relationship between forest patch size and suitability index (SI) scores for red-cockaded woodpecker habitat

Forest patch size (ha)	SI score
17[a]	0.0
49[b]	0.5
170[a]	1.0

[a]Doster and James (1998).

[b]USDI Fish and Wildl. Serv. (2003).

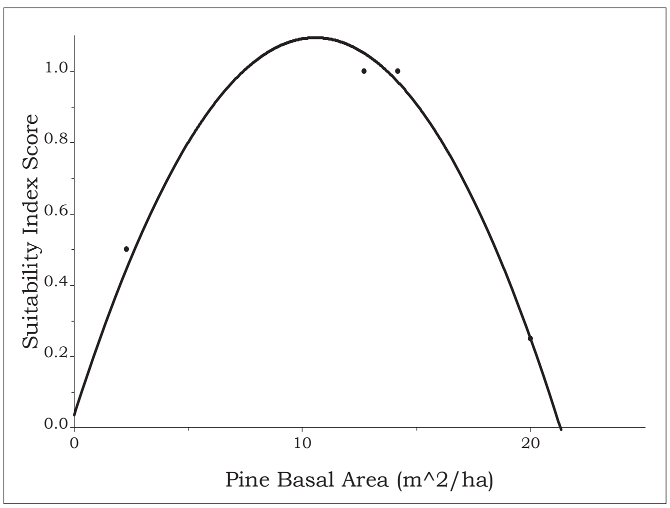


Figure 70.—Relationship between pine basal area and suitability index (SI) scores for red-cockaded woodpecker habitat. Equation: SI score = 0.0367 + 0.2006 * (pine basal area) – 0.009507 * (pine basal area)^2.

Table 119.—Relationship between basal area of pines and suitability index (SI) scores for red-cockaded woodpecker habitat

Pine basal area (m^2/ha)	SI score
0.0[a]	0.00
2.3[b]	0.50
12.7[c]	1.00
14.2[c]	1.00
20.0[a]	0.25

[a]Assumed value.

[b]Walters and others (2000).

[c]Conner and others (1995).

Mid- and overstory hardwoods reduce habitat suitability for red-cockaded woodpeckers. We fit an inverse logistic function (Fig. 71) to data from Kelly and others (1993) and Wilson and others (1995) (Table 120) on the amount of hardwood basal area (SI4) around woodpecker nest cavities to predict habitat suitability based on this habitat feature.

As a resident species occupying disjunct habitat patches, the red-cockaded woodpecker exists in metapopulations. Therefore, dispersal between suitable forest patches is critical for the persistence of this species on the landscape. Isolated patches lacking a breeding female have no productivity, so we used the median dispersal distance for females (3.2 km; Jackson

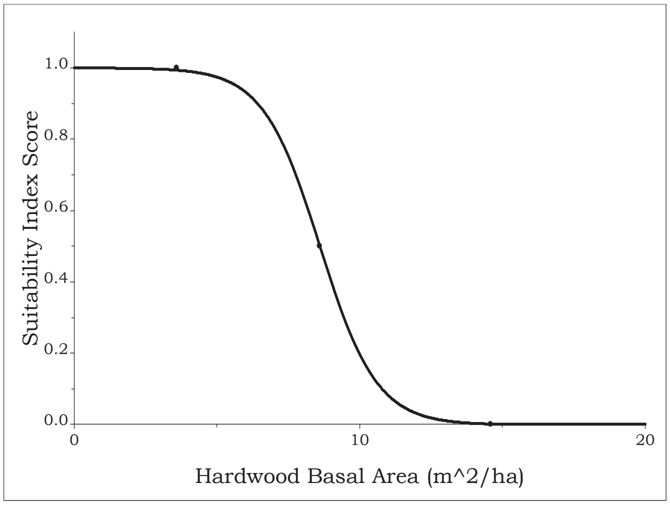


Figure 71.—Relationship between hardwood basal area and suitability index (SI) scores for red-cockaded woodpecker habitat. Equation: SI score = 1 - (1.001 / (1 + (5745.304 * e $^{-1.006 * \text{hardwood basal area}}$))).

Table 120.—Relationship between basal area of hardwoods (m^2/ha) and suitability index (SI) scores for red-cockaded woodpecker habitat

Hardwood basal area (m^2/ha)	SI score
0.0[a]	1.0
3.9[b]	1.0
8.6[c]	0.5
14.6[c]	0.0
20.0[a]	0.0

[a]Assumed value.
[b]Wison and others (1995).
[c]Kelly and others (1993).

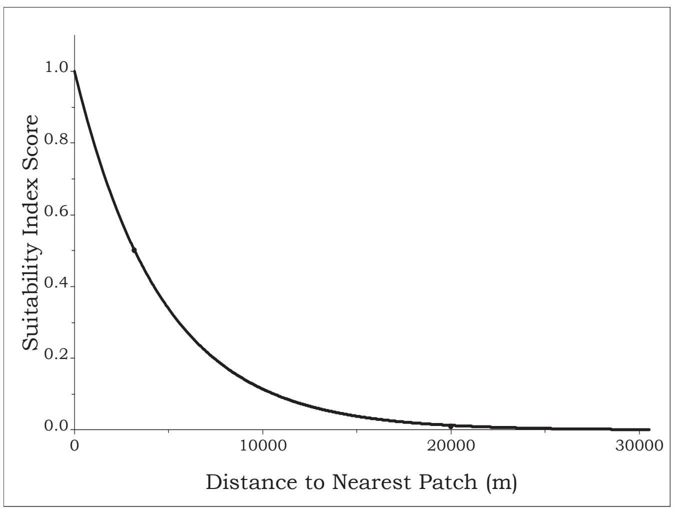


Figure 72.—Relationship between habitat connectivity and suitability index (SI) scores for red-cockaded woodpecker habitat. Equations: SI score = e $^{-0.0002 * \text{distance to nearest habitat patch}}$.

Table 121.—Relationship between distance to nearest habitat patch and suitability index (SI) scores for red-cockaded woodpecker habitat

Distance to nearest habitat patch (m)	SI score
0[a]	1.00
3,200[b]	0.50
20,000[a]	0.01

[a]Assumed value.
[b]Jackson (1994).

1994) to define average SI score (0.500). However, long-distance dispersal does occur (Larry Hedrick, 2006, U.S. Forest Service, pers. commun.), so we assigned to patches isolated more than 20 km from any other suitable site at least some residual suitability (0.010). We fit an exponential relationship (Fig. 72) through these data points (Table 121) to describe how the connectivity of patches influences habitat suitability.

Large pines (SI6) are a necessary component of red-cockaded woodpecker habitat because this bird disproportionately forages and nests in large pines. However, there is a threshold above which habitat suitability declines and increasingly large trees reduce the preferred open

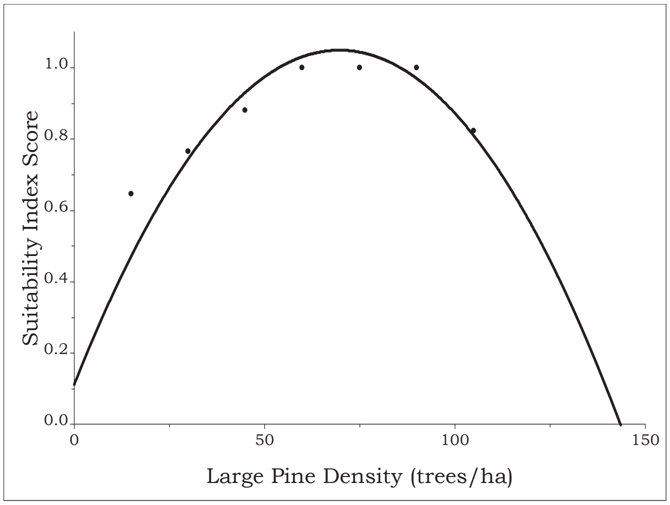


Figure 73.—Relationship between large pine tree (> 35 cm d.b.h.) density and suitability index (SI) scores for red-cockaded woodpecker habitat. Equation: SI score = 0.0269 * (pine tree density) – 0.000193 * (pine tree density)^2 + 0.1127.

Table 122.—Relationship between large pine (> 35 cm d.b.h.) density (trees/ha) and suitability index (SI) scores for red-cockaded woodpecker habitat

Large pine density	SI score
0[a]	0.000
15[b]	0.647
30[b]	0.765
45[b]	0.882
60[b]	1.000
75[b]	1.000
90[b]	1.000
105[b]	0.824

[a]Assumed value.
[b]Walters and others (2002).

character of the forest. We fit a quadratic function (Fig. 73) to data from Walters and others (2002), who identified this threshold at 60 to 90 large pines per ha (Table 122).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1, SI3, SI4, and SI6) and landscape composition (SI2 and SI5) separately and then the geometric mean of these means together.

$$\text{Overall HSI} = ((SI1 * SI3 * SI4 * SI6)^{0.250} * (SI2 * SI5)^{0.500})^{0.500}$$

Verification and Validation

The red-cockaded woodpecker was found in only 10 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.49$) between average HSI score and mean BBS route abundance across all subsections. However, when subsections where the red-cockaded woodpecker was not found were removed from the analysis, the relationship was not significant ($P = 0.645$; $r_s = 0.17$). Thus, the HSI model predicts the absence of the red-cockaded woodpecker better than its abundance in subsections where it is found. The generalized linear model predicting BBS abundance from BCR and HSI for the red-cockaded woodpecker was significant ($P \leq 0.001$; $R^2 = 0.203$), and the coefficient on the HSI predictor variable was both positive ($\beta = 0.094$) and significantly different from zero ($P = 0.042$). Therefore, we considered the HSI model for the red-cockaded woodpecker both verified and validated (Tirpak and others 2009a).

Red-headed Woodpecker

Dave Menke, U.S. Fish & Wildlife Service

Status

The red-headed woodpecker (*Melanerpes erythrocephalus*) is found throughout North America east of the Rocky Mountains; however, it is absent from New England and the higher elevations of the central and southern Appalachians. Since 1967, populations have declined by 3.2 percent per year in the WGCP and by 1 percent in the CH (Sauer and others 2005) (Table 5). This species is a Bird of Conservation Concern and a management attention priority in both the CH and WGCP (regional combined score = 16 and 17, respectively; Table 1).

Natural History

The red-headed woodpecker is one of the most recognizable birds of the eastern United States and southern Canada, but few in-depth studies of this species have been conducted (Smith and others 2000). Nesting habitat consists of deciduous woodlands, including upland and bottomland hardwoods, riparian strips, open woods, open wooded swamps, groves of dead and dying trees, orchards, shelterbelts, parks, open agricultural lands, savannas, forest edges, roadsides, and utility poles (Smith and others 2000). It prefers xeric sites with large, tall trees, high basal area, and a sparse understory.

The red-headed woodpecker exhibits seasonal shifts in habitat use. Population dynamics are linked to annual fluctuations in oak acorn crops, and migration occurs in northern and western populations when hard mast is limited (Rodewald 2003). More locally, winter territories are established around small food caches within forest interiors; breeding territories are larger (3.1 to 8.5 ha in Florida) and concentrated along edges (Smith and others 2000).

Occurrence of the red-headed woodpecker varies with mean patch dimension, edge density of agricultural land, and the area of urban landcover (Lukomski 2003). It is a primary cavity excavator and snag availability may drive habitat selection (Giese and Cuthbert 2003). This species often is associated with high snag densities (Conner and others 1994) in mature stands near openings (Conner and Adkisson 1977, Brawn and others 1984). Snag density and basal area of dead elm distinguish nest sites from random sites in Minnesota (Giese and Cuthbert 2003). Similarly, loblolly pine stands with both standing and down dead woody debris removed contain fewer birds (Lohr and others 2002). Snags retained as groups provide multiple snags for roosting and foraging. Hardwood snags are used predominantly for foraging, whereas pine snags are more commonly used for nesting (Smith and others 2000). Thinnings and prescribed fires that open the understory and create snags are beneficial.

Model Description

The HSI model for the red-headed woodpecker includes seven variables: landform, landcover, successional age class, snag density, large snag (> 20 cm d.b.h.) density, sawtimber tree (> 28 cm d.b.h.) density, and the occurrence of edge.

Table 123.—Relationship of landform, landcover type, and successional age class to suitability index scores for red-headed woodpecker habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.125	0.250	0.250
	Transitional-shrubland	0.000	0.000	0.125	0.250	0.250
	Deciduous	0.000	0.000	0.125	0.250	0.250
	Evergreen	0.000	0.000	0.250	0.500	0.500
	Mixed	0.000	0.000	0.250	0.500	0.500
	Orchard-vineyard	0.000	0.000	0.125	0.250	0.250
	Woody wetlands	0.000	0.000	0.250	0.625	0.750
Terrace-mesic	Low-density residential	0.000	0.000	0.125	0.375	0.500
	Transitional-shrubland	0.000	0.000	0.250	0.500	0.500
	Deciduous	0.000	0.000	0.125	0.375	0.500
	Evergreen	0.000	0.000	0.250	0.500	0.500
	Mixed	0.000	0.000	0.250	0.500	0.500
	Orchard-vineyard	0.000	0.000	0.125	0.375	0.500
	Woody wetlands	0.000	0.000	0.250	0.500	0.500
Xeric-ridge	Low-density residential	0.000	0.000	0.250	0.750	1.000
	Transitional-shrubland	0.000	0.000	0.250	0.500 (0.750)	0.500 (1.000)
	Deciduous	0.000	0.000	0.250	0.750	1.000
	Evergreen	0.000	0.000	0.250	0.500 (0.750)	0.500 (1.000)
	Mixed	0.000	0.000	0.250	0.500	0.500
	Orchard-vineyard	0.000	0.000	0.250	0.750	1.000
	Woody wetlands	0.000	0.000	0.250	0.750	1.000

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 123). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the relative value of various vegetation types and successional age classes as red-headed woodpecker habitat in the Southeast.

This species relies heavily on snags for nesting, foraging, and roosting. King and others (2007) observed 31.8 snags per ha in savanna habitat used by the red-headed woodpecker, though basal area was only 0.9 m^2 per ha in that study. Therefore, we adjusted snag densities to reflect the intermediate basal area values (12 to 15 m^2/ha; Heltzel and Leberg 2006) characteristic of stands used by the red-headed woodpecker in the WGCP and CH BCRs. We assumed that 500 snags per ha represented an upper threshold above which maximal suitability was achieved and that 200 snags per ha represented a threshold below which sites were unsuitable (Table 124). We fit a logistic function (Fig. 74) through these data to predict how habitat suitability varied with snag density (SI2). Because the snag density in SI2 includes all dead trees greater than 2.5 cm d.b.h., we also included large snag (> 20 cm d.b.h.) density (SI3) as a variable. This additional requirement ensured the presence of snags suitable for nesting

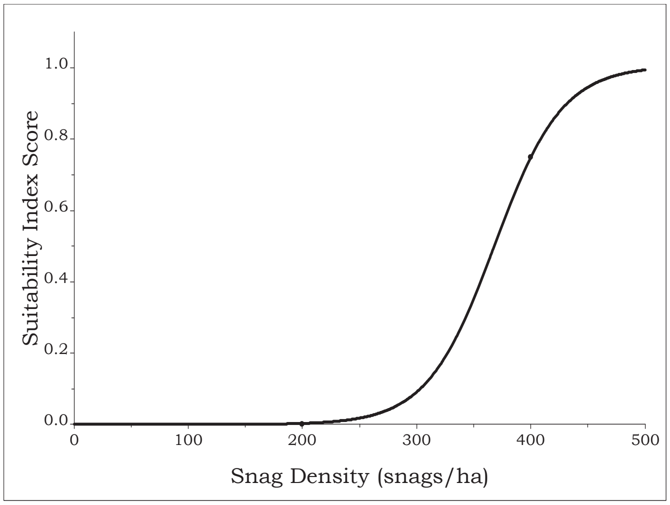


Figure 74.—Relationship between snag density (snags * 100/ha) and suitability index (SI) scores for red-headed woodpecker habitat. Equation: SI score = 1.006 / (1 + (249051.2 * e $^{(-0.0338 * \text{snag density})}$)).

Table 124.—Influence of snag density on suitability index (SI) scores for red-headed woodpecker habitat

Snag density (snags/ha)[a]	SI score
0	0.00
200	0.00
400	0.75
500	1.00

[a]Assumed value.

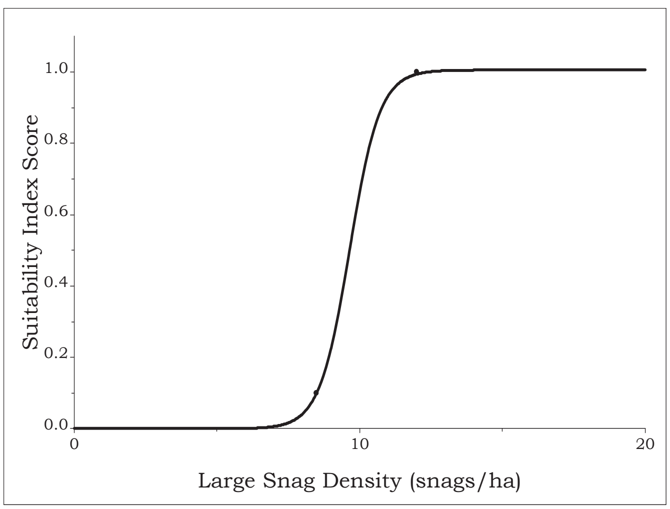


Figure 75.—Relationship between large snag (> 20 cm d.b.h.) density and suitability index (SI) scores for red-headed woodpecker habitat. Equation: SI score = 1.006 / (1 + (90614077 * e $^{(-1.899 * \text{large snag density})}$)).

Table 125.—Influence of large snag (> 20 cm d.b.h.) density (snags/ha) on suitability index (SI) scores for red-headed woodpecker habitat

Large snag density	SI score
0.0[a]	0.0
8.5[b]	0.1
12.0[a]	1.0

[a]Assumed value.
[b]Lohr and others (2002).

in high-quality habitats. We relied on data from Lohr and others (2002) to inform an inverse logistic function (Fig. 75) that linked habitat suitability to large snag density (Table 125).

The red-headed woodpecker breeds in relatively open habitats with widely spaced large trees near openings (King and others 2007). Therefore, we included sawtimber tree density (SI4) and edge occurrence (SI5) as variables. We assumed that habitat suitability was highest when sawtimber tree density was 20 or fewer trees per ha and lowest when sawtimber tree density exceeded 50 trees per ha (Table 126). We fit a logistic function (Fig. 76) through these data points to quantify the relationship between sawtimber tree density and SI scores. To identify edges, we used a 7 × 7 pixel moving window (210 x 210 m) to locate the transitions between

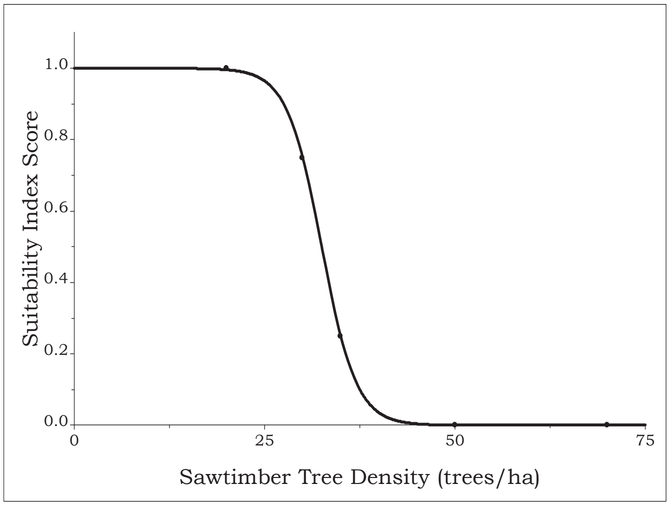


Figure 76.—Relationship between sawtimber tree (≥ 28 cm d.b.h.) density (trees * 10/ha) and suitability index (SI) scores for red-headed woodpecker habitat. Equation: SI score =1 – (1.000 / (1 + (1615169 * e $^{(-0.4398 * \text{sawtimber tree density})}$))).

Table 126.—Influence of sawtimber tree (> 28 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for red-headed woodpecker habitat

Sawtimber tree density[a]	SI score
0	1.00
20	1.00
30	0.75
35	0.25
50	0.00
70	0.00

[a]Assumed value.

Table 127.—Influence of edge on suitability index (SI) scores for red-headed woodpecker habitat

7 × 7 window around forest pixel includes field[a]	SI score
Yes	1.0
No	0.1

[a]Field defined as any shrub-seedling or grass-forb age class pixel, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any used sapling, pole, or sawtimber age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands.

forest and non-forest landcovers or sapling-pole-sawtimber and grass-forb-shrub-seedling successional age class stands. We assigned to edge habitats the maximal SI score and discounted areas with no edge (Table 127).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1, SI2, SI3, and SI4) and multiplied this product by the SI score for edge occurrence (SI5).

Overall HSI = $((SI1 * SI2 * SI3 * SI4)^{0.250}) * SI5$

Verification and Validation

The red-headed woodpecker was found in all 88 subsections of the CH and WGCP. Spearman rank correlation failed to identify a positive association between average HSI score and mean BBS abundance. The generalized linear model predicting BBS abundance from BCR and HSI for the red-headed woodpecker was significant ($P \leq 0.001$; $R^2 = 0.225$); however, the coefficient on the HSI predictor variable was negative (β = -3.359). Therefore, we considered the HSI model for the red-headed woodpecker neither verified nor validated (Tirpak and others 2009a).

Swainson's Warbler


Chandler S. Robbins,
Patuxent Bird Identification InfoCenter
Photo used with permission

Status

The Swainson's warbler (*Limnothlypis swainsonii*) is a neotropical migrant that breeds in dense thickets across the Southeast. Due to its overall low density and occurrence in habitats not well sampled by BBS, estimates of population trends based on this dataset are not reliable (Sauer and others 2005) (Table 5). Nonetheless, this species is a Bird of Conservation Concern and has a regional combined score of 20 in both the CH and WGCP (Table 1). An estimated 46 percent of the continental population of the Swainson's warbler breeds in the WGCP (Panjabi and others 2001).

Natural History

The Swainson's warbler is distributed locally across the Southeast (Brown and Dickson 1994). Once believed to be restricted to canebrakes in bottomland hardwood and swamp forests of the Atlantic and Gulf Coastal Plains, it now has been documented breeding at low densities in regenerating clearcuts in Texas and rhododendron-mountain laurel thickets in the southern Appalachians (Graves 2002). Territory size is large for a wood warbler (3.2 ha) (Brown and Dickson 1994), and this species demonstrates area sensitivity. In Illinois, the Swainson's warbler is not observed on tracts smaller than 350 ha (Eddleman and others 1980).

This species does not use canopy height, basal area, successional age class, or species composition as habitat cues (Eddleman and others 1980, Graves 2002), but selects habitat based on understory characteristics. Dense thickets are required, and stem densities of about 35,000 stems per ha are optimal (Graves 2002). Canopy gaps are important for encouraging this dense growth, and canopy cover typically is high (70 to 80 percent) but rarely closed (> 90 percent) (Eddleman and others 1980, Graves 2001, Somershoe and others 2003). Understory vegetation is primarily woody; herbaceous cover is typically sparse (< 25 percent) (Eddleman and others 1980, Brown and Dickson 1994). Leaf litter is abundant and provides an important foraging substrate (Graves 2001, Somershoe and others 2003).

Hydrology is a critical factor influencing the habitat suitability for this warbler. In bottomland and floodplain habitats, birds select areas that typically are drier than surrounding sites (Graves 2001, Somershoe and others 2003). Inundation of otherwise suitable habitat from March - September negatively affects the quality of an otherwise suitable site (Graves 2002). This species occasionally breeds in xeric uplands with appropriate understory characteristics (Carrie 1996).

Model Description

The HSI model for the Swainson's warbler includes six variables: landform, landcover, successional age class, forest patch size, proportion of forest in a 1-km radius, and small stem (< 2.5 cm d.b.h.) density.

Table 128.—Relationship of landform, landcover type, and successional age class to suitability index scores for Swainson's warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.400	0.000	0.000
	Deciduous	0.000	0.000	0.400	0.900	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.400	0.900	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.200	0.000	0.000
	Deciduous	0.000	0.000	0.200	0.500	0.600
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.400	0.800	0.800
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.200	0.000	0.000
	Deciduous	0.000	0.000	0.200	0.500	0.600
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.400	0.800	0.800

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 128). We adjusted the relative habitat quality rankings of Hamel (1992) for Swainson's warbler vegetation and successional age class associations to maximize habitat suitability in woody wetland habitats along floodplains, and to ensure that transitional sapling stands that may be used in the WGCP were assigned SI scores (Carrie 1996).

We included forest patch size (SI2) in the model because of the preference of the Swainson's warbler for interior sites within large forest tracts. We assumed that the minimum patch size in which Eddleman and others (1980) observed this species (350 ha) represented optimal habitat. Because this study was at the northern limit of the range of the Swainson's warbler, we assumed that birds would occupy significantly smaller tracts (Table 129). We based a logistic function on these assumptions to predict the impact of forest patch size on habitat suitability (Fig. 77). Nevertheless, the suitability of a specific patch size also is influenced by its landscape context (SI3). In predominantly forested landscapes, small forest patches that otherwise may not be suitable may be occupied due to their proximity to large forest blocks (Rosenberg and others 1999). To capture this relationship, we fit a logistic function (Fig. 78) to data (Table 130) derived from Donovan and others (1997), who observed differences

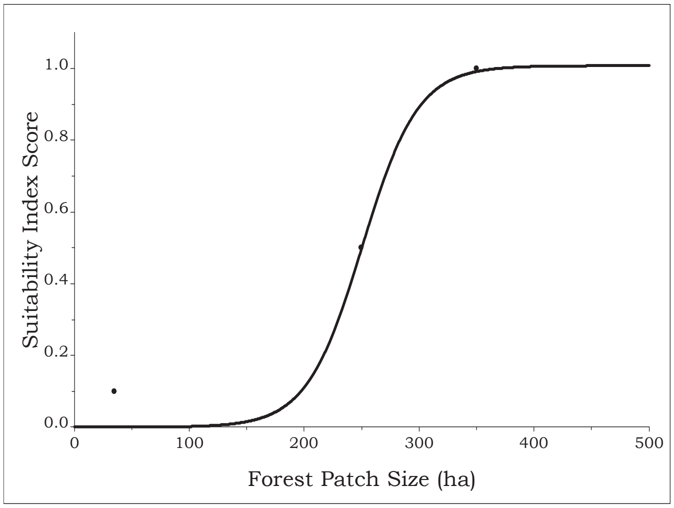


Figure 77.— Relationship between forest patch size and suitability index (SI) scores for Swainson's warbler habitat. Equation: SI score = (1.001 / (1 + (31096.960 * e $^{-0.041 * (\text{forest patch size})}$))).

Table 129.—Influence of forest patch size on suitability index (SI) score for Swainson's warbler habitat

Forest patch size (ha)	SI score
0[a]	0.00
35[a]	0.01
250[a]	0.50
350[b]	1.00
500[a]	1.00

[a]Assumed value.
[b]Eddleman and others (1980).

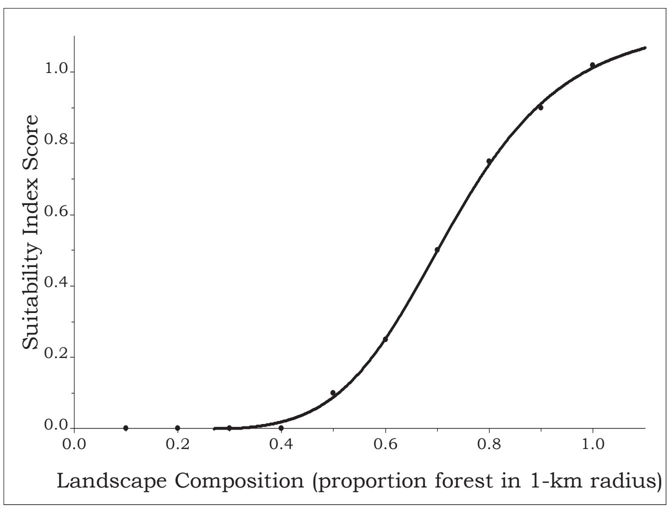


Figure 78.—Relationship between landscape composition and suitability index (SI) scores for Swainson's warbler habitat. Equation: SI score = 1.047 / (1.000 + (1991.516 * e $^{-10.673 * \text{landscape composition}}$)).

Table 130.—Relationship between landscape composition (proportion forest in 1-km radius) and suitability index (SI) scores for Swainson's warbler habitat

Landscape composition	SI score
0.00[a]	0.00
0.10[a]	0.00
0.20[a]	0.00
0.30[a]	0.00
0.40[a]	0.00
0.50[a]	0.10
0.60[a]	0.25
0.70[b]	0.50
0.80[a]	0.75
0.90[a]	0.90
1.00[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoint between moderately and lightly fragmented forest defined the specific cutoff for average (SI score = 0.500) habitat. We used the maximum score from SI2 or SI3 to account for the higher suitability of small patches in predominantly forested landscapes relative to their size alone.

The Swainson's warbler breeds in dense thickets and stem densities of approximately 35,000 stems per ha are optimal (SI score = 1.000) (Graves 2002). Stem densities can be even higher in early-successional bottomland hardwoods (> 200,000/ha), but we assumed habitat

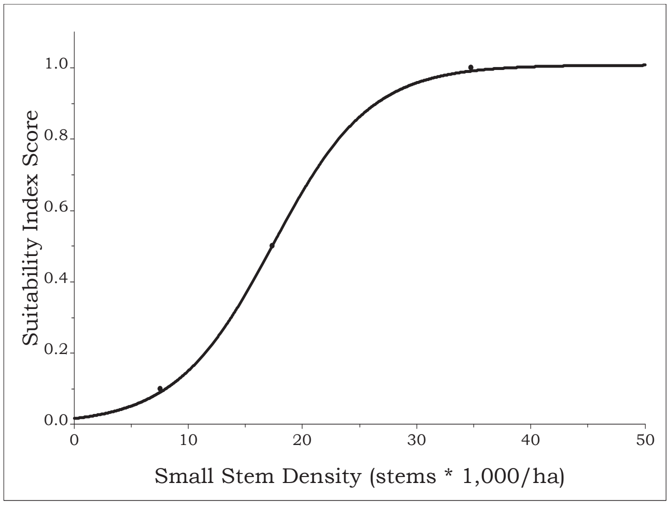


Figure 79.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for Swainson's warbler habitat. Equation: SI score = 1.008 / (1.000 + (59.233 * $e^{-0.235 * (\text{small stem density} / 1000)}$)).

Table 131.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for Swainson's warbler habitat

Small stem density	SI score
0.000[a]	0.0
7.550[b]	0.1
17.365[b]	0.5
34.773[b]	1.0
72.999[b]	1.0

[a]Assumed value.
[b]Graves (2002).

suitability was not negatively affected by stem density. Therefore, we fit a logistic function (Fig. 79) to data from Graves (2002) that captured the effect of varying stem density on habitat suitability (Table 131).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI4) and multiplied that by the maximum SI score for forest patch size (SI2) or percent forest in the 1-km landscape (SI3) and finally calculated the geometric mean of that product.

Overall HSI = $((\text{SI1} * \text{SI4})^{0.500} * \text{Max}(\text{SI2 or SI3}))^{0.500}$

Verification and Validation

The Swainson's warbler was found only in 31 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.010$) positive relationship ($r_s = 0.31$) between average HSI score and mean BBS route abundance across all subsections. However, when subsections where this species was not found were removed from the analysis, the relationship was not significant ($P = 0.893$; $r_s = -0.03$). Thus, the HSI model better predicts the absence of the Swainson's warbler than its abundance in subsections where this species is found. The generalized linear model predicting BBS abundance from BCR and HSI for the Swainson's warbler was significant ($P \leq 0.001$; $R^2 = 0.260$); however, the coefficient on the HSI predictor variable was negative (β = -0.298). Therefore, we considered the HSI model for the Swainson's warbler verified but not validated (Tirpak and others 2009a).

Swallow-tailed Kite


D.A. Rintoul, Patuxent Bird Identification InfoCenter
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Status

The swallow-tailed kite (*Elanoides forficatus*) is a neotropical raptor that reaches the northern limit of its distribution in the Unites States. Once ranging throughout the Mississippi River drainage as far north as Minnesota, this species now is restricted to seven states in the Southeast. There are too few swallow-tailed kites detected on BBS routes in the WGCP to estimate a population trend; however, this species is a Bird of Conservation Concern and immediate management attention priority in this BCR (regional combined score = 18; Table 1). The swallow-tailed kite no longer breeds in the CH and this species warrants critical recovery efforts in this region (regional combined score = 19).

Natural History

The swallow-tailed kite is a rare breeder in the continental United States. The current restriction of this species to seven southern states (with limited distributions in all but Florida) represents a significant contraction of its former range. Most of the information on this bird in the United States is from Florida (Meyer 1995).

The swallow-tailed kite has a large home range (500 to 1800 ha) that increases substantially (> 20,000 ha) when the long but regular foraging forays characteristic of this species are included. With such a large home range, the important role of landscape structure on habitat suitability is not surprising. Critical habitat elements are large, tall trees for nesting and open habitats containing prey (Meyer 1995, Sykes and others 1999). Any interspersion of these features is useable (e.g., trees adjacent to prairie, wetlands, or marsh). Landscapes containing bottomland hardwood forest interspersed with scattered openings are particularly attractive. The edges of pine forests along swamps and riparian zones also are commonly used along the Coastal Plains. The Mississippi kite typically occupies habitats that are drier and contain more contiguous forest than the habitats of the swallow-tailed kite.

Model Description

The HSI model for the swallow-tailed kite includes six variables: landform, landcover, successional age class, forest patch size, landscape composition, and dominant tree density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 132). We then directly assigned SI scores to these combinations on the basis of relative habitat quality rankings from Hamel (1992) for the swallow-tailed kite. However, we assumed that only stands in the sawtimber successional age class provided suitable habitat for this species

We also included forest patch size (SI2) as a variable because of this bird's large home range and association with large blocks of forested wetlands. We fit a logarithmic function (Fig. 80)

Table 132.—Relationship of landform, landcover type, and successional age class to SI scores for swallow-tailed kite habitat

Landform	Landcover type	Successional age class: Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.500
	Mixed	0.000	0.000	0.000	0.000	0.500
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.800
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.000	0.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.000	0.800

to data (Table 133) from Zimmerman (2004) on the mean value of forest in 5-km buffers around swallow-tailed kite nest sites and the maximum home range size reported by Cely and Sorrow (1990) to assess the impact of forest patch size on habitat suitability scores for the swallow-tailed kite.

Like the Mississippi kite, the swallow-tailed kite forages aerially in open habitats, so it requires both forested sites for nesting and open areas for foraging (SI3). We based the ideal composition of vegetation types in the landscape on data from Sykes and others (1999), who observed 20 percent open habitat within 200-ha core areas in Florida. We maximized habitat suitability at this threshold and reduced SI scores in landscapes containing greater or lower proportions of open habitat (Table 134, Fig. 81).

The swallow-tailed kite nests in dominant trees (SI4) that extend above the canopy. We assumed that trees with a d.b.h. greater than 76.2 cm would extend above the canopy in the sawtimber stands that provide the exclusive habitat for this species. We assumed that one dominant tree per ha would satisfy this requirement and that the swallow-tailed kite would be absent from stands with a uniform canopy (zero dominant trees/ha). We fit an exponential function (Fig. 82) to the values between these data points and assumed that

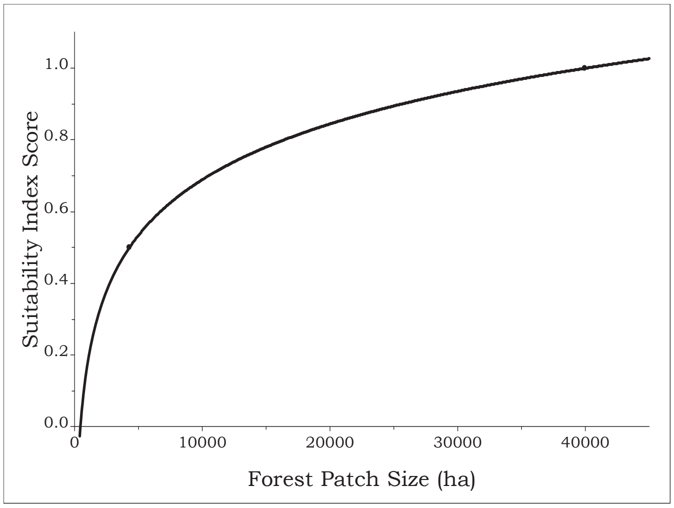

Figure 80.—Relationship between forest patch size and suitability index (SI) scores for swallow-tailed kite habitat. Equation: SI score = 0.224 * ln(forest patch size) – 1.376.

Table 133.—Influence of forest patch size on suitability index (SI) scores for swallow-tailed kite habitat

Forest patch size (ha)	SI score
4,300[a]	0.5
40,000[b]	1.0

[a]Zimmerman (2004).
[b]Cely and Sorrow (1990).

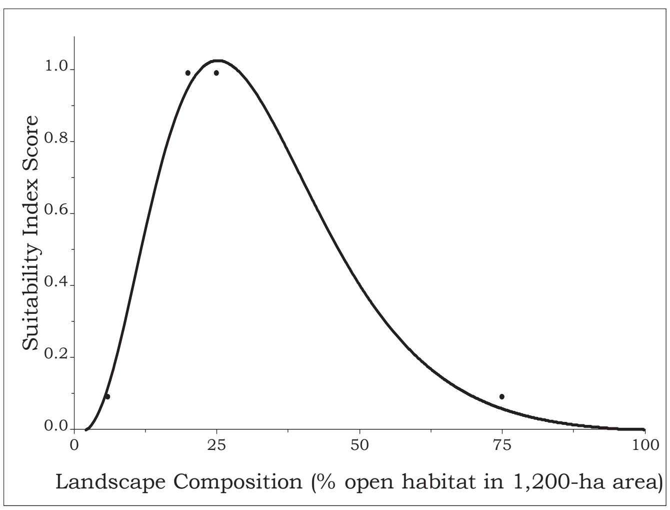

Figure 81.—Relationship between landscape composition and suitability index (SI) scores for swallow-tailed kite habitat. Equation: SI score = $(0.001 * 0.885^{(\text{percent open habitat})}) * (\text{percent open habitat})^{3.065}$.

Table 134.—Suitability index scores for swallow-tailed kite habitat based on landscape composition (percent of open habitat) within 1,200-ha landscape

Landscape composition[a]	SI score
6[b]	0.1
20[c]	1.0
25[b]	1.0
75[b]	0.1

[a]Water, grasslands, cultivated lands, and emergent wetlands.
[b]Assumed value.
[c]Sykes and others (1999).

stands with 14 dominant trees per ha (the maximum value from the WGCP during the FIA surveys of the 1990s) were associated with maximum habitat suitability (Table 135).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1 and SI4) and landscape composition (SI2 and SI3) separately and then the geometric mean of these means together.

$$\text{Overall HSI} = ((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$$

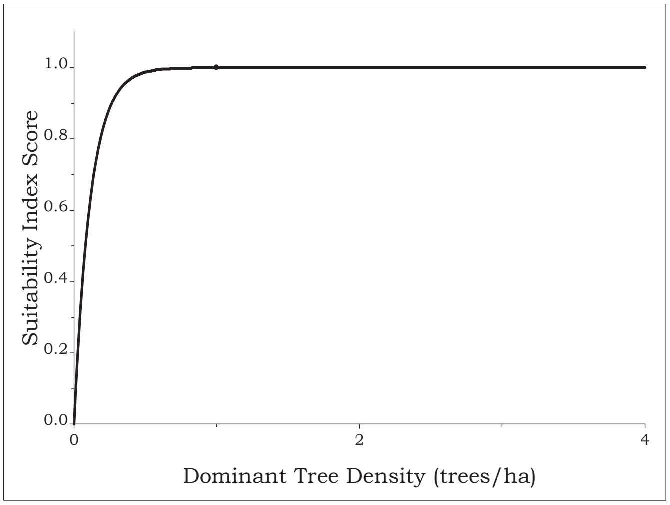

Figure 82.—Relationship between dominant tree density and (SI) scores for swallow-tailed kite habitat. Equation: SI score = $1 - e^{-8.734 * \text{dominant tree density}}$.

Table 135.—Influence of dominant tree (> 76.2 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for swallow-tailed kite habitat

Dominant tree density[a]	SI score
0	0.0
1	1.0
14	1.0

[a]Assumed value.

Verification and Validation

The swallow-tailed kite was found in 8 of the 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.73$) between average HSI score and mean BBS route abundance across all subsections. However, when subsections where this species was not found were removed from the analysis, the relationship was not significant ($P = 0.432$; $r_s = 0.33$). Thus, the HSI model better predicts the absence of the swallow-tailed kite than its abundance in subsections where this species is found. The generalized linear model predicting BBS abundance from BCR and HSI for the swallow-tailed kite was significant ($P \leq 0.001$; $R^2 = 0.522$), and the coefficient on the HSI predictor variable was both positive ($\beta = 0.725$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the swallow-tailed kite both verified and validated (Tirpak and others 2009a).

Whip-poor-will


Chandler S. Robbins,
Patuxent Bird Identification InfoCenter
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Status

The whip-poor-will (*Caprimulgus vociferus*) is a neotropical migrant with a more northerly range than the chuck-will's-widow, though the ranges of the two are not exclusive and overlap broadly across the CH. The whip-poor-will has declined by 1.8 percent per year since 1967 in the CH (Sauer and others 2005) (Table 5), where this species is a Bird of Conservation Concern and has a regional combined score of 17 (Table 1). A large proportion of the continental population (35.5 percent) breeds in the CH (Panjabi and others 2001). This species is a rare breeder in the WGCP (regional combined score = 13).

Natural History

Owing to its cryptic coloration and crepuscular activity pattern, the whip-poor-will is one of the least studied birds in North America (Cink 2002). Breeding habitat in the CH and WGCP consists of xeric deciduous and mixed forests with a sparse understory. This species also is associated with open areas, such as rural farmland, powerline and roadway rights-of-way, clearcuts and selectively logged forest, old fields, and reclaimed surface mines. Shaded forest stands with limited ground cover adjacent to open areas for foraging provide ideal whip-poor-will habitat. This species usually is absent from extensive areas of closed canopy forest, but there are no data on minimum or maximum thresholds for forest patch size. Small, isolated woodlots in a Maryland agricultural landscape are not used (Reese 1996, cited in Cink 2002). In Massachusetts, Grand and Cushman (2003) found that the whip-poor-will is strongly associated with complex patch shapes and high contrast edges. This species nests on the forest floor and hatching is synchronized with the full moon to optimize the foraging time of adults. Whip-poor-wills are not strongly territorial; home range varies from 2.8 to 11.1 ha.

Model Description

The HSI model for whip-poor-will includes four variables: landform, landcover, successional age class, and the relative composition of forest and open habitats in the landscape.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 136). We directly assigned SI scores to these combinations on the basis of relative habitat rankings for vegetation and successional age class associations of the whip-poor-will reported by Hamel (1992).

The whip-poor-will nests in forest and forages in openings. As a result, it requires landscapes with an interspersion (SI2) of these landcover types. We assumed that a landscape with 70 percent forest and 30 percent open habitat was optimal (Michael Wilson, 2006, College of William & Mary, pers. commun.) and that landscapes with a greater proportion of forest

Table 136.—Relationship of landform, landcover type, and successional age class to suitability index scores for whip-poor-will habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.667	0.667
	Deciduous	0.000	0.000	0.334	0.667	0.667
	Evergreen	0.000	0.000	0.334	0.667	0.667
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.333	0.333
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.334	0.667	0.667
	Evergreen	0.000	0.000	0.334	0.667	0.667
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.333	0.333
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.334	0.834	1.000
	Deciduous	0.000	0.000	0.334	0.667	0.667
	Evergreen	0.000	0.000	0.334	0.667	0.667
	Mixed	0.000	0.000	0.334	0.834	1.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.167	0.333	0.333

were more suitable than those with less forest cover so long as some openings were present (Table 137; sensu Cooper 1981).

We calculated the overall HSI score as the geometric mean of the two component variables.

Overall HSI = $(SI1 * SI2)^{0.500}$

Verification and Validation

The whip-poor-will was found in 76 of the 88 subsections within the CH and WGCP. Spearman rank correlation identified a significant (P = 0.005) positive relationship (r_s = 0.30) between average HSI score and mean BBS route abundance across subsections. This relationship was even stronger (r_s = 0.47) when subsections in which the whip-poor-will was not detected were removed from the analysis. The generalized linear model predicting BBS abundance from BCR and HSI for the whip-poor-will was significant (P = 0.002; R^2 = 0.139), and the coefficient on the HSI predictor variable was positive (β = 1.270) but not significantly different from zero (P = 0.229). Therefore, we considered the HSI model for the whip-poor-will verified but not validated (Tirpak and others 2009a).

Table 137.—Suitability index scores for whip-poor-will habitat based on the relative proportion of cells providing open and forest landcover within 500-m radius

Proportion forest[b]	Proportion open[a]										
	0.0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
0.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.0
0.1	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
0.2	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00		
0.3	0.00	0.10	0.10	0.10	0.10	0.10	0.10	0.10			
0.4	0.00	0.25	0.25	0.25	0.25	0.25	0.25				
0.5	0.00	0.50	0.50	0.50	0.50	0.50					
0.6	0.00	0.70	0.90	0.90	0.90						
0.7	0.00	0.80	0.90	1.00							
0.8	0.00	0.80	0.90								
0.9	0.00	0.80									
1.0	0.00										

[a]Open = pasture/hay, recreational grasses, grasslands/herbaceous, and emergent herbaceous wetland landcovers or grass-forb and shrub-seedling successional age class stands.

[b]Forest = any habitats with positive SI1 values (Table 136).

White-eyed Vireo


David Arbour, U.S. Forest Service

Status

The white-eyed vireo (*Vireo griseus*) is a neotropical migrant that breeds throughout the southeastern United States. Populations have been stable in both the CH and WGCP over the last 40 years, but have been increasing in the WGCP by 1.6 percent annually since 1980 (Sauer and others 2005; Table 5). This species requires management attention in both the CH and WGCP (regional combined score = 15 and 16, respectively) but is not a Bird of Conservation Concern in either BCR (Table 1).

Natural History

A small secretive songbird, the white-eyed vireo is associated with dense vegetation in secondary deciduous scrub-shrub, wood margins, overgrown pastures, abandoned farmlands, streamside thickets, and even mid- to late successional forests (Hopp and others 1995). This species shares habitats with the blue-gray gnatcatcher, Carolina wren, gray catbird, and brown thrasher, but prefers later successional forest than the yellow-breasted chat, prairie warbler, and Bell's vireo.

In Texas, the white-eyed vireo breeds in areas of shrubby vegetation (0 to 1 m) with dense foliage (Conner and Dickson 1997). Similarly, in Virginia, it prefers habitats with an extensive undergrowth of shrubs, brambles, and saplings interspersed with taller trees (10 to 20 percent of area). Vireo densities are higher in glade and regenerating forest habitat than edges in Missouri (Fink and others 2006). Densities also are inversely related to vegetation height, foliage density at 12 to 15 m, density of pole trees, and percent canopy closure (Conner and others 1983). Prather and Smith (2003) found that this species was more abundant in tornado-damaged forest in Arkansas than in undamaged areas. In South Carolina, abundance was positively related to gap size in bottomland forest that had been harvested by group-selection (Moorman and Guynn 2001). Territory size (0.1 to 1.8 ha) and population density vary with habitat quality. Brood parasitism affects nearly half of all nests and may significantly reduce productivity. The white-eyed vireo is more abundant in wide riparian strips of bottomland hardwood forest than in narrow strips (Kilgo and others 1998).

Model Description

The HSI model for the white-eyed vireo includes six variables: landform, landcover, successional age class, edge occurrence, canopy cover, and small stem (< 2.5 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 138). We directly assigned SI scores to these combinations on the basis of data from Hamel (1992) on the habitat associations of the white-eyed vireo in the Southeast.

Table 138.—Relationship of landform, landcover type, and successional age class to suitability index (SI) scores for white-eyed vireo habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000	0.834	0.500	0.333
	Deciduous	0.000	1.000	0.834	0.500	0.333
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.000	0.000
	Orchard-vineyard	0.000	1.000	0.834	0.500	0.333
	Woody wetlands	0.000	1.000	0.834	0.500	0.333
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.667	0.500	0.333	0.167
	Deciduous	0.000	0.667	0.500	0.333	0.167
	Evergreen	0.000	0.667	0.500	0.333	0.167
	Mixed	0.000	0.667	0.500	0.333	0.167
	Orchard-vineyard	0.000	0.667	0.500	0.333	0.167
	Woody wetlands	0.000	1.000	0.834	0.500	0.333
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.667	0.500	0.333	0.167
	Deciduous	0.000	0.667	0.500	0.333	0.167
	Evergreen	0.000	0.667	0.500	0.333	0.167
	Mixed	0.000	0.667	0.500	0.333	0.167
	Orchard-vineyard	0.000	0.667	0.500	0.333	0.167
	Woody wetlands	0.000	1.000	0.834	0.500	0.333

In older forest stands, the white-eyed vireo concentrates on edges (SI2) and other areas with dense vegetation (Conner and Dickson 1997). We used a 3 × 3 pixel window (90 x 90 m) to identify the interfaces between pole and sawtimber successional age class forest and herbaceous and nonforest landcovers (hard edge) or shrub-seedling, grass-forb, and sapling successional age class forest (soft edge). We assumed that pole and sawtimber stands adjacent to these edges would have the highest SI score but applied a residual suitability value (0.01) to areas not identified as edge habitats to compensate for small forest gaps and openings that may be used. Shrub-seedling and sapling stands were suitable habitat regardless of edge (Table 139).

Table 139.—Influence of edge on suitability index (SI) scores for white-eyed vireo habitat

3 × 3 pixel window around forest pixel includes field? [a]	SI score
Yes[b]	1.00
No	0.01

[a]Field defined as any sapling, shrub-seedling, or grass-forb age class pixel, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high-intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any pole or sawtimber age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands.

[b]Seedling-shrub and sapling habitats used regardless of edge.

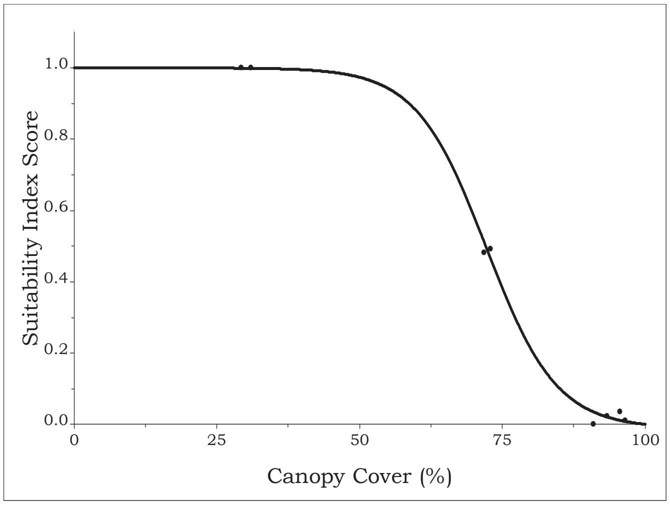

Figure 83.—Relationship between canopy cover and suitability index (SI) scores for white-eyed vireo habitat. Equation: SI score = 1 - (1.0101 / (1 + (127952.58 * e $^{-0.1629 * \text{canopy cover}}$))).

Table 140.—Influence of canopy cover on suitability index (SI) scores for white-eyed vireo habitat

Canopy cover (percent)	SI score
29.26[a]	1.000
31.00[b]	1.000
71.86[a]	0.482
73.00[b]	0.493
91.00[b]	0.000
93.38[a]	0.024
95.58[a]	0.036
96.59[b]	0.012

[a]Annand and Thompson (1997).
[b]Prather and Smith (2003).

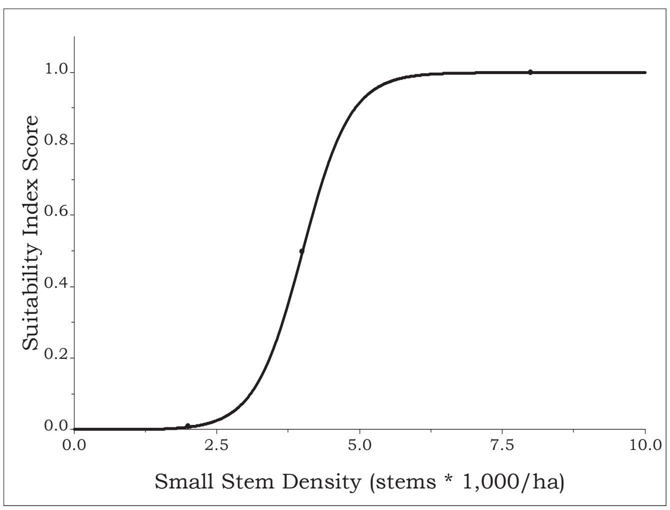

Figure 84.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for white-eyed vireo habitat. Equation: SI score = (1.000 / (1 + (14512.121 * e $^{-2.396 * (\text{small stem density} / 1000)}$))).

Table 141.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for white-eyed vireo habitat

Small stem density[a]	SI score
2	0.01
4	0.50
8	1.00

[a]Annand and Thompson (1997).

To refine the association of the white-eyed vireo with canopy gaps, we modeled the effect of canopy cover (SI3) on SI scores as an inverse logistic function (Fig. 83) that captured the absence of this species in closed-canopy forests (Table 140).

Finally, we fit a logistic function (Fig. 84) to data from Annand and Thompson (1997) (Table 141) on the influence of small stem (< 2.5 cm d.b.h.) density (SI4) on the relative density of the white-eyed vireo to quantify the relationship between SI scores and this habitat feature.

Assuming that this species uses edge as a surrogate to its preferred shrub-seedling and sapling habitats, we calculated HSI scores separately for shrub-seedling-sapling and pole-sawtimber forest stands. In the former, the geometric mean of forest structure variables alone defines the suitability score. For the latter, landscape composition (edge occurrence) also was a factor in the calculation.

Shrub-seedling and sapling (young) successional age classes:

HSI_{Young}: $(SI1 * SI3 * SI4)^{0.333}$

Pole and sawtimber (old) successional age classes:

HSI_{Old}: $((SI1 * SI3 * SI4)^{0.333} * SI2)^{0.500}$

To determine the overall HSI score, we summed the age class specific HSIs:

Overall HSI = $HSI_{Young} + HSI_{Old}$

Verification and Validation

The white-eyed vireo was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant (P = 0.002) positive association (r_s = 0.33) between average HSI score and mean BBS route abundance across all subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the white-eyed vireo was significant ($P \leq 0.001$; R^2 = 0.529); however, the coefficient on the HSI predictor variable was negative (β = -9.070). Therefore, we considered the HSI model for the white-eyed vireo verified but not validated (Tirpak and others 2009a).

Wood Thrush


Steve Maslowski, U.S. Fish & Wildlife Service

Status

The wood thrush (*Hylocichla mustelina*) is a familiar woodland migrant to the forests of the eastern and central United States. Population declines for this species in the Midwest are linked to higher predation and parasitism rates in fragmented landscapes (Robinson and others 1995, Sauer and others 2005) (Table 5). The wood thrush is both a Bird of Conservation Concern and a management attention priority in the CH and WGCP (regional combined score = 16 and 15, respectively; Table 1).

Natural History

The wood thrush is a long-distance neotropical migrant that exemplifies the decline in songbirds due to forest fragmentation. Due to its general abundance, ease of nest location and monitoring, and area sensitivity, the wood thrush is easy to study and there is a large body of knowledge on this bird (Roth and others 1996). This species is common in deciduous and mixed forests but rare in pure evergreen stands (Roth and others 1996). Mesic, upland forests with a moderate density of midcanopy trees and shrubs for nesting and an open understory with abundant leaf litter for foraging are optimal (Roth and others 1996). Closed overstory canopies are commonly used (Roth and others 1996, Bell and Whitmore 2000).

The wood thrush displays area sensitivity in productivity but not in its occupancy of habitats. It nests in forest fragments as small as 0.3 ha, albeit at low densities (Tilghman 1987, Weinberg and Roth 1998), and in narrow (< 150 m wide) riparian strips (Sargent and others 2003). However, nest predation and parasitism rates are extremely high in fragments of less than 80 ha and in riparian buffers less than 530 m wide (Donovan and others 1995, Hoover and others 1995, Peak and others 2004). Landscapes with greater amounts of forest cover (particularly unfragmented forest) mitigate some of these effects in small woodlots (Donovan and others 1997, Driscoll and Donovan 2004, Driscoll and others 2005). Nest success is predicted better by the amount of forest in the landscape than by the structural characteristics of microhabitat around nests (Hoover and Brittingham 1998, Driscoll and others 2005).

Model Description

The HSI model for the wood thrush includes seven variables: landform, landcover, successional age class, forest patch size, percent forest in the local (1-km radius) landscape, small stem (< 2.5 cm d.b.h.) density, and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 142). We directly assigned SI scores to these combinations on the basis of habitat associations reported by Hamel (1992) but made minor adjustments to increase SI scores for sapling stands on the basis of data from Thompson and others (1992).

Table 142.—Relationship of landform, landcover type, and successional age class to suitability index scores for wood thrush habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.250	0.750	0.750	1.000
	Transitional-shrubland	0.000	0.250	0.750	0.750	1.000
	Deciduous	0.000	0.250	0.750	0.750	1.000
	Evergreen	0.000	0.167	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.667
	Orchard-vineyard	0.000	0.250	0.333	0.333	0.667
	Woody wetlands	0.000	0.250	0.500	0.500	1.000
Terrace-mesic	Low-density residential	0.000	0.250	0.500	0.500	0.834
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.667 (0.000)
	Deciduous	0.000	0.250	0.500	0.500	0.834
	Evergreen	0.000	0.167	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.667
	Orchard-vineyard	0.000	0.250	0.333	0.333	0.667
	Woody wetlands	0.000	0.334	0.667	0.667	1.000
Xeric-ridge	Low-density residential	0.000	0.334	0.667	0.667	1.000
	Transitional-shrubland	0.000	0.167 (0.000)	0.333 (0.000)	0.333 (0.000)	0.667 (0.000)
	Deciduous	0.000	0.334	0.667	0.500	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.167	0.333	0.333	0.667
	Orchard-vineyard	0.000	0.334	0.333	0.333	0.667
	Woody wetlands	0.000	0.334	0.667	0.667	1.000

Although the wood thrush will occupy small forest fragments, its density may be lower within them. Therefore, we included forest patch size (SI2) in the HSI model. We fit an exponential function (Fig. 85) to data from Robbins and others (1989) and Kilgo and others (1998) (riparian strips in this study were assumed to be 10 km long) that documented changes in relative occurrence with changes in patch size (Table 143). Nevertheless, the suitability of a forest patch is influenced not only by its size but also by its landscape context (SI3). To capture this relationship, we fit a logistic function (Fig. 86) to data (Table 144) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We used the maximum SI score from SI2 or SI3 to increase the suitability of small patches in heavily forested landscapes.

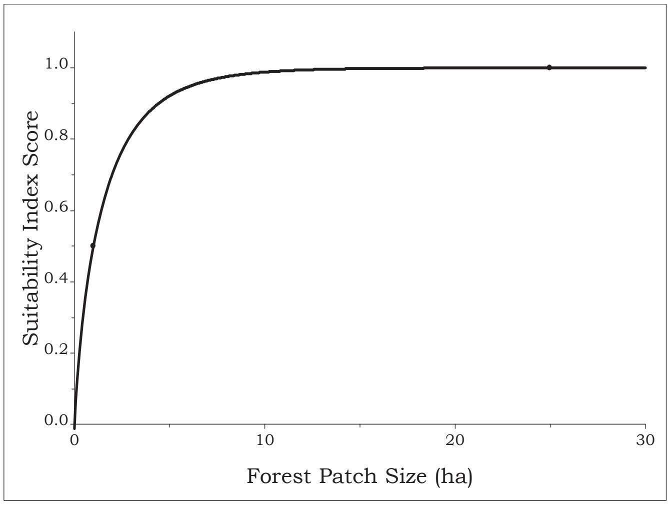

Figure 85.—Relationship between forest patch size and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1.000 – (1.017 * $e^{-0.710 * (\text{forest patch size} \wedge 0.797)}$).

Table 143.—Influence of forest patch size on suitability index (SI) scores for wood thrush habitat

Forest patch size (ha)	SI score
0[a]	0.0
1[a]	0.5
25[b]	1.0
500[a]	1.0

[a]Robbins and others (1989).
[b]Kilgo and others (1998).

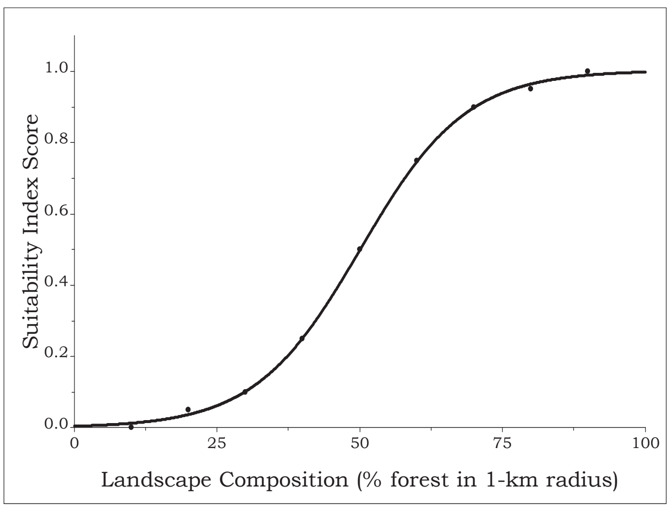

Figure 86.—Relationship between landscape composition and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * $e^{-0.108 * \text{landscape composition}}$)).

Table 144.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for wood thrush habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

The wood thrush forages in leaf litter on the forest floor and is most common in stands with an open understory. We included small stem density (SI4) in the model as a proxy to understory cover. Although some researchers suggest that the wood thrush selects habitats with higher stem densities than generally are available, the controls in these studies typically are in mature forest and the wood thrush may simply be selecting habitats with locally high stem densities (Artman and Downhower 2003). We assumed that the average stem density (1,988 stems/ha) observed by Hoover and Brittingham (1998) around wood thrush nests was representative of optimal habitat. We discounted habitat suitability as small stem density increased due to presumed reductions in leaf litter, the preferred foraging substrate (Roth and others 1996). Nonetheless, Hoover and Brittingham (1998) observed wood thrush

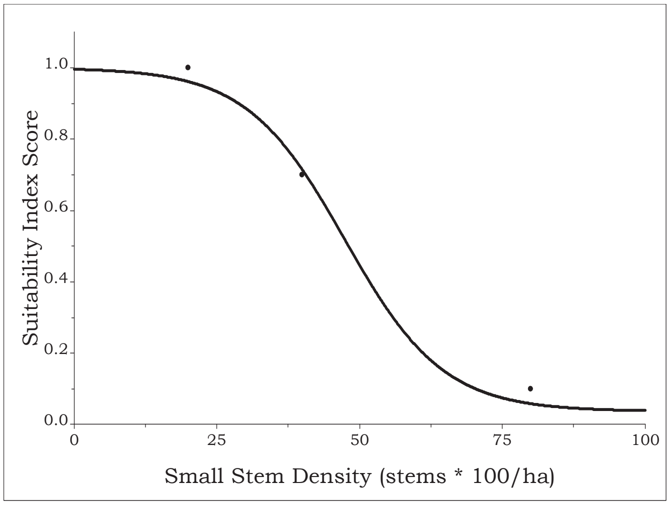

Figure 87.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 100/ha) and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1 - (0.963 / (1 + (243.780 * e $^{-0.116 * (\text{small stem density} / 100)}$)).

Table 145.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 100/ha) on suitability index (SI) scores for wood thrush habitat

Small stem density[a]	SI score
0	1.0
20	1.0
40	0.7
80	0.1
100	0.0

[a]Assumed value.

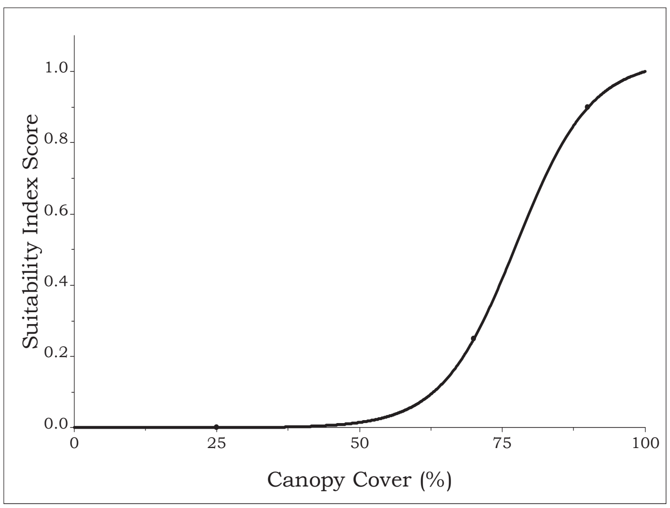

Figure 88.—Relationship between canopy cover and suitability index (SI) scores for wood thrush habitat. Equation: SI score = 1.032 / (1 + (141241.64 * e $^{-0.153 * \text{canopy cover}}$)).

Table 146.—Influence of canopy cover (percent) on suitability index (SI) scores for wood thrush habitat

Canopy cover (percent)	SI score
25[a]	0.00
70[b]	0.25
90[b]	0.90
100[b]	1.00

[a]Hoover and Brittingham (1998).
[b]Annand and Thompson (1997).

utilizing sites with extraordinarily high small stem densities (58,500 stems/ha, no doubt localized). Therefore, we assigned residual SI scores to sites with these characteristics. We fit an inverse logistic function (Fig. 87) to small stem density numbers that reflected this relationship (Table 145).

The wood thrush also is associated with closed-canopied forests, so we included canopy cover (SI5) as a variable and fit a logistic function (Fig. 88) to data from Annand and Thompson (1997) and Hoover and Brittingham (1998) to predict SI scores from canopy cover values (Table 146).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure attributes (SI1, SI4, and SI5) and then calculated the geometric mean of this value and the maximum of SI scores from forest patch size or percent forest in the landscape (Max(SI2 or SI3)).

$$\text{Overall HSI} = ((\text{SI1} * \text{SI4} * \text{SI5})^{0.333} * \text{Max}(\text{SI2 or SI3}))^{0.500}$$

Verification and Validation

The wood thrush was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.52$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the wood thrush was significant ($P \leq 0.001$; $R^2 = 0.311$), and the coefficient on the HSI predictor variable was both positive ($\beta = 9.992$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the wood thrush both verified and validated (Tirpak and others 2009a).

Worm-eating Warbler

Charles H. Warren, images.nbii.gov

Status

The worm-eating warbler (*Helmitheros vermivorus*) breeds on forested slopes of the eastern deciduous forest. It is notably absent from the Mississippi floodplain and the relatively flat forest-prairie ecotone immediately east of the Great Plains. Its preference for rugged terrain and its high-pitched, insect-like song result in underestimations of its density from roadside surveys. As a result, there are no credible trends from BBS data for this species (Table 5). Nevertheless, this species is a Bird of Conservation Concern in both BCRs. However, PIF designates the worm-eating warbler as a management attention priority in the CH (regional combined score = 18) and a planning and responsibility species in the WGCP (regional combined score = 15; Table 1).

Natural History

The worm-eating warbler is a neotropical migrant that breeds in forest interiors of the Eastern United States (Hanners and Patton 1998). Minimum area requirements range from 21 ha in the mid-Atlantic (Robbins and others 1989) to more than 800 ha in Missouri (Wenny and others 1993). This species nests on the ground along moderate to steep slopes (≥ 20 percent) with dense (≥ 48 percent) shrub understories in mature deciduous and mixed deciduous-coniferous forests (Gale and others 1997). Both Artman and others (2001) and Blake (2005) found that the worm-eating warbler was less abundant in recently burned stands due to the loss of leaf litter, a preferred nesting and foraging substrate. Canopy closure exceeded 95 percent in both Missouri (Wenny and others 1993) and Connecticut (Gale and others 1997).

Model Description

The HSI model for the worm-eating warbler includes seven variables: landform, landcover, successional age class, slope, forest patch size, percent forest in the landscape, and small stem (< 2.5 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 147). We directly assigned SI scores to these combinations on the basis of habitat associations reported by Hamel (1992).

We included slope (SI2) in our model because of the prevalence of steep slopes in the territories of the worm-eating warbler. We defined slope classes on the basis of data from Gale and others (1997) who identified the relative preference of various slopes for this species (Table 148).

We also included forest patch size (SI3) as a variable to account for the preference of the worm-eating warbler for forest interiors. We fit a modified exponential function (Fig. 89) to data from Robbins and others (1989) to quantify the relationship between patch size

Table 147.—Relationship of landform, landcover type, and successional age class to suitability index scores for worm-eating warbler habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.300	0.700	0.800
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.500	0.600
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.300	0.800	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.400	0.400
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.200	0.600	0.800
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.200	0.400	0.400
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.200	0.400	0.400

and habitat suitability (Table 149). The suitability of a forest patch is influenced by its size and landscape context (SI4). To capture this relationship, we fit a logistic function (Fig. 90) to data (Table 150) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively. We assigned the maximum SI score of SI3 or SI4 to each site to account for the higher suitability of small forest patches in heavily forested landscapes.

We relied on data from Wenny and others (1993) and Annand and Thompson (1997) (Table 151) to quantify the relationship between SI scores and small stem density (SI5; Fig. 91). We assumed that the worm-eating warbler occupied forests with low stem densities, but these sites had lower suitability scores than sites with well developed understories characterized by dense stems.

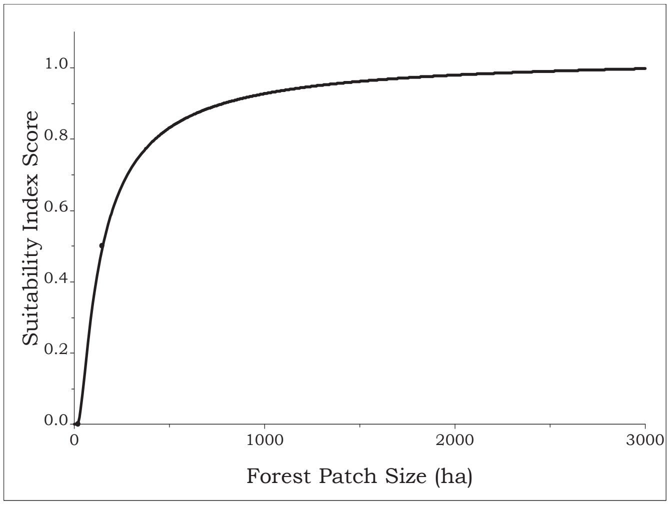

Figure 89.—Relationship between forest patch size and suitability index (SI) scores for worm-eating warbler habitat. Equation: SI score = 1.035 * e $^{-109.238 / (\text{forest patch size})}$.

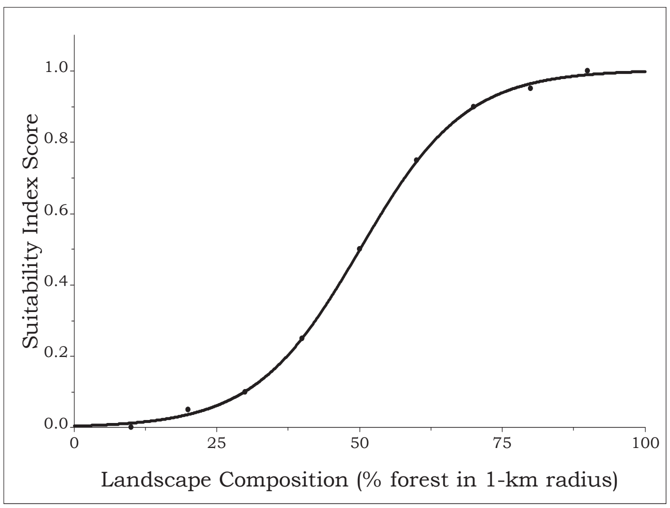

Figure 90.—Relationship between landscape composition and suitability index (SI) scores for worm-eating warbler habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 148.—Influence of slope on suitability index (SI) scores for worm-eating warbler habitat

Slope (percent)[a]	SI score
< 5	0.0
5-20	0.5
21	1.0

[a]Gale and others (1997).

Table 149.—Influence of forest patch size on suitability index (SI) scores for worm-eating warbler habitat

Forest patch size (ha)	SI score
21[a]	0.0
120[b]	0.5
3,200[a]	1.0

[a]Robbins and others (1989).
[b]Assumed value.

Table 150.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for worm-eating warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.
[b]Donovan and others (1997).

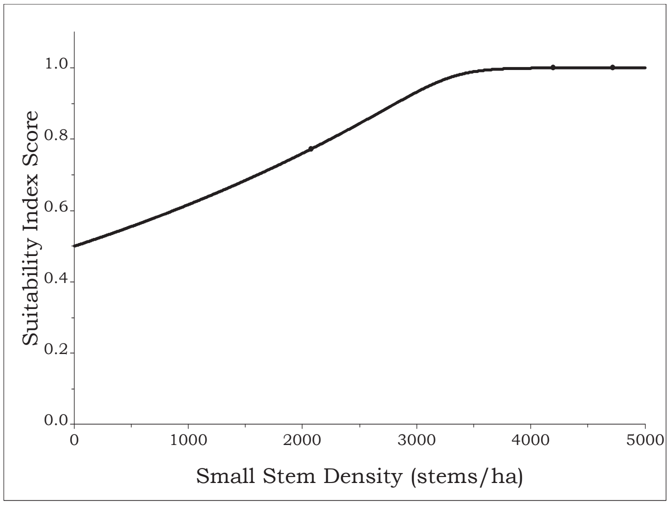

Figure 91.—Relationship between small stem (< 2.5 cm d.b.h.) density and suitability index (SI) scores for worm-eating warbler habitat.
Equation: SI score = $1.000 / (1 + e^{18.707 - 0.006 * (\text{small stem density})})^{1 / 26.989}$
Equation takes the general form: $y = a/(1 + e^{b-cx})^{1/d}$.

Table 151.—Influence of small stem (< 2.5 cm d.b.h.) density (stems/ha) on suitability index (SI) scores for worm-eating warbler habitat

Small stem density	SI score
0[a]	0.500
2,077[b]	0.773
4,200[c]	1.000
4,717[b]	1.000

[a]Assumed value.
[b]Annand and Thompson (1997).
[c]Wenny and others (1993).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI5) and landscape composition (Max(SI3 or SI4) and SI2) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI5)^{0.500} * (Max(SI3 \text{ or } SI4) * SI2)^{0.500})^{0.500}$

Verification and Validation

The worm-eating warbler was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.66$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the worm-eating warbler was significant ($P \leq 0.001$; $R^2 = 0.408$), and the coefficient on the HSI predictor variable was both positive (β = 1.798) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the worm-eating warbler both verified and validated (Tirpak and others 2009a).

Yellow-billed Cuckoo


U.S. Forest Service

Status

The yellow-billed cuckoo (*Coccyzus americanus*) is a neotropical migrant that breeds throughout North America east of the Rocky Mountains. The yellow-billed cuckoo is abundant in the CH and WGCP (10.43 and 12.93 birds/route, respectively), but populations in these BCRs have declinded slightly (Table 5). Although the yellow-billed cuckoo is not a Bird of Conservation Concern in either BCR, it is a management attention priority in both due to the importance of these regions (the core of this bird's range) for the sustainability of the continental population (Table 1).

Natural History

A long-distance migrant, the yellow-billed cuckoo breeds in low, dense scrub near streams, marshes, and wetlands within otherwise open woodlands (Hughes 1999). It is among the most common birds in floodplain habitats along the Mississippi River and occupies both young cottonwood-willow stands and mature silver maple forests (Knutson and others 2005). This species exhibits some area sensitivity. Conner and others (2004) found that the yellow-billed cuckoo was most abundant in riparian strips more than 70 m wide, and Aquilani and Brewer (2004) recorded highest abundances in forest tracts larger than 55 ha.

Breeding success is correlated with insect outbreaks, particularly those of hairy caterpillars, and population densities vary greatly with food supply. Nests are located in dense, broad-leaved, deciduous shrubs or trees within 10 m of the ground. Twedt and others (2001) reported no difference in nest success between bottomland hardwoods and cottonwood plantations, nor did Wilson (1999) report a difference in nest success among stands subject to alternative thinning rates in Arkansas. On the basis of anticipated harvest scenarios, Klaus and others (2005) predicted that populations of the yellow-billed cuckoo would decline by approximately 37 percent on the Cherokee National Forest over the next 60 years.

Model Description

The HSI model for the yellow-billed cuckoo includes seven variables: landform, landcover, successional age class, edge occurrence, midstory tree (11 to 25 cm d.b.h.) density, percent forest in the landscape (10-km radius), and forest patch size.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 152). We directly assigned SI scores to these combinations on the basis of habitat associations of the yellow-billed cuckoo reported by Hamel (1992). We increased SI scores within floodplain-valley and terrace-mesic landforms to account for the higher abundance of the yellow-billed cuckoo on these sites in the CH and WGCP.

Table 152.—Relationship of landform, landcover type, and successional age class to suitability index scores for yellow-billed cuckoo habitat. Values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.500	0.667	1.000
	Transitional-shrubland	0.000	0.000	0.500	0.667	1.000
	Deciduous	0.000	0.000	0.500	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.500	0.667	1.000
	Woody wetlands	0.000	0.000	0.333	0.667	0.667
Terrace-mesic	Low-density residential	0.000	0.000	0.500	0.667	1.000
	Transitional-shrubland	0.000	0.000	0.500 (0.000)	0.667 (0.000)	1.000 (0.000)
	Deciduous	0.000	0.000	0.500	0.667	1.000
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.167	0.333	0.333
	Orchard-vineyard	0.000	0.000	0.500	0.667	1.000
	Woody wetlands	0.000	0.000	0.333	0.667	0.667
Xeric-ridge	Low-density residential	0.000	0.000	0.250	0.333	0.500
	Transitional-shrubland	0.000	0.000	0.250 (0.000)	0.333 (0.000)	0.500 (0.000)
	Deciduous	0.000	0.000	0.250	0.333	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.083	0.167	0.167
	Orchard-vineyard	0.000	0.000	0.250	0.333	0.500
	Woody wetlands	0.000	0.000	0.167	0.333	0.333

This species is more abundant within edge (SI2) habitats than within forest interiors (Kroodsma 1984). We used a 9 × 9 pixel moving window (270 x 270 m) to identify habitat edges and assumed that these locations represented optimal habitat. Nevertheless, nonedge habitats also are used by the yellow-billed cuckoo so we assigned to these sites only a slightly lower SI score (0.667; Table 153).

The yellow-billed cuckoo breeds in forest stands with well-developed midstories (SI3). We fit a quadratic function (Fig. 92) to data from Annand and Thompson (1997) on the relative densities of this species in stands with different midstory tree densities (Table 154) to predict how SI scores responded to changes in this habitat variable.

Table 153.—Influence of edge on suitability index (SI) scores for yellow-billed cuckoo habitat

9 × 9 pixel window around forest pixel includes field[a]	SI score
Yes	1.000
No	0.667

[a]Field defined as any shrub-seedling or grass-forb age class pixel, or natural grasslands, pasture-hay, fallow, urban-recreational grasses, emergent herbaceous wetlands, open water, high-intensity residential, commercial-industrial-transportation, bare rock-sand-clay, quarries-strip mines-gravel pits, row crops, or small grains. Forest defined as any used sapling, pole, or sawtimber age class pixel of low-density residential, transitional, shrublands, deciduous, mixed, evergreen, orchard, or woody wetlands.

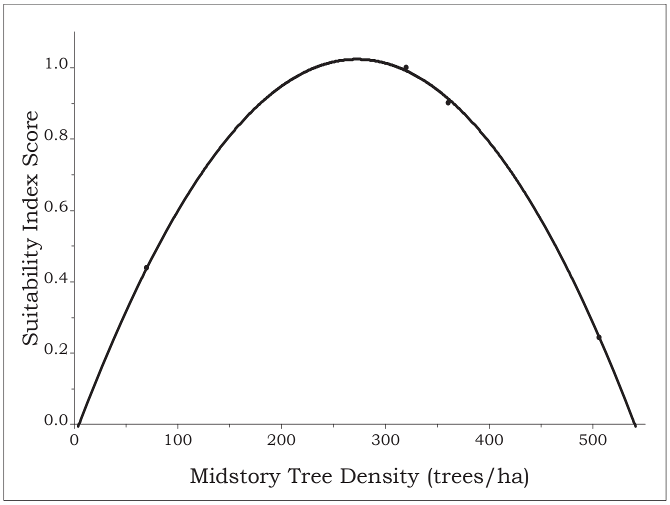

Figure 92.—Relationship between midstory tree (11–25 cm d.b.h.) density and suitability index (SI) scores for yellow-billed cuckoo habitat. Equation: SI score = 0.0078 * (midstory tree density) – 0.00001 * (midstory tree density)^2 – 0.0355.

Table 154.—Influence of midstory tree (11–25 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for yellow-billed cuckoo habitat

Midstory tree density[a]	SI score
70	0.439
320	1.000
361	0.902
506	0.244

[a]Annand and Thompson (1997).

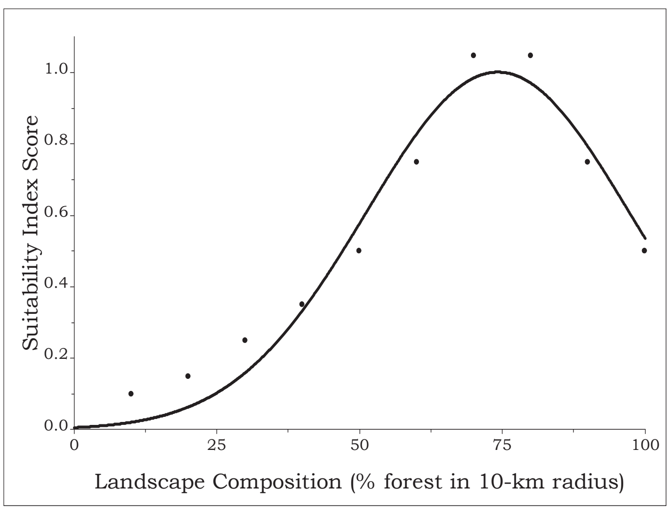

Figure 93.—Relationship between landscape composition and suitability index (SI) scores for yellow-billed cuckoo habitat. Equation: SI score = 1.002 * $e^{((0 – ((\text{landscape forest composition} * 100) – 74.165) \wedge 2) / 1064.634)}$.

Table 155.—Relationship between landscape composition (percent forest in 10-km radius) and suitability index (SI) scores for yellow-billed cuckoo habitat

Landscape composition[a]	SI score
0	0.00
10	0.10
20	0.20
30	0.30
40	0.40
50	0.50
60	0.75
70	1.00
80	1.00
90	0.75
100	0.50

[a]Assumed value.

Although a forest-breeding species, the yellow-billed cuckoo is associated with fragmented landscapes (Robbins and others 1989, Hughes 1999). We assumed that 70 to 80 percent forest in a 10-km landscape (SI4) was characteristic of ideal habitat (Table 155) and fit a function that reduced SI scores symmetrically as forest compositions departed from these ideal proportions (Fig. 93). Nevertheless, the cuckoo exhibits area sensitivity and may be absent or at low densities in small fragments (Robbins and others 1989, Bancroft and others 1995, Hughes 1999). Therefore, we used data from these sources to derive a logistic function (Fig. 94) that quantified the relationship between habitat suitability and forest patch size (SI5; Table 156).

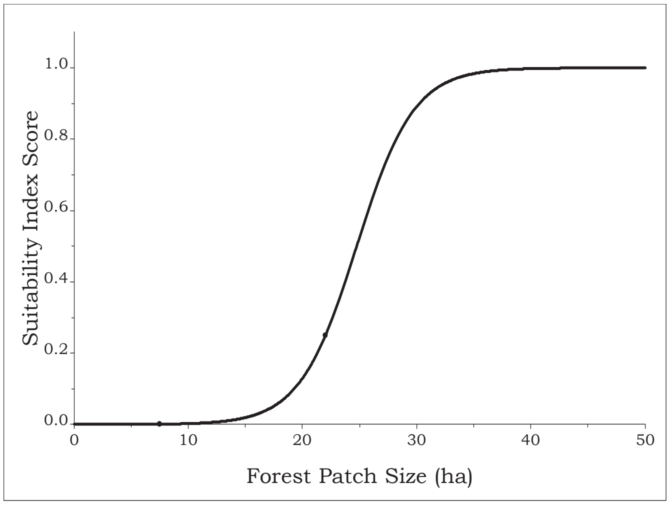

Figure 94.—Relationship between forest patch size and suitability index (SI) scores for yellow-billed cuckoo habitat. Equation: SI score = 1.000 / (1.000 + (20350.850 * e $^{-0.401 * \text{forest patch size}}$)).

Table 156.—Influence of forest patch size on suitability index (SI) scores for yellow-billed cuckoo habitat

Forest patch size (ha)	SI score
0[a]	0.00
7.5[b]	0.00
22[c]	0.25
50[d]	1.00

[a]Assumed value.
[b]Bancroft and others (1995).
[c]Hughes (1999).
[d]Robbins and others (1989).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI3) and landscape composition (SI2, SI4, and SI5) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI3)^{0.500} * (SI2 * SI4 * SI5)^{0.333})^{0.500}$

Verification and Validation

The yellow-billed cuckoo was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant (P = 0.024) positive relationship (r_s = 0.24) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the yellow-billed cuckoo was significant ($P \leq 0.001$; R^2 = 0.190), and the coefficient on the HSI predictor variable was positive (β = 5.265) but not significantly different from zero (P = 0.302). Therefore, we considered the HSI model for the yellow-billed cuckoo verified but not validated (Tirpak and others 2009a).

Yellow-breasted Chat

Chandler S. Robbins, Patuxent Bird Identification InfoCenter
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Status

The yellow-breasted chat (*Icteria virens*) is a neotropical migrant that breeds in early successional habitats across the eastern United States. The distribution of this species in the West is patchy. Populations have responded to the loss of early successional habitat and have declined sharply across the northern edge of this bird's distribution (Sauer and others 2005). Within the CH, where this species has a regional combined score of 16 and is a management attention priority, populations have declined by approximately 2 percent per year during the last 40 years (Table 5). Conversely, at the southern limit of their range, populations have increased (1.3 percent annual increases in the WGCP from 1966 to 2005; Table 5).

Natural History

The yellow-breasted chat breeds in low, dense, deciduous and evergreen vegetation within forests lacking a closed canopy (Eckerle and Thompson 2001). Habitat associations include forest edges and openings, regenerating forest, powerline rights-of-way, fencerows, upland thickets, abandoned farms, and shrubby areas along streams, swamps, and ponds. Chats are most abundant in 6- to 9-year-old cottonwood plantations in the Mississippi Alluvial Valley (Twedt and others 1999). However, Annand and Thompson (1997) observed similar abundance across stands subject to alternative forest management prescriptions. In east Texas, density is positively correlated with foliage density at 0 to 3 m, the percentage of saplings that are pine, and the number of shrub species. Densities are negatively affected by increasing vegetation height, percent canopy cover, foliage density at 12 to 15 m, and density of pole trees (Conner and others 1983).

In Missouri, the yellow-breasted chat nests more than 20 m from the edge of large early successional patches characterized by high densities of small stems (Burhans and Thompson 1999). Nest success increases with patch size; territories range from 0.5 to 1.6 ha.

Model Description

The HSI model for the yellow-breasted chat includes six variables: landform, landcover, successional age class, edge, early successional patch size, and small stem (< 2.5 cm d.b.h.) density.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 157). We directly assigned SI scores to these combinations based on data from Hamel (1992). However, we assumed that shrub-seedling habitats were optimal and that pole stands were nonhabitat. We ignored landform effects in assessing habitat suitability for this species.

Chats prefer to nest more than 20 m from the edge of mature forest (SI2) (Woodward and others 2001). Thus, we used a 3 × 3 pixel window (90 x 90 m) to identify suitable early

Table 157.—Relationship of landform, landcover type, and successional age class to suitability index scores for yellow-breasted chat habitat

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.000	1.000	0.500	0.000	0.000
	Deciduous	0.000	1.000	0.500	0.000	0.000
	Evergreen	0.333	0.667	0.500	0.000	0.000
	Mixed	0.333	0.667	0.334	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.667	0.334	0.000	0.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.333	1.000	0.500	0.000	0.000
	Deciduous	0.167	1.000	0.500	0.000	0.000
	Evergreen	0.333	0.667	0.500	0.000	0.000
	Mixed	0.333	0.667	0.334	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.667	0.334	0.000	0.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.000	0.000
	Transitional-shrubland	0.333	1.000	0.500	0.000	0.000
	Deciduous	0.333	1.000	0.500	0.000	0.000
	Evergreen	0.333	0.667	0.500	0.000	0.000
	Mixed	0.333	0.667	0.334	0.000	0.000
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.667	0.334	0.000	0.000

successional forest sites immediately adjacent to pole or sawtimber successional age class forest. We reduced the suitability of these sites by half (SI score = 0.500; Table 158).

Table 158.—Influence of edge on suitability index (SI) scores for yellow-breasted chat habitat

3 × 3 pixel window around early successional pixel includes mature forest[a]	SI score
Yes	0.5
No	1.0

[a]Early successional = grass-forb, shrub-seedling, and sapling successional age classes; mature forest = pole or sawtimber successional age classes.

The yellow-breasted chat is associated with large patches of early successional forest (SI3). We aggregated all grass-forb, shrub-seedling, and sapling successional age class sites to calculate patch sizes for this species. We fit a logarithmic function (Fig. 95) to data from Rodewald and Vitz (2005) on the relative abundance of the yellow-breasted chat in early successional patches of various sizes to quantify the relationship between patch size and habitat suitability (Table 159).

This species occupies sites with high small stem densities (SI4). Therefore, we fit a logistic function (Fig. 96) to data from Annand and Thompson (1997) relating the relative density of the yellow-breasted chat to small stem densities (Table 160) to predict the effect of this habitat characteristic on habitat suitability.

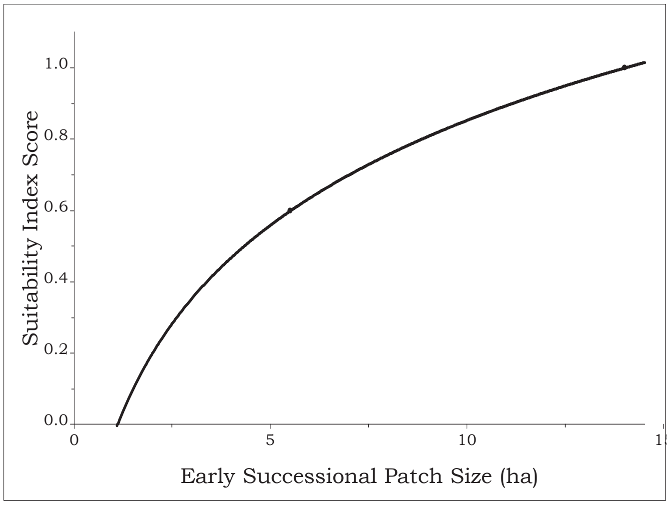

Figure 95.—Relationship between early successional patch size and suitability index (SI) scores for yellow-breasted chat habitat. Equation: SI score = -0.212 + 0.453 * ln(forest patch size).

Table 159.—Influence of early successional patch size on suitability index (SI) scores for yellow-breasted chat habitat; early successional patches only include grass-forb, shrub-seedling, and sapling successional age classes

Early successional patch size (ha)[a]	SI score
6	0.6
14.5	1.0

[a]Rodewald and Vitz (2005).

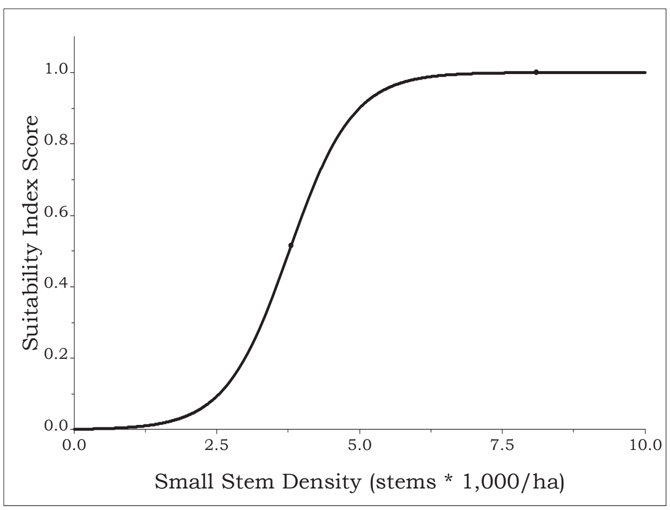

Figure 96.—Relationship between small stem (< 2.5 cm d.b.h.) density (stems * 1000/ha) and suitability index (SI) scores for yellow-breasted chat habitat. Equation: SI score = (1.000 / (1 + (1148216.200 * e $^{-3.689 * (\text{small stem density} / 1000)}$))).

Table 160.—Influence of small stem (< 2.5 cm d.b.h.) density (stems * 1,000/ha) on suitability index (SI) scores for yellow-breasted chat habitat

Small stem density[a]	SI score
0.0	0.000
3.8	0.516
8.1	1.000

[a]Annand and Thompson (1997).

To calculate the overall HSI score for the yellow-breasted chat, we determined the geometric mean of the SI scores for forest structure attributes (SI1 and SI4) and the SI score for landscape composition (SI2 and SI3) separately and then the geometric mean of these values together.

Overall HSI = $((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$

Verification and Validation

The yellow-breasted chat was found in all 88 subsections of the CH and WGCP. Spearman rank correlation identified a significant ($P \leq 0.001$) positive relationship ($r_s = 0.40$) between average HSI score and mean BBS route abundance across subsections. The generalized linear model predicting BBS abundance from BCR and HSI for the yellow-breasted chat was significant ($P \leq 0.001$; $R^2 = 0.379$), and the coefficient on the HSI predictor variable was both positive ($\beta = 93.367$) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the yellow-breasted chat both verified and validated (Tirpak and others 2009a).

Yellow-throated Vireo

Chandler S. Robbins,
Patuxent Bird Identification InfoCenter
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Status

The yellow-throated vireo (*Vireo flavifrons*) is a neotropical migrant found throughout North America east of the Great Plains. Populations in both the CH and WGCP are stable (Sauer and others 2005) (Table 5). This species is not a Bird of Conservation Concern in either region (Table 1) but is a planning and responsibility species in both the CH (regional combined score = 16) and WGCP (regional combined score = 15). Approximately 20 percent of the continental population breeds in these two BCRs (Panjabi and others 2001).

Natural History

The yellow-throated vireo breeds along the edges of mature forest stands; its abundance may even decline within forest interiors (Rodewald and James 1996). Appropriate edges include streams, rivers, swamps, and roads. Parks, orchards, and suburban habitats also may be used (Rodewald and James 1996). This species uses both bottomland and upland sites but is restricted to deciduous and mixed-forest habitats. As a forest edge species, it is not area sensitive and may benefit from canopy gaps. However, Robbins and others (1989) observed a positive relationship between the abundance of the yellow-throated vireo and forest cover within a 2-km buffer. Similarly, this bird did not use riparian forests strips that were less than 70 m wide in east Texas (Conner and others 2004). Thus, the yellow-throated vireo prefers canopy gaps within forested landscapes. The key component of its habitat is canopy structure, and this species selects taller trees (> 20 m) than other vireos (James 1976). Robbins and others (1989) also noted a positive relationship between abundance and canopy height. Specific tree species do not affect selection (Gabbe and others 2002).

Model Description

Our HSI model for the yellow-throated vireo includes six variables: landform, landcover, successional age class, forest patch size, percent forest in the landscape (1-km radius), and canopy cover.

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 161). We directly assigned SI scores to these combinations on the basis of relative rankings of habitat associations for the yellow-throated vireo described in Hamel (1992).

Although a forest edge species, the yellow-throated vireo is affected by forest area (SI2) and the percentage of forest in the landscape (SI3). We fit a logarithmic function (Fig. 97) to data from Blake and Karr (1987) and Kilgo and others (1998) to describe the relationship between forest patch size and habitat suitability (Table 162). Similarly, we used a logistic function to predict habitat suitability from percent forest cover in a 1-km radius landscape (Fig. 98) based on data (Table 163) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15

Table 161.—Relationship of landform, landcover type, and successional age class to SI scores for yellow-throated vireo habitat

Landform	Landcover type	Successional age class: Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.333	0.667
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.333	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.333	0.667
	Woody wetlands	0.000	0.000	0.000	0.417	0.834
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.250	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.250	0.500
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.250	0.500
	Woody wetlands	0.000	0.000	0.000	0.500	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.334	0.667
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.334	0.667
	Evergreen	0.000	0.000	0.000	0.000	0.000
	Mixed	0.000	0.000	0.000	0.167	0.333
	Orchard-vineyard	0.000	0.000	0.000	0.334	0.667
	Woody wetlands	0.000	0.000	0.000	0.500	1.000

percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively.

The affinity of the yellow-throated vireo for canopy gaps led us to incorporate canopy cover in the HSI model for this species (SI4). We fit a smoothed quadratic function (Fig. 99) to data from Kahl and others (1985) (Table 164) on the relative density of this species at varying canopy closures, and assumed that Kahl's optimal designation of canopy cover (80 to 90 percent) was associated with maximum SI scores. Further, we assumed that habitat suitability declined symmetrically as canopy cover departed from this optimum.

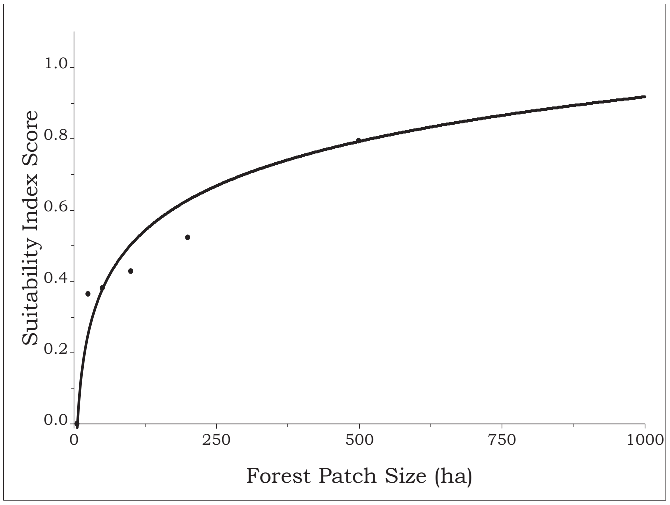

Figure 97.—Relationship between forest patch size and suitability index (SI) scores for yellow-throated vireo habitat. Equation: SI score = 0.180 * ln(forest patch size) – 0.323.

Table 162.—Influence of forest patch size on suitability index (SI) scores for yellow-throated vireo habitat

Forest patch size (ha)	SI score
6.5[a]	0.000
25[b]	0.365
50[b]	0.381
100[b]	0.429
200[b]	0.524
500[b]	0.794
1000[b]	1.000

[a]Blake and Karr (1987).

[b]Kilgo and others (1998).

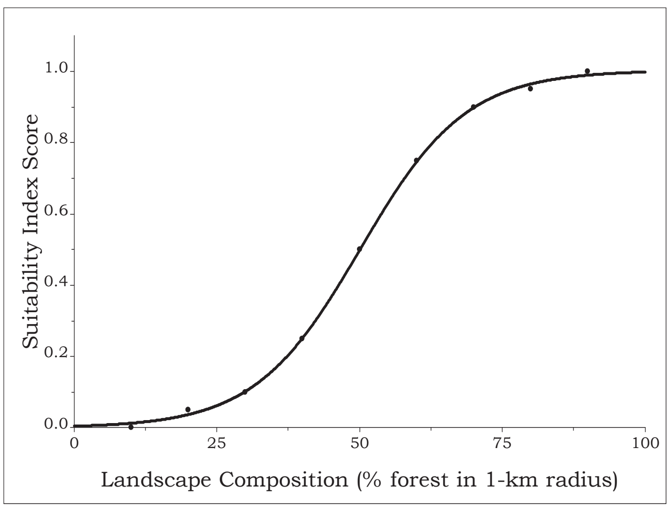

Figure 98.—Relationship between landscape composition and suitability index (SI) scores for yellow-throated vireo habitat. Equation: SI score = 1.005 / (1.000 + (221.816 * e $^{-0.108 * (landscape composition)}$)).

Table 163.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for yellow-throated vireo habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.

[b]Donovan and others (1997).

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI4) and landscape composition attributes (SI2 and SI3) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI4)^{0.500} * (SI2 * SI3)^{0.500})^{0.500}$

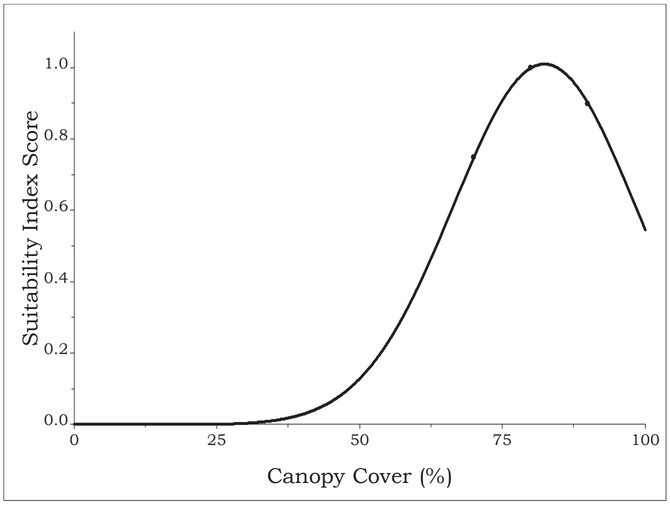

Figure 99.—Relationship between canopy cover and suitability index (SI) scores for yellow-throated vireo habitat. Equation: SI score = 1.011 * e $^{(0-((\text{canopy cover} - 82.319)^{\wedge}2 / 508.869))}$.

Table 164.—Influence of canopy cover (percent) on suitability index (SI) scores for yellow-throated vireo habitat

Canopy cover (percent)	SI score
0[a]	0.00
70[b]	0.75
80[b]	1.00
90[a]	0.90

[a]Assumed value.
[b]Kahl and others (1985).

Verification and Validation

The yellow-throated vireo was found in all 88 subsections of the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance per subsection identified a significant ($P \leq 0.001$) positive association ($r_s = 0.51$) between these two variables. The generalized linear model predicting BBS abundance from BCR and HSI for the yellow-throated vireo was significant ($P = 0.002$; $R^2 = 0.133$), and the coefficient on the HSI predictor variable was both positive (β = 2.811) and significantly different from zero ($P \leq 0.001$). Therefore, we considered the HSI model for the yellow-throated vireo both verified and validated (Tirpak and others 2009a).

Yellow-throated Warbler

Deanna K. Dawson, Patuxent Bird Identification InfoCenter
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Status

The yellow-throated warbler (*Dendroica dominica*) is a neotropical migrant that breeds in the southeastern United States and reaches its highest densities in the Ohio River Valley. This species has remained relatively stable in the WGCP over the past 40 years but has increased considerably in the CH (3.8 percent per year since 1967; Table 5). The yellow-throated warbler is not a Bird of Conservation Concern in either BCR but is a planning and responsibility species in the CH (regional combined score = 15; Table 1).

Natural History

The yellow-throated warbler breeds in two distinct habitat types: mature bottomland hardwood forest and dry, upland oak-pine forest (Hall 1996). It is more common in the former. This species shows a strong affinity for cypress along the Coastal Plains, but prefers sycamore along inland rivers (Hall 1996, Gabbe and others 2002). Where Spanish moss is found, it is used for both foraging and nesting (Hall 1996). Elsewhere, the warbler forages by creeping along limbs and probing leaf clusters and pinecones. This bird is both an interior and edge species and may occupy woodlots as small as 6 ha (Blake and Karr 1987). Robbins and others (1989) associated this species with large tree (> 38 cm d.b.h.) density, forest in a 2-km buffer, and coniferous canopy cover.

Model Description

Our HSI model for the yellow-throated warbler includes six variables: landform, landcover, successional age class, large tree (> 50 cm d.b.h.) density, distance to water, and percent forest in the landscape (1-km radius).

The first suitability function combines landform, landcover, and successional age class into a single matrix (SI1) that defines unique combinations of these classes (Table 165). We directly assigned SI scores to these combinations on the basis of habitat associations outlined by Hamel (1992) for the yellow-throated warbler in the Southeast.

We also incorporated large tree density (SI2) into the HSI model for the yellow-throated warbler because of its affinity for nesting and foraging in large trees (Hamel 1992, Robbins and others 1989). Lacking data points from the literature to fit a curve, we assumed that SI scores were logistically related to large tree density up to 50 trees per ha and remained optimal above this threshold (Fig. 100, Table 166).

The yellow-throated warbler typically nests near water (Hall 1996, Hamel 1992). Thus, we included distance to water (SI3) in the HSI model. We assumed that sites closer to water had a higher suitability. Lacking quantitative data on the potential effect of water on habitat suitability, we assumed that the size of the yellow-throated warbler's territory is similar to that of the Acadian flycatcher but that the warbler is not as dependent on water as the

Table 165.—Relationship of landform, landcover type, and successional age class to suitability index (SI) scores for yellow-throated warbler habitat; values in parentheses apply to West Gulf Coastal Plain/Ouachitas

		Successional age class				
Landform	Landcover type	Grass-forb	Shrub-seedling	Sapling	Pole	Saw
Floodplain-valley	Low-density residential	0.000	0.000	0.000	0.250	0.500
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.250	0.500
	Evergreen	0.000	0.000	0.000	0.333	0.667
	Mixed	0.000	0.000	0.000	0.333	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.834	1.000
Terrace-mesic	Low-density residential	0.000	0.000	0.000	0.167	0.167
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.167	0.167
	Evergreen	0.000	0.000	0.000	0.333	0.667
	Mixed	0.000	0.000	0.000	0.333	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.500	1.000
Xeric-ridge	Low-density residential	0.000	0.000	0.000	0.167	0.333
	Transitional-shrubland	0.000	0.000	0.000	0.000	0.000
	Deciduous	0.000	0.000	0.000	0.167	0.333
	Evergreen	0.000	0.000	0.000	0.333 (0.167)	0.667 (0.334)
	Mixed	0.000	0.000	0.000	0.333	0.667
	Orchard-vineyard	0.000	0.000	0.000	0.000	0.000
	Woody wetlands	0.000	0.000	0.000	0.500	1.000

flycatcher. Therefore, we assumed that all sites less than 100 m from water were optimal but reduced SI more slowly for the yellow-throated warbler than the Acadian flycatcher as distance to water increased (Fig. 101; Table 167).

The yellow-throated warbler responds to the percentage of forest in the landscape (SI4). To capture this relationship, we fit a logistic function (Fig. 102) to data (Table 168) derived from Donovan and others (1997), who observed differences in predator and brood parasite communities among highly fragmented (< 15 percent), moderately fragmented (45 to 50 percent), and lightly fragmented (> 90 percent forest) landscapes. We assumed that the midpoints between these classes (30 and 70 percent forest) defined the specific cutoffs for poor (SI score ≤ 0.10) and excellent (SI score ≥ 0.90) habitat, respectively.

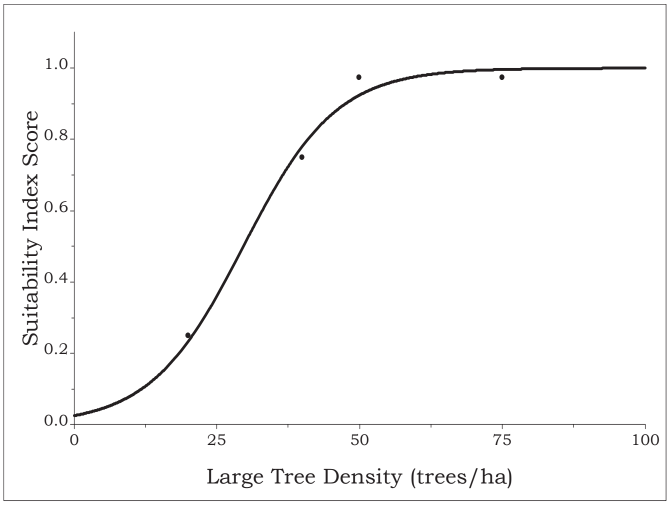

Figure 100.—Relationship between large tree (> 50 cm d.b.h.) density and suitability index (SI) scores for yellow-throated warbler habitat. Equation: SI score = 1.000 / (1.0000 + (38.185 * e $^{-0.123 * \text{large tree density}}$)).

Table 166.—Influence of large tree (> 50 cm d.b.h.) density (trees/ha) on suitability index (SI) scores for yellow-throated warbler habitat

Large tree density[a]	SI score
0	0.00
20	0.25
40	0.75
50	1.00
75	1.00

[a]Assumed value.

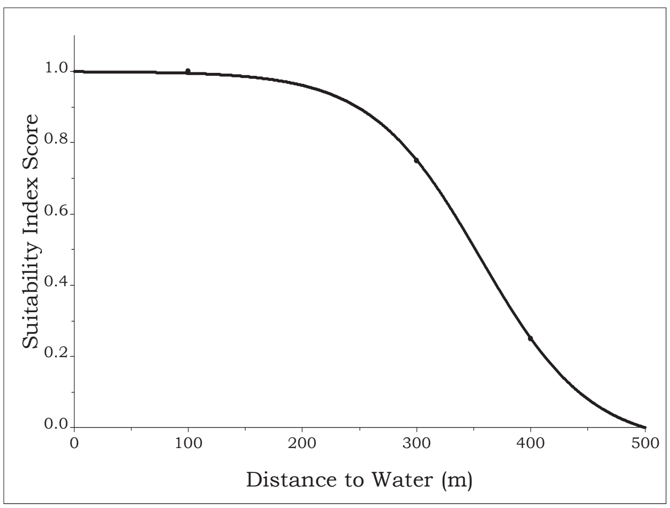

Figure 101.—Relationship between distance to water and suitability index (SI) scores for yellow-throated warbler habitat. Equation: SI score = 1 - (1.050 / (1 + (1661.322 * e $^{-0.021 * \text{distance to water}}$))).

Table 167.—Relationship between distance to water and suitability index (SI) scores for yellow-throated warbler habitat

Distance to water (m)[a]	SI score
100[b]	1.00
300[b]	0.75
400[b]	0.25
500[b]	0.00

[a]Water defined as NHD streams or NLCD water, woody wetlands, and emergent herbaceous wetlands classes.
[b]Assumed value.

To calculate the overall HSI score, we determined the geometric mean of SI scores for forest structure (SI1 and SI2) and landscape composition attributes (SI3 and SI4) separately and then the geometric mean of these means together.

Overall HSI = $((SI1 * SI2)^{0.500} * (SI3 * SI4)^{0.500})^{0.500}$

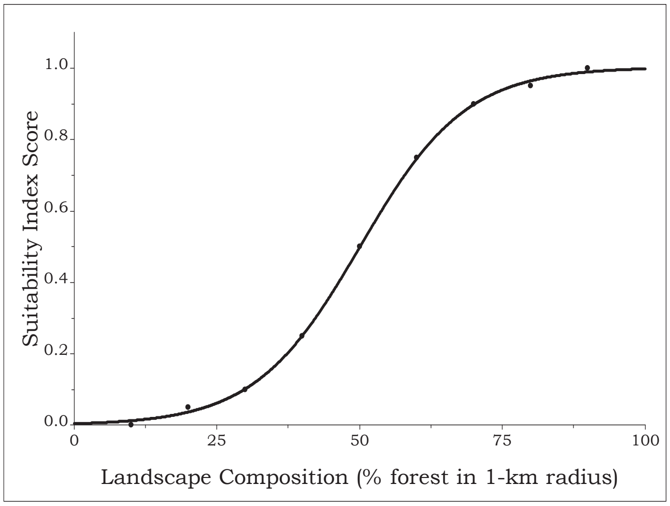

Figure 102.—Relationship between landscape composition and suitability index (SI) scores for yellow-throated warbler habitat. Equation: SI score= 1.005 / (1.000 + (221.816 * e $^{-0.108 * (\text{landscape composition})}$)).

Table 168.—Relationship between landscape composition (percent forest in 1-km radius) and suitability index (SI) scores for yellow-throated warbler habitat

Landscape composition	SI score
0[a]	0.00
10[a]	0.00
20[a]	0.05
30[b]	0.10
40[a]	0.25
50[b]	0.50
60[a]	0.75
70[b]	0.90
80[a]	0.95
90[b]	1.00
100[a]	1.00

[a]Assumed value.

[b]Donovan and others (1997).

Verification and Validation

The yellow-throated warbler was found in 87 of the 88 subsections within the CH and WGCP. Spearman rank correlation on average HSI score and mean BBS route abundance identified a significant ($P \leq 0.001$) positive association ($r_s = 0.48$) between these two variables within subsections where this species was detected. The generalized linear model predicting BBS abundance from BCR and HSI for the yellow-throated warbler was significant ($P = 0.003$; $R^2 = 0.125$), and the coefficient on the HSI predictor variable was both positive (β = 2.870) and significantly different from zero ($P = 0.020$). Therefore, we considered the HSI model for the yellow-throated warbler both verified and validated (Tirpak and others 2009a).

CURRENT MODEL USE AND FUTURE DIRECTIONS

For species with verified and validated models, we developed geospatial datasets that summarize the habitat suitability and estimated population size of these species within each subsection for two periods (1992 and 2001). These datasets are being used to assess changes in habitats through time and identify which model variables are associated with these changes. We also are using these datasets as conservation design tools to identify the specific location and type of management practice that may most effectively increase the habitat quality and population size of target species. Population estimates explicitly tied to habitat suitability are allowing the refinement of landbird population objectives and spatial depiction of these objectives at the ecological subsection scale. We are developing a decision-support tool based on these model outputs that will estimate the magnitude of management that may be required to achieve population objectives for a particular species and will assess the simultaneous impacts of different management options on populations of multiple species.

With conservation informed by these models in both the CH and WGCP, these models are informing the status at the continental scale of species with a significant portion of their populations in these BCRs (e.g., Kentucky warbler; Panjabi and others 2005). Adoption and application of these models in other BCRs (the East Gulf Coastal Plain Joint Venture references the use of these models in its Implementation Plan [East Gulf Coastal Plain Joint Venture 2008]) may provide a framework for assessing the status of additional species at the continental scale. However, the use of these models outside the CH and WGCP will require careful scrutiny and additional testing to ensure that the habitat associations remain valid as differences in forest types among regions (particularly outside the Southeast) likely will affect the SI scores in the landform, forest type, and successional age class matrix derived from Hamel (1992).

ACKNOWLEDGMENTS

We thank the following reviewers who provided invaluable feedback for improving our HSI models: Eric Baka, Laurel Moore Barnhill, Charles Baxter, Michelle Beck, Jim Bednarz, Jeff Buler, Wes Burger, Dirk Burhans, Bob Cooper, Dean Demarest, Randy Dettmers, Jim Dickson, Therese Donovan, Rob Doster, John Dunning, Jane Fitzgerald, Jim Giocomo, Bill Giuliano, Gypsy Gooding, Fred Guthery, Carola Haas, Tom Haggerty, Paul Hamel, Kirsten Hazler, Larry Hedrick, Mark Howery, Pamela Hunt, Chuck Hunter, James Ingold, Brad Jacobs, Christopher Kellner, Eric Kershner, John Kilgo, Melinda Knutson, Jeff Kopachena, David Krementz, Scott Lanyon, Chester Martin, Dan McAuley, Joe Meyers, Warren Montague, Christopher Moorman, Rua Mordecai, Allan Mueller, Wayne Norling, Brainard Palmer-Ball, David Pashley, Bruce Reid, Rochelle Renken, Amanda Rodewald, Scott Rush, Kristin Schaumburg, Brian Smith, Phil Stauffer, Jeffrey Stratford, Wayne Thogmartin, Bill Vermillion, Shawchyi Vorisek, R. Montague Whiting, Jr., Mike Wilson, Randy Wilson, and Doug Zollner.

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Habitat Suitability Index (HSI) models were developed to assess habitat quality for 40 priority bird species in the Central Hardwoods and West Gulf Coastal Plain/ Ouachitas Bird Conservation Regions. The models incorporated both site and landscape environmental variables from one of six nationally consistent datasets. Potential habitat was first defined from unique landform, landcover, and successional age class combinations. Species-specific environmental variables identified from the literature were used to refine initial habitat estimates. Models were verified by comparing subsection-level HSI scores and Breeding Bird Survey (BBS) abundance via Spearman rank correlation. Generalized linear models that predicted BBS abundance as a function of HSI were used to validate models.

KEY WORDS: Conservation planning, ecoregion, forest, Forest Inventory and Analysis, National Landcover Dataset, validation.

Capitalizing on the strengths of existing science capacity in the Northeast and Midwest to attain a more integrated, cohesive, landscape-scale research program

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Rapid Assessment Metrics to Enhance Wildlife Habitat and Biodiversity within Southern Open Pine Ecosystems

Carl Nordman, Rickie White, Randy Wilson, Clay Ware, Catherine Rideout, Milo Pyne, Chuck Hunter

Version 1.0
Date of current draft: 5-12-2016

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Acknowledgements

Our project core team (Chuck Hunter, Carl Nordman, Milo Pyne, Catherine Rideout, Clay Ware, Rickie White, and Randy Wilson) is indebted to the many institutions and individuals who contributed to our work or who made our work possible through previously published research. In particular, we recognize that this project could not have been accomplished without the financial support of the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative and their dedicated staff, past and present. In particular, John Tirpak (previous Science Coordinator of the LCC) and Todd Jones-Farrand (current Science Coordinator) organized the technical advisory team that oversaw our work and checked in with us as needed to ensure that the project ran smoothly. We appreciate the effort and input of the technical advisory team members for our project, including Mike Conner, Jeffrey Gleason, Jane Fitzgerald, Tom Foti, Tim Fotinos, Anne Mini, and Rua Mordecai.

We further appreciate the in-kind support of the East Gulf Coastal Plain Joint Venture, the Mississippi Migratory Bird Field Office, and the Longleaf Pine Recovery Team of USFWS.

Much of the work featured here was based on or influenced by previous projects. In 2006, with support from Office Depot, NatureServe conducted literature review and rapid assessment metric development for certain ecological systems in the Alabama and Mississippi (NatureServe 2006). The Southern Region of the US Forest Service worked closely with NatureServe to produce an interim report on longleaf pine rapid assessment metrics that influenced our current work (NatureServe 2011). In particular, NatureServe collaborated with the late Erik Johnson of USFS prior to 2011 on rapid assessment metrics for longleaf pine dominated communities (NatureServe 2011). His input was important for the development of metrics included here. In addition, our core team used Florida Natural Areas Inventory's longleaf pine ecosystem metrics (FNAI and FFS 2014), the Longleaf Partnership Council metrics (Longleaf Partnership Council 2014), and the West Gulf Coastal Plain/Ouachitas Open Pine Landbird Plan (Lower Mississippi Valley Joint Venture WGCPO Landbird Working Group 2011) to inform our initial drafts that were presented for review to key stakeholders and experts.

Finally (and most importantly), we are thankful for the many experts who agreed to review our products at various stages in the process. Although we don't have the room to name everyone in the acknowledgments, we would like to point out experts who were instrumental in helping us edit the original metrics and create a stronger final version. These include Andy Vanderyacht, Brian Camposano, Bryan Rupar, Carol Denhof, Chris Oswalt, Chuck Hunter, Clarence Coffey, Dan Hipes, Amy Knight, Doug Zollner, Doyle Shook, Gary Burger, Jim Guldin, Joan Walker, Joanne Baggs, Jon Scott, Kevin Mcintyre, Lora Smith, Martin Blaney, Matt Hinderliter, McRee Anderson, Mike Black, Mike Conner, Russ Walsh, Tom Foti, Wally Akins, Will McDearman, Al Schotz, Amity Bass, Ben Wigley, Carl Schmidt, Forbes Boyle, Gary Kauffman, Haven Barnhill, Jack Culpepper, Jeff Marcus, Joanne Baggs, John Gruchy, Joseph Reinman, Lisa Kruse, Matt Elliott, Nancy Jordan, Randy Browning, and Sara Aicher. The full list of workshop attendees and reviewers can be found in Appendix D.

Preferred Citation:
Nordman, Carl, Rickie White, Randy Wilson, Clay Ware, Catherine Rideout, Milo Pyne, and Chuck Hunter. 2016. Rapid Assessment Metrics to Enhance Wildlife Habitat and Biodiversity within Southern Open Pine Ecosystems, Version 1.0. U.S. Fish and Wildlife Service and NatureServe, for the Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative. March 31, 2016.

Cover Photo: Bobwhite photo courtesy of Dr. John Brunjes of Kentucky Dept. of Fish and Wildlife Resources, controlled burn photo courtesy of Louisiana Dept. of Wildlife and Fisheries, longleaf community photo in Croatan National Forest courtesy of Milo Pyne, NatureServe.

Executive summary

Open woodlands dominated by southern yellow pine were historically a large component of the landscape across the southeastern United States. These woodlands have an open canopy of longleaf, slash, shortleaf, and/or loblolly pines, with scattered shrubs and a grassy understory. These southern open pine ecosystems support many species of wildlife, many of which have declined in recent years as the amount and condition of their habitat has declined. This troubling decline in wildlife species has led to a focus on regional conservation efforts by America's Longleaf, the National Fish and Wildlife Foundation, Landscape Conservation Cooperatives, state wildlife agencies, the U.S. Forest Service, National Bobwhite Quail Initiative, regional Bird Conservation Joint Ventures, The Nature Conservancy, the Shortleaf Pine Initative, and other conservation partners. These groups all agree that there is a need for more high quality open pine acreage, but until now there has been no efficient, agreed upon, way to identify those tracts that are providing the best habitat for key wildlife species.

In partnership with the Gulf Coastal Plain and Ozarks Landscape Conservation Cooperative (GCPO LCC), NatureServe, the U.S. Fish and Wildlife Service and the East Gulf Coastal Plain Joint Venture have developed desired forest condition (rapid assessment) metrics to measure wildlife habitat value and ecological integrity of tracts of land, with a primary focus on those lands being managed primarily for conservation. These desired forest condition metrics help conservation-minded landowners understand how their properties are contributing to the habitat needs of priority wildlife of southern open pine ecosystems, as determined by the Gulf Coastal Plain and Ozarks Landscape Conservation Cooperative (GCPO LCC).

To create this metrics based approach, our team first reviewed previous studies and reports pertaining to the condition of southern open pine ecosystems and the habitat needs of priority wildlife. We then incorporated their findings into a draft set of desired forest condition metrics. The project partners then reached out to wildlife conservation stakeholders and experts to review these metrics at two regional in-person meetings (at Newton, GA and Knoxville, TN), and through other outreach efforts. Stakeholders and experts participated in a structured method that allowed all participants to contribute input on the proposed desired forest condition metrics for southern open pine ecosystems. The team used the information and viewpoints gathered from all interactions to revise the draft metrics. In late 2015, the team shared the revised metrics and introductory material with an additional broad set of reviewers, many of whom were local land managers and other stakeholders who did not attend the two regional meetings. The team compiled the review comments received and used them to finalize the desired forest condition metrics.

Included in this final report are thirteen desired forest condition metrics, subdivided into sets of metrics for the condition of the canopy, midstory and ground layer (the full metrics are found in Appendix C, this document). These metrics can be applied to any of seven broad ecosystems we are calling "Southern Open Pine Groupings" (Appendix B). These are stand level metrics, and generally can be applied at sets of points or small plots across stands, in a manner similar to a timber cruise.

These metrics are an important new tool that is intended for use by conservation-focused landowners and managers to evaluate the wildlife habitat value and ecological integrity of southern open pine ecosystems that they own and manage.

Introduction

Savannas and woodlands dominated by longleaf, slash, shortleaf, and loblolly pines (open pine) were historically a large component of the overall landscape across the southeastern United States. As human populations increased and land management practices and land use patterns changed, these once dominant open pine ecosystems were cleared for agriculture and/or development, resulting in significant declines in both extent and quality of pine systems across the southeast (Oswald 2012). In fact, longleaf dominated pine systems have declined so that only a small fraction of their original historic acreage remains today. With so little healthy open pine forests left, the stakes are already very high. These open pine communities support extremely high plant, reptile, and amphibian diversity, with over 900 plant species considered endemic to this and adjacent ecosystems (America's Longleaf 2009). This project will facilitate identification, prioritization, and enhancement of sites to advance the conservation of these precious systems.

In 2009, a Range-wide Conservation Plan for Longleaf Pine was created (http://www.americaslongleaf.org/media/86/conservation_plan.pdf) with a 15-year goal of increasing longleaf acreage from 3.4 million to 8 million acres. But even more important, a goal was also established to specifically move at least 3 million acres into good health/quality to serve as vital habitat for key/representative species found within this iconic ecosystem (America's Longleaf 2009). Longleaf dominated forest is the main focus of much of the effort to restore and maintain open-canopied natural pine stands in the Southeast (open pine), but there are other similar open pine stands dominated by shortleaf, slash, and loblolly pines in this region as well. These pine stands also contribute to the overall conservation effort by providing habitat for many of the same target species, so we have included all of these stands in our current region-wide metrics-based effort.

Our team has prepared this document to further the conservation goals and objectives of the Gulf Coastal Plain and Ozarks Landscape Conservation Cooperative (GCPO LCC) across the West Gulf Coastal Plain, East Gulf Coastal Plain, Mississippi Alluvial Valley and Ozarks physiographic regions (Figure 1). The GCPO LCC is a self-directed, non-regulatory partnership that exists for the purpose of advancing science and landscape-level planning as community of practice representing private, state, and federal agencies and organizations to support and sustain endemic fish and wildlife populations and the ecological functions and processes on which they depend (GCPO LCC 2009). To facilitate and advance this "conservation agenda" the GCPO LCC partnership put forth an integrated science agenda (GCPO LCC Adaptation Science Management Team 2013; http://tinyurl.com/GCPOLCC-Sci-Agenda) that outlined science needs across resources and disciplines with pine systems. More specifically, the integrated science agenda identified the desire and need to articulate stand-level metrics that define desired habitat conditions to support priority wildlife species with longleaf pine systems.

Purpose and Use of this Document

To provide the GCPO LCC partnership with information to advance the conservation of open pine systems, our team set out to address three specific needs/goals: (1) provide a common framework for delineating open pine systems; (2) define desired forest conditions that result from management of pine systems where the primary objective is conservation of wildlife and biodiversity maintenance; and (3) provide a rapid assessment protocol to allow land managers to quickly assess stand conditions. We envision these products will aid not only public land managers but also private landowners who target wildlife conservation as part of their overall land stewardship objectives (e.g., lands under conservation easements). The data presented herein is not intended to be regulatory or administratively prescriptive, nor to conflict with any GCPO LCC partner's ability to meet their underlying legislative mandates. As the data and recommendations put forth here reflect the contemporary, collective expertise of many foresters, biologists and researchers, we encourage the GCPO LCC partnership to iteratively update and refine these data and recommendations as we increase our knowledge and understanding of wildlife species habitat needs and management strategies within open pine systems across the southeastern United States.

Study Area / Scope and Scale of Project

In the southeastern United States, there are several large-scale (or formerly large-scale) ecosystems dominated by an open canopy of pine trees that are used by a great variety of game and non-game wildlife species and plants. Due to changes in land use and fire regime, these open pine ecosystems have undergone extensive declines over the last 100 years and continue to be threatened with further decline. These ecosystems are found from the West Gulf Coastal Plain and Ozark and Ouachita Mountains to the Southern Appalachians, Piedmont, Atlantic and Southeastern Coastal Plains, and south into the Florida Peninsula. In the past, these ecosystems have consisted of open pine stands with a diverse ground cover composed of native warm-season grasses and forbs, often with some low shrubs and only sparse tall shrubs. These open conditions were historically maintained by natural processes, including fire and grazing. Today, these ecosystems require active management to maintain or to restore the open herbaceous conditions preferred by the many wildlife species adapted to these systems.

Utilizing the aforementioned definition of open pine, the geographic footprint of this project includes all open pine dominated ecosystems within the administrative boundary of the GCPO LCC (see below for concessions), as well as the historic range of longleaf pine (*Pinus palustris*) and slash pine (*Pinus elliottii*). More specifically, we included mixed longleaf pine-shortleaf pine woodlands found in limited areas of the Piedmont and southernmost Appalachians as well as peninsular Florida flatwoods (e.g. spodosol woodlands) dominated by South Florida slash pine (*Pinus elliottii* var. *densa*) whereas we excluded the pine rocklands along the Miami Rock Ridge. These pine rocklands represent a fundamentally different type of open pine ecosystem that is associated with a subtropical climate, calcareous substrate, and a distinct suite of wildlife species; hence we did not address them within this project. Additionally, we did not address forests dominated by pond pine (*Pinus serotina*), sand pine (*Pinus clausa*), spruce pine (*Pinus glabra*), pitch pine (*Pinus rigida*), table mountain pine (*Pinus pungens*), white pine (*Pinus strobus*) or Virginia pine (*Pinus virginiana*).

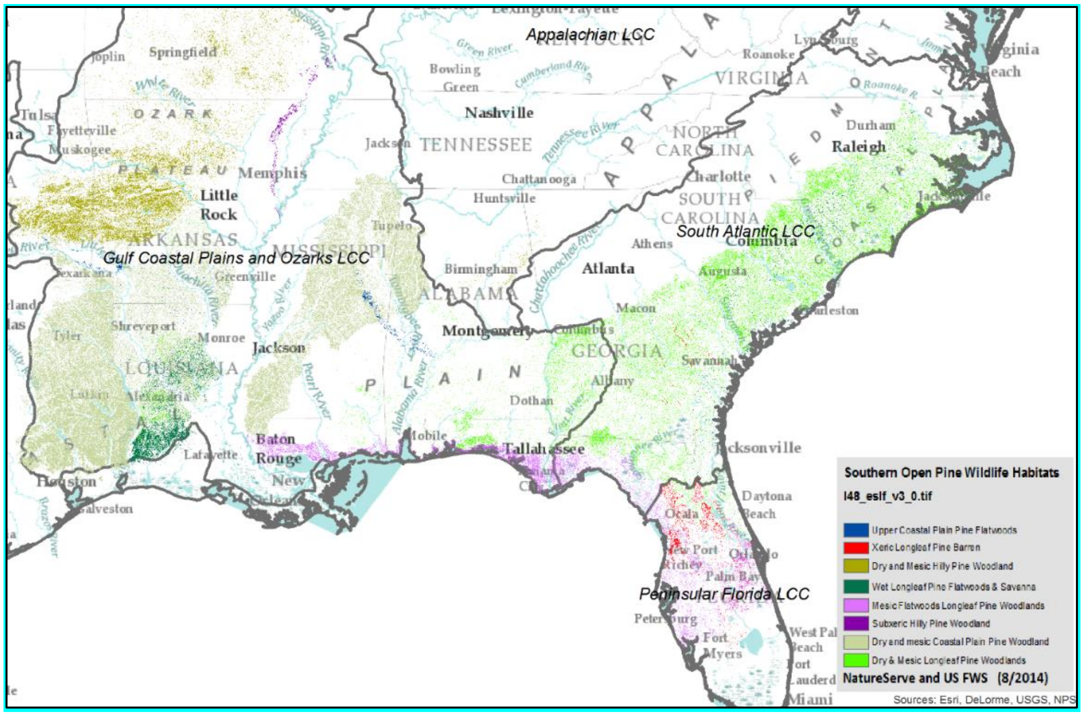

Figure 1. Areas currently having open pine communities in the Gulf Coast and Ozarks LCC as well as longleaf dominated communities in the South Atlantic and Peninsular Florida LCCs.

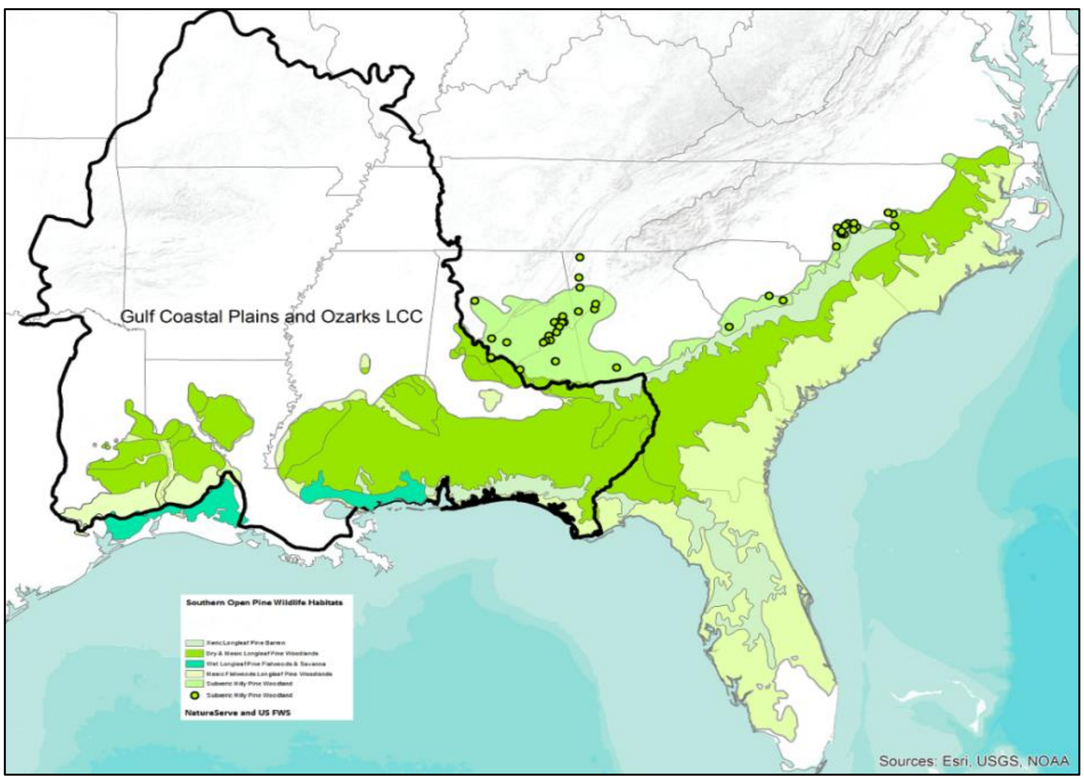

Figure 2. Areas historically dominated by open longleaf and slash pine groupings (tree ranges from Little 1971) as well as the footprint of the Gulf Coastal Plains and Ozarks LCC. Shortleaf pine areas not included in this map.

Priority Species

The GCPO LCC identified sets of species associated with general ecosystems (GCPO LCC Adaptation Science Management Team 2013) as part of their integrated science agenda. This list included 43 fish and wildlife species (see Table 1 and Appendix F), the representative species pool for Coastal Plain Open Pine Woodland and Savanna. From the representative species pool, 12 terrestrial wildlife species serve

Table 1. Representative Species Pool for Coastal Plain Open Pine Woodland and Savanna (GCPO LCC), with Priority Species in bold.

Scientific Name	Common Name	Taxon
Ambystoma bishopi	Flatwoods Salamander	Amphibians
Ambystoma talpoideum	Mole Salamander	Amphibians
Ambystoma tigrinum	Tiger Salamander	Amphibians
Anaxyrus (*Bufo*) *quercicus*	Oak Toad	Amphibians
Eurycea cf. quadridigitata	Bog Dwarf Salamander	Amphibians
Eurycea quadridigitata	Dwarf Salamander	Amphibians
Hyla andersonii	Pine Barrens Treefrog	Amphibians
Rana areolata areolata	Southern Crawfish Frog	Amphibians
Rana capito	Gopher Frog	Amphibians
Rana sevosa	Mississippi Gopher Frog	Amphibians
Aimophila aestivalis	**Bachman's Sparrow**	**Birds**
Ammodramus henslowii	Henslow's Sparrow	Birds
Caprimulgus carolinensis	Chuck-will's-widow	Birds
Caprimulgus vociferus	Whip-poor-will	Birds
Coccyzus americanus	Yellow-billed Cuckoo	Birds
Colinus virginianus	**Northern Bobwhite**	**Birds**
Dendroica discolor	**Prairie Warbler**	**Birds**
Dendroica dominica	Yellow-throated Warbler	Birds
Dendroica pinus	**Pine Warbler**	**Birds**
Dryocopus pileatus	Pileated Woodpecker	Birds
Falco sparverius paulus	Southeastern American Kestrel	Birds
Geococcyx californianus	Greater Roadrunner	Birds
Grus canadensis pulla	Mississippi Sandhill Crane	Birds
Melanerpes erythrocephalus	Red-headed Woodpecker	Birds
Meleagris gallopavo	Wild Turkey	Birds
Picoides borealis	**Red-cockaded Woodpecker**	**Birds**
Picoides villosus	Hairy Woodpecker	Birds
Pipilo erythrophthalmus	Eastern Towhee	Birds
Sitta pusilla	**Brown-headed Nuthatch**	**Birds**
Geomys pinetis	**Southeastern Pocket Gopher**	**Mammals**
Sciurus niger niger	Southeastern Fox Squirrel	Mammals
Cemophora coccinea	Scarlet Snake	Reptiles
Crotalus adamanteus	**Eastern Diamondback Rattlesnake**	**Reptiles**
Drymarchon couperi	Eastern Indigo Snake	Reptiles
Gopherus polyphemus	**Gopher Tortoise**	**Reptiles**
Lampropeltis getula	Common Kingsnake	Reptiles
Masticophis flagellum	Eastern Coachwhip	Reptiles
Micrurus fulvius	Coral Snake	Reptiles
Micrurus tener tener	Texas Coral Snake	Reptiles
Pituophis melanoleucus	**Northern Pine Snake**	**Reptiles**
Pituophis ruthveni	**Louisiana Pine Snake**	**Reptiles**
Sistrurus miliarius	Pygmy Rattlesnake	Reptiles
Tantilla coronata	Southeastern Crowned Snake	Reptiles

as priority species to guide this project (Table 2). Because this project area also includes the southeastern coastal plain, some additional subspecies of pocket gophers and pine snakes have been included.

Common name	**Scientific name**	**Project area states where it occurs**	**States where listed as Species of Greatest Conservation Need (SGCN) in 2005 State Wildlife Action Plan**	**Open Pine Groupings**
Red-cockaded Woodpecker	*Picoides borealis*	All project area states, except MO (Extirpated)	AL, AR, FL, GA, KY (Extirpated) , LA, MD, MO (Extirpated), MS, NC, OK, SC, TX, VA	All?
Louisiana Pine Snake	*Pituophis ruthveni*	LA, TX	LA, TX	Xeric Longleaf Pine Barrens
Black Pine Snake	*Pituophis melanoleucus lodingi*	AL, LA, MS	AL, LA, MS	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands
Florida Pine Snake	*Pituophis melanoleucus mugitus*	AL, FL, GA, SC	AL, FL, GA, SC	Xeric Longleaf Pine Barrens
Brown-headed Nuthatch	*Sitta pusilla*	All project area states, except MO (Extirpated)	AR, DE, FL, LA, MD, MO (Extirpated), MS, NC, OK, SC, TN, TX, VA	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands, Mesic Longleaf Pine Flatwoods, Wet Longleaf & Slash Pine Flatwoods & Savannas, Dry & Mesic Hilly Pine Woodlands (East Gulf), Dry & Mesic Hilly Pine Woodlands (West Gulf), Upper Coastal Plain Pine Flatwoods
Bachman's Sparrow	*Peucaea* (*Aimophila*) *aestivalis*	All project area states	AL, AR, FL, GA, KY, LA, MD, MO, MS, NC, OH (Extirpated), OK, SC, TN, TX, VA, WV	All?
Northern Bobwhite	*Colinus virginianus*	All project area states	AR, CT, DC, DE, FL, GA, IA, IL, KS, KY, LA, MA, MD, MI, MS, NC, NE, NJ, NY, OH, OK, PA, RI, SC, TX, VA, WI, WV	All?
Pine Warbler	*Setophaga pinus*	All project area states	NJ, OH	All?
Gopher Tortoise	*Gopherus polyphemus*	AL, FL, GA, LA, MS, SC	AL, FL, GA, LA, MS, SC	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands, Mesic Longleaf Pine Flatwoods
Prairie Warbler	*Setophaga discolor*	All project area states	AR, CT, DE, IL, KY, LA, MA, MD, ME, MI, MS, NC, NJ, NY, OH, OK, PR, RI, SC, TN, TX, VA, VI, VT, WV	All?
Eastern Diamondback Rattlesnake	*Crotalus adamanteus*	AL, FL, GA, LA, MS, NC, SC	AL, FL, GA, LA, MS, NC	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands, Mesic Longleaf Pine Flatwoods
Southeastern Pocket Gopher	*Geomys pinetis*	AL, FL, GA	AL, FL, GA	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands
Baird's Pocket Gopher	*Geomys breviceps*	LA, TX		Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands, Dry & Mesic Hilly Pine Woodlands (West Gulf)
Plains Pocket Gopher	*Geomys bursarius*	AR (Izard County), MO	IN, WY	Dry & Mesic Highlands Pine Woodlands
Ozark Pocket Gopher	*Geomys bursarius ozarkensis*	AR	AR	Dry & Mesic Highlands Pine Woodlands

Table 2. Priority Species of Open Pine Woodlands of the Gulf Coastal Plain and Ozarks LCC; relationships derived from literature searches, including US Fish and Wildlife Service Species Profiles

Summary information for Priority Wildlife Species

Brown-headed Nuthatch

Brown-headed nuthatch primarily uses mature pine forests and woodlands, both longleaf pine (*Pinus palustris*) and loblolly pine (*Pinus taeda*). Stands less than 35 years old are probably unsuitable, and deciduous forest does not support the species. The primary management concern is the loss of habitat as a result of lack of fire, conversion of old-growth forest to short-rotation pine plantations, urbanization, and agricultural conversion. Successful management requires the preservation and controlled burning of existing mature pine stands and selective thinning of pole-sized plantation timber. In all suitable habitats, the creation and preservation of snags is essential. Due to its dependence on snags, a site with sufficient standing deadwood to sustain brown-headed nuthatch populations will also likely provide sufficient standing deadwood for other primary and secondary cavity nesting species (NatureServe 2016).

Northern Bobwhite

Within open pine habitats, northern bobwhite requires a well-developed herbaceous layer for nesting and brood cover but also exhibits a negative response to an herbaceous layer that is too dense or shrubby. As the lack of frequent fire allows encroachment of woody species; frequent (2 – 5 year intervals) prescribed fires contribute to development of a robust and diverse herbaceous layer favored by this species. The presence or absence of this species can be used as an indicator of the quality of the herbaceous component in open pine habitat and provides feedback on prescribed management actions.

Bachman's Sparrow

Conversion of longleaf pine stands to plantations of fast-growing pines (mainly loblolly pine and slash pine), shortage of newly abandoned farmland, and urbanization apparently are important factors in the population declines of Bachman's sparrow (Dunning 1993). Bachman's sparrow appears to readily colonize new habitats, although high connectivity among open pine patches likely enhances their dispersal, thus isolated patches of habitat are less likely to support populations. The species requires frequent fire, a well-developed herbaceous understory, and is negatively affected by lack of fire which increases understory and its shrubby components (NatureServe 2016).

Prairie Warbler

Most populations of prairie warbler (*Setophaga discolor*) prefer early successional, shrubby vegetation. Active management with prescribed burning can encourage a broad ecotone or shrubby transition from southern open pine into adjacent vegetative communities. Small areas cannot provide enough suitable habitat, thus a landscape should be managed to provide a mosaic of sites in different stages of succession or time since last prescribed fire. Transitions (including ecotones) or edges of southern open pine areas which are burned less frequently can provide shrubby vegetation for prairie warbler. Declines of the prairie warbler might be influenced by resources in winter (such as on islands in the Caribbean) or by a decrease in old field breeding habitat. Loss of breeding habitat to succession or conversion is the most immediate threat. A loss of early-successional habitats across the range has occurred, as young forests matured and land was converted to residential or industrial uses. Lack of fire is also a cause of habitat loss. Predation and parasitism by cowbirds likely also contribute to declines of prairie warbler (NatureServe 2016).

Red-cockaded Woodpecker

The Red-cockaded woodpecker (*Picoides borealis*) has a fairly large range in the southeastern United States, but both quantity and quality of suitable habitat are much reduced; historical extents of suitable habitat and probably population size have been reduced by about 97 percent. Short-term rotation timber management eliminated mature pines required for roosting, nesting, and foraging; lack of fire has allowed invasion of pine stands by hardwoods. This rare bird is threatened by the loss of habitat (either gradually through incompatible forest management or rapidly through the outright destruction of old-growth forests), forest fragmentation, competition with other species for cavities, catastrophic events such as hurricanes, and demographic and genetic processes affecting populations confined to isolated conservation areas (U.S. Fish and Wildlife Service 2003, Ligon et al. 1986, Walters 1991). Recent management innovations (e.g., more prescribed burns, cavity management) have alleviated certain threats and resulted in population increases in most areas managed for the species, but a stable or increasing trend independent of continuing artificial cavity installation (a short-term solution) can be achieved only when large old pines are available in abundance. Further population increases, independent from continuing artificial cavity installation, eventually should allow the conservation status to become more secure (NatureServe 2016).

Louisiana Pinesnake

The primary factors leading to degradation of Louisiana pinesnake (*Pituophis ruthveni*) habitat are intensive pine silviculture and alteration of the pre-European fire regime (Rudolph et al. 2006), with the lack of prescribed fire. Over time, the extensive loss, degradation, and fragmentation of the longleaf pine ecosystem, coupled with the disruption of natural fire regimes, have resulted in extant Louisiana pinesnake populations that are isolated and small. These remnant populations are now vulnerable to factors associated with low population sizes and demographic isolation, such as reduced genetic heterozygosity. Intensive silviculture and reduction in fire frequency eliminate or reduce the microhabitat conditions needed by pinesnakes and also may result in declines of Baird's pocket gopher (*Geomys breviceps*), a primary prey of Louisiana pinesnake (Rudolph et al. 2006). Restoration measures should include prescribed burning, thinning, and replanting of longleaf pine in appropriate areas (NatureServe 2016).

Northern Pinesnake

The Northern pinesnake (*Pituophis melanoleucus melanoleucus*) uses open areas with early successional vegetation, especially upland pine and pine-oak forests subjected to occasional fire, and prefers dry, forested, or partially forested areas where soil is fairly sandy or loose and gravelly. Closed-canopy forest is often avoided. Northern pinesnakes have been well-studied in the northern part of their range (i.e. New Jersey), although specific habitat characteristics have not been established anywhere throughout its range. In the Coastal Plain, life history and ecology are not as well-documented (Godwin 2016. http://www.outdooralabama.com/northern-pine-snake). Threats to northern pinesnakes include habitat fragmentation, habitat alteration, excessive collecting, and road mortality. Loss of habitat occurs when land is converted to agriculture, housing, or densely planted pine, and remaining areas are often degraded so that their suitability for pinesnakes is greatly diminished. Exclusion of fire leads to the oak component becoming too dominant, and densely stocked stands may not provide adequate openings for nesting or hibernacula.

Black Pinesnake

The Black pinesnake (*Pituophis melanoleucus lodingi*) is associated with dry to xeric, fire-maintained longleaf pine forest with sandy, well-drained soils preferred, usually on hilltops, ridges, and toward the tops of slopes, with open canopy, reduced midstory, and dense herbaceous understory. Riparian areas, hardwood forests, or other closed-canopy conditions are not regularly used (Duran 1998). It will use dry, periodically burned open pine or mixed pine-scrub oak forest with abundant groundcover vegetation. The limited distribution of the Black pinesnake has dwindled with the decline of the longleaf pine ecosystem (Duran 1998). Much habitat has been eliminated through urban development, or conversion to agricultural fields and pine plantations. Most remaining longleaf pine forests on private land are fragmented and degraded by lack of fire. In addition, forest management practices which increase tree stocking densities, and remove downed trees and stumps continue to degrade preferred Black pinesnake habitats. The Black pinesnake was listed as threatened under the Endangered Species Act in 2015 by the U.S. Fish and Wildlife Service (Nelson and Bailey 2016; http://www.outdooralabama.com/black-pine-snake).

Florida Pinesnake

The Florida pinesnake (*Pituophis melanoleucus mugitus*) inhabits areas with well-drained sandy soils and a moderate to open canopy (Franz 1992, Ernst and Ernst 2003). This species can be found from southern South Carolina, west to Mobile Bay in Alabama, south to south Florida (excluding the Everglades) (Conant and Collins 1991, Ernst and Ernst 2003, Florida Natural Areas Inventory 2001). Florida pinesnakes prefer natural habitats including upland pine forests and sandhills, but they are also found in scrubby flatwoods, oak scrub, dry oak forests, old fields, and agricultural borders. Studies have shown that Florida pine snakes, like other species in the genus, are extremely fossorial. Similar to the Louisiana pinesnake, the Florida pinesnake is highly dependent on the southeastern pocket gopher (Geomys pinetis) for food and refugia; a study in southern Georgia found snakes predominantly used G. pinetis burrows as refugia. The Florida pinesnake suffers from loss of habitat: by 1987, 88% of scrub habitat in Florida had been lost to development (Kautz et al. 1993). Habitat loss and fragmentation can result from commercial and residential development, silviculture, mining, and road construction. The lack of fire leads to habitat degradation for the Florida pinesnake due to the encroachment of hardwoods and reduciton in herbaceous vegetation vital for cover and prey. (http://myfwc.com/wildlifehabitats/imperiled/profiles/reptiles/florida-pine-snake/)

Pine Warbler

Perhaps no bird is more characteristic of the pine forests of eastern North America than the Pine warbler (*Setophaga pinus*). This species rarely occurs in purely deciduous vegetation, except uncommonly during migration and occasionally during winter. The Pine warbler is a common breeding bird and permanent resident in the southeastern United States. It breeds at lower densities as far north as southeastern Canada and the northeastern United States, where it is migratory and among the earliest warblers to arrive in spring and latest to depart in fall (Poole and Gill 1992). Some forest management practices, such as clearcutting, should adversely affect the warbler because of its dependence on forest habitat. Single-tree and group-selection cutting, while removing fewer canopy trees from forest areas, may cause increased nest predation from birds and mammals, and nest parasitism from brown-headed cowbirds (*Molothrus ater*). Spread of suburban areas in pine forest regions could also cause local declines or extirpation through increased fragmentation and/or loss of forest habitat (NatureServe 2016).

Gopher Tortoise

The gopher tortoise (*Gopherus polyphemus*) is a large, long-lived, herbivorous terrestrial turtle that is found in six states in the southeastern United States. Gopher tortoises are most commonly found in upland fire-maintained longleaf pine forests and sandhills that are characterized by a deep, well-drained, sandy substrate suitable for construction of burrows. The gopher tortoise prefers relatively open-canopied habitats that provide sunlit areas for nesting and thermoregulation, and ample herbaceous groundcover vegetation for forage (NatureServe 2016).
Historically, gopher tortoises were considered common in upland habitats throughout their range, however, they now have numerous threats including habitat destruction, degradation, and

fragmentation; overharvesting by humans; and disease. Due to low fecundity, gopher tortoise populations which have declined are slow to recover. Management schemes must be formulated to address the needs of the specific population under consideration.

Eastern Diamondback Rattlesnake

The original range of the eastern diamondback rattlesnake (*Crotalus adamanteus*) has been reduced and fragmented by agriculture, forestry practices, urbanization, and plant succession resulting from lack of fire (Martin and Means 2000). Current threats to local populations include conversion of native habitat to planted slash or loblolly pine plantations, agricultural fields, and urban and suburban uses. Human alteration of native longleaf pine upland ecosystems, including fire suppression and lack of prescribed fire, is shrinking and fragmenting the suitable habitat base for this species. Preferred habitats include pine and wiregrass flatwoods, pine-palmetto flatwoods, longleaf pine-turkey oak sandhills, rosemary scrub, mesophytic and coastal maritime hammocks, xeric hammocks, barrier islands and coastal scrub habitats, vicinity of wet savannas, wet prairies (during dry periods), dry prairie, mixed pine-hardwood successional woodland, and abandoned farms and fields (especially near pine-dominated habitats), particularly areas with abundant cover (Mount 1975, Dundee and Rossman 1989, Palmer and Braswell 1995, Tennant 1997, Ernst and Ernst 2003, Campbell and Lamar 2004). Large tracts of habitat are most suitable. Controlled burning that mimics the natural fire frequency and season of burning is the principal management requirement necessary to maintain the landscape in the condition most suitable for this species (NatureServe 2016).

Pocket Gophers

(Consisting of Southeastern Pocket Gopher, Baird's Pocket Gopher, Plains Pocket Gopher, and Ozark Pocket Gopher)

Pocket gophers (*Geomys* spp.) are fossorial rodents named for their fur-lined cheek pouches. Their cheek pouches, or pockets, are used for transporting bits of plant food that they gather while foraging underground. They have special adaptations for their burrowing lifestyle, including clawed front paws for digging, small eyes and ears, and sensitive whiskers and tails. They are also able to close their lips behind their long incisors so that they can use their teeth to loosen soil without getting any dirt in their mouths. Most pocket gopher species are relatively common and not of conservation concern, but serve as a major food source for species of pinesnakes. (National Wildlife Federation) http://www.nwf.org/Wildlife/Wildlife-Library/Mammals/Pocket-Gophers.aspx

Methods

This project began in May of 2014 with the goal of developing rapid assessment desired forest condition metrics for southern open pine ecosystems. It was clear from the start that, in order to be successful, our project core team would need to clearly define goals and terminology, review and incorporate previous research and reports, identify a large group of experts to rely on for additional input and feedback, and engage an even larger group in final review. These steps were necessary to ensure that the resulting protocols were both scientifically sound and widely accepted by stakeholders.

Our project core team began by discussing the project's geographic footprint and our definition of open pine ecosystems. Based on discussions with the project funder (Gulf Coastal Plains and Ozarks Landscape Conservation Cooperative) we determined that the geographic footprint would include all open pine dominated ecosystems of the Gulf Coastal Plains and Ozarks LCC footprint. In addition, we agreed to include all longleaf pine (*Pinus palustris*) and slash pine (*Pinus elliottii*)dominated ecosystems within and outside of the Gulf Coastal Plain and Ozarks LCC footprint (see Figures 1 and 2).

Priority Species

Our team believed it was important to ensure that our approach addressed key priority species dependent on open pine conditions in the Southeast. The wildlife of southern open pine includes birds, mammals, reptiles, and amphibians which depend on these typically grassy, fire prone woodlands.

We heavily borrowed from the Gulf Coastal Plain and Ozarks science agenda when creating our list of species to focus on for the project. As part of developing their science agenda, the Gulf Coastal Plain and Ozarks Landscape Conservation Cooperative had already identified sets of species associated with general ecosystems. This was part of a larger effort to sustain natural resources at desired levels (GCPO LCC Adaptation Science Management Team 2013).

To build the final species list, we started with the "representative species pools" developed for Coastal Plain Open Pine Woodland and Savanna (Appendix F and Table 1), which includes 43 wildlife taxa (GCPO LCC Adaptation Science Management Team. 2013). From the representative species pool, there are about a dozen priority taxa, listed in bold (Appendix F and Table 1). Priority wildlife species of the southern open pine ecosystems are the focus of this project.

Through the science agenda planning process of the Gulf Coastal Plain and Ozarks Landscape Conservation Cooperative (GCPO LCC), the representative species pool had been further focused on a subset of priority species (bold in Appendix F and Table 1, listed in Appendix G and Table 2). We chose these species as the wildlife priorities for our project. Since our project area also includes the southeastern coastal plain, we included additional taxa of pocket gopher and pine snakes. These taxa better represent the similar taxa of the southeastern coastal plain. To see more detailed information about the species, please refer to Appendix G and Table 2. Status reviews for the wildlife species in the above tables can be found on NatureServe Explorer.

Definition of Southern Open Pine

To ensure that our protocols were based on clearly defined parameters, we next worked to create a draft definition of open pine. Our core team used a combination of expert opinion and definitions from previous reports (see Table 4) to craft a draft definition for southern open pine. We then identified additional experts outside of the group to review the open pine draft and submit additional edits before finalizing the definition in Summer 2014. The project definition of southern open pine is as follows:

In the southeastern United States, there are several large-scale (or formerly large-scale) ecosystems dominated by an open canopy of pine trees that are used by a great variety of game and non-game wildlife species and plants. Due to changes in land use and fire regime, these open pine ecosystems have undergone extensive declines over the last 100 years and continue to be threatened with further decline. These ecosystems are found from the West Gulf Coastal Plain and Ozark and Ouachita Mountains to the Southern Appalachians, Piedmont, Atlantic and East Gulf Coastal Plains, and south into the Florida Peninsula. In the past, these ecosystems have consisted of open pine stands with a diverse ground cover composed of native warm-season grasses and forbs, often with some low shrubs and only sparse tall shrubs. These open conditions were historically maintained by natural processes, including fire and grazing. Today, these ecosystems require active management to maintain or to restore the open herbaceous conditions preferred by a large suite of wildlfe species. While these ecosystems occur across the southeastern United States, this current project more specifically focuses on southern open pine wildlife systems dominated by southern yellow pines, particularly longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*), which occur in the southern coastal plains and the Ozark and Ouachita mountains. We also focus on natural stands of slash pine (*Pinus elliottii*) and loblolly pine (*Pinus taeda*).

Southern Open Pine Groupings

Once we determined the geographic footprint of the study and the definition of open pine, we then needed to compile and finalize the ecological community types that would be included as open pine types so that we could focus effort on those types and avoid getting distracted by other adjacent community types that are out of scope. NatureServe ecologists queried the latest version of the United States National Vegetation Classification (USNVC) (NatureServe 2016) to identify and list all associations that were considered to be part of "open pine" ecosystems. Since the list included many associations, it was impractical to develop separate sets of metrics for each ecosystem at the association scale. Instead, USFWS and NatureServe ecologists grouped associations that shared key ecological and geographical characteristics to create seven groupings of associations called "Southern Open Pine Groupings".

Our development and definition of the Southern Open Pine Groupings was built upon previous work that had been completed on the Terrestrial Ecological Systems Classification by NatureServe ecologists and state partners (Comer et al. 2003). Ecological systems represent recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding. They are intended to provide a classification unit that is readily mappable, often from remote imagery, and readily identifiable by conservation and resource managers in the field. A previous collaboration between NatureServe and the Southeast Region of the U.S. Fish and Wildlife Service had resulted in an arrangement that placed the Terrestrial Ecological Systems of the Southeastern United States into an informal hierarchy for habitat classification purposes (M. Pyne and C. Hunter pers. comm.). The upper levels of this informal hierarchy are known as "Groups of Ecological Systems" (GES) and "Broadly Defined Habitats" (BDH).

This arrangement of Broadly Defined Habitats as a habitat framework has been adopted by the Gulf Coast Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC). It is available at: http://tinyurl.com/GCPOLCC-Sci-Agenda. This habitat type delineation was adopted by the LCC because it is broadly applicable geographically for both terrestrial and aquatic systems, has a limited subset of habitat types that are universally recognizable, and these habitat types are readily mappable to many existing classification systems (GCPO LCC 2013).

These units served as a useful reference point to resolve and refine the conceptual limits of the final Southern Open Pine Groupings that we used for this project. While this process of refining the units was underway, NatureServe was also finalizing the concepts and descriptions of new middle level units of the USNVC at a global scale. These units immediately above the Alliance are known as the Group and Macrogroup, and are based on combinations of dominant and diagnostic growth forms, compositional similarity, and dominant and diagnostic plant species that reflect continental and regional biogeographic factors. The final suite of Open Pine Groupings (Table 3) bears a close relationship to the related Groups of the revised USNVC (G009 Dry-Mesic Loamy Longleaf Pine Woodland, G013 Loblolly & Shortleaf Pine - Oak Forest & Woodland, G130 Loblolly Pine & Hardwood Wet Flatwoods, G596 Mesic Longleaf Pine Flatwoods - Spodosol Woodland, G012 Shortleaf Pine - Oak Forest, G190 Wet-Mesic Longleaf Pine Woodland, and G154 Xeric Longleaf Pine Woodland).

After additional expert review and edits, these seven Southern Open Pine Groupings became our base units for developing rapid assessment metrics, allowing us to be most efficient in development and application of metrics while also allowing flexibility where there was a need to apply metrics in different ways to different habitat groupings.

Southern Open Pine Groupings	**US NVC Group**
Dry & Mesic Longleaf Pine Woodlands	G009
Mesic Longleaf Pine Flatwoods	G596
Wet Longleaf & Slash Pine Flatwoods & Savannas	G190
Xeric Longleaf Pine Barrens	G154
Dry & Mesic Highlands Pine Woodlands	G012
Dry & Mesic Hilly Pine Woodlands	G012, G013
Upper Coastal Plain Pine Flatwoods	G130

Table 3. Crosswalk of Southern Open Pine Groupings, and US NVC Group codes.

Review of Literature and Previous Studies

Throughout 2014, our team compiled all relevant literature and previous studies pertaining to open pine condition and drafted a list of metrics and descriptions to be proposed for inclusion in our final products (see Literature Cited for a full list of the references used in this study and Table 4 below for a subset of the key projects that we drew from most heavily for this work).

Important Background Reports and Studies
Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2015. Appendix 1. Desired Future Conditions (DFC) for Shortleaf Pine-bluestem and Pine-oak Restoration Sites in the Interior Highlands. Pages 12-31 in Fitzgerald, J. and T. Foti. 2015. The Interior Highlands Shortleaf Pine Restoration Initiative: An Overview (6 August 2015 Draft). Central Hardwoods Joint Venture.
Bragg, Don C. 2002. Reference conditions for old-growth pine forests in the Upper West Gulf Coastal Plain. Jour. Torrey Botanical Society 129(4):261-288.
Bragg, Don C., Ricky O'Neill, William Holimon, Joe Fox, Gary Thornton, and Roger Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.
FNAI and FFS. 2014. Longleaf Pine Ecosystem Geodatabase v.1 Final Report. A cooperative project between Florida Natural Areas Inventory and the Florida Forest Service. <http://www.fnai.org/LongleafGDB.cfm>
GCPO LCC Adaptation Science Management Team. 2013. Integrated Science Agenda, Draft v4. Gulf Coastal Plains & Ozarks Landscape Conservation Cooperative. 5/6/2013. Starkville, MS. <http://lccnetwork.org/sites/default/files/Resources/GCPO_draft_integrated_science_agenda_5-6-2013.pdf> Accessed 7 January 2016.
Hinderliter, M. 2014. Gopher Tortoise Open Pine DFCs. US Fish and Wildlife Service. Jackson, MS.
James, Frances C., Charles A. Hess; Bart C. Kicklighter; and Ryan A. Thum. 2001. Ecosystem Management and the Niche Gestalt of the Red-Cockaded Woodpecker in Longleaf Pine Forests. Ecological Applications 11(3): 854-870.
Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America's Longleaf Restoration Initiative, Longleaf Partnership Council.
Lower Mississippi Valley Joint Venture WGCPO Landbird Working Group. 2011. West Gulf Coastal Plain/Ouachitas Open Pine Landbird Plan. A Report to the Lower Mississippi Valley Joint Venture Management Board. <http://www.lmvjv.org/library/WGCPO_Landbird_Open_Pine_Plan_Oct_2011.pdf>
McIntyre, R.K. 2012. Longleaf Pine Restoration Assessment: Conservation Outcomes and Performance Metrics. Final Report with financial support provided by the National Fish and Wildlife Foundation and the Robert W. Woodruff Foundation. Joseph W. Jones Ecological Research Center.
NatureServe. 2006. International Ecological Classification Standard: Terrestrial Ecological Classifications. Classification and Integrity Indicators for Selected Forest Types of Office Depot's Sourcing Areas of the Southeastern United States. NatureServe Central Databases. Arlington, VA. Data current as of 29 March 2006.
NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.
Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (Peucaea aestivalis). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.
The National Bobwhite Technical Committee. 2011. Palmer, W. E., T. M. Terhune, and D. F. McKenzie (eds.). The National Bobwhite Conservation Initiative: A range-wide plan for recovering bobwhites. National Bobwhite Technical Committee Technical Publication, ver. 2.0 , Knoxville, TN.
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.

Table 4. Important Background Reports and Studies

Stakeholder and Expert Meetings to Refine Metrics

To ensure that our overall process included broad stakeholder and expert input, we sponsored two in-person meetings (in Newton, GA and Knoxville, TN) in 2015. At these meetings, our team used a highly inclusive process to engage as many voices as possible. We presented draft metrics and metric descriptions derived from literature and expert opinion, and facilitated a multi-day discussion to collect input on the metrics themselves as well as input on the wildlife habitat value and ecological integrity value for different measures for each metric. Key questions we explored included:

- Which metrics are most important in determining overall wildlife habitat value or ecological integrity?
- How do we best define each metric?
- What are the metric values that are associated with high, medium, and low wildlife habitat value in southern open pine ecosystems?

Table 5. Participants at in-person project meetings in Newton, GA and Knoxville, TN.

Name	Affiliation	State
Sara Aicher	US Fish & Wildlife Service	GA
Wally Akins	Tennessee Wildlife Resources Agency	TN
McRee Anderson	The Nature Conservancy	AR
Joanne Baggs	US Forest Service	GA
Haven Barnhill	US Fish & Wildlife Service	GA
Amity Bass	Natural Heritage Program, Louisiana Department of Wildlife and Fisheries	LA
Mike Black	Shortleaf Initiative	TN
Martin Blaney	Arkansas Game and Fish Commission	AR
Forbes Boyle	US Fish & Wildlife Service	GA
Randy Browning	US Fish & Wildlife Service	MS
Gary Burger	South Carolina DNR	SC
Brian Camposano	Florida Forest Service	FL
Clarence Coffey	Tennessee Wildlife Resources Agency (Retired)	TN
Mike Conner	Jones Center	GA
Jack Culpepper	US Fish & Wildlife Service	SC
Carol Denhof	Longleaf Alliance	AL
Matt Elliott	Georgia DNR, Wildlife Resources Division	GA
Tom Foti	Arkansas Natural Heritage Commission	AR
John Gruchy	Mississippi Department of Wildlife, Fisheries, and Parks	MS
Jim Guldin	USFS Research Station	AR
Matt Hinderliter	US Fish & Wildlife Service	MS
Dan Hipes	Florida Natural Areas Inventory	FL
Chuck Hunter	US Fish & Wildlife Service	GA
Nancy Jordan	US Fish & Wildlife Service	SC
Gary Kauffman	US Forest Service	NC
Amy Knight	Florida Natural Areas Inventory	FL
Lisa Kruse	Georgia DNR, Wildlife Resources Division	GA
Jeff Marcus	The Nature Conservancy	NC
Will McDearman	US Fish & Wildlife Service	MS
Kevin McIntyre	Jones Center	GA
Carl Nordman	NatureServve	NC

Name	Affiliation	State
Chris Oswalt	US Forest Service	TN
Milo Pyne	NatureServe	NC
Joseph Reinman	US Fish & Wildlife Service	FL
Catherine Rideout	East Gulf Coastal Plain Joint Venture	GA
Bryan Rupar	Arkansas Natural Heritage Commission	AR
Carl Schmidt	US Fish & Wildlife Service	GA
Al Schotz	Alabama Natural Heritage Program, Auburn University	AL
Jon Scott	National Fish and Wildlife Foundation	DC
Doyle Shook	Lower Mississippi Joint Venture	AR
Lora Smith	Jones Center	GA
Andy Vanderyacht	Center for Native Grasslands Management	TN
Joan Walker	USFS Research Station	SC
Russ Walsh	US Fish & Wildlife Service	MS
Clay Ware	US Fish & Wildlife Service	GA
Rickie White	NatureServe	NC
Ben Wigley	NCASI	SC
Randy Wilson	US Fish & Wildlife Service	MS
Doug Zollner	The Nature Conservancy	AR

For each workshop, we invited more than 50 potential participants who represented key stakeholder and expert groups. During the workshops, we applied the Delphi method (Hsu and Sandford 2007), which was designed to maximize participant input in complex scenarios in a structured way. We then summarized the input and presented it back to the group to allow for a second round of expert input. From this process we created graphs that summarized mean and median perceived values to wildlife for each metric in each Southern Open Pine Grouping. We also used measures of variation (standard error and maximum and minimum scores) to assess whether scores were relatively bunched together or widely divergent (see figures 3 and 4). For any scores that were widely divergent, we circled back with experts to determine what might be causing this lack of consensus and attempted to address and reintroduce the metric descriptions.

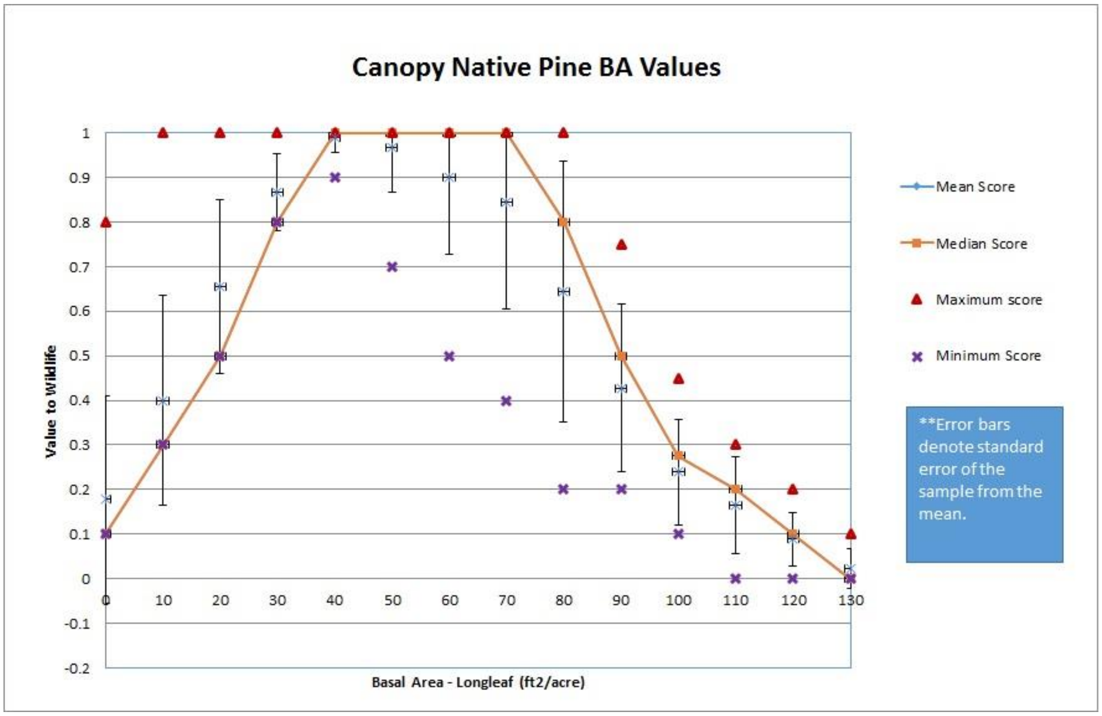

Figure 3. Example graph showing scores developed based on expert input.

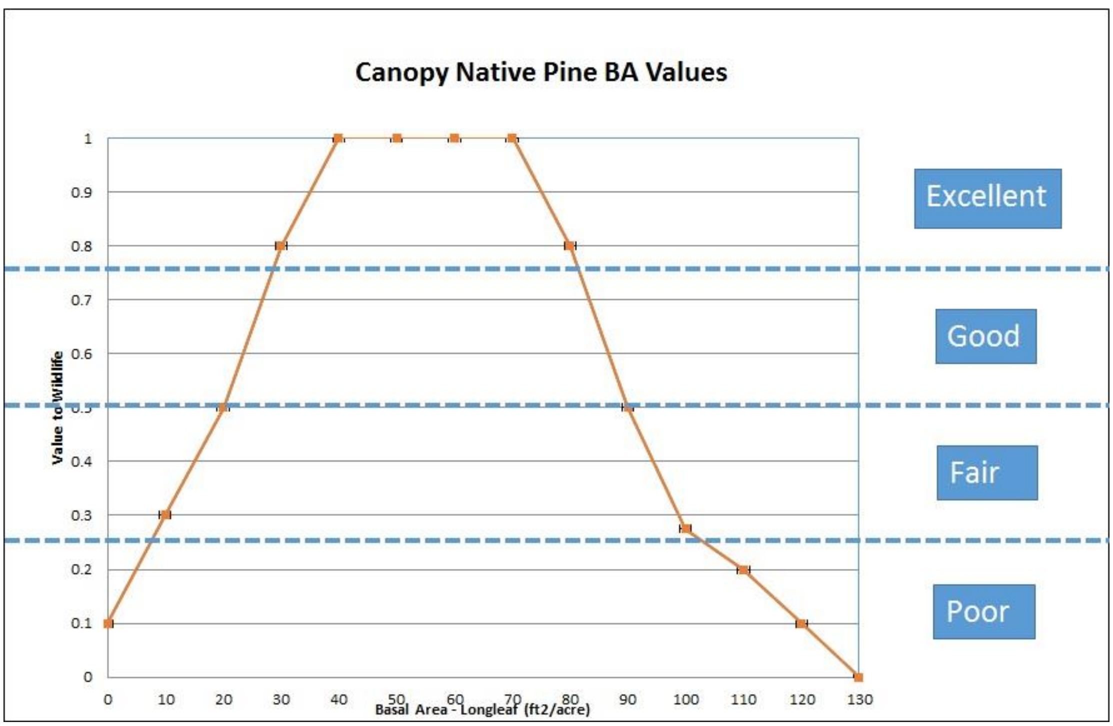

Figure 4. Example of output of Delphi process.

Our starting point for all scoring, for longleaf and other pines, was the Longleaf Partnership Council longleaf metrics (where they applied). We then used the Delphi process (Hsu and Sandford 2007) with experts to generate the value curves (i.e., habitat suitability curves) using median values (see Figure 3 above), then vetted these initial scores with additional experts for review to generate the final curves (see Figure 4 above). Because the y-axis represents values scored 0-1 with 1 being optimum, we used 25^{th} percentiles to determine excellent (>0.75), good (0.5-0.75), fair (0.25-0.5), and poor (<0.25). Because these break points results in very specific and non-intuitive metric scores (e.g., 28 BA), we rounded up or down to the nearest whole number using increments of 5 for the x-axis values (e.g., 30BA). As a result, these metric values represent general approximations of habitat suitability for priority wildlife species and ecological integrity.

Our project core team considered all final input (both potential edits to metrics and changes to metric value "cutoffs") and incorporated these as best as possible into the final version of the metrics. In addition, we worked with the same team of experts to determine which metrics deserved further development, which ones should be considered optional rather than core metrics, and which were to be dropped altogether.

External Review of Metrics

The process of engaging experts and refining metrics into a draft suitable for final review lasted from January 2015 to October 2015. At that point, we had incorporated input from over 60 expert participants from the full range of stakeholder sectors. We identified a larger set of teams and individuals from which to solicit further input. We sent the metrics out to all Migratory Bird Joint Ventures in the region, longleaf implementation teams, and a long list of additional stakeholders for further input. Once that input was received, we compiled it and used it to improve the final metrics that are being released in this report.

Based on expert input, we dropped some metrics that we had considered to be important and added at least one new metric. We removed downed coarse woody debris and snag metrics due to consensus from reviewers that these were not helpful or reliable indicators since scores for these metrics are often highly variable between stands with similar condition and wildlife habitat value. In addition, we removed fire frequency since reviewers felt that other metrics captured the effects of fire better than any rapid field based fire frequency estimate. Fire frequency is better used as a natural resource management benchmark than as a stand condition metric. We added the stand density index at the urging of a sizable number of reviewers to help address concerns reviewers have about the ability of basal area and cover measures to adequately indicate ecosystem health.

Results

Our effort to develop rapid assessment metrics culminated in choosing a set of 13 metrics that serve as the best indicators of ecological health. When taken together, these indicators can help land managers and other interested parties understand the ecological health of their open pine forest stands. These 13 metrics are in three subsets representing the canopy, midstory, and ground layer. This approach of grouping metrics by strata allows users to assess the condition of the canopy, midstory, and ground layer separately (Longleaf Partnership Council 2014).

This document focuses on stand-level metrics. These metrics are best implemented within a similarly managed stand to assess the ecological health at that scale. We have not addressed the landscape scale, an equally important part of ecological health. Landscape scale metrics such as size, landscape context, and buffers help us distinguish between areas that may have high levels of integrity at a smaller scale but may not sustain priority wildlife long term because of their small stand size. We hope to address landscape scale metrics in future work.

To implement these rapid assessment metrics, users must first choose the open pine habitat grouping which best fits the area they are managing (in essence, the ecosystem type). This could be implemented in one of two ways: 1) the area of interest is currently considered to be in one or more of these habitat groupings or 2) the manager wishes to restore one of these habitat groupings in an area that has been degraded and whose current land cover is not open pine. Below is a summary of the seven habitat groupings we have developed.

Summary Descriptions of Open Pine Habitat Groupings

Southern Open Pine Groupings are broad ecological classification units for southern open pine wildlife habitats, encompassing woodlands with relatively open, pine-dominated canopies and grassy understories. These woodlands are fire dependent and many examples occur on infertile soils. These Southern Open Pine Groupings are related to the variation in vegetation structure or physiognomy, dominant and characteristic species, soils, landform, and biogeography of open pine habitats across the southeastern United States. They are comparable to Groups of the U.S. National Vegetation Classification and are compliant with the standards for vegetation from the Federal Geographic Data Committee (Faber-Langendoen et al. 2009, Faber-Langendoen et al. 2012, Faber-Langendoen et al. 2014, FGDC 2008). These Southern Open Pine Groupings are also closely related to the Groups of Ecological Systems used by the U.S. Fish and Wildlife Service (Pyne et al. 2013) and are related to several widely used classifications of vegetation, natural communities, and ecological systems (Comer et al. 2003, Edwards et al. 2013, Eyre 1980, FNAI 2010, Palmquist et al. 2016, Peet 2006).

The Groups of Ecological Systems (GES) referred to below lump significantly different ecosystems together under Shortleaf-Loblolly Woodlands and under Longleaf - Slash Flatwoods. The Southern Open Pine Groupings were supported in the stakeholder and expert meetings. There was consensus that the Dry & Mesic Highlands Pine Woodlands, Dry & Mesic Hilly Pine Woodlands, and Upper Coastal Plain Pine Flatwoods should be used for the application of metrics. Likewise, the Mesic Longleaf Pine Flatwoods, and Wet Longleaf & Slash Pine Flatwoods & Savannas were also recognized as distinct. These Southern Open Pine Groupings seem to appropriately represent the broadly distinguished southern open pine ecosystems for the purposes of defining the desired future condition rapid assessment metrics.

Groups of Ecological Systems (GES)	Southern Open Pine Groupings	US NVC Group
Longleaf Woodlands	Dry & Mesic Longleaf Pine Woodlands	G009
Longleaf - Slash Flatwoods	Mesic Longleaf Pine Flatwoods	G596
Longleaf - Slash Flatwoods	Wet Longleaf & Slash Pine Flatwoods & Savannas	G190
Longleaf-Turkey Oak Sandhills	Xeric Longleaf Pine Barrens	G154
Mountain Longleaf	Dry & Mesic Highlands Pine Woodlands	G012
Shortleaf-Loblolly Woodlands	Dry & Mesic Highlands Pine Woodlands	G012
Shortleaf-Loblolly Woodlands	Dry & Mesic Hilly Pine Woodlands	G012
Shortleaf-Loblolly Woodlands	Dry & Mesic Hilly Pine Woodlands	G013
Shortleaf-Loblolly Woodlands	Upper Coastal Plain Pine Flatwoods	G130

Table 6. Crosswalk of Groups of Ecological Systems, Southern Open Pine Groupings, and US NVC Group codes.

The general information provided for each of the seven Southern Open Pine Groupings comes from the Type Concept and Geographic Range fields of NatureServe's Ecology Element Databases (NatureServe 2015). These data have been edited to follow the Southern Open Pine Groupings. These different ways of organizing information about "open pine" vegetation and other plant community and habitat types is presented as a way of referencing the other arrangements, which were developed at different times and for different purposes. The Southern Open Pine Groupings were designed specifically for this project and differ in some respects from the other arrangements which are part of classifications which are more comprehensive both conceptually and in a regional sense.

Dry & Mesic Longleaf Pine Woodlands

These stands of longleaf pine are on sandy to loamy soils on gently rolling uplands, broad ridgetops, side slopes, and in mesic swales and terraces. The canopy is open, with irregularly scattered longleaf pine trees, clumps of midstory scrub oaks and a grassy understory of wiregrass, bluestems, Indian grasses, with a variety of composites and legumes. It is found from southeastern Virginia to east Texas, including most of Florida.

Mesic Longleaf Pine Flatwoods

These open pine woodlands are found on flat sites on soils with a spodic horizon which can cause sites to be wet in the winter and dry in the summer. Sites are mostly mesic upland flats but also include moist flats. These open woodlands have irregularly scattered longleaf pine, slash pine or South Florida slash pine and an herbaceous layer with wiregrass, bluestems, Indian grasses, and with a variety of composites and legumes. Low shrubs, including saw palmetto, blueberries, huckleberries and hollies may be abundant. Mesic Longleaf Pine Flatwoods are found from southeastern Virginia to southern Mississippi, including most of Florida. It might occur in Louisiana, and occurs only in very small areas in eastern Texas.

Wet Longleaf & Slash Pine Flatwoods & Savannas

Wet pine flatwoods and savannas are characterized by wet mineral soils with seasonally high water tables, on a wide range of soil textures in low elevation areas of the outer coastal plains. In natural condition, canopies are open and mostly dominated by longleaf pine. There is a diverse mix of grasses, herbs, and low shrubs in high-quality stands. Among the grasses, wiregrass often dominates high quality sites, but toothache grass, cutover muhly, little bluestem, Florida dropseed, Carolina dropseed, wireleaf dropseed, chalky bluestem, other bluestems, or other grasses may also dominate. The Wet Longleaf &

Slash Pine Flatwoods & Savannas range from eastern Texas across the Gulf Coastal Plain to Florida, and north in the Atlantic Coastal Plain to southern Virginia.

Xeric Longleaf Pine Barrens

Xeric Longleaf Pine Barrens are open woodlands dominated by longleaf pine with an understory of turkey oak. Bluejack oak and sand post oak occur in the subcanopy, but not on the coarsest dry sands. Turkey oak is absent west of the Mississippi River, where it is replaced by bluejack oak. Sites are consistently dry and have low nutrient availability. All but the driest associations have a well-developed grass layer with little bluestem common throughout, often with wiregrass. The gopher tortoise is a keystone protected species that digs extensive subterranean burrows in deep dry sandy soils within this habitat; hundreds of other species rely on its burrows for shelter. This vegetation occurs in the coastal plain from North Carolina south to Florida and west to eastern Texas.

Dry & Mesic Highlands Pine Woodlands

Dry & Mesic Highlands Pine Woodlands have their most extensive areas in the Ozark-Ouachita Highlands, with shortleaf pine (*Pinus echinata*) as the canopy dominant. Also included, in certain areas of Alabama, Georgia, and the Carolinas are Mountain and Piedmont longleaf pine woodlands, which generally are mixed with oaks, shortleaf pine, hickories, and other hardwoods. In more open stands the understory is characterized by big bluestem, little bluestem, and other prairie grasses and forbs.

Dry & Mesic Hilly Pine Woodlands

These Coastal Plain upland woodlands are dominated by a mix of shortleaf pine and loblolly pine with hardwoods, primarily white oak, southern red oak, post oak, and the scrub oaks bluejack oak, sand post oak, and Arkansas oak. Other trees include black oak, mockernut hickory, black hickory, hawthorn, and hophornbeam. Some typical grasses include woodoats, roundseed panicgrass, and little bluestem.

Upper Coastal Plain Pine Flatwoods

These are nonriverine wetland pine-hardwood forests of the Atlantic and Gulf coastal plains, and are well known from the coastal plain of southern Arkansas and northern Louisiana. Stands are primarily dominated by loblolly pine with shortleaf pine interspersed with laurel oak, swamp chestnut oak, and willow oak, and also with a variety of other hardwoods, including sweetgum, swamp tupelo, and blackgum. It occurs on Pleistocene high terraces or other high flat landforms. Wet hardwood flatwoods occur on seasonally flooded depressions within these terraces. Both types are precipitation driven wetlands in a hydrogeomorphic classification. Within its range, dwarf palmetto (*Sabal minor*) will be abundant in the lower strata of some stands.

Summaries of Metrics by Habitat Grouping

As part of our collaborative process to create metrics, we determined that each habitat grouping varied enough to justify its own set of metrics. The metrics are summarized for each of the seven habitat groupings below. Please refer to Appendix C for more detailed information on each of the metrics.

Dry & Mesic Longleaf Pine Woodlands				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	30-80 ft^2/acre basal area of longleaf pine	20 to <30 or >80 to 90 ft^2/acre basal area of longleaf pine	10 to <20 or >90 to 105 ft^2/acre basal area of longleaf pine	<10 or >105 ft^2/acre basal area of longleaf pine
Southern Yellow Pine Canopy Cover	30-65% canopy cover of longleaf pine	>20 to <30% canopy cover or >65 to 75% canopy cover of longleaf pine	10-20% canopy cover or >75 to 85% canopy cover of longleaf pine	<10% cover or >85% cover of longleaf pine
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf pine of any diameter and/or longleaf pine trees ≥14" DBH class	BA ≥10 ft^2/acre of longleaf pine trees ≥14" DBH class	Longleaf pine trees ≥ 14" DBH class are present, but at <10 ft^2/acre BA	No longleaf pine trees ≥14" DBH or flat-top longleaf pine are present
Canopy Hardwood Basal Area	<20 ft^2/acre BA of hardwood trees	≥20 to 25 ft^2/acre BA of hardwood trees	>25 to 35 ft^2/acre BA of hardwood trees	>35 ft^2/acre BA of hardwood trees
Stand Density Index (applies to longleaf pine)	SDI = 60 – 125 (15 - 31% of Maximum SDI of 400)	SDI = 40 – 60 or 125 - 160 (10-15% or 31-40% of Maximum SDI of 400)	SDI = 20 – 40 or 160 - 200 (5-10% or 40-50% of maximum SDI)	SDI <20 or >200 (<5% or >50%, 240 is 60% of Maximum SD of 400)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<15% cover of midstory fire tolerant hardwoods	15 to <20% cover of midstory fire tolerant hardwoods	20-25% cover of midstory fire tolerant hardwoods	>25% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	20 to <30% cover of woody midstory	30-40% cover of woody midstory	>40% cover of woody midstory
Short Shrub (<3 ft tall) Cover	Short shrubs average <30% cover	Short shrubs average 30 to 35% cover	Short shrubs average >35 to 45% cover	Short shrubs average >45% cover
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <20% cover.	Tall shrubs average 20 to 30% cover.	Tall shrubs average >30 to 40% cover.	Tall shrubs average >40% cover.
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	40-98% herbaceous cover	30 to <40% or >98% herbaceous cover	20 to <30% herbaceous cover	<20% herbaceous cover
Longleaf Pine Regeneration	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand
Native Warm Season Grass Cover	>25 to 97% foliar cover of all native warm season grasses	>15 to 25% or >97% foliar cover of native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Mesic Longleaf Pine Flatwoods				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	30-80 ft^2/acre basal area of longleaf or slash pine	20 to <30 or >80 to 90 ft^2/acre basal area of longleaf or slash pine	10 to <20 or >90 to 105 ft^2/acre basal area of longleaf or slash pine	<10 or >105 ft^2/acre basal area of longleaf or slash pine
Southern Yellow Pine Canopy Cover	30 to 65% canopy cover of longleaf or slash pine	20 to <30% canopy cover or >65 to75% canopy cover of longleaf or slash pine	10 to <20% canopy cover or >75 to 85% canopy cover of longleaf or slash pine	<10% cover or >85% cover of longleaf or slash pine
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf or slash pine of any diameter and/or longleaf or slash pine trees ≥14” DBH class	BA ≥10 ft^2/acre of longleaf or slash pine trees ≥ 4” DBH class	Longleaf or slash pine trees ≥14” DBH class are present, but at < 10 ft^2/acre BA	No longleaf or slash pine trees ≥14” DBH or flat-top slash or longleaf pine
Canopy Hardwood Basal Area	<20 ft^2/acre BA of hardwood trees	≥20 to 25 ft^2/acre BA of hardwood trees	>25 to 35 ft^2/acre BA of hardwood trees	>35 ft^2/acre BA of hardwood trees
Stand Density Index (applies to longleaf and slash pine)	SDI = 60 – 125 (15 - 31% of Maximum SDI of 400)	SDI = 40 – 60 or 125 - 160 (10-15% or 31-40% of Maximum SDI of 400)	SDI = 20 – 40 or 160 - 190 (5-10% or 40-48% of maximum SDI)	SDI <20 or >190 (<5% or >48%, 240 is 60% of Maximum SD of 400)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10 to <20% cover of midstory fire tolerant hardwoods	20 to 25% cover of midstory fire tolerant hardwoods	>25% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	20 to <30% cover of woody midstory	30-40% cover of woody midstory	>40% cover of woody midstory
Short Shrub (<3 ft tall) Cover	Short shrubs average <30% cover	Short shrubs average 30 to <40% cover	Short shrubs average 40-45% cover	Short shrubs average >45% cover
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <20% cover.	Tall shrubs average 20 to <30% cover.	Tall shrubs average 30-35% cover.	Tall shrubs average >35% cover.
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	40-98% herbaceous cover	30 to <40% or >98% herbaceous cover	20 to <30% herbaceous cover	<20% herbaceous cover
Longleaf Pine Regeneration	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand
Native Warm Season Grass Cover	>25 to 97% foliar cover of all native warm season grasses	>15 to 25% or >97% foliar cover of native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Wet Longleaf & Slash Pine Flatwoods & Savannas				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	20-80 ft^2/acre basal area of longleaf or slash pine	10 to <20 or >80 to <90 ft^2/acre basal area of longleaf or slash pine	5 to <10 or 90 to <100 ft^2/acre basal area of longleaf or slash pine	<5 or ≥100 ft^2/acre basal area of longleaf or slash pine
Southern Yellow Pine Canopy Cover	20-65% canopy cover of longleaf or slash pine	15 to <20% canopy cover or >65-75% canopy cover of longleaf or slash pine	10 to <15% canopy cover or >75-85% canopy cover of longleaf or slash pine	<10% cover or >85% cover of longleaf or slash pine
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf or slash pine of any diameter and/or longleaf or slash pine trees ≥14" DBH class	BA ≥10 ft^2/acre of longleaf or slash pine trees ≥14" DBH class	Longleaf or slash pine trees ≥14" DBH class present, but at <10 ft^2/acre BA	No longleaf or slash pine trees ≥14" DBH or with flat-top slash or longleaf pine
Canopy Hardwood Basal Area	<20 ft^2/acre BA of hardwood trees	≥20 to 25 ft^2/acre BA of hardwood trees	>25 to 35 ft^2/acre BA of hardwood trees	>35 ft^2/acre BA of hardwood trees
Stand Density Index (applies to longleaf and slash pine)	SDI = 35 – 120 (9 - 30% of Maximum SDI of 400)	SDI = 20 – 35 or 120 - 155 (5-9% or 30-39% of Maximum SDI of 400)	SDI = 10 – 20 or 155 - 180 (2.5-5% or 39-45% of maximum SDI)	SDI <10 or >180 (<2.5% or > 45%, 240 is 60% of Maximum SD of 400)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-15% cover of midstory fire tolerant hardwoods	>15 to 25% cover of midstory fire tolerant hardwoods	>25% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	20-30% cover of woody midstory	>30 to 40% cover of woody midstory	>40% cover of woody midstory
Short Shrub (<3 ft tall) Cover	Short shrubs average <30% cover	Short shrubs average 30 to <40% cover	Short shrubs average 40-45% cover	Short shrubs average >45% cover
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average < 15% cover.	Tall shrubs average 15 to <25% cover.	Tall shrubs average 25-35% cover.	Tall shrubs average >35% cover.
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	40-100% herbaceous cover	30 to <40% herbaceous cover	20 to <30% herbaceous cover	<20% herbaceous cover
Longleaf Pine Regeneration	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand
Native Warm Season Grass Cover	25-97% foliar cover of all native warm season grasses	>15 to <25% or >97% foliar cover of native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Xeric Longleaf Pine Barrens

Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	25-80 ft^2/acre basal area of longleaf pine	>15 to <25 or >80 to 90 ft^2/acre basal area of longleaf pine	10 to 15 or >90 to <100 ft^2/acre basal area of longleaf pine	<10 or ≥100 ft^2/acre basal area of longleaf pine
Southern Yellow Pine Canopy Cover	>20 to 55% canopy cover of longleaf pine	>15 to 20% canopy cover or >55 to 70% canopy cover of longleaf pine	5-15% canopy cover or >70 to 80% canopy cover of longleaf pine	<5% cover or >80% cover of longleaf pine
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf pine of any diameter and/or longleaf pine trees ≥12" DBH class	BA ≥10 ft^2/acre of longleaf pine trees ≥12" DBH class	Longleaf pine trees ≥12" DBH class are present, but at <10 ft^2/acre BA	No longleaf pine trees ≥12" DBH or flat-top longleaf pine are present
Canopy Hardwood Basal Area	<20 ft^2/acre BA of hardwood trees	≥20 to 25 ft^2/acre BA of hardwood trees	>25 to 35 ft^2/acre BA of hardwood trees	>35 ft^2/acre BA of hardwood trees
Stand Density Index (applies to longleaf pine)	SDI = 50 – 120 (13 - 30% of Maximum SDI of 400)	SDI = 30 – 50 or 120 - 160 (8-13% or 30-40% of Maximum SDI of 400)	SDI = 20 – 30 or 160 - 180 (5-8% or 40-45% of maximum SDI)	SDI <20 or >180 (<5% or >45%, 240 is 60% of Maximum SD of 400)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-20% cover of midstory fire tolerant hardwoods	>20 to 25% cover of midstory fire tolerant hardwoods	>25% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	20 to <30% cover of woody midstory	30-40% cover of woody midstory	>40% cover of woody midstory
Short Shrub (<3 ft tall) Cover	Short shrubs average <25% cover	Short shrubs average 25 - 35% cover	Short shrubs average >35 to 45% cover	Short shrubs average >45% cover
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 to <25% cover.	Tall shrubs average 25-30% cover.	Tall shrubs average >30% cover.
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	40-100% herbaceous cover	>25 to <40% herbaceous cover	>15 to 25% herbaceous cover	0-15% herbaceous cover
Longleaf Pine Regeneration	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand
Native Warm Season Grass Cover	25-95% foliar cover of all native warm season grasses	15 to <25% or >95% foliar cover of native warm season grasses	10 to <15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Dry & Mesic Highlands Pine Woodlands				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft^2/acre basal area of shortleaf pine	30 to 35 or >75 to 90 ft^2/acre basal area of shortleaf pine	10 to <30 or >90 to 110 ft^2/acre basal area of shortleaf pine	<10 or >110 ft^2/acre basal area of shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of shortleaf pine	20-25% or >70 to 80% canopy cover of shortleaf pine	10 to <20% or >80 to 90% canopy cover of shortleaf pine	<10% or >90% canopy cover of shortleaf pine
Southern Yellow Pine Stand Age Structure	Basal area ≥20 ft^2/acre of shortleaf pine trees ≥14" DBH class	Basal area ≥10 ft^2/acre of shortleaf pine trees ≥14" DBH class	Shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No shortleaf pine trees ≥14" DBH are present
Canopy Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 40 ft^2/acre BA of hardwood trees	>40 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees
Stand Density Index (applies to shortleaf pine)	SDI = 65 – 135 (14 - 30% of Maximum SDI of 450)	SDI = 45 – 65 or 135 - 180 (10-14% or 30-40% of Maximum SDI of 450)	SDI = 20 – 45 or 180 - 225 (4-10% or 40-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-30% cover of midstory fire tolerant hardwoods	>30 to 40% cover of midstory fire tolerant hardwoods	>40% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	20-25% cover of woody midstory	>25 to 35% cover of woody midstory	>35% cover of woody midstory
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 25% cover	Short shrubs average >25 to 40% cover	Short shrubs average >40% cover
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average < 15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	>45 to 80% herbaceous cover	30-45% or >80% herbaceous cover	15 to <30% herbaceous cover	<15% herbaceous cover
Native Warm Season Grass Cover	>25 to 85% foliar cover of all native warm season grasses	>15 to 25% or >85% foliar cover of native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Dry & Mesic Highlands Pine Woodlands (Mountain Longleaf)

Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft^2/acre basal area of longleaf & shortleaf pine	30 to 35 or >75 to 90 ft^2/acre basal area of longleaf & shortleaf pine	10 to <30 or >90 to 110 ft^2/acre basal area of longleaf & shortleaf pine	<10 or >110 ft^2/acre basal area of longleaf & shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of longleaf & shortleaf pine	20-25% or >70 to 80% canopy cover of longleaf & shortleaf pine	10 to <20% or >80 to 90% canopy cover of longleaf & shortleaf pine	<10% or >90% canopy cover of longleaf & shortleaf pine
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf pine of any diameter and/or longleaf or shortleaf pine trees ≥14" DBH class	BA ≥10 ft^2/acre of longleaf or shortleaf pine trees ≥14" DBH class	Longleaf or shortleaf pine trees ≥14" DBH class are present, but at<10 ft^2/acre BA	No longleaf or shortleaf pine trees ≥14" DBH or flat-top longleaf pine are present
Canopy Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 40 ft^2/acre BA of hardwood trees	>40 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees
Stand Density Index (applies to longleaf pine)	SDI = 55 – 120 (14 - 30% of Maximum SDI of 400)	SDI = 40 – 55 or 120 - 160 (10-14% or 30-40% of Maximum SDI of 400)	SDI = 15 – 40 or 160 - 200 (4-10% or 40-50% of maximum SDI)	SDI <15 or >200 (<4% or >50%, 240 is 60% of Maximum SD of 400)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-30% cover of midstory fire tolerant hardwoods	>30 to 40% cover of midstory fire tolerant hardwoods	>40% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	≥20 to 25% cover of woody midstory	>25 to 35% cover of woody midstory	>35% cover of woody midstory
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20- 25% cover	Short shrubs average >25 to 40% cover	Short shrubs average >40% cover
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average < 15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	>45 to 80% herbaceous cover	30-45% or >80% herbaceous cover	15 to <30% herbaceous cover	<15% herbaceous cover
Longleaf Pine Regeneration	Longleaf pine regeneration cover is >1% of stand (Good and Excellent)	Longleaf pine regeneration cover is >1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand
Native Warm Season Grass Cover	>25 to 85% foliar cover of all native warm season grasses	20-25% or >85% foliar cover of all native warm season grasses	10 to <20% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Dry & Mesic Hilly Pine Woodlands				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	30-85 ft^2/acre basal area of loblolly or shortleaf pine	20 to <30 or >85 to 100 ft^2/acre basal area of loblolly or shortleaf pine	10 to <20 or >100 to 115 ft^2/acre basal area of loblolly or shortleaf pine	<10 or >115 ft^2/acre basal area of loblolly or shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 75% canopy cover of loblolly or shortleaf pine	>15 to 25% canopy cover or >75 to 85% canopy cover of loblolly or shortleaf pine	10-15% canopy cover or >85 to 95% canopy cover of loblolly or shortleaf pine	<10% cover or >95% cover of loblolly or shortleaf pine
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	BA ≥10 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	Loblolly and/or shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No loblolly and/or shortleaf pine trees ≥14" DBH are present
Canopy Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 30 ft^2/acre BA of hardwood trees	>30 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees
Stand Density Index (applies to shortleaf and loblolly pine)	SDI = 55 – 155 (12 - 34% of Maximum SDI of 450)	SDI = 35 – 55 or 155 - 205 (8-12% or 34-45% of Maximum SDI of 450)	SDI = 20 – 35 or 205 - 225 (4-8% or 45-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-20% cover of midstory fire tolerant hardwoods	>20 to 35% cover of midstory fire tolerant hardwoods	>35% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	≥20 to 30% cover of woody midstory	>30 to 50% cover of woody midstory	>50% cover of woody midstory
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 30% cover	Short shrubs average >30 to 45% cover	Short shrubs average >45% cover
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 to 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	35-80% herbaceous cover	20 to <35% or >80% herbaceous cover	10 to <20% herbaceous cover	<10% herbaceous cover
Native Warm Season Grass Cover	25-100% foliar cover of all native warm season grasses	>15 to <25% foliar cover of all native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Upper Coastal Plain Pine Flatwoods				
Canopy Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Canopy Southern Yellow Pine Basal Area	30-80 ft^2/acre basal area of loblolly or shortleaf pine	20 to <30 or >80 to 90 ft^2/acre basal area of loblolly or shortleaf pine	10 to <20 or >90 to 110 ft^2/acre basal area of loblolly or shortleaf pine	<10 or >110 ft^2/acre basal area of loblolly or shortleaf pine
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of loblolly or shortleaf pine	>15 to 25% canopy cover or >70 to 80% canopy cover of loblolly or shortleaf pine	10-15% canopy cover or >80 to 90% canopy cover of loblolly or shortleaf pine	<10% cover or >90% cover of loblolly or shortleaf pine
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	BA ≥10 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	Loblolly and/or shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No loblolly and/or shortleaf pine trees ≥14" DBH are present
Canopy Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 30 ft^2/acre BA of hardwood trees	>30 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees
Stand Density Index (applies to shortleaf and loblolly pine)	SDI = 55 – 145 (12 - 32% of Maximum SDI of 450)	SDI = 35 – 55 or 145 - 180 (8-12% or 32-40% of Maximum SDI of 450)	SDI = 20 – 35 or 180 - 225 (4-8% or 40-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)
Midstory/Shrub Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10 to 20% cover of midstory fire tolerant hardwoods	>20 to 35% cover of midstory fire tolerant hardwoods	>35% cover of midstory fire tolerant hardwoods
Midstory Overall Cover	<20% cover of woody midstory	20-30% cover of woody midstory	>30 to 50% cover of woody midstory	>50% cover of woody midstory
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 to 30% cover	Short shrubs average >30 to 45% cover	Short shrubs average >45% cover
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.
Ground Layer Metrics				
	Excellent	**Good**	**Fair**	**Poor**
Overall Native Herbaceous Ground Cover	35-80% herbaceous cover	20 to <35% or >80% herbaceous cover	10 to <20% herbaceous cover	<10% herbaceous cover
Native Warm Season Grass Cover	>25% foliar cover of all native warm season grasses	20-25% foliar cover of all native warm season grasses	10 to <20% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)

Discussion/Summary

Open pine habitats, especially those dominated by longleaf pine, provide the last refuge for a large number of at-risk and declining vertebrates and an even larger number of at-risk and declining plant species. A few species that depend upon this habitat wholly or in part include red-cockaded woodpecker (*Picoides borealis*), Bachman's sparrow (*Aimophilus aestivalis*), northern bobwhite (*Colinus virginianus*), gopher frog (*Rana sevosa*), gopher tortoise (*Gopherus polyphemus*), brown-headed nuthatch (*Sitta pusilla*), pine warbler (*Setophaga pinus*), prairie warbler (*Setophaga discolor*), Eastern diamondback rattlesnake (*Crotalus adamanteus*), pocket gopher (*Geomys pinetis*), and pine snake/Louisiana pine snake (*Pituophis ruthveni* and *Pituophis melanoleucus*). The America's Longleaf Restoration Initiative's (ALRI) Longleaf Partnership Council recently developed a region-wide approach to ensuring the future viability of longleaf-dominated communities and the species reliant upon them by establishing definitions of high quality longleaf acreage. However, until now, no single region-wide metrics-based approach existed to assess condition of longleaf. Furthermore, other open pine habitat types dominated by shortleaf, slash, and loblolly were not always included in the discussion of longleaf pine even though they often provide habitat to similar types of wildlife. Land managers and private landowners need guidance on how to efficiently and accurately quantify the condition and wildlife habitat value of the pine stands they manage. The Shortleaf Pine Initiative plans to formally release their Shortleaf Pine Restoration Plan in the near future at the 2016 Southeast Conference for Land and Community Conservation http://shortleafpine.net/shortleaf-pine-initiative/news-from-director.

Furthermore, because of limited resources, landowners and land managers need metrics that are easy to collect and analyze with limited time and staff. By finalizing a single set of desired forest condition/rapid assessment metrics for wildlife habitat and ecological integrity, we can help conservation-minded land managers efficiently assess wildlife habitat and ecological integrity and also better understand how key lands are contributing to the regional goals set in the ALRI *Range-Wide Conservation Plan for Longleaf Pine* (America's Longleaf 2009) and other open pine habitats.

Our work combines existing metrics developed by USFS and NatureServe with metrics developed to assess wildlife habitat value as part of the East Gulf Coastal Plain Joint Venture's desired forest conditions project. The final desired forest condition metrics address wildlife habitat and ecological integrity for the full range of open pine ecosystems within the study area. Our approach provides an important new way to rapidly assess ecosystem health for lands primarily being managed for wildlife habitat and biodiversity and to help the GCPO LCC and the Longleaf Partnership Council more accurately document progress towards their acreage goals for open pine (GCPO LCC Adaptation Science Management Team 2013).

Our intent is for this approach to provide an ecological habitat –based solution to species management. For instance, we believe a stand that scores high using the rapid assessment metrics will likely be a better area for bobwhite quail habitat than a stand that scores low. Providing habitat for characteristic wildlife species of southern open pine ecosystems is a goal for many land managers in the South. The metrics presented here can assist land managers who have conservation as an objective on lands being managed for wildlife or for multiple uses. Prescribed fire, thinning, targeted use of herbicides, and planting for reforestation or wildlife food are some of the land management actions used to promote the wildlife of southern open pine ecosystems. By reevaluating stands before and after management, landowners will be able to determine how effective their actions are in improving the ecosystem and the habitat needs of open-pine dependent wildlife.

NatureServe has conducted extensive tests of the Ecological Integrity Assessment (EIA) methodology for wetlands across the United States (Faber-Langendoen et al. 2016). We recently completed a rigorous evaluation from 220 sites across six states (CO, IN, MI, NH, NJ, WA), testing for both the discriminatory power of the metrics and major ecological factors and the levels of redundancy. These have also been investigated for upland forest systems (Tierney et al. 2009). This testing has given us confidence that our use of this methodology for open pine systems can also be an efficient and scientifically valid way to assess open pine stands for overall wildlife habitat value and ecological integrity.

Although we believe that the rapid assessment approach can help conservation-minded landowners to understand and manage the health of their open pine stands, we also believe it is important to understandits limitations and potential pitfalls.

1) We consider this current document to be version 1.0. Since the testing of the methodology for this project has been based on an initial dataset, we feel that the document and metrics can and should be revisited and adjusted with new information. We hope to test the metrics in all key ecosystems in 2016 by collecting data from multiple stands and multiple condition classes so that we can adjust the metrics and metric cutoff values as necessary and issue a new version in the future.
2) There are different vegetation and environmental classifications for open pine. We have involved many partners and put considerable effort into the definition of a workable set of units (general open pine groupings) that encompass the variation in open pine habitats and communities across the geographic range of the project. These groupings are general types which are largely equivalent to vegetation group types of the United States National Vegetation Classification (USNVC). We recognize that other classification categories may also be useful.
3) It is important to understand the implications of current or existing vs. potential vegetation and what one's management goals are when applying these metrics. In areas where open pine was historically present, current vegetation could be something different (old field, fire-suppressed hardwood dominated forest, etc.). When applying these metrics, the manager should use the metrics that apply to the ecosystem type/ habitat grouping that they are managing towards rather than the current type.

Now that this report has been issued, we have a number of future objectives:

1) Issue a companion document that shows how to implement rapid assessment metrics in open pine using the metrics detailed in this report.
2) Identify partners to collect data on a range of open pine sites and summarize that data. Use the summary information to assess how well the metrics are performing and adjust the metrics if needed.
3) Incorporate landscape scale metrics such as size, landscape context, etc. to complement stand scale work

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Appendices

Appendix A. Key to Southern Open Pine Habitat Groupings

This key should enable a user of the desired forest condition metrics for southern open pine to easily determine what set of metrics is most appropriate for their lands. It is necessary that a user of the key be familiar with where their land(s) are located in terms of state and USDA Forest Service ecoregions (Cleland et al. 2007), at least to the section level. Some of the habitat groupings, by definition, occur within the range of longleaf pine (*Pinus palustris*) as defined by Little (1971). This general range is not precise in all places, so it is certainly possible that a genuine stand of a longleaf grouping could be found in an area that is not included in this range, but in the vast majority of cases, a user should be able to place a stand in a grouping.

The key is specifically designed for use within the boundaries of the Gulf Coast Plains and Ozarks Landscape Conservation Cooperative (GCPO LCC), which includes the Missouri and Arkansas highlands of the Ozark, Boston and Ouachita mountain ranges, and the Gulf Coastal Plains, which extend from eastern Texas to the Florida panhandle. It also applies to stands dominated by Longleaf Pine (*Pinus palustris*) throughout the range of this species, but makes no attempt to accommodate other related vegetation east and north of the GCPO LCC footprint.

The key will lead a user through a series of choices ("couplets") related to the geographic location of the area under consideration, as well as choices about stand composition and environment. At its higher levels, the key is constructed around these Forest Service regions. Further into the key, the choices related to stand composition and environment come into play. A user should read both statements and see which one best applies to the area and stands under question. If an obviously incorrect answer is obtained, it may be necessary to repeat the exercise.

Common terms rather than highly technical ones are used (wet, dry, sandy, upland, seasonally, etc.). One term that may be unfamiliar to some users is "mesic". This is a kind of shorthand for an environment that is neither very dry nor very wet (i.e. "in the middle" of a broad ecological moisture continuum). It is most frequently applied to species-rich hardwood stands ("coves"), but in this context it would refer to stands that are not "wet", i.e. without standing water), but have enough available soil moisture to support diverse and possibly dense herbaceous layers. Similarly "dry-mesic" refers to stands that are on the dry side of mesic, but not notably dry. These terms may roughly correlate with soil texture, in that under similar hydrological conditions, coarser-textured soils are more likely to be drier that those with finer particle size.

Following the key, a table of distributions of the open pine groupings by state and region (Table A-1), a map of the relevant USDA Forest Service Sections (Figure A-1), and a table of USDA Forest Service Provinces and Sections referred to in the key (Table A-2) are provided to assist in its use.

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Key to Open Pine Groupings

1a. Forests and woodlands in the coastal plains (Outer Coastal Plains Mixed Forest Province 232; Southeastern Mixed Forest Province 231, southern parts of Sections 231B, 231E and 231H within the range of Longleaf Pine [*Pinus palustris*] as defined by Little [1971]), typically dominated by Longleaf Pine (*Pinus palustris*) and/or Slash Pine (*Pinus elliottii*), habitat ranging from very dry sandy uplands, mesic finer-textured soils, and seasonally wet or saturated flatwoods and savannas......................... 2

1b. Forests and woodlands landward of the coastal plains (Southeastern Mixed Forest Province 231, Sections 231A, 231C, 231D, 231G, 231I; also Central Interior Broadleaf Forest Province 223, Section 223A; Ozark Broadleaf Forest Province M223, and Ouachita Mixed Forest-Meadow Province M231); or in the inner portions of the coastal plains landward of the range of Longleaf Pine (Southeastern Mixed Forest Province 231, most of Sections 231B, 231E, lowland parts of Section 231G, 231H) dominated by Shortleaf Pine (*Pinus echinata*) and/or Loblolly Pine (*Pinus taeda*), OR dominated by Longleaf Pine (*Pinus palustris*) and found landward of the coastal plains as mentioned above.......... 3

2a. Longleaf Pine / Slash Pine Woodlands (wet and mesic flatwoods and savannas); the wet examples found on poorly drained, somewhat poorly drained, and seasonally saturated mineral soils with seasonally high water tables; the mesic examples found on flat sites with spodic horizons (Spodosols) or some factor impeding drainage which can cause sites to be wet in the winter and dry in the summer 4

2b. Stands of longleaf pine (*Pinus palustris*) on sandy to loamy soils on upland sites ranging from gently rolling lands, broad ridgetops to steeper side slopes, and in mesic swales and terraces 5

3a. Stands with Longleaf Pine (*Pinus palustris*) in combination with Shortleaf Pine (*Pinus echinata*) and dry Oak (*Quercus*) species, found landward of the coastal plains (Southeastern Mixed Forest Province 231, Sections 231A, 231C, 231D, 231I) .... "**Mountain Longleaf" .... Dry & Mesic Highlands Pine Woodlands, in part; [part of US NVC GROUP G012]**

3b. Forests and woodlands dominated by Shortleaf Pine (*Pinus echinata*) and/or Loblolly Pine (*Pinus taeda*) found landward of the coastal plains (Southeastern Mixed Forest Province 231, Sections 231E, 231G); and in the inner portions of the coastal plains landward of the range of Longleaf Pine (Southeastern Mixed Forest Province 231, most of Sections 231B, 231E and 231H); also west of the Mississippi River in the Central Interior Broadleaf Forest Province 223, Section 223A; Ozark Broadleaf Forest Province M223, and Ouachita Mixed Forest-Meadow Province M231, as well as the Crowley's Ridge Subsection 234Db) 6

4a. Mesic Longleaf Pine flatwood woodlands found on flat sites with spodic horizons (Spodosols) or some factor impeding drainage which can cause sites to be wet in the winter and dry in the summer.. ....**Mesic Longleaf Pine Flatwoods [US NVC GROUP G596]**

4b. Wet Longleaf Pine / Slash Pine flatwoods and savannas found on poorly drained, somewhat poorly drained, and seasonally saturated mineral soils with seasonally high water tables .... **Wet Longleaf & Slash Pine Flatwoods & Savannas [US NVC GROUP G190]**

5a. Stands of longleaf pine (*Pinus palustris*) on deep sandy soils, in the fall-line sandhills (Subsection 232Bq) as well as on other sandy sites in the outer coastal plains, typically with scrub oaks (Turkey Oak, Bluejack Oak, Sand Post Oak) in the subcanopy ....**Xeric Longleaf Pine Barrens [US NVC GROUP G154]**

5b. Other stands of longleaf pine (*Pinus palustris*) on sandy to loamy soils on upland sites ranging from gently rolling lands, broad ridgetops to steeper side slopes, and in mesic swales and terraces. Subcanopy oaks include White Oak, Southern Red Oak, Black Oak, Blackjack Oak ....**Dry & Mesic Longleaf Pine Woodlands [US NVC GROUP G009]**

6a. Dry and dry-mesic forests and woodlands dominated by Shortleaf Pine (*Pinus echinata*) found west of the Mississippi River in the Central Interior Broadleaf Forest Province 223, Section 223A; Ozark Broadleaf Forest Province M223; Ouachita Mixed Forest-Meadow Province M231; Southeastern Mixed Forest Province 231, Section 231G ....**"Shortleaf-Loblolly Woodlands"** .... **Dry & Mesic Highlands Pine Woodlands, in part; [part of US NVC GROUP G012]**

6b. Forests and woodlands, including flatwoods, dominated by Shortleaf Pine (*Pinus echinata*) and/or Loblolly Pine (*Pinus taeda*) found in the inner portions of the coastal plains landward of the range of Longleaf Pine (Southeastern Mixed Forest Province 231, most of Sections 231B, 231E, 231H), as well as in portions of the Mississippi River Alluvial Basin Section 234A. [this Grouping would also apply to the lower/outer parts of the Piedmont (Sections 231A, 231I but this area is not within the GCPO LCC footprint] 7

7a. Dry and dry-mesic forests and woodlands dominated by Shortleaf Pine (*Pinus echinata*) and/or Loblolly Pine (*Pinus taeda*) found in the inner portions of the coastal plains landward of the range of Longleaf Pine (Southeastern Mixed Forest Province 231, most of Sections 231B, 231E, 231H), as well as the Crowley's Ridge Subsection 234Db (Lower Mississippi Riverine Forest Province 234) [this Grouping would also apply to the lower/outer parts of the Piedmont (Sections 231A, 231I) but this area is not within the GCPO LCC footprint].. .... **Dry and Mesic Hilly Pine Woodlands [US NVC GROUP G013, part of G012]**

7b. Flatwoods (nonriverine wetland or seasonally wet pine-hardwood forests) in the coastal plains (Outer Coastal Plains Mixed Forest Province 232; Southeastern Mixed Forest Province 231, most of Sections 231B, 231E, 231H) and the Lower Mississippi Riverine Forest Province 234 .... **Upper Coastal Plain Flatwoods [US NVC GROUP G130]**

States	Region	Dominant Pines	Site	Southern Open Pine Grouping
AR, MO, OK	Ozark and Ouachita Highlands	Shortleaf Pine	Dry & Mesic Uplands	Dry & Mesic Highlands Pine Woodlands
AR, LA, TX	Coastal Plain	Shortleaf Pine, Loblolly Pine	Dry & Mesic Uplands	Dry & Mesic Hilly Pine Woodlands
AR, LA, TX	Coastal Plain	Shortleaf Pine, Loblolly Pine	Wet-Mesic to Wet Flats	Upper Coastal Plain Pine Flatwoods
LA, TX	Coastal Plain	Longleaf Pine	Xeric Uplands on deep sandy soils	Xeric Longleaf Pine Barrens
LA, TX	Coastal Plain	Longleaf Pine	Dry & Mesic Uplands	Dry & Mesic Longleaf Pine Woodlands
LA, TX	Coastal Plain	Longleaf Pine	Wet Flats	Wet Longleaf & Slash Pine Flatwoods & Savannas
AL, GA, NC, SC	Appalachians and Piedmont	Longleaf Pine	Dry Uplands, on ridges and upper slopes	Dry & Mesic Highlands Pine Woodlands
AL, GA, NC, SC	Piedmont	Shortleaf Pine, Loblolly Pine	Dry & Mesic Uplands	Dry & Mesic Hilly Pine Woodlands
AL, GA, FL, MS, NC, SC	Coastal Plain	Shortleaf Pine, Loblolly Pine	Dry & Mesic Uplands	Dry & Mesic Hilly Pine Woodlands
AL, GA, MS, NC, SC	Coastal Plain	Longleaf Pine	Xeric Uplands on deep sandy soils	Xeric Longleaf Pine Barrens
AL, GA, MS, NC, SC	Coastal Plain	Longleaf Pine	Dry & Mesic Uplands	Dry & Mesic Longleaf Pine Woodlands
AL, GA, MS, NC, SC	Coastal Plain	Longleaf Pine, Slash Pine	Mesic to Wet Flats, Spodosols	Mesic Longleaf Pine Flatwoods
AL, GA, MS, NC, SC	Coastal Plain	Longleaf Pine, Slash Pine	Wet Flats	Wet Longleaf & Slash Pine Flatwoods & Savannas
FL	Coastal Plain	Longleaf Pine	Dry & Mesic Uplands	Dry & Mesic Longleaf Pine Woodlands
FL	Coastal Plain	Longleaf Pine	Xeric Uplands on deep sandy soils	Xeric Longleaf Pine Barrens
FL	Coastal Plain	Longleaf Pine, Slash Pine, South Florida Slash Pine	Mesic to Wet Flats, Spodosols	Mesic Longleaf Pine Flatwoods
FL	Coastal Plain	Longleaf Pine, Slash Pine, South Florida Slash Pine	Wet Flats	Wet Longleaf & Slash Pine Flatwoods & Savannas

Table A-1. States, Regions, and Southern Open Pine Groupings

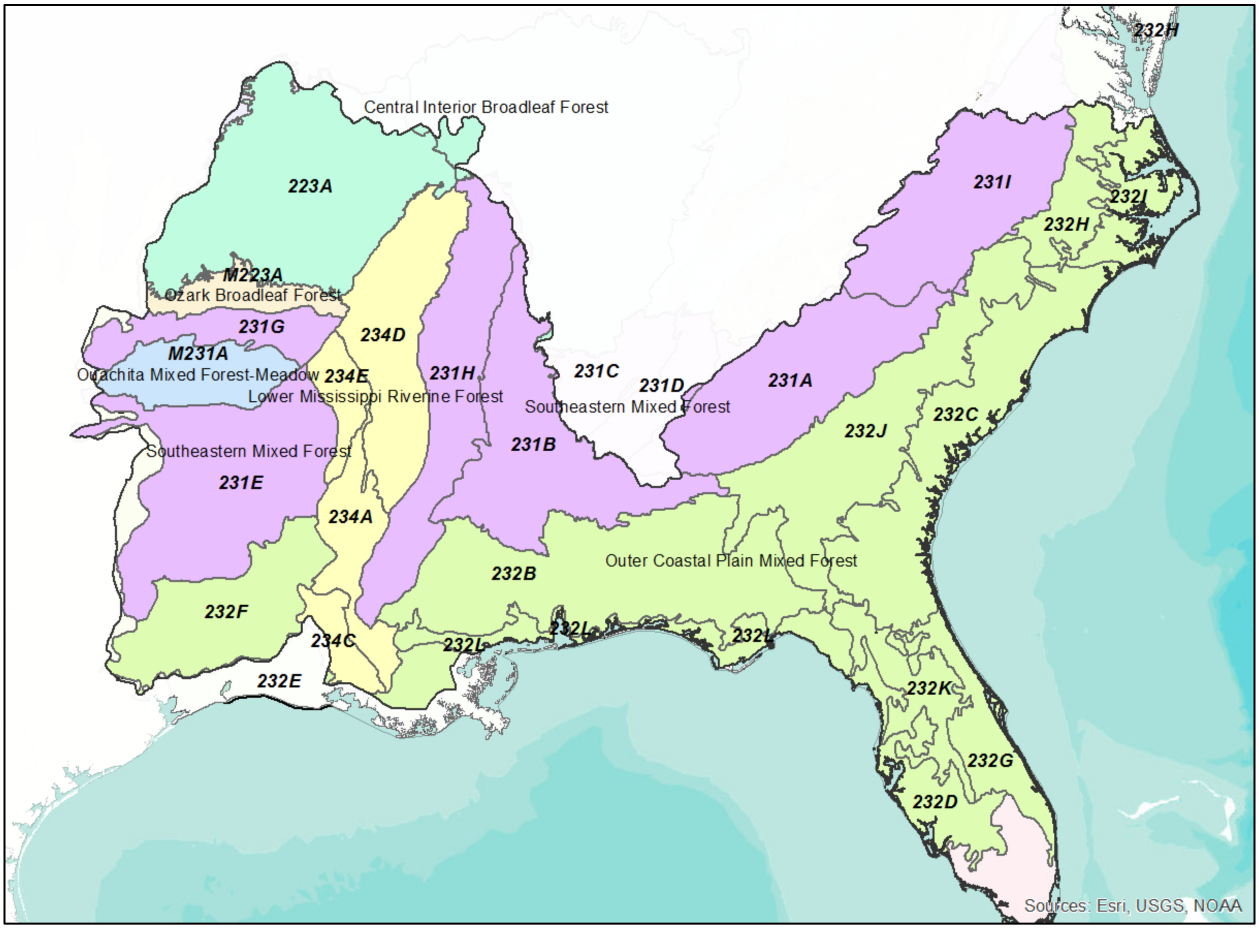

Figure A-1. USDA Forest Service Provinces and Sections (from Cleland et al. 2007)

PROVINCE /SECTION	**PROVINCE**/SECTION_NAME
223	**Central Interior Broadleaf Forest**
223A	Ozark Highlands
M223	**Ozark Broadleaf Forest**
M223A	Boston Mountains
231	**Southeastern Mixed Forest**
231A	Southern Appalachian Piedmont
231B	Coastal Plains-Middle
231C	Southern Cumberland Plateau
231D	Southern Ridge and Valley
231E	Mid Coastal Plains-Western
231G	Arkansas Valley
231H	Coastal Plains-Loess
231I	Central Appalachian Piedmont
M231	**Ouachita Mixed Forest-Meadow**
M231A	Ouachita Mountains

232	**Outer Coastal Plain Mixed Forest**
232B	Gulf Coastal Plains and Flatwoods
232C	Atlantic Coastal Flatwoods
232D	Florida Coastal Lowlands-Gulf
232F	Coastal Plains and Flatwoods-Western Gulf
232G	Florida Coastal Lowlands-Atlantic
232H	Middle Atlantic Coastal Plains and Flatwoods
232I	Northern Atlantic Coastal Flatwoods
232J	Southern Atlantic Coastal Plains and Flatwoods
232K	Florida Coastal Plains Central Highlands
232L	Gulf Coastal Lowlands
234	**Lower Mississippi Riverine Forest**
234A	Southern Mississippi Alluvial Plain
234C	Atchafalaya and Red River Alluvial Plains
234D	White and Black River Alluvial Plains
234E	Arkansas Alluvial Plains

Table A-2. USDA Forest Service Provinces and Sections referred to in the Key

Notes on Some Ambiguous or Confusing Habitats

There are some possible situations related to open pine habitats in the southeastern United States which are ambiguous or may present uncertainties in terms of which habitat is best managed for in a particular locale.

1. Sites found landward of the coastal plains (Southeastern Mixed Forest Province 231, Sections 231A, 231C, 231D) with Longleaf Pine as a dominant or codominant should be treated as examples of "Mountain Longleaf". These could be proximal to, or interfingered with, stands dominated by Shortleaf Pine without Longleaf Pine. The issue here is that "Mountain Longleaf" would be evaluated with the metrics for the Dry & Mesic Highlands Pine Woodlands Grouping, and the adjacent Shortleaf Pine stands would be evaluated with the metrics for the Dry & Mesic Hilly Pine Woodlands Grouping. In this area, both of these Groupings are related to US NVC GROUP G012. A distinction may need to be made between stands dominated by Shortleaf Pine without Longleaf Pine which are landward of the coastal plain and do **not** have loblolly pine or are outside the range of loblolly pine, versus stands dominated by Shortleaf Pine that are **within** the range of Loblolly Pine. In the first case they should be assigned to Dry & Mesic Highlands Pine Woodlands Grouping, and in the second case, these stands within the range of Loblolly Pine would be part of the Dry & Mesic Hilly Pine Woodlands Grouping. This is an issue we are investigating in South Carolina, in regard to Shortleaf Pine stands in the western versus the eastern Piedmont.

2. In a portion of the Southeastern Mixed Forest Province (Section 231B), there are quite rugged landforms found north of the black belt region and southwest of the southern end of the Ridge and Valley (this is within the ranges of both Longleaf Pine and Chestnut Oak [*Quercus prinus*]). Using our key to Open Pine Groupings, this would be part of the Dry & Mesic Longleaf Pine Woodlands, but has some characteristics of the "Mountain Longleaf" discussed above. This area

includes the Oakmulgee District of the Talladega National Forest in Bibb, Hale, Perry, and Tuscaloosa counties of Alabama. It is not clear which metrics are better applied in this area.

3. The third exception or anomaly would be stands dominated by Shortleaf Pine found within the range of Longleaf Pine in Provinces 231 and 232, the Southeastern Mixed Forest Province and Outer Coastal Plain Mixed Forest Province, respectively. This type of stand would have been far less common in the outer coastal plain, and more likely in the inner coastal plain. More information is needed about this vegetation and its characteristics and environment. One example is Shortleaf Pine vegetation of the Red Hills of Florida and Georgia. In this case, the metrics for Dry & Mesic Hilly Pine Woodlands [US NVC GROUP G012] would apply.

Appendix B. Full Descriptions of Southern Open Pine Groupings

Southern Open Pine Groupings are broad ecological classification units for southern open pine wildlife habitats, encompassing woodlands with relatively open, pine-dominated canopies and grassy understories. These woodlands are fire dependent and many examples occur on low fertility soils. These Southern Open Pine Groupings are related to the variation in vegetation structure or physiognomy, dominant and characteristic species, soils, landform, and biogeography of open pine habitats across the southeastern United States. They are comparable to Groups of the U.S. National Vegetation Classification and are compliant with the standards for vegetation from the Federal Geographic Data Committee (Faber-Langendoen et al. 2009, Faber-Langendoen et al. 2012, Faber-Langendoen et al. 2014, FGDC 2008). These Southern Open Pine Groupings are also closely related to the Groups of Ecological Systems used by the U.S. Fish and Wildlife Service (Pyne et al. 2013) and are related to several widely used classifications of vegetation, natural communities, and ecological systems (Comer et al. 2003, Edwards et al. 2013, Eyre 1980, FNAI 2010, Palmquist et al. 2016, Peet 2006).

Groups of Ecological Systems (GES)	**Southern Open Pine Groupings**	**US NVC Group**
Longleaf Woodlands	Dry & Mesic Longleaf Pine Woodlands	G009
Longleaf - Slash Flatwoods	Mesic Longleaf Pine Flatwoods	G596
Longleaf - Slash Flatwoods	Wet Longleaf & Slash Pine Flatwoods & Savannas	G190
Longleaf-Turkey Oak Sandhills	Xeric Longleaf Pine Barrens	G154
Mountain Longleaf	Dry & Mesic Highlands Pine Woodlands	G012
Shortleaf-Loblolly Woodlands	Dry & Mesic Highlands Pine Woodlands	G012
Shortleaf-Loblolly Woodlands	Dry & Mesic Hilly Pine Woodlands	G012
Shortleaf-Loblolly Woodlands	Dry & Mesic Hilly Pine Woodlands	G013
Shortleaf-Loblolly Woodlands	Upper Coastal Plain Pine Flatwoods	G130

Table B-1. Crosswalk of Groups of Ecological Systems, Southern Open Pine Groupings, and US NVC Group codes.

The general information provided for each of the seven Southern Open Pine Groupings comes from the Type Concept and Geographic Range fields of NatureServe’s Ecology Element Databases (NatureServe 2015). These data have been edited to follow the Southern Open Pine Groupings.

Dry & Mesic Longleaf Pine Woodlands

This Southern Open Pine Grouping represents stands of longleaf pine (*Pinus palustris*) on sandy to loamy soils on upland sites ranging from gently rolling lands, broad ridgetops to steeper side slopes, and in mesic swales and terraces. The canopy is generally open, with irregularly scattered longleaf pine trees, clumps of midstory oak (*Quercus* spp.) and a grassy understory. Scrub oaks, such as bluejack oak (*Quercus incana*) and sand post oak (*Quercus margarettiae*), as well as blackjack oak (*Quercus marilandica*), southern red oak (*Quercus falcata*), and sometimes turkey oak (*Quercus laevis*) form a sparse or clumped understory in all but the most mesic stands. Low shrubs may be abundant. East of the Mississippi River, Carolina wiregrass or pineland threeawn (*Aristida stricta*) (in North and South Carolina) or Southern wiregrass or Beyrich's threeawn (*Aristida beyrichiana*) (from South Carolina to Mississippi) are usually the dominant or at least a characteristic species. Some typical grasses include splitbeard bluestem (*Andropogon ternarius*), Elliott's bluestem (*Andropogon gyrans var. gyrans*), broomsedge bluestem (*Andropogon virginicus*), pineywoods dropseed (*Sporobolus junceus*), rough dropseed (*Sporobolus clandestinus*), little bluestem (*Schizachyrium scoparium*), slender little bluestem (*Schizachyrium tenerum*), Indiangrass (*Sorghastrum nutans*), slender Indiangrass (*Sorghastrum elliottii*),

lopsided Indiangrass (*Sorghastrum secundum*), and switchgrass (*Panicum virgatum*). There tends to be a fairly high diversity of forbs (broadleaf herbaceous plants), especially in sites that have been burned frequently (i.e., three or more times per decade). This Southern Open Pine Grouping does not include the xeric and subxeric longleaf pine - turkey oak habitats (Xeric Longleaf Pine Barrens).
The Dry & Mesic Longleaf Pine Woodlands are found from southeastern Virginia to east Texas, including most of Florida. This type does not occur in the Mississippi Alluvial Plain.

Mesic Longleaf Pine Flatwoods

This Southern Open Pine Grouping represents open longleaf pine woodlands found on flat sites with Spodosol soils. These are soils which have a spodic horizon which can cause sites to be wet in the winter and dry in the summer. Sites within Mesic Longleaf Pine Flatwoods are mostly uplands but also include moist flatwoods. These open woodlands have irregularly scattered longleaf pine trees and a grass-dominated herbaceous layer. Low shrubs, including blueberries (*Vaccinium*) and hollies (*Ilex*), may be abundant. In addition, saw palmetto (*Serenoa repens*) is a characteristic species, particularly in South Carolina, Georgia, and Florida. East of the Mississippi River, Carolina wiregrass or pineland threeawn (*Aristida stricta*) (in North and South Carolina) or Southern wiregrass or Beyrich's threeawn (*Aristida beyrichiana*) (from South Carolina to Mississippi) is usually the dominant or at least a characteristic herb. Some additional typical grasses include slender bluestem (*Schizachyrium tenerum*), splitbeard bluestem (*Andropogon ternarius*), Elliott's bluestem (*Andropogon gyrans var. gyrans*), little bluestem (*Schizachyrium scoparium*), Indiangrass (*Sorghastrum nutans*), and switchgrass (*Panicum virgatum*). Stands in south-central Florida may contain cutthroat grass (*Panicum abscissum*). There tends to be a high diversity of forbs (broadleaf herbaceous plants), especially in sites that have been burned frequently (i.e., every one to three years).

This Southern Open Pine Grouping does not include dry nor dry-mesic longleaf pine (Dry & Mesic Longleaf Pine Woodlands), but represents those that have more available moisture, at least seasonally. It also does not include the wettest flatwoods, which are included in Wet Longleaf & Slash Pine Flatwoods & Savannas.

These Mesic Longleaf Pine Flatwoods are found from southeastern Virginia to eastern Texas, including most of Florida. It does not occur in the Mississippi Alluvial Plain, might not occur in Louisiana, and occurs only in very small areas in eastern Texas.

Wet Longleaf & Slash Pine Flatwoods & Savannas

This Southern Open Pine Grouping includes wet pine flatwoods and wet pine savannas of the coastal plains. These habitats are characterized by poorly drained, somewhat poorly drained, and seasonally saturated mineral soils with seasonally high water tables. Examples occur on a wide range of soil textures, mostly in low elevation areas of the outer coastal plains. This variability in soil texture strongly affects the composition of the ground cover vegetation, which accounts for various different plant associations in this grouping. In natural condition, canopies are open and dominated by longleaf pine, sometimes with slash pine (*Pinus elliottii var. elliottii*), pond pine (*Pinus serotina*), or loblolly pine (*Pinus taeda*). In south Florida, very open stands are naturally dominated by South Florida slash pine (*Pinus elliottii var. densa*). There is a diverse mix of grasses, herbs, and low shrubs in the ground layer in high-quality stands of this vegetation. Grasses are typically dominant, but there is often a large diversity of other herbs. Among the grasses, Carolina wiregrass or pineland threeawn (*Aristida stricta*) or Southern wiregrass or Beyrich's threeawn (*Aristida beyrichiana*) often dominates within its ranges, but toothache grass (*Ctenium aromaticum*), cutover muhly (*Muhlenbergia expansa*), little bluestem (*Schizachyrium scoparium*), Florida dropseed (*Sporobolus floridanus*), Carolina dropseed (*Sporobolus pinetorum*), wireleaf dropseed (*Sporobolus teretifolius*), chalky bluestem (*Andropogon capillipes*), other bluestems

(*Andropogon* spp.), or other grasses may also dominate. Understory conditions are influenced by fire frequency and seasonality.

Exposure to frequent, low-intensity fires (every one to two years, and less commonly to three or four years) in the transition from a dry Spring to a wet Summer is the dominant natural ecological process maintaining the open savanna and promoting local biodiversity. Historically, in some parts of the coastal plain, this vegetation was dominant over large areas. Extensive alterations to ecological processes following European settlement, including the interruption of natural fire regimes, have significantly degraded the quality of remaining examples of Wet Longleaf & Slash Pine Flatwoods & Savannas. The remaining large, intact examples are managed using frequent prescribed fire. Stands which have not burned for long periods of time show greater dominance by shrubs, including saw palmetto, and may have denser canopies of slash pine rather than longleaf pine. The ground cover of low-elevation pine savannas also are being invaded by non-native plant species, including cogongrass (*Imperata cylindrica*), Chinese privet (*Ligustrum sinense*) Chinese tallow (*Triadica sebifera*), Japanese climbing fern (*Lygodium japonicum*), and small-leaf climbing fern (*Lygodium microphyllum*).

The Wet Longleaf & Slash Pine Flatwoods & Savannas range from eastern Texas across the Gulf Coastal Plain to Florida (with one distinctive set of associations ranging into south Florida), and north in the Atlantic Coastal Plain to southern Virginia.

Xeric Longleaf Pine Barrens

This Southern Open Pine Grouping encompasses dry upland forest or woodland vegetation on deep, coarse sands and loamy sands on the Southern Coastal Plain from North Carolina south to central Florida and west to eastern Texas. Generally, these are open woodlands dominated by longleaf pine with an understory of turkey oak, though sites that have not been burned frequently or have experienced high-grading of the pine canopy can be dominated by turkey oak. Bluejack oak and sand post oak occur in the subcanopy, most commonly on somewhat silty sites. Turkey oak is absent west of the Mississippi River, where it is replaced by bluejack oak. These habitats are consistently dry and have low nutrient availability. As a result, longleaf pine grows slower and reaches smaller stature than in Dry & Mesic Longleaf Pine Woodlands (G009), Wet Longleaf & Slash Pine Flatwoods & Savannas (G190) and Mesic Longleaf Pine Flatwoods (G596).

On the driest sites, often referred to as barrens, the natural frequency of fire is less than in other longleaf pine habitats; therefore, the grass layer is minimal and litter accumulation is slower than in other habitats where longleaf pine grows. All but the driest associations have a well-developed grass layer with little bluestem (*Schizachyrium scoparium*) common throughout, often with one of the wiregrass forms of threeawn (*Aristida* spp.). The dominant threeawn (*Aristida* sp.) shifts geographically with Carolina wiregrass or pineland threeawn (*Aristida stricta*) important in the southern two-thirds of North Carolina and northern-most South Carolina and Southern Wiregrass or Beyrich's threeawn (*Aristida beyrichiana*) dominant in southern South Carolina and west across southern Georgia and Florida, to eastern Mississippi, although west of the Apalachicola River it is confined to the lower regions of the coastal plain. In southern South Carolina and west across Georgia, Florida, Alabama, and Mississippi to eastern Louisiana, gopher tortoise (*Gopherus polyphemus*) is a keystone protected species that digs extensive subterranean burrows in suitable soils within this habitat; hundreds of other species rely on its burrows for shelter. This vegetation occurs in the coastal plain from North Carolina south to Florida and west to eastern Texas.

Dry & Mesic Highlands Pine Woodlands

This Southern Open Pine Grouping encompasses forests and woodlands with most extensive areas in the Ozark-Ouachita Highlands, as well as the northern portion of Crowley's Ridge in which shortleaf pine (*Pinus echinata*) is the canopy dominant species or an important component. In Alabama, Georgia, and the Carolinas, Mountain and Piedmont longleaf pine woodlands are also included in this grouping, which generally are mixed with oaks and shortleaf pine. Examples can occur on a variety of acidic soils or bedrock types, and on a variety of topographic and landscape positions, including ridgetops, upper and midslopes, and at lower elevations (generally below 2300 feet). Stands may be codominated by oaks, hickories (*Carya* spp.), and other hardwoods, with the varying proportion of pine versus hardwood species depending on both forestry practices and ecological management, as well as natural disturbances, particularly the length of time since fire. There is considerable local variation in the extent of the Dry & Mesic Highlands Pine Woodlands in the landscape and in their structure and composition. In the Ozark-Ouachita Highlands, communities range from pine-bluestem to dry mesic shortleaf pine woodlands to dry rock outcrops with shortleaf pine. Pine-bluestem is open canopied, the southern yellow pine canopy cover metric and the canopy hardwood basal area metric values will generally be lower than those for the dry mesic shortleaf woodlands (see Blaney et al. 2015 for further clarification). In more open stands (such as ones in naturally drier regions or ones which have experienced more recent or frequent fire), the understory is characterized by big bluestem (*Andropogon gerardii*), little bluestem (*Schizachyrium scoparium*), and other prairie grasses and forbs. Species of blueberries (*Vaccinum* spp.) may be present in the shrub layer along with forbs including cream wild indigo (*Baptisia bracteata*), goldenrod (*Solidago odora*), and Pale purple coneflower (*Echinacea pallida*). In the lower elevations of the Southern Appalachians, and under current conditions, stands may be dominated by shortleaf pine or Virginia pine (*Pinus virginiana*). Stands found outside of the coastal plains in which longleaf pine is a component are included here. Hardwoods are sometimes abundant, especially dry-site oaks such as southern red oak, chestnut oak (*Quercus prinus*), post oak (*Quercus stellata*), and scarlet oak (*Quercus coccinea*), but also mockernut hickory (*Carya glabra*) and other hickories. The shrub layer may be well-developed, with Blue Ridge blueberry (*Vaccinium pallidum*), farkleberry (*Vaccinium arboreum*), deerberry (*Vaccinium stamineum*), or other acid-tolerant species being most characteristic of this habitat type. Herbaceous cover can be sparse but component species may include narrowleaf silkgrass (*Pityopsis graminifolia*) and goat's-rue (*Tephrosia virginiana*).

There is some regional variation in composition across the range of this Dry & Mesic Highlands Pine Woodlands, with examples in the Ozark-Ouachita Highlands and Crowley's Ridge lacking pitch pine (*Pinus rigida*), Virginia pine, and chestnut oak. Where fire is more frequent, stands may develop a relatively pure and open canopy of shortleaf pine with scattered overstory trees and an herbaceous-dominated understory, but such examples are rare on the modern landscape unless maintained by ecological management such as on Ouachita National Forest, as well as the Ozark and Mark Twain National Forests. More typical are examples in which oaks, hickories (*Carya*), sweetgum (*Liquidambar styraciflua*), tuliptree (*Liriodendron tulipifera*), red maple (*Acer rubrum*), and blackgum (*Nyssa sylvatica*) have become prominent in the midstory and overstory and in which herbaceous vegetation is sparse.

Examples of this Southern Open Pine Grouping mainly occur in the Ozark-Ouachita Highland areas of Arkansas, adjacent Oklahoma, and southeastern Missouri. It also occurs on Crowley's Ridge, and in small areas of the southern Piedmont and Appalachians, where examples have longleaf pine interspersed with oaks. Shortleaf pine dominated or codominated vegetation in the Upper East Gulf Coastal Plain of Alabama and Mississippi, and the West Gulf Coastal Plain of Arkansas, Louisiana and Texas, and the East Gulf and Atlantic Coastal Plains and Piedmont is accommodated in the Dry & Mesic Hilly Pine Woodlands (G013) Southern Open Pine Grouping.

Dry & Mesic Hilly Pine Woodlands

This Southern Open Pine Grouping consists of vegetation typically dominated by a mix of shortleaf pine and/or loblolly pine in combination with a suite of dry- to dry-mesic-site hardwood species, primarily white oak (*Quercus alba*), southern red oak, and post oak, but also the scrub oaks bluejack oak, sand post oak, and Arkansas oak (*Quercus arkansana*). It is primarily found in the Gulf Coastal Plain and Upper East and West Gulf Coastal Plains of Alabama, Mississippi, southern Arkansas, northwestern Louisiana, and parts of eastern Texas. It also occurs in the East and Upper East Gulf Coastal Plains, Atlantic Coastal Plain and Piedmont. The range of this type is predominantly north of the historic range of longleaf pine, and was the historic matrix vegetation type for large portions of the Upper West Gulf Coastal Plain. Within this area, this type was historically present on nearly all upland sites in the region (except on the most edaphically limited sites, such as droughty sands, calcareous clays, and shallow soil barrens/rock outcrops). The upland sites are underlain by loamy to fine-textured soils of variable depths. On ridgetops and adjacent sideslopes, it occurs on soils with moderate fertility and moisture retention. In more limited areas of the West Gulf Coastal Plain (USFS Section 232F), stands typically are confined to sideslopes and other less fire-prone locations not dominated by longleaf pine. Other tree species that may occur include black oak (*Quercus velutina*), mockernut hickory (*Carya alba*), black hickory (*Carya texana*), hawthorn (*Crataegus*), and hophornbeam (*Ostrya virginiana*). Typical shrubs include common sweetleaf (*Symplocos tinctoria*), wax-myrtle (*Morella cerifera*), farkleberry, Elliott's blueberry (*Vaccinium elliottii*), mapleleaf viburnum (*Viburnum acerifolium*), and southern arrow-wood (*Viburnum dentatum*). Some typical grasses include longleaf woodoats (*Chasmanthium sessiliflorum*), roundseed panicgrass (*Dichanthelium sphaerocarpon*), and little bluestem (*Schizachyrium scoparium*).
This vegetation is primarily found in the Gulf Coastal Plain and Upper East and West Gulf Coastal Plains of Alabama, Mississippi, southern Arkansas, northwestern Louisiana, and parts of eastern Texas. In the Upper East Gulf Coastal Plain, this vegetation was the historical matrix in large areas of the region in Alabama and Mississippi, north to the Tennessee state line. It also occurs in the East Gulf Coastal Plain, Atlantic Coastal Plain and Piedmont.

Upper Coastal Plain Pine Flatwoods

These are nonriverine wetland pine-hardwood forests of the Atlantic and Gulf coastal plains, and are well known from the coastal plain of southern Arkansas and northern Louisiana. Stands are primarily dominated by loblolly pine with shortleaf pine interspersed with laurel oak (*Quercus laurifolia*), swamp chestnut oak (*Quercus michauxii*), and willow oak (*Quercus phellos*), and also with a variety of other hardwoods, including sweetgum, swamp tupelo (*Nyssa biflora*), and blackgum. Spruce pine (*Pinus glabra*) may be codominant in some examples. This also includes mesic flatwoods, which are drier forests and woodlands of the upper coastal plains and adjacent regions; their canopies are dominated by southern red oak and post oak, with mockernut hickory and white oak. It occurs on Pleistocene high terraces or other high flat landforms. Wet hardwood flatwoods occur on seasonally flooded depressions within these terraces. Both types are precipitation driven wetlands in a hydrogeomorphic classification. Some other examples in southern Arkansas, Alabama and Mississippi encompass a mosaic of open forests dominated by loblolly pine interspersed with patches of willow oak (*Quercus phellos*) and other tree species. Within its range, dwarf palmetto (*Sabal minor*) will be abundant in the lower strata of some stands. These communities are generally known as "flatwoods," and are found on a variety of sites which are generally flat to very gently sloping, including broad upland flats and terraces. These sites typically have poor internal drainage and/or strata in the soil that limit permeability (claypans, hardpans, etc.). This limited permeability of the soil contributes to shallowly perched water tables during portions of the year when precipitation is greatest and evapotranspiration is lowest. The hydrologic regime is primarily influenced by groundwater and rainwater rather than overbank flooding. Soil moisture fluctuates widely throughout the growing season, from saturated to very dry, a condition which is sometimes referred to as xerohydric or hydroxeric. Soils are primarily mineral but may have some organic matter or muck. In some areas (e.g., the coastal plain of Arkansas), the local topography is a complex of ridges and swales, often in close proximity to one another (Bragg et al. 2014). Ridges are typically drier than swales. Swales may hold water for varying periods of time. Within both ridges and swales, vegetation is influenced by soil texture, soil moisture and disturbance history.

Upper Coastal Plain Pine Flatwoods are well known from the coastal plain of southern Arkansas (Bragg et al. 2014) and are also found in the Atlantic and Gulf coastal plains from the Embayed Region of northeastern North Carolina and southeastern Virginia (south of the James River) to Arkansas and Texas, the Florida peninsula, and may occur in southeastern Oklahoma, and the Missouri "Bootheel."

Appendix C. Full Descriptions of all Metrics.

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RANK FACTOR: VEGETATION

Metric Name:

Canopy Southern Yellow Pine Basal Area

Definition: Combined basal area of southern yellow pine species appropriate to the Southern Open Pine Grouping of the site, primarily longleaf pine or shortleaf pine. The cross section area of longleaf pine, slash pine, South Florida slash pine, shortleaf pine, and/or loblolly pine tree stems (defined here as square feet /acre) for trees > 4 inches DBH, and measured using a 10x basal area prism or gauge at the center point of the plot or rapid assessment area or by measuring all longleaf pine trees > 4 inches DBH within a plot of a defined area.

Background: An open canopy of southern yellow pine is important for the functioning of southern open pine ecosystems, and it is especially important for management with fire and promoting the grassy herbaceous understory and associated wildlife. This metric accommodates each of the Southern Open Pine Groupings, which may have longleaf pine, slash pine, shortleaf pine, and/or loblolly pine tree stems. This metric emphasizes longleaf pine and shortleaf pine basal area. These two pines have large natural ranges, have declined dramatically during the 20th century and naturally grow in open stands which support characteristic wildlife species. Basal area of trees by species is data very commonly collected as part of forestry inventory. It is a widely used measure quantifying the dominance of tree species, and is repeatable using a 10x basal area prism or gauge.

Certain ranges of southern yellow pine basal area have been identified as characteristic of optimal habitat for southern open pine wildlife species. For red-cockaded woodpecker, open pine with large trees and <90 ft^2/acre of pine is optimal (Lower Mississippi Valley Joint Venture WGCPO Landbird Working Group 2011, USFWS 2003). For brown-headed nuthatch 20-70 ft^2/acre of pine is optimal, and for Bachman's sparrow <60 ft^2/acre of pine (Richardson 2014a). The prairie warbler prefers low canopy basal area, which includes open pine woodlands, thinned pine stands, and cut over areas (NatureServe 2015, Thompson et al. 1992). However for the pine warbler, habitat quality increases with higher southern yellow pine basal area (Schroeder 1985). The prairie warbler and pine warbler occur in sites which are on the low and high ends, respectively of the range of southern yellow pine basal area which is best suited to the other open pine dependent wildlife species. Although rare throughout its range, the gopher tortoise occurs most commonly in stands which have ≤70 ft^2/acre basal area on average (Hinderliter 2014). Maintenance condition for longleaf pine woodlands is considered to be basal area ≤ 40-70 ft^2/acre of longleaf pine. (Longleaf Partnership Council 2014). Shortleaf pine basal area is measured in stands of Dry & Mesic Highlands Pine Woodlands, however in Mountain Longleaf examples, longleaf pine and shortleaf pine basal area should be measured. In Dry & Mesic Hilly Pine Woodlands, shortleaf pine and loblolly pine basal area should be measured (Bragg 2002). This metric is applied to Upper Coastal Plain Pine Flatwoods based on the basal area of shortleaf pine and loblolly pine (Bragg et al. 2014). In Dry & Mesic Longleaf Pine Woodlands, and Xeric Longleaf Pine Barrens, longleaf pine basal area is measured. In Mesic

Longleaf Pine Flatwoods and in Wet Longleaf & Slash Pine Flatwoods & Savannas, basal area is measured for longleaf pine, slash pine, and South Florida slash pine.

The values for canopy tree basal area, tree stems per acre, and canopy cover are interrelated, and can be shown in a Gingrich table (Gingrich 1967). A Gingrich table for Dry & Mesic Highlands Pine Woodlands was developed as part of the Interior Highlands Shortleaf Pine Restoration Initiative, Desired Future Conditions effort (Blaney et al. 2015), shown below.

	Percent Canopy Closure for forest grown Shortleaf Pine Stands											
	10%		20%		25%		30%		40%		50%	
DBH	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA
10	30	16	59	32	74	40	89	49	119	65	148	81
12	14	11	28	22	35	28	42	33	57	44	71	56
14	10	11	21	22	26	27	31	33	41	44	51	55
16	9	12	17	24	22	30	26	36	35	49	44	61
18	7	12	14	25	17	31	21	37	28	49	35	62
20	7	15	14	30	17	37	20	45	27	59	34	74
22	6	17	13	34	16	42	19	51	26	68	32	84
24	4	14	9	28	11	35	13	42	18	57	22	71

	Percent Canopy Closure for forest grown Shortleaf Pine Stands									
	60%		70%		80%		90%		100%	
DBH	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA
10	178	97	208	113	237	129	267	146	297	162
12	85	67	99	78	113	89	127	100	142	111
14	62	66	72	77	82	88	92	99	103	110
16	52	73	61	85	70	97	78	109	87	122
18	42	74	49	86	56	99	63	111	70	123
20	41	89	48	104	55	119	61	134	68	149
22	38	101	45	118	51	135	58	152	64	169
24	27	85	31	99	36	113	40	127	45	141

These Gingrich tables show average tree diameter at breast height (DBH) as rows, and in columns show percent tree canopy cover, number of trees per acre (#/ac), and basal area (BA). By using Gingrich tables, the relationships between these measures can be seen, and the measures can be applied to southern open pine wildlife habitat in a more informed way. Also, the canopy cover of 1 sq. foot BA of hardwood equals the canopy cover of 2 sq. feet of BA of shortleaf pine. Keep this in mind when assigning canopy cover metric values.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Basal area is a widely used measure quantifying the dominance of tree species, and is repeatable using a 10x basal area prism or gauge. Since many stands of longleaf pine (or other southern yellow pines) have uneven tree sizes and spacing, measures of basal area need to be collected at multiple locations to get a stand level estimate of basal area.

Measurement Protocol: Basal area by species of trees of longleaf pine, slash pine, South Florida slash pine, shortleaf pine, and loblolly pine greater than 4" diameter at 4.5 feet (54"), diameter at breast height (DBH). **Option 1**: A 10x factor basal area prism or gauge is used from the center of the data collection area, and trees are tallied by species. The tallied count of longleaf pines is multiplied by the basal area factor of 10 to get the basal area in ft^2/acre. **Option 2**: Delineate a plot of at least 0.1 acre or 400 m^2 and measure all longleaf pine, slash pine, South Florida slash pine, shortleaf pine, and loblolly pine greater than 4" diameter at 4.5 feet (54"), diameter at breast height (DBH), then convert diameter measurements to ft^2/acre using formula:

Basal area (ft^2/acre) = $0.005454 * DBH^2$

For the final value of basal area the per plot size value must be converted to a per acre value.

A value of "0" should be listed for species with stems > 4" DBH within the plot which are not included in the tallied basal area (i.e., not picked up in prism or gauge sample). This attribute is directly linked to the respective canopy species as indicated by the ending number designation.

These values below represent results in ft^2/acre using Option 2. Calculated values other than multiples of 10 are accommodated.

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	30-80 ft^2/acre basal area of longleaf pine (*Pinus palustris*)
GOOD (B)	20 to <30 or >80 to 90 ft^2/acre basal area of longleaf pine (*Pinus palustris*)
FAIR (C)	10 to <20 or >90 to 105 ft^2/acre basal area of longleaf pine (*Pinus palustris*)
POOR (D)	<10 or >105 ft^2/acre basal area of longleaf pine (*Pinus palustris*)

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	30-80 ft^2/acre basal area of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
GOOD (B)	20 to <30 or >80 to 90 ft^2/acre basal area of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
FAIR (C)	10 to <20 or >90 to 105 ft^2/acre basal area of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
POOR (D)	<10 or >105 ft^2/acre basal area of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	20-80 ft^2/acre basal area of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
GOOD (B)	≥10 to <20 or >80 to <90 ft^2/acre basal area of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), or South Florida slash pine (*Pinus elliottii* var. *densa*)
FAIR (C)	5 to <10 or 90 to <100 ft^2/acre basal area of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), or South Florida slash pine (*Pinus elliottii* var. *densa*)
POOR (D)	<5 or ≥100 ft^2/acre basal area of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	25-80 ft^2/acre basal area of longleaf pine (*Pinus palustris*)
GOOD (B)	>15 to <25 or >80 to 90 ft^2/acre basal area of longleaf pine (*Pinus palustris*)
FAIR (C)	10 to 15 or > 90 to <100 ft^2/acre basal area of longleaf pine (*Pinus palustris*)
POOR (D)	<10 or ≥100 ft^2/acre basal area of longleaf pine (*Pinus palustris*)

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	>35-75 ft^2/acre basal area of shortleaf pine (*Pinus echinata*)
GOOD (B)	30 to 35 or >75 to 90 ft^2/acre basal area of shortleaf pine (*Pinus echinata*)
FAIR (C)	10 to <30 or >90 to 110 ft^2/acre basal area of shortleaf pine (*Pinus echinata*)
POOR (D)	<10 or >110 ft^2/acre basal area of shortleaf pine (*Pinus echinata*)

Metric Rating	***Dry & Mesic Highlands Pine Woodlands (Mountain Longleaf)***
EXCELLENT (A)	>35-75 ft^2/acre basal area of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*)
GOOD (B)	30 to 35 or >75 to 90 ft^2/acre basal area of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*)
FAIR (C)	10 to <30 or >90 to 110 ft^2/acre basal area of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*)
POOR (D)	<10 or >110 ft^2/acre basal area of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*)

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***
EXCELLENT (A)	30-85 ft^2/acre basal area of shortleaf pine (*Pinus echinata*) and/or loblolly pine (*Pinus taeda*)
GOOD (B)	20 to <30 or >85 to 100 ft^2/acre basal area of shortleaf pine (*Pinus echinata*) and/or loblolly pine (*Pinus taeda*)
FAIR (C)	10 to <20 or >100 to 115 ft^2/acre basal area of shortleaf pine (*Pinus echinata*) and/or loblolly pine (*Pinus taeda*)
POOR (D)	<10 or >115 ft^2/acre basal area of shortleaf pine (*Pinus echinata*) and/or loblolly pine (*Pinus taeda*)

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	30-80 ft^2/acre basal area of shortleaf pine (*Pinus echinata*) and/or loblolly pine (*Pinus taeda*)

GOOD (B)	20 to <30 or >80 to 90 ft^2/acre basal area of shortleaf pine (*Pinus echinata*) and/or loblolly pine (*Pinus taeda*)
FAIR (C)	10 to <20 or >90 to 110 ft^2/acre basal area of shortleaf pine (*Pinus echinata*) and/or loblolly pine (*Pinus taeda*)
POOR (D)	<10 or >110 ft^2/acre basal area of shortleaf pine (*Pinus echinata*) and/or loblolly pine (*Pinus taeda*)

Data for Metric Rating: Published data that support the basis for the metric rating

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Thompson, F. R., III, W. D. Dijak, T. G. Kulowiec, and D. A. Hamilton. 1992. Breeding bird populations in Missouri Ozark forests with and without clearcutting. Journal of Wildlife Management 56(1): 23-29. <http://www.nrs.fs.fed.us/pubs/jrnl/1992/nc_1992_thompson_001.pdf>

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Scaling Rationale: Two options are provided, the first is using the 10x basal area prism or gauge in ft^2/acre. The second option uses calculated values, or the 5x basal area prism or gauge in ft^2/acre.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name:

Southern Yellow Pine Canopy Cover

Definition: Percentage of the ground within the plot or rapid assessment area covered by canopy foliage, branches, and stems of southern yellow pine, (primarily longleaf pine or shortleaf pine) as determined by ocular estimate. Southern yellow pine canopy is defined as the canopy trees of longleaf pine, slash pine, South Florida slash pine, shortleaf pine, or loblolly pine with stems greater than 4" at 4.5 feet (54”), diameter at breast height (DBH).

Background: A variety of characteristic wildlife species occur in open canopy longleaf pine and shortleaf pine dominated woodlands. These include reptiles such as Louisiana pine snake, Florida pine snake, black pine snake, eastern diamondback rattlesnake, and gopher tortoise (Hinderliter 2015, NatureServe 2015). Eastern diamondback rattlesnake prefers upland longleaf pine woodlands, managed with prescribed fire. These reptiles require enough longleaf pine to provide needle drop and resulting fine fuels adequate for burning every few years. The gopher tortoise can do well in upland longleaf pine woodlands with 20-70% canopy cover of longleaf pine (Hinderliter 2014). While the pine warbler does well in dense pine stands (Schroeder 1985), other bird species of concern occur in open canopy pine stands (NatureServe 2015, Richardson 2014a, Tucker 2006).

The values for canopy tree basal area, tree stems per acre, and canopy cover are interrelated, and can be shown in a Gingrich table (Gingrich 1967). A Gingrich table for Dry & Mesic Highlands Pine Woodlands was developed as part of the Interior Highlands Shortleaf Pine Restoration Initiative, Desired Future Conditions effort (Blaney et al. 2015), shown below.

	Percent Canopy Closure for forest grown Shortleaf Pine Stands											
	10%		20%		25%		30%		40%		50%	
DBH	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA
10	30	16	59	32	74	40	89	49	119	65	148	81
12	14	11	28	22	35	28	42	33	57	44	71	56
14	10	11	21	22	26	27	31	33	41	44	51	55
16	9	12	17	24	22	30	26	36	35	49	44	61
18	7	12	14	25	17	31	21	37	28	49	35	62
20	7	15	14	30	17	37	20	45	27	59	34	74
22	6	17	13	34	16	42	19	51	26	68	32	84
24	4	14	9	28	11	35	13	42	18	57	22	71

	Percent Canopy Closure for forest grown Shortleaf Pine Stands									
	60%		70%		80%		90%		100%	
DBH	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA	#/ac	BA
10	178	97	208	113	237	129	267	146	297	162
12	85	67	99	78	113	89	127	100	142	111
14	62	66	72	77	82	88	92	99	103	110
16	52	73	61	85	70	97	78	109	87	122
18	42	74	49	86	56	99	63	111	70	123
20	41	89	48	104	55	119	61	134	68	149
22	38	101	45	118	51	135	58	152	64	169
24	27	85	31	99	36	113	40	127	45	141

These Gingrich tables show average tree diameter at breast height (DBH) as rows, and in columns show percent tree canopy cover, number of trees per acre (#/ac), and basal area (BA). By using Gingrich tables, the relationships between these measures can be seen, and the measures can be applied to southern open pine wildlife habitat in a more informed way. Also, the canopy cover of 1 sq. foot BA of hardwood equals the canopy cover of 2 sq. feet of BA of shortleaf pine. Keep this in mind when assigning canopy cover metric values.

This metric emphasizes longleaf pine and shortleaf pine canopy cover. These two pines have large natural ranges, have declined dramatically during the 20th century and naturally grow in open stands which support characteristic wildlife species. Other southern yellow pines are also included. Shortleaf pine canopy cover is measured in stands of Dry & Mesic Highlands Pine Woodlands, however in Mountain Longleaf examples, longleaf pine and shortleaf pine canopy cover should be measured. In Dry & Mesic Hilly Pine Woodlands, shortleaf pine and loblolly pine canopy cover should be measured (Bragg 2002). This metric is applied to Upper Coastal Plain Pine Flatwoods based on the canopy cover of shortleaf pine and loblolly pine (Bragg et al. 2014). In Dry & Mesic Longleaf Pine Woodlands, and Xeric Longleaf Pine Barrens, longleaf pine canopy cover is measured. In Mesic Longleaf Pine Flatwoods and in Wet Longleaf & Slash Pine Flatwoods & Savannas, canopy cover is measured for longleaf pine, slash pine, and South Florida slash pine.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: The measure of canopy cover by ocular estimate (by eye), is repeatable to the precision of the cover classes used here. This is a fast and easy metric which complements the measure of basal area of longleaf pine.

Measurement Protocol: For assessment area, percentage of the ground within the plot covered by canopy foliage, branches, and stems as determined by ocular estimate. Southern yellow pine canopy is defined as only the canopy trees of longleaf pine, slash pine, South Florida slash pine, shortleaf pine, or loblolly pine with stems greater than 4" at 4.5 feet (54"), diameter at breast height (DBH). Cover estimate classes will be used. Ocular estimate of the percent of ground within the plot covered by foliage and branches.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	30-65% canopy cover of longleaf pine (*Pinus palustris*)
GOOD (B)	>20 to <30% canopy cover or >65 to 75% canopy cover of longleaf pine (*Pinus palustris*)
FAIR (C)	10-20% canopy cover or >75 to 85% canopy cover of longleaf pine (*Pinus palustris*)
POOR (D)	<10% cover or >85% cover of longleaf pine (*Pinus palustris*)

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	30 to 65% canopy cover of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
GOOD (B)	20 to <30% canopy cover or >65 to 75% canopy cover of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
FAIR (C)	10 to <20% canopy cover or >75 to 85% canopy cover of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
POOR (D)	<10% canopy cover or >85% canopy cover of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	20-65% canopy cover of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
GOOD (B)	15 to <20% canopy cover or >65 to 75% canopy cover of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
FAIR (C)	10 to <15% canopy cover or >75 to 85% canopy cover of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
POOR (D)	<10% canopy cover or >85% canopy cover of longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	>20 to 55% canopy cover of longleaf pine (*Pinus palustris*)
GOOD (B)	>15 to 20% canopy cover or >55 to 70% canopy cover of longleaf pine (*Pinus palustris*)

FAIR (C)	5-15% canopy cover or >70 to 80% canopy cover of longleaf pine (*Pinus palustris*)
POOR (D)	<5% canopy cover or >80% canopy cover of longleaf pine (*Pinus palustris*)

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	>25 to 70% canopy cover of shortleaf pine (*Pinus echinata)*
GOOD (B)	20-25% canopy cover or >70 to 80% canopy cover of shortleaf pine (*Pinus echinata)*
FAIR (C)	10 to <20% canopy cover or >80 to 90% canopy cover of shortleaf pine (*Pinus echinata)*
POOR (D)	<10% canopy cover or >90% canopy cover of shortleaf pine (*Pinus echinata)*

Metric Rating	***Dry & Mesic Highlands Pine Woodlands (Mountain Longleaf)***
EXCELLENT (A)	>25 to 70% canopy cover of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*)
GOOD (B)	20-25% canopy cover or >70 to 80% canopy cover of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*)
FAIR (C)	10 to <20% canopy cover or >80 to 90% canopy cover of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*)
POOR (D)	<10% canopy cover or >90% canopy cover of longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*)

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***
EXCELLENT (A)	>25 to 75% canopy cover of shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)
GOOD (B)	>15 to 25% canopy cover or >75 to 85% canopy cover of shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)
FAIR (C)	10-15% canopy cover or >85 to 95% canopy cover of shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)
POOR (D)	<10% canopy cover or >95% canopy cover of shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	>25 to 70% canopy cover of shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)
GOOD (B)	>15 to 25% canopy cover or >70 to 80% canopy cover of shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)
FAIR (C)	10 to 15% canopy cover or >80 to 90% canopy cover of shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)
POOR (D)	<10% canopy cover or >90% canopy cover of shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)

Data for Metric Rating: Published data that support the basis for the metric rating

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2015. Appendix 1. Desired Future Conditions (DFC) for Shortleaf Pine-bluestem and Pine-oak Restoration Sites in the Interior Highlands. Pages 12-31 in Fitzgerald, J. and T. Foti. 2015. The Interior Highlands Shortleaf Pine Restoration Initiative: An Overview (6 August 2015 Draft). Central Hardwoods Joint Venture.

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Bragg, Don C., Ricky O'Neill, William Holimon, Joe Fox, Gary Thornton, and Roger Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

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NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.

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Tucker, J. W., W. D. Robinson, and J. B. Grand. 2006. Breeding productivity of Bachman's sparrows in fire-managed longleaf pine forests. The Wilson Journal of Ornithology 118(2):131–137. <http://www.nwtf.org/NAWTMP/downloads/Literature/Breeding_Productivity_Bachman_Sparrows.pdf>

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.

Scaling Rationale: Scaling of this metric is informed by the cited literature, and by expert input from a project experts meeting held in March 2015.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name:

Southern Yellow Pine Stand Age Structure

Definition: Southern yellow pine, especially longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*) stand age structure.

Background: Age structure for southern yellow pine, especially longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*) is an important ecological integrity metric for woodlands where it is naturally present. This is combined with abundance of large trees, to better reflect actual life history functions in the mixed shortleaf pine (*Pinus echinata*) stands (Bragg 2002, NatureServe 2006). This metric is applied to Upper Coastal Plain Pine Flatwoods based on the age structure of shortleaf pine or loblolly pine (Bragg et al. 2014). Presence of large (basal area at least 20 ft^2/acre of trees ≥ 14” DBH class) or flat-top longleaf pine is evidence of mature characteristics in a southern open pine stand (Longleaf Partnership Council 2014). Due to the slow growth of longleaf pine in the Xeric Longleaf Pine Barrens, the presence of large longleaf pine ≥ 12” DBH is used rather than ≥ 14” DBH.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Age structure for the southern yellow pines, especially longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*) is an important ecological integrity metric for woodlands where it is naturally present in stands (Bragg 2002, NatureServe 2006). Presence of large (basal area at least 20 ft^2/acre of trees ≥ 14” DBH class) or flat-top longleaf pine is evidence of mature characteristics in a stand (Longleaf Partnership Council 2014).

Measurement Protocol: In longleaf pine (*Pinus palustris*) stands determine if flat-top longleaf pine are present in the canopy, and measure the basal area of southern yellow pine trees in the ≥ 14” DBH class. In addition to longleaf pine and shortleaf pine, in the Wet Longleaf & Slash Pine Flatwoods & Savannas, slash pine in included, in Mesic Longleaf Pine Flatwoods, slash pine, and South Florida slash pine is included, in Dry & Mesic Hilly Pine Woodlands and in Upper Coastal Plain Pine Flatwoods, loblolly pine is included. Due to the slow growth of longleaf pine in the Xeric Longleaf Pine Barrens, the presence of large longleaf pine ≥ 12” DBH is used rather than ≥ 14” DBH.

Metric Rating:

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of longleaf pine trees ≥14” DBH class or flat-top longleaf pine is present
GOOD (B)	Basal area ≥10 ft^2/acre of longleaf pine trees ≥14” DBH class
FAIR (C)	Longleaf pine trees ≥14” DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No longleaf pine trees ≥14” DBH or flat-top longleaf pine are present

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of longleaf pine, slash pine or South Florida slash pine trees ≥14” DBH class or flat-top longleaf pine or South Florida slash pine is present
GOOD (B)	Basal area ≥10 ft^2/acre of longleaf pine or South Florida slash pine trees ≥14” DBH class
FAIR (C)	Longleaf pine or South Florida slash pine trees ≥14” DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No longleaf pine or South Florida slash pine trees ≥14” DBH or flat-top longleaf pine or South Florida slash pine are present

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of longleaf pine or slash pine trees ≥14” DBH class or flat-top longleaf pine or slash pine is present
GOOD (B)	Basal area ≥10 ft^2/acre of longleaf pine or slash pine trees ≥14” DBH class
FAIR (C)	Longleaf pine or slash pine trees ≥14” DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No longleaf pine or slash pine trees ≥14” DBH or flat-top longleaf pine or slash pine are present

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of longleaf pine trees ≥ 12” DBH class or flat-top longleaf pine is present
GOOD (B)	Basal area ≥10 ft^2/acre of longleaf pine trees ≥ 12” DBH class
FAIR (C)	Longleaf pine trees ≥12” DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No longleaf pine trees ≥12” DBH or flat-top longleaf pine are present

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of shortleaf pine trees ≥14” DBH class
GOOD (B)	Basal area ≥10 ft^2/acre of shortleaf pine trees ≥14” DBH class
FAIR (C)	Shortleaf pine trees ≥14” DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No shortleaf pine trees ≥14” DBH are present

Metric Rating	***Dry & Mesic Highlands Pine Woodlands (Mountain Longleaf)***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of longleaf pine and/or shortleaf pine trees ≥14” DBH class or flat-top longleaf pine is present
GOOD (B)	Basal area ≥10 ft^2/acre of longleaf pine and/or shortleaf pine trees ≥14” DBH class
FAIR (C)	Longleaf pine and/or shortleaf pine trees ≥14” DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No longleaf pine and/or shortleaf pine trees ≥14” DBH or flat-top longleaf pine are present

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of loblolly pine and/or shortleaf pine trees ≥14” DBH class
GOOD (B)	Basal area ≥10 ft^2/acre of loblolly pine and/or shortleaf pine trees ≥14” DBH class
FAIR (C)	Loblolly pine and/or shortleaf pine trees ≥14” DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No loblolly pine and/or shortleaf pine trees ≥14” DBH are present

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	Basal area ≥20 ft^2/acre of loblolly pine and/or shortleaf pine trees ≥14” DBH class
GOOD (B)	Basal area ≥10 ft^2/acre of loblolly pine and/or shortleaf pine trees ≥14” DBH class
FAIR (C)	Loblolly pine and/or shortleaf pine trees ≥14” DBH class are present, but <10 ft^2/acre basal area of those large trees
POOR (D)	No loblolly pine and/or shortleaf pine trees ≥14” DBH are present

Data for Metric Rating: Published data that support the basis for the metric rating

Bragg, Don C. 2002. Reference conditions for old-growth pine forests in the Upper West Gulf Coastal Plain. Jour. Torrey Botanical Society 129(4):261-288.

Bragg, Don C., Ricky O’Neill, William Holimon, Joe Fox, Gary Thornton, and Roger Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America’s Longleaf Restoration Initiative, Longleaf Partnership Council.

NatureServe. 2006. International Ecological Classification Standard: Terrestrial Ecological Classifications. Classification and Integrity Indicators for Selected Forest Types of Office Depot's Sourcing Areas of the Southeastern United States. NatureServe Central Databases. Arlington, VA. Data current as of 29 March 2006.

NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.

White, David L. and F. Thomas Lloyd. 1998. An Old-Growth Definition for Dry and Dry-Mesic Oak Pine Forests. USDA Forest Service - Southern Research Station. Gen. Tech. Rept. SRS-23.

Scaling Rationale: Scaling is consistent and based on recent literature, for nearly all ecosystems the presence of large pine ≥ 14” DBH is used. Due to the slow growth of longleaf pine in the Xeric Longleaf Pine Barrens, the presence of large longleaf pine ≥ 12” DBH is used rather than ≥ 14” DBH.

Confidence that reasonable logic and/or data support the index: Moderate to high.

RANK FACTOR: VEGETATION

Metric Name:

Canopy Hardwood Basal Area

Definition: Combined basal area of all canopy hardwood trees. The cross section area of hardwood tree stems (defined here as square feet /acre) for canopy trees ≥ 5 inches DBH, and measured using a 10x basal area prism or gauge at the center point of the plot or rapid assessment area or by measuring all canopy hardwood trees ≥ 5 inches DBH within a plot of a defined area.

Background: Basal area of trees by species is data very commonly collected as part of forestry inventory. It is a widely used measure quantifying the dominance of tree species, and is repeatable using a 10x basal area prism or gauge. Hardwood trees in southern open pine can include ruderal and fire-intolerant hardwood trees, including red maple (*Acer rubrum),* sweetgum (*Liquidambar styraciflua),* tulip-tree (*Liriodendron tulipifera),* blackgum (*Nyssa sylvatica),* water oak (*Quercus nigra),* and especially in wet flatwoods and savannas, Chinese tallow tree (*Triadica sebifera)* (Bragg 2014, NatureServe 2011). A small amount of hardwood tree basal area naturally occurs in many upland southern open pine ecosystems, especially oaks such as southern red oak (*Quercus falcata),* post oak (*Quercus stellata*)*,* black oak (*Quercus velutina),* turkey oak *(Quercus laevis),* sand post oak (*Quercus margarettiae),* and blackjack oak (*Quercus marilandica)* (Bragg 2002, Bragg 2014, Hiers et al. 2014, NatureServe 2015b). There are various wildlife benefits to retention of some fire tolerant hardwoods, especially oaks, in southern open pine ecosystems (Hiers et al. 2014). Increasing dominance or codominance by hardwoods can result from lack of fire, and is associated with declines of southern open pine wildlife. For brown-headed nuthatch and pine warbler, hardwood basal area less than 22 ft^2/acre is best, when deciduous hardwoods begin to reach the canopy of stands, these birds are rarely present (Richardson 2014). Bachman's sparrow and prairie warbler habitat should lack or have a low proportion of hardwood in the canopy (Richardson 2014a). In good red-cockaded woodpecker areas, the canopy lacks hardwood, or has low proportion of hardwoods, only 10 to 30% of the canopy trees (USFWS 2003). Several declining reptiles prefer open canopy longleaf pine dominated woodlands, these include Louisiana pine snake, Florida pine snake, black pine snake, eastern diamondback rattlesnake, and gopher tortoise (Hinderliter 2015, NatureServe 2015b). The eastern diamondback rattlesnake also uses hardwood dominated areas, in addition to southern open pine woodlands. Maintenance condition for longleaf pine woodlands is considered to be basal area ≤ 10 ft^2/acre of canopy hardwoods or off-site pines ≥ 5" DBH. (Longleaf Partnership Council 2014).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Basal area is a widely used measure quantifying the dominance of tree species, and is repeatable using a 10x basal area prism or gauge. Measures of basal area need to be collected at multiple locations to get a stand level estimate of basal area.

Measurement Protocol: Basal area of canopy hardwood trees ≥ 5" diameter at 4.5 feet (54"), diameter at breast height (DBH). **Option 1**: A 10x factor basal area prism or gauge is used from the center of the data collection area, and trees are tallied by species. The tallied counts of canopy hardwood tree species are multiplied by the basal area factor of 10 to get the basal area in ft^2/acre, and all canopy hardwood species basal areas are totaled. **Option 2**: Delineate a plot of at least 0.1 acre or 400 m^2 and measure all canopy tree species ≥5" diameter at 4.5 feet (54"), diameter at breast height (DBH), then convert diameter measurements to ft^2/acre using formula:

Basal area (ft^2/acre) = $0.005454 * DBH^2$

Then, all canopy hardwood species basal areas are totaled. For the final value of basal area the per plot size value must be converted to a per acre value.

A value of "0" should be listed for species with stems > 5" DBH within the plot, but that are not included in the tallied basal area (i.e., not picked up in prism or gauge sample). This attribute is directly linked to the respective canopy species as indicated by the ending number designation.

Metric Rating: These values represent results in ft^2/acre using Option 1, the 10x basal area prism or gauge. Basal area values such as 15, 35, 75, and 95 are not accommodated.

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	0 to 10 ft^2/acre basal area of hardwood trees
GOOD (B)	20 ft^2/acre basal area of hardwood trees
FAIR (C)	30 ft^2/acre basal area of hardwood trees
POOR (D)	$\geq$ 40 ft^2/acre basal area of hardwood trees

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	0 to 10 ft^2/acre basal area of hardwood trees
GOOD (B)	20 ft^2/acre basal area of hardwood trees
FAIR (C)	30 ft^2/acre basal area of hardwood trees
POOR (D)	$\geq$ 40 ft^2/acre basal area of hardwood trees

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	0 to 10 ft^2/acre basal area of hardwood trees
GOOD (B)	20 ft^2/acre basal area of hardwood trees
FAIR (C)	30 ft^2/acre basal area of hardwood trees
POOR (D)	$\geq$ 40 ft^2/acre basal area of hardwood trees

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	0 to 10 ft^2/acre basal area of hardwood trees
GOOD (B)	20 ft^2/acre basal area of hardwood trees
FAIR (C)	30 ft^2/acre basal area of hardwood trees
POOR (D)	$\geq$ 40 ft^2/acre basal area of hardwood trees

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	$\leq$ 20 ft^2/acre basal area of hardwood trees
GOOD (B)	30-40 ft^2/acre basal area of hardwood trees
FAIR (C)	50 ft^2/acre basal area of hardwood trees
POOR (D)	$\geq$ 60 ft^2/acre basal area of hardwood trees

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***
EXCELLENT (A)	$\leq$ 20 ft^2/acre basal area of hardwood trees
GOOD (B)	30 ft^2/acre basal area of hardwood trees
FAIR (C)	40 to 50 ft^2/acre basal area of hardwood trees
POOR (D)	$\geq$ 60 ft^2/acre basal area of hardwood trees

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	$\leq$ 20 ft^2/acre basal area of hardwood trees
GOOD (B)	30 ft^2/acre basal area of hardwood trees
FAIR (C)	40-50 ft^2/acre basal area of hardwood trees
POOR (D)	$\geq$ 60 ft^2/acre basal area of hardwood trees

These values below represent results in ft^2/acre using Option 2. Calculated values other than multiples of 10 are accommodated.

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	$<$20 ft^2/acre basal area of hardwood trees
GOOD (B)	$\geq$20 to 25 ft^2/acre basal area of hardwood trees
FAIR (C)	$>$25 to 35 ft^2/acre basal area of hardwood trees
POOR (D)	$>$35 ft^2/acre basal area of hardwood trees

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	$<$20 ft^2/acre basal area of hardwood trees
GOOD (B)	$\geq$20 to 25 ft^2/acre basal area of hardwood trees
FAIR (C)	$>$25 to 35 ft^2/acre basal area of hardwood trees
3POOR (D)	$>$35 ft^2/acre basal area of hardwood trees

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	$<$20 ft^2/acre basal area of hardwood trees
GOOD (B)	$\geq$20 to 25 ft^2/acre basal area of hardwood trees

FAIR (C)	>25 to 35 ft^2/acre basal area of hardwood trees
POOR (D)	>35 ft^2/acre basal area of hardwood trees

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	<20 ft^2/acre basal area of hardwood trees
GOOD (B)	≥20 to 25 ft^2/acre basal area of hardwood trees
FAIR (C)	>25 to 35 ft^2/acre basal area of hardwood trees
POOR (D)	>35 ft^2/acre basal area of hardwood trees

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	≤20 ft^2/acre basal area of hardwood trees
GOOD (B)	>20 to 40 ft^2/acre basal area of hardwood trees
FAIR (C)	>40 to 50 ft^2/acre basal area of hardwood trees
POOR (D)	>50 ft^2/acre basal area of hardwood trees

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***
EXCELLENT (A)	≤20 ft^2/acre basal area of hardwood trees
GOOD (B)	>20 to 30 ft^2/acre basal area of hardwood trees
FAIR (C)	>30 to 50 ft^2/acre basal area of hardwood trees
POOR (D)	>50 ft^2/acre basal area of hardwood trees

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	≤20 ft^2/acre basal area of hardwood trees
GOOD (B)	>20 to 30 ft^2/acre basal area of hardwood trees
FAIR (C)	>30 to 50 ft^2/acre basal area of hardwood trees
POOR (D)	>50 ft^2/acre basal area of hardwood trees

Data for Metric Rating: Published data that support the basis for the metric rating

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2015. Appendix 1. Desired Future Conditions (DFC) for Shortleaf Pine-bluestem and Pine-oak Restoration Sites in the Interior Highlands. Pages 12-31 in Fitzgerald, J. and T. Foti. 2015. The Interior Highlands Shortleaf Pine Restoration Initiative: An Overview (6 August 2015 Draft). Central Hardwoods Joint Venture.

Bragg, D. C. 2002. Reference conditions for old-growth pine forests in the Upper West Gulf Coastal Plain. Jour. Torrey Botanical Society 129(4):261-288.

Bragg, D. C., R. O'Neill, W. Holimon, J. Fox, G. Thornton, and R. Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

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Hinderliter, M. 2014. Gopher Tortoise Open Pine DFCs. US Fish and Wildlife Service. Jackson, MS.

Hinderliter, M. 2015. Black Pine Snake Questions and Answers. US Fish and Wildlife Service. Jackson, MS. < http://www.fws.gov/mississippies/_pdf/Black%20Pinesnake%20-%20QUESTIONS%20AND%20ANSWERS.pdf>

Hiers, J. K., J. R. Walters, R. J. Mitchell, J. M. Varner, L. M. Conner, L. A. Blanc, and J. Stowe. 2014. Commentary: Ecological Value of Retaining Pyrophytic Oaks in Longleaf Pine Ecosystems. The Journal of Wildlife Management 78(3):383–393.

Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America's Longleaf Restoration Initiative, Longleaf Partnership Council.

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Elledge, J. and B. Barlow. 2012. Basal Area: A Measure Made for Management. ANR-1371. Alabama Cooperative Extension System (Alabama A&M University and Auburn University). <http://www.aces.edu/pubs/docs/A/ANR-1371/ANR-1371.pdf>

NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.

NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: April 28, 2015).

NatureServe. 2015b. International Ecological Classification Standard: Terrestrial Ecological Classifications. U.S. National Vegetation Classification. Southern Open Pine Groupings. NatureServe Central Databases. Arlington, VA. Data current as of 10 March 2015.

Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (*Peucaea aestivalis*). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.

Scaling Rationale: The scaling here for stands with less than 10 basal area of hardwood may need more work. It might be worth clarifying in the metric scoring, the differences between hardwoods which may be a natural component of dry site southern open pine woodlands, and those which are ruderal or indicative of lack of fire.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name:

Stand Density Index

Definition: Stand Density Index (SDI) is a measure of tree density which incorporates the size (quadratic mean diameter) and density (trees per acre) of trees in a stand. Trees per acre (TPA) alone is not as useful a measure of stand density since it does not account for differences in tree diameter (Ziede 2005). The tree count must incorporate some measure of tree size to have meaning in forest management. SDI has two significant advantages over basal area (BA): 1) BA varies in equally dense stands (stands of equal BA can have differing amounts of competition for resources since TPA may vary), and 2) BA is not independent of site and age (BA values that indicate a need for thinning vary with stand age and site quality). A primary benefit to SDI is its independence of stand age and site quality (Harrington 2001, Ziede 2005).

Background: Stand Density Index (SDI) was first developed in the 1930s (Reineke 1933), and has been used more in forestry during recent years (Ducey and Valentine 2008, Shaw and Long 2010). SDI has been used in the assessment and management of goshawk nesting habitat (Lilieholm et al. 1993, Lilieholm et al. 1994) and elk thermal cover, in both ponderosa pine (McTague and Patton 1989) and lodgepole pine (Smith and Long 1987). More recently, SDI has been shown to be useful in managing longleaf pine for the recovery of red-cockaded woodpecker (Shaw and Long 2007) and as a measure of canopy trees in relation to functioning herbaceous groundcover in longleaf pine woodlands in Georgia (Mulligan et al. 2002). Commercial forestry uses SDI for scheduling thinning in intensively managed southern pine stands (Doruska and Nolan 1999, Harrington 2001, Williams 1996).

Stand Density Index (SDI) is calculated:

$$SDI = TPA * (Dq/10)^{1.6}$$

where TPA is the density, in trees per acre
Dq is quadratic mean stand diameter in inches at breast height
10 is the reference diameter in inches
1.6 is the slope factor

Quadratic mean diameter is different from the common arithmetic mean diameter. Quadratic mean diameter is the diameter of a tree of average basal area, and is calculated:

$$Dq = \sqrt{BA/(0.005454 * n)}$$

Where *BA* is the basal area in square feet per acre
n is the corresponding number of trees

Quadratic mean diameter is also simply calculated as the square root of the average of the squared diameters of the tallied trees, calculated:

$Dq = \sqrt{(\sum d_i^2)/n}$

Where *d* is the diameter of each tree
n is the number of trees

Stand Density Index is grounded in the "-3/2 self-thinning law", which describes the inverse relationship between the average mass of plants, and their density (Shaw and Long 2010). For use in forestry, the quadratic mean diameter (*Dq*) is substituted for average mass of trees.

For many kinds of trees, maximum SDI values have been calculated. The maximum SDI values for longleaf pine and slash pine are 400 (Harrington 2001, Reineke 1933, Shaw and Long 2007), and the maximum SDI values for shortleaf pine and loblolly pine are 450 (Harrington 2001, Reineke 1933). Various percentages of the maximum SDI values relate to levels of canopy closure, effects of canopy trees on understory plants, and density dependent mortality in forest stands. For instance:

- 25% SDI is where the overstory begins to have significant negative effects on the understory (Mulligan et al. 2002, Shaw and Long 2007), and is associated with the transition from open-grown to competing trees (Long 1985, Shaw and Long 2007)
- 35% SDI is the lower limit of full site occupancy, i.e. stand growth continues to increase with increasing relative density above this point, but at a decreasing rate (Long 1985)
- 35 – 40% SDI is the range of maximum stand tree growth (Long 1985, Shaw and Long 2007)
- 60% SDI is the onset of self-thinning, i.e. density dependent tree mortality (Long 1985, Shaw and Long 2007)

In practice, larger diameter stands of southern pines do not follow the maximum SDI, but follow a lower curve called mature stand boundary (Shaw and Long 2007, Shaw and Long 2010). This relates to higher mortality of large trees which is not density dependent, and perhaps is due to the inability of tree growth to quickly recapture the canopy gaps were large pines have died (Shaw and Long 2010).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Forest managers who have been managing southern open pine for wildlife have found that Stand Density Index (Shaw and Long 2007) has many advantages over basal area, or measures of canopy cover (such as visual estimates, or densiometer). Research indicates that Stand Density Index has a predicable relationship to grassy herbaceous groundcover conditions in open pine stands (Moore and Deiter 1992, Mulligan et al. 2002).

Measurement Protocol: Stand Density Index is calculated from the density in trees per acre (TPA) and the quadratic mean diameters (*Dq*) at breast height of the pine trees in sample plots. Within a stand, SDI can be calculated from either a set of fixed area plots or variable area plots (i.e. prism sampling), where trees are tallied and the diameters of each tree is measured. Both are easy to apply. Simple calculations in the office can average values across the stand, spreadsheets make this easier. Silvicultural treatments occur at the scale of the stand, not a specific point within a stand, so the stand level data is most useful for informing management.

Metric Rating: Values are calculated and averaged from sample plots within a stand.

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands*** applies to longleaf pine (*Pinus palustris)*
EXCELLENT (A)	SDI = 60 – 125 (15 - 31% of Maximum SDI of 400)
GOOD (B)	SDI = 40 – 60 or 125 -160 (10-15% or 31-40% of Maximum SDI of 400, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 20 – 40 or 160 - 200 (5-10% or 40-50% of Maximum SDI, 240 is 60% of Maximum SD of 400, *which is the onset of self-thinning*)
POOR (D)	SDI <20 or >200 (<5% or > 50%, 240 is 60% of Maximum SD of 400, *the onset of self-thinning*)

Metric Rating	***Mesic Longleaf Pine Flatwoods*** applies to longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
EXCELLENT (A)	SDI = 60 – 125 (15-31% of Maximum SDI of 400)
GOOD (B)	SDI = 40 – 60 or 125 -160 (10-15% or 31-40% of Maximum SDI of 400, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 20 – 40 or 160 - 190 (5-10% or 40-48% of Maximum SDI, 240 is 60% of Maximum SD of 400, *which is the onset of self-thinning*)
POOR (D)	SDI <20 or >190 (<5% or > 48%, 240 is 60% of Maximum SD of 400, *the onset of self-thinning*)

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas*** applies to longleaf pine (*Pinus palustris*), slash pine (*Pinus elliottii*), and/or South Florida slash pine (*Pinus elliottii* var. *densa*)
EXCELLENT (A)	SDI = 35 – 120 (9-30% of Maximum SDI of 400)
GOOD (B)	SDI = 20 – 35 or 120 -155 (5-9% or 30-39% of Maximum SDI of 400, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 10 – 20 or 155 - 180 (2.5-5% or 39-45% of Maximum SDI, 240 is 60% of Maximum SD of 400, *which is the onset of self-thinning*)
POOR (D)	SDI <10 or >180 (<2.5% or > 45%, 240 is 60% of Maximum SD of 400, *the onset of self-thinning*)

Metric Rating	***Xeric Longleaf Pine Barrens*** applies to longleaf pine (*Pinus palustris)*
EXCELLENT (A)	SDI = 50 – 120 (13-30% of Maximum SDI of 400)
GOOD (B)	SDI = 30 – 50 or 120 -160 (8-13% or 30-40% of Maximum SDI of 400, *35 – 40% SDI is near maximum of stand growth*)

FAIR (C)	SDI = 20 – 30 or 160 - 180 (5-8% or 40-45% of Maximum SDI, 240 is 60% of Maximum SD of 400, *which is the onset of self-thinning*)
POOR (D)	SDI <20 or >180 (<5% or > 45%, 240 is 60% of Maximum SD of 400, *the onset of self-thinning*)

Metric Rating	***Dry & Mesic Highlands Pine Woodlands*** applies to shortleaf pine (*Pinus echinata)*
EXCELLENT (A)	SDI = 65 – 135 (14-30% of Maximum SDI of 450)
GOOD (B)	SDI = 45 – 65 or 135 -180 (10-14% or 30-40% of Maximum SDI of 450, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 20 – 45 or 180 - 225 (4-10% or 40-50% of Maximum SDI, 270 is 60% of Maximum SD of 450, *which is the onset of self-thinning*)
POOR (D)	SDI <20 or >225 (<4% or > 50%, 270 is 60% of Maximum SD of 450, *the onset of self-thinning*)

Metric Rating	***Dry & Mesic Highlands Pine Woodlands*** applies to mountain longleaf pine (*Pinus palustris*)
EXCELLENT (A)	SDI = 55 – 120 (14-30% of Maximum SDI of 400)
GOOD (B)	SDI = 40 – 55 or 120 -160 (10-14% or 30-40% of Maximum SDI of 400, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 15 – 40 or 160 - 200 (4-10% or 40-50% of Maximum SDI, 240 is 60% of Maximum SD of 400, *which is the onset of self-thinning*)
POOR (D)	SDI <15 or >200 (<4% or > 50%, 240 is 60% of Maximum SD of 400, *the onset of self-thinning*)

Metric Rating	***Dry & Mesic Hilly Pine Woodlands*** applies to shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)
EXCELLENT (A)	SDI = 55 – 155 (12-34% of Maximum SDI of 450)
GOOD (B)	SDI = 35 – 55 or 155 -205 (8-12% or 34-45% of Maximum SDI of 450, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 20 – 35 or 205 - 225 (4-8% or 45-50% of Maximum SDI, 270 is 60% of Maximum SD of 450, *which is the onset of self-thinning*)
POOR (D)	SDI <20 or >225 (<4% or > 50%, 270 is 60% of Maximum SD of 450, *the onset of self-thinning*)

Metric Rating	***Upper Coastal Plain Pine Flatwoods*** applies to shortleaf pine (*Pinus echinata)* and/or loblolly pine (*Pinus taeda*)
EXCELLENT (A)	SDI = 55 – 145 (12-32% of Maximum SDI of 450)
GOOD (B)	SDI = 35 – 55 or 145 -180 (8-12% or 32-40% of Maximum SDI of 450, *35 – 40% SDI is near maximum of stand growth*)
FAIR (C)	SDI = 20 – 35 or 180 - 225 (4-8% or 40-50% of Maximum SDI, 270 is 60% of Maximum SD of 450, *which is the onset of self-thinning*)
POOR (D)	SDI <20 or >225 (<4% or > 50%, 270 is 60% of Maximum SD of 450, *the onset of self-thinning*)

Data for Metric Rating: Published data that support the basis for the metric rating

Doruska, P.F. and Nolen, W.R., Jr. 1999. Use of stand density index to schedule thinnings in loblolly pine plantations: a spreadsheet approach. Southern Journal of Applied Forestry. 23(1): 21-29.

Ducey, M. J. and H. T. Valentine. 2007. Direct Sampling for Stand Density Index. Western Journal of Applied Forestry 23(2): 78-82.

Lilieholm, R. J., W. B. Kessler, and K. Merrill. 1993. Stand density index applied to timber and goshawk habitat objectives in Douglas-fir. Environmental Management 17(6): 773-779.

Lilieholm, R. J., J. N. Long, and S. Patla. 1994. Assessment of goshawk nest area habitat using stand density index. Pp. 18-23 *In* Block, W.M., M.L. Morrison, and M.H. Rieser, eds. The northern goshawk: ecology and management. Proceedings of a Symposium of the Cooper Ornithological Society. Studies in Avian Biology No. 16.

Long, J. N. 1985. A practical approach to density management. The Forestry Chronicle 61(1):23-27.

Harrington, T. B. 2001. Silvicultural approaches for thinning southern pines: method, intensity and timing. Warnell School of Forest Resources and Georgia Forestry Commission. Publication No. FSP002. <http://www.gfc.state.ga.us/resources/publications/SilviculturalApproaches.pdf>

McTague, J. P. and D. R. Patton. 1989. Stand density index and its application in describing wildlife habitat. Wildlife Society Bulletin 17(1):58-62.

Moore, M. M. and D. A. Deiter. 1992. Stand Density Index as a predictor of forage production in northern Arizona pine forests. Journal of Range Management 45:267-271.

Mulligan, M. K., L. K. Kirkman, and R. J. Mitchell. 2002. *Aristida beyrichiana* (wiregrass) establishment and recruitment: implications for restoration. Restoration Ecology 10(1): 68-76.

Reineke, L. H. 1933. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research. 46(7): 627–637.

Shaw, J. D. and J. N. Long. 2007. A density management diagram for longleaf pine stands with application to red-cockaded woodpecker habitat. Southern Journal of Applied Forestry 31(1): 28–38.

Shaw, J. D., and Long, J. N. 2010. Consistent definition and application of Reineke's stand density index in silviculture and stand projection. In Integrated Management of Carbon Sequestration and Biomass Utilization Opportunities in a Changing Climate. Proceedings of the 2009 National Silviculture Workshop, 15‑18 June 2009, Boise, Idaho. Jain, T. B., R. T. Graham, and J. Sandquist (eds.). RMRS-P-61. pp. 199‑209.

Smith, F. W. and J. N. Long. 1987. Elk hiding and thermal cover guidelines in the context of lodgepole pine stand density. Western Journal of Applied Forestry 2(1):6-10.

Williams, R. A. 1996. Stand density index for loblolly pine plantations in North Louisiana. Southern Journal of Applied Forestry 20(2): 110-113.

Zeide. B. 2005. How to measure stand density. Trees 19(1):1-14.

Scaling Rationale: Scaling is informed by the research pertaining to SDI in open pine stands which have a grass dominated ground cover (Moore and Deiter 1992, Mulligan et al. 2002, Shaw and Long 2007). The range of 15–30 % of maximum SDI correlates well with the ranges of basal area considered to indicate excellent condition by external expert reviewers. Values below 25% of maximum SDI are best for the functioning of native wiregrass (Mulligan et al. 2002), but in longleaf pine ecosystems adequate basal area is needed to provide needle drop which is necessary as fuel for frequent prescribed fire.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name:

Midstory Fire Tolerant Hardwood Cover

Definition: Midstory Fire Tolerant Hardwood Cover. Percentage of the ground within the plot covered by fire tolerant hardwood midstory foliage, branches, and stems as determined by ocular (visual) estimate. Midstory is defined as any woody stems (including tall shrubs, small trees, and vines) which are > 10 feet tall, up to the height of the bottom of the tree canopy. Young trees of this size are commonly called saplings. Fire tolerant hardwood tree species include turkey oak, sand post oak, bluejack oak, blackjack oak, black oak, post oak, southern red oak, black hickory and flowering dogwood. Individuals which grow into the canopy are considered to be tree size and are included in the canopy basal area metrics.

Background: Southern open pine ecosystems with an open midstory can provide better habitat for many of the characteristic wildlife. Metrics similar to this have been used successfully on other southern open pine projects (FNAI and FFS 2014, NatureServe 2011). Many of these wildlife species rely on grassy herbaceous groundcover with some dwarf shrubs, often associated with open midstory and open canopy of longleaf pine. Wildlife which prefer an open midstory include reptiles such as Louisiana pine snake, Florida pine snake, black pine snake, eastern diamondback rattlesnake, and gopher tortoise (Hinderliter 2014, Hinderliter 2015, NatureServe 2015). While also preferring an open midstory, the northern bobwhite and Bachman's sparrow both use scattered tall shrubs and saplings for perching, including oaks, sassafras, black cherry and persimmon (NatureServe 2015, Richardson 2014a). Fire tolerant hardwood species naturally occur in upland southern open pine ecosystems, and include turkey oak, sand post oak, bluejack oak, blackjack oak, post oak, southern red oak and flowering dogwood. There are various wildlife benefits to retention of some fire tolerant hardwoods in southern open pine ecosystems (Hiers et al. 2014). For longleaf pine woodlands, maintenance conditions are considered to be 20% or less mid-story cover, with most of this fire tolerant species and < 5% cover of fire-intolerant hardwood or off-site pine trees over 16 feet tall (Longleaf Partnership Council 2014). To recover the biodiversity associated with shortleaf pine natural communities of the Interior Highlands (Ozark and Ouachita region), desired future conditions for cover of the midstory layer were determined to be <10% for Shortleaf Pine-Bluestem, <30% for Dry Mesic Shortleaf Pine-Oak Woodland, and 15% for Dry Shortleaf Pine-Oak. Midstory was defined as >10 feet (>3 m) tall and below the bottom of the canopy (Blaney et al. 2015), which is followed here. Most of the midstory would be composed of fire tolerant or fire resistant trees and tall shrubs.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: The presence of a midstory greater than 25% cover is associated with the decline in habitat quality for many wildlife species of southern open pine ecosystems. Generally there is a decline in herbaceous groundcover with an increase in midstory greater than 25% cover.

Measurement Protocol: For assessment area, estimate percentage of the ground within the plot covered by fire tolerant hardwood midstory foliage, branches, and stems as determined by ocular (visual) estimate. Midstory is defined to include any woody stems (including tall shrubs, small trees and vines) which are > 10 feet tall, up to the height of the bottom of the tree canopy. Measure fire tolerant hardwood cover (turkey oak, sand post oak, bluejack oak, blackjack oak, black oak, post oak, southern red oak, black hickory and flowering dogwood). Cover estimate classes will be used. Ocular (visual) estimate of the percent of ground within the plot covered by foliage and branches. Because forest vegetation layers can overlap, total percent cover may exceed 100%.

Metric Rating: This metric might not apply well to Wet Longleaf & Slash Pine Flatwoods & Savannas, since the fire tolerant hardwoods listed are upland species, not generally found in wetter areas.

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	<15% cover of midstory fire tolerant hardwoods
GOOD (B)	15 to <20% cover of midstory fire tolerant hardwoods
FAIR (C)	20 to 25% cover of midstory fire tolerant hardwoods
POOR (D)	>25% cover of midstory fire tolerant hardwoods

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	<10% cover of midstory fire tolerant hardwoods
GOOD (B)	10 to <20% cover of midstory fire tolerant hardwoods
FAIR (C)	20 to 25% cover of midstory fire tolerant hardwoods
POOR (D)	>25% cover of midstory fire tolerant hardwoods

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	<10% cover of midstory fire tolerant hardwoods
GOOD (B)	10-15% cover of midstory fire tolerant hardwoods
FAIR (C)	>15 to 25% cover of midstory fire tolerant hardwoods
POOR (D)	>25% cover of midstory fire tolerant hardwoods

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	<10% cover of midstory fire tolerant hardwoods
GOOD (B)	10-20% cover of midstory fire tolerant hardwoods
FAIR (C)	>20 to 25% cover of midstory fire tolerant hardwoods
POOR (D)	>25% cover of midstory fire tolerant hardwoods

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	<10% cover of midstory fire tolerant hardwoods
GOOD (B)	10-30% cover of midstory fire tolerant hardwoods
FAIR (C)	>30 to 40% cover of midstory fire tolerant hardwoods
POOR (D)	>40% cover of midstory fire tolerant hardwoods

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***

EXCELLENT (A)	<10% cover of midstory fire tolerant hardwoods
GOOD (B)	10-20% cover of midstory fire tolerant hardwoods
FAIR (C)	>20 to 35% cover of midstory fire tolerant hardwoods
POOR (D)	>35% cover of midstory fire tolerant hardwoods

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	<10% cover of midstory fire tolerant hardwoods
GOOD (B)	10 to 20% cover of midstory fire tolerant hardwoods
FAIR (C)	>20 to 35% cover of midstory fire tolerant hardwoods
POOR (D)	>35% cover of midstory fire tolerant hardwoods

Data for Metric Rating: Published data that support the basis for the metric rating

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2015. Appendix 1. Desired Future Conditions (DFC) for Shortleaf Pine-bluestem and Pine-oak Restoration Sites in the Interior Highlands. Pages 12-31 in Fitzgerald, J. and T. Foti. 2015. The Interior Highlands Shortleaf Pine Restoration Initiative: An Overview (6 August 2015 Draft). Central Hardwoods Joint Venture.

Bragg, D. C., R. O'Neill, W. Holimon, J. Fox, G. Thornton, and R. Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

FNAI and FFS. 2014. Longleaf Pine Ecosystem Geodatabase v.1 Final Report. A cooperative project between Florida Natural Areas Inventory and the Florida Forest Service. <http://www.fnai.org/LongleafGDB.cfm>

Hinderliter, M. 2014. Gopher Tortoise Open Pine DFCs. US Fish and Wildlife Service. Jackson, MS.

Hinderliter, M. 2015. Black Pine Snake Questions and Answers. US Fish and Wildlife Service. Jackson, MS. < http://www.fws.gov/mississippies/_pdf/Black%20Pinesnake%20-%20QUESTIONS%20AND%20ANSWERS.pdf>

Hiers, J. K., J. R. Walters, R. J. Mitchell, J. M. Varner, L. M. Conner, L. A. Blanc, and J. Stowe. 2014. Commentary: Ecological Value of Retaining Pyrophytic Oaks in Longleaf Pine Ecosystems. The Journal of Wildlife Management 78(3):383–393.

Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America's Longleaf Restoration Initiative, Longleaf Partnership Council.

NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: April 28, 2015).

NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.

Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (Peucaea aestivalis). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.

Scaling Rationale: The scaling of this metric may need to be reviewed and edited depending on the final midstory definition used. Here this is defined as woody plants of tree sapling size, 1-4” DBH. These will be above the height of shrubs, > 6 feet tall and are not considered trees for the basal area measures used in other metrics (which are limited to trees > 4” DBH).

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name:

Midstory Overall Cover

Definition: Midstory Overall Cover. Percentage of the ground within the plot covered by midstory foliage, branches, and stems as determined by ocular (visual) estimate. Spaces between leaves and stems do NOT count as cover. Midstory is defined to include any woody stem (including tall shrubs, trees and vines) which are > 10 feet tall, up to the height of the bottom of the tree canopy.

Background: Southern open pine ecosystems with an open midstory can provide better habitat for many of the characteristic wildlife. Metrics similar to this have been used successfully on other southern open pine projects (FNAI and FFS 2014, NatureServe 2011). Many of these wildlife species rely on grassy herbaceous groundcover with some dwarf shrubs, often associated with open midstory and open canopy of longleaf pine. Wildlife which prefer an open midstory include reptiles such as Louisiana pine snake, Florida pine snake, black pine snake, eastern diamondback rattlesnake, and gopher tortoise (Hinderliter 2014, Hinderliter 2015, NatureServe 2015). While also preferring an open midstory, the northern bobwhite and Bachman's sparrow both use scattered tall shrubs and saplings for perching, including oaks, sassafras, black cherry and persimmon (NatureServe 2015, Richardson 2014a). To recover the biodiversity associated with Shortleaf Pine natural communities of the Interior Highlands (Ozark and Ouachita region), desired future conditions for cover of the midstory layer were determined to be <10% for Shortleaf Pine-Bluestem, <30% for Dry Mesic Shortleaf Pine-Oak Woodland, and 15% for Dry Shortleaf Pine-Oak. Midstory was defined as >10 feet (>3 m) tall and below the bottom of the canopy (Blaney et al. 2015). For longleaf pine woodlands, maintenance conditions are considered to be 20% or less mid-story cover, with < 5% cover of fire-intolerant hardwood or off-site pine trees over 16 feet tall (Longleaf Partnership Council 2014).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: The presence of a midstory greater than 25% cover is associated with the decline in habitat quality for many wildlife species of southern open pine ecosystems. Generally there is a decline in herbaceous groundcover with an increase in midstory greater than 25% cover.

Measurement Protocol: For the assessment area, estimate the percent of the ground within the plot covered by midstory foliage, branches, and stems as determined by ocular (visual) estimate. Midstory is defined to include any woody stem (including tall shrubs, trees and woody vines) which are > 10 feet tall, up to the height of the bottom of the tree canopy. Cover estimate classes will be used. Ocular (visual) estimate of the percent of ground within the plot covered by foliage and branches. Because forest vegetation layers can overlap, total percent cover of the canopy, midstory and shrub layers may exceed 100%.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	<20% cover of woody midstory
GOOD (B)	20 to 30% cover of woody midstory
FAIR (C)	>30 to 40% cover of woody midstory
POOR (D)	>40% cover of woody midstory

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	<20% cover of woody midstory
GOOD (B)	20 to <30% cover of woody midstory
FAIR (C)	30 to 40% cover of woody midstory
POOR (D)	>40% cover of woody midstory

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	<20% cover of woody midstory
GOOD (B)	20-30% cover of woody midstory
FAIR (C)	>30 to 40% cover of woody midstory
POOR (D)	>40% cover of woody midstory

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	<20% cover of woody midstory
GOOD (B)	20 to <30% cover of woody midstory
FAIR (C)	30 to 40% cover of woody midstory
POOR (D)	>40% cover of woody midstory

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	<20% cover of woody midstory
GOOD (B)	20-25% cover of woody midstory
FAIR (C)	>25 to 35% cover of woody midstory
POOR (D)	>35% cover of woody midstory

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***
EXCELLENT (A)	<20% cover of woody midstory
GOOD (B)	≥20 to 30% cover of woody midstory
FAIR (C)	>30 to 50% cover of woody midstory
POOR (D)	>50% cover of woody midstory

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	<20% cover of woody midstory
GOOD (B)	20 to 30% cover of woody midstory
FAIR (C)	>30 to 50% cover of woody midstory

POOR (D)	>50% cover of woody midstory

Data for Metric Rating: Published data that support the basis for the metric rating.

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2015. Appendix 1. Desired Future Conditions (DFC) for Shortleaf Pine-bluestem and Pine-oak Restoration Sites in the Interior Highlands. Pages 12-31 in Fitzgerald, J. and T. Foti. 2015. The Interior Highlands Shortleaf Pine Restoration Initiative: An Overview (6 August 2015 Draft). Central Hardwoods Joint Venture.

Bragg, D. C., R. O'Neill, W. Holimon, J. Fox, G. Thornton, and R. Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

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Hinderliter, M. 2015. Black Pine Snake Questions and Answers. US Fish and Wildlife Service. Jackson, MS. < http://www.fws.gov/mississippies/_pdf/Black%20Pinesnake%20-%20QUESTIONS%20AND%20ANSWERS.pdf>

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NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: April 28, 2015).

NatureServe. 2011. Rapid Assessment Metrics for Longleaf Pine Dominated Woodlands. Draft Report to the USDA Forest Service, Region 8. NatureServe Central Databases. Durham, NC. U.S.A.

Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (Peucaea aestivalis). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.

Scaling Rationale: Scaling includes a definition of excellent which has a low amount of midstory, such as might provide perching sites for Bachman's sparrow and northern bobwhite.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name:

Short Shrub (<3 feet tall) Cover and Tall Shrub (3-10 feet tall) Cover

Definition: An assessment of cover by shrubs and small broad-leaved trees less than 10 feet tall. Percentage of the ground within the plot covered by the general extent of woody plants including small broad-leaved trees and short shrubs (< 3 feet tall) and tall shrubs (3-10 feet tall).

Background: This metric is drafted to accommodate both longleaf pine and shortleaf pine-bluestem vegetation and all other Southern Open Pine Groupings. Information is incorporated from Southern Open Pine workshops held at the Jones Center in March 2015 and Knoxville in September 2015. Maintenance condition class for shrub cover in longleaf pine woodlands exists when shrubs average ≤ 30% cover and average ≤ 3 feet tall (Longleaf Partnership Council 2014).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable:
Both longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*) are shade-intolerant species, and both species are canopy dominants in fire-maintained southern open pine ecosystems. Both require a regime of frequent low intensity surface fires to provide open structure and adequate regeneration of the overstory trees. In addition, fire exposes mineral soil which is necessary for seed germination and seedling recruitment.

The natural range of Virginia pine (*Pinus virginiana*) is broadly Appalachian, and does not include the Coastal Plain or areas west of the Mississippi River, such as the Ozarks or Ouachita Mountains. On open sites where both shortleaf pine and Virginia pine occur, and in the absence of fire, shortleaf pine is badly out-competed by Virginia pine (*Pinus virginiana*) due to several factors. Shortleaf pines generally bear seeds at a much later age than Virginia pine (Carter and Snow 1990, Lawson 1990). Although mature shortleaf produce some seed almost every year, abundant crops occur only sporadically (Haney 1957), and these seeds may not be disseminated far from the original seed source (Stephenson 1963). This example points to the special conditions which are needed to sustain open woodlands dominated by shortleaf pine, throughout its natural range.

A dense and tall shrub layer shades the ground, inhibiting both the regeneration of longleaf pine and shortleaf pine seedlings as well as the vigor and reproduction of native warm season grasses and forbs that constitute the fuels needed to carry fire in the stand. Competition from woody plants (including shrubs) is highly detrimental to the growth and development of these pine seedlings and saplings (Lawson 1986, Lowery 1986). To recover the biodiversity associated with shortleaf pine natural communities of the Interior Highlands (Ozark and Ouachita region), desired future conditions for shrubs of the understory (1-3 m tall) were determined to be <10% for Shortleaf Pine-Bluestem, <30% for Dry Mesic Shortleaf Pine-Oak Woodland, and <30% for Dry Shortleaf Pine-Oak in the Ouachita and Boston Mountains, and 20-80% shrub cover in the Ozarks, further north (Blaney et al. 2015).

Longleaf pine (*Pinus palustris*) is a very intolerant pioneer species (Landers et al. 1995, cited in Jose et al. 2006) and does not compete well with other more aggressive canopy species (Boyer 1990). Fire exclusion results in accumulation of litter that hinders proper germination of longleaf pine seeds (Croker 1975 cited in Jose et al. 2006). With the absence of fire (or other disturbance), the less fire-adapted shrubs can spread into the understory, competing for site resources, nutrients, and light and hindering the growth and regeneration of longleaf pine seedlings, as well as inhibiting and suppressing the vigor and growth of grasses and forbs in the ground layer (LMJV WGCPO Landbird Working Group 2011). Mature shortleaf pine-bluestem stands with abundant herbaceous ground cover and little to no hardwood midstory, managed with late-dormant season fire at 3-year intervals, show dramatic increases in both richness and density of small mammals and songbirds (Wilson and others 1995, Masters and others 1998, 2001, 2002; cited in Masters 2007). Periodic fire can control the size of understory hardwoods, but only annual summer burning (for decades) is likely to completely remove hardwood sprouts (Waldrop et al., 1992, cited in Van Lear et al. 2005).

Measurement Protocol: This metric consists of a visual evaluation of the cover and height of shrubs and small broad-leaved trees (less than 10 feet tall) within a delimited assessment area, including small broad-leaved trees and short shrubs (< 3 feet tall) and small trees and tall shrubs (3-10 feet tall). This assessment area should be at least 0.1 acre or 400 m^2 and can be delimited either with tapes, by pacing distances, or with a range-finder. Within this area, a visual assessment is made of the cover of shrubs, including small individuals of broad-leaved trees. This should not include longleaf pine or shortleaf pine regeneration. For assessment area, estimate percentage of the ground within the plot covered by the general extent of the foliage, branches, and stems from all shrubs (all woody plants, single- or multi-stemmed, including woody seedlings, tree saplings, saw palmetto, scrub palmetto and woody vining plants). Spaces between leaves and stems count as cover. Cover estimate classes will be used. Ocular (visual) estimate of the percent of ground within the plot covered by foliage and branches. Because forest vegetation layers can overlap, total percent cover may exceed 100%.

Shrub Cover Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor. Variants are provided.

Short Shrubs (<3 feet tall)

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	Shrubs < 3 feet in height average <30% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 30 to 35% cover in the assessment area
FAIR (C)	Shrubs < 3 feet in height average >35 to 45% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >45% cover in the assessment area

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	Shrubs < 3 feet in height average <30% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 30 to <40% cover in the assessment area
FAIR (C)	Shrubs < 3 feet in height average 40 to 45% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >45% cover in the assessment area

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	Shrubs < 3 feet in height average <30% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 30 to <40% cover in the assessment area

FAIR (C)	Shrubs < 3 feet in height average 40 to 45% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >45% cover in the assessment area

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	Shrubs < 3 feet in height average <25% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 25 to 35% cover in the assessment area
FAIR (C)	Shrubs < 3 feet in height average >35 to 45% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >45% cover in the assessment area

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	Shrubs < 3 feet in height average <20% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 20 to 25% cover in the assessment area
FAIR (C)	Shrubs < 3 feet in height average >25 to 40% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >40% cover in the assessment area

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***
EXCELLENT (A)	Shrubs < 3 feet in height average <20% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 20 to 30% cover in the assessment area
FAIR (C)	Shrubs < 3 feet in height average >30 to 45% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >45% cover in the assessment area

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	Shrubs < 3 feet in height average <20% cover in the assessment area
GOOD (B)	Shrubs < 3 feet in height average 20 to 30% cover in the assessment area
FAIR (C)	Shrubs < 3 feet in height average >30 to 45% cover in the assessment area
POOR (D)	Shrubs < 3 feet in height average >45% cover in the assessment area

Tall Shrubs (3-10 feet tall)

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	Shrubs 3-10 feet in height average <20% cover.
GOOD (B)	Shrubs 3-10 feet in height average 20 to 30% cover.
FAIR (C)	Shrubs 3-10 feet in height average >30 to 40% cover.
POOR (D)	Shrubs 3-10 feet in height average >40% cover.

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	Shrubs 3-10 feet in height average <20% cover.
GOOD (B)	Shrubs 3-10 feet in height average 20 to <30% cover.
FAIR (C)	Shrubs 3-10 feet in height average 30 to 35% cover.
POOR (D)	Shrubs 3-10 feet in height average >35% cover.

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	Shrubs 3-10 feet in height average <15% cover.
GOOD (B)	Shrubs 3-10 feet in height average 15 to <25% cover.
FAIR (C)	Shrubs 3-10 feet in height average 25-35% cover.
POOR (D)	Shrubs 3-10 feet in height average >35% cover.

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	Shrubs 3-10 feet in height average <15% cover.
GOOD (B)	Shrubs 3-10 feet in height average 15 to <25% cover.
FAIR (C)	Shrubs 3-10 feet in height average 25 to 30% cover.
POOR (D)	Shrubs 3-10 feet in height average >30% cover.

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	Shrubs 3-10 feet in height average <15% cover.
GOOD (B)	Shrubs 3-10 feet in height average 15 to 20% cover.
FAIR (C)	Shrubs 3-10 feet in height average >20 to 30% cover.
POOR (D)	Shrubs 3-10 feet in height average >30% cover.

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***
EXCELLENT (A)	Shrubs 3-10 feet in height average <15% cover.
GOOD (B)	Shrubs 3-10 feet in height average 15 to 20% cover.
FAIR (C)	Shrubs 3-10 feet in height average >20 to 30% cover.
POOR (D)	Shrubs 3-10 feet in height average >30% cover.

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	Shrubs 3-10 feet in height average <15% cover.
GOOD (B)	Shrubs 3-10 feet in height average 15 to 20% cover.
FAIR (C)	Shrubs 3-10 feet in height average >20 to 30% cover.
POOR (D)	Shrubs 3-10 feet in height average >30% cover.

Data for Metric Rating: Published data that support the basis for the metric rating

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2015. Appendix 1. Desired Future Conditions (DFC) for Shortleaf Pine-bluestem and Pine-oak Restoration Sites in the Interior Highlands. Pages 12-31 in Fitzgerald, J. and T. Foti. 2015. The Interior Highlands Shortleaf Pine Restoration Initiative: An Overview (6 August 2015 Draft). Central Hardwoods Joint Venture.

Boyer, W. B. 1990. *Pinus palustris* Mill. Shortleaf Pine. Pages 405-412. In: Burns, R. M., and B. H. Honkala, technical coordinators. 1990. Silvics of North America: Volume 1. Conifers. USDA Forest Service. Agriculture Handbook 654. Washington, DC. 675 pp.

Bragg, D. C., R. O'Neill, W. Holimon, J. Fox, G. Thornton, and R. Mangham. 2014. Moro Big Pine: Conservation and Collaboration in the Pine Flatwoods of Arkansas. Journal of Forestry 112(5):446–456.

Carter, K. K. and A. G. Snow. 1990. *Pinus virginiana* Mill. Virginia Pine. Pages 513-519. In: Burns, R. M., and B. H. Honkala, technical coordinators. 1990. Silvics of North America: Volume 1. Conifers. USDA Forest Service. Agriculture Handbook 654. Washington, DC. 675 pp.

Gulden, J. M., 1986. Ecology of shortleaf pine. pp. 25-40. In: Murphy, P. A. 1986. Proceedings, Symposium on the Shortleaf Pine Ecosystem, March 31-April 2, 1986, Little Rock, AR. Arkansas Cooperative Extension Service, Monticello.

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Landers, J., L. Van Lear, D.H. Boyer, and D. William, 1995. The longleaf pine forests of the Southeast: requiem or renaissance? J. Forestry 9, 39 – 44.

Lawson, E. R. 1986. Natural Regeneration of Shortleaf Pine. pp. 53-63 In: Murphy, P. A. 1986. Proceedings, Symposium on the Shortleaf Pine Ecosystem. Arkansas Cooperative Extension Service, Monticello.

Lawson, E. R. 1990. *Pinus echinata* Mill. Shortleaf Pine. Pages 316-326. In: Burns, R. M., and B. H. Honkala, technical coordinators. 1990. Silvics of North America: Volume 1. Conifers. USDA Forest Service. Agriculture Handbook 654. Washington, DC. 675 pp.

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Lower Mississippi Valley Joint Venture (LMJV) WGCPO Landbird Working Group. 2011. West Gulf Coastal Plains/Ouachitas Open Pine Landbird Plan. Report to the Lower Mississippi Valley Joint Venture Management Board. 33 pp. http://www.lmvjv.org/library/WGCPO_Landbird_Open_Pine_Plan_Oct_2011.pdf

Lowery, R. F. 1986. Woody competition control. pp. 147-148 In: Murphy, P. A. 1986. Proceedings, Symposium on the Shortleaf Pine Ecosystem. Arkansas Cooperative Extension Service, Monticello.

Van Lear, D. H., W. D. Carroll, P. R. Kapeluck, and R. Johnson. 2005. History and restoration of the longleaf pine-grassland ecosystem: Implications for species at risk. Forest Ecology and Management. 211:150-165.

Scaling Rationale: This metric has been scaled based on scientific judgment of NatureServe ecologists and other expert ecologists and wildlife biologists. The metric is scaled based on the similarity between the observed vegetation structure and what is expected based on reference (or appropriately managed natural disturbance) conditions. Reference conditions reflect the accumulated experience of field ecologists, studies from sites where natural processes are intact, regional surveys and historic sources. The basis for assigning the ratings should be documented on the field forms.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name:

Overall Native Herbaceous Ground Cover (foliar cover)

Definition: Percentage cover of all (native) species in the ground layer.

Background: The native herbaceous groundcover is an important part of the habitat needs of many species of wildlife found in southern open pine ecosystems.

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Native herbaceous groundcover provides fine fuel which can allow frequent low intensity fires. The amount of native herbaceous groundcover is an important part of the habitat needs of many species of wildlife found in southern open pine ecosystems. Some southern open pine woodlands have many species of herbaceous legumes. These legumes provide food for wildlife and fix nitrogen which helps maintain site productivity. Maintenance condition class for herbaceous cover in longleaf pine woodlands is considered to be herbaceous cover > 35% with native pyrogenic species present in stand (Longleaf Partnership Council 2014). Birds of southern open pine ecosystems that benefit from native herbaceous ground cover include northern bobwhite (McIntyre 2012), Bachman's sparrow (Richardson 2014a), prairie warbler (NatureServe 2015), and red-cockaded woodpecker (James et al. 2001). Reptiles of southern open pine ecosystems that benefit from native herbaceous ground cover include Louisiana pine snake, black pine snake, Florida pine snake, eastern diamondback rattlesnake, and gopher tortoise (Hinderliter 2014, Hinderliter 2015, NatureServe 2015). To recover the biodiversity associated with shortleaf pine natural communities of the Interior Highlands (Ozark and Ouachita region), desired future conditions for cover of the ground layer were determined to be 80-100% for Shortleaf Pine-Bluestem, 50-80% for Dry Mesic Shortleaf Pine-Oak Woodland, and 40-60% for Dry Shortleaf Pine-Oak (Blaney et al. 2015).

Measurement Protocol: For assessment area, estimate the foliar cover of all native herbaceous ground cover (FNAI and FFS 2014). This includes all native non-woody, soft-tissued plants regardless of height, including non-woody vines, legumes, composites, graminoids (grasses, sedges, and rushes, including beaked rushes), and other herbaceous plants. Cover estimate classes will be used. Note: Foliar cover is the ocular (visual) estimate of the percent of ground within the plot covered by foliage and stems. Spaces between leaves and stems do NOT count as cover.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***Dry & Mesic Longleaf Pine Woodlands***
EXCELLENT (A)	40-98% herbaceous cover
GOOD (B)	30 to <40% or >98% herbaceous cover
FAIR (C)	20 to <30% herbaceous cover
POOR (D)	<20% herbaceous cover

Metric Rating	***Mesic Longleaf Pine Flatwoods***
EXCELLENT (A)	40-98% herbaceous cover
GOOD (B)	30 to <40% or >98% herbaceous cover
FAIR (C)	20 to <30% herbaceous cover
POOR (D)	<20% herbaceous cover

Metric Rating	***Wet Longleaf & Slash Pine Flatwoods & Savannas***
EXCELLENT (A)	40-100% herbaceous cover
GOOD (B)	30 to <40% herbaceous cover
FAIR (C)	20 to <30% herbaceous cover
POOR (D)	<20% herbaceous cover

Metric Rating	***Xeric Longleaf Pine Barrens***
EXCELLENT (A)	40-100% herbaceous cover
GOOD (B)	>25 to <40% herbaceous cover
FAIR (C)	>15 to 25% herbaceous cover
POOR (D)	0-15% herbaceous cover

Metric Rating	***Dry & Mesic Highlands Pine Woodlands***
EXCELLENT (A)	>45 to 80% herbaceous cover
GOOD (B)	30-45% or >80% herbaceous cover
FAIR (C)	15 to <30% herbaceous cover
POOR (D)	<15% herbaceous cover

Metric Rating	***Dry & Mesic Hilly Pine Woodlands***
EXCELLENT (A)	35-80% herbaceous cover
GOOD (B)	20 to <35% or >80% herbaceous cover
FAIR (C)	10 to <20% herbaceous cover
POOR (D)	<10% herbaceous cover

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	35-80% herbaceous cover
GOOD (B)	20 to <35% or >80% herbaceous cover
FAIR (C)	10 to <20% herbaceous cover
POOR (D)	<10% herbaceous cover

Data for Metric Rating: Published data that support the basis for the metric rating.

Blaney, M., B. Rupar, T. Foti, J. Fitzgerald, P. Nelson, S. Hooks, M. Lane, W. Carromero, and T. Witsell. 2015. Appendix 1. Desired Future Conditions (DFC) for Shortleaf Pine-bluestem and Pine-oak Restoration Sites in the Interior Highlands. Pages 12-31 in Fitzgerald, J. and T. Foti. 2015. The Interior

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NatureServe. 2015. NatureServe Explorer: An online encyclopedia of life [web application]. Version 7.1. NatureServe, Arlington, Virginia. Available http://explorer.natureserve.org. (Accessed: April 28, 2015).

Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (Peucaea aestivalis). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.

Scaling Rationale:

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name:

Longleaf Pine Regeneration

Definition: Advance longleaf pine regeneration cover is 5-15% of stand. Includes grass stage or regeneration < 2" DBH (Longleaf Partnership Council 2014).

Background: This metric has gone through extensive review and was adopted as part of the longleaf pine maintenance class definitions by the Longleaf Partnership Council (Longleaf Partnership Council 2014).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Regeneration of longleaf pine is critical to the maintenance of stands (Brockway and Outcalt 1998, Brockway et al. 2004, Brockway et al. 2005). Large scale disturbances such as hurricane force winds can break many canopy trees, and dramatically reduce seed trees. For this reason, presence of advance regeneration is an important metric.

Measurement Protocol: Advance longleaf pine regeneration cover is ≥1% of stand. Includes grass stage or regeneration < 2" DBH (Longleaf Partnership Council 2014). This is a stand level metric, longleaf pine recruitment may be very patchy, and regeneration may not be found in small assessment plots.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***All Open Longleaf Pine Ecosystems***
EXCELLENT (A) or GOOD (B)	Longleaf pine regeneration cover is ≥1% of stand
FAIR (C)	Longleaf pine regeneration cover is present but is <1% of stand, or no regeneration seen, but cone producing longleaf pine are present
POOR (D)	Longleaf pine regeneration cover is apparently absent, and no cone producing longleaf pine are present in the stand

Data for Metric Rating: Published data that support the basis for the metric rating

Brockway, D. G., and K. W. Outcalt. 1998. Gap-phase regeneration in longleaf pine wiregrass ecosystems. Forest Ecology and Management 106: 125–139.

Brockway, D. G., K. W. Outcalt, J. M. Guldin, W. D. Boyer, J. L. Walker, D. C. Rudolph, R. B. Rummer, J. P. Barnett, S. Jose, J. Nowak. 2005. Uneven-aged management of longleaf pine forests: a scientist and manager dialogue. Gen. Tech. Rep. SRS-78. Asheville, NC: U.S. Department of Agriculture, Forest Service, Southern Research Station. 38 p. <http://www.srs.fs.usda.gov/pubs/9636>

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Longleaf Partnership Council. 2014. Longleaf Pine Maintenance Condition Class Definitions: A Guide to Assess Optimal Forest Habitat Conditions for Associated Plant and Wildlife Species. October 2014. America's Longleaf Restoration Initiative, Longleaf Partnership Council.

RANK FACTOR: VEGETATION

Metric Name:

Native Warm Season Grass Cover

Definition: Native warm season grass cover is also called cover of pryrophytic graminoids which include grasses and grass-like plants. This metric is the percent cover of native warm season grasses and other perennial graminoids that are maintained by periodic fire. These are the native grasses and grass-like plants (mostly native warm season grasses) which are natural groundcover in southern open pine stands. For open longleaf pine woodlands in Florida, these include wiregrass (*Aristida stricta*), pineywoods dropseed (*Sporobolus junceus*), Florida dropseed (*Sporobolus floridanus*), Chapman's beaksedge (*Rhynchospora chapmanii*), cutover muhly (*Muhlenbergia capillaris* var. *trichopodes*), toothache grass (*Ctenium aromaticum*), little bluestem (*Schizachyrum scoparium*) and Florida toothache grass (*Ctenium floridanum*). However, switchgrass (*Panicum virgatum*) is not included, as it can become so dominant that other grasses, legumes and small bare ground areas are crowded out. Some typical wide ranging southern native warm season grasses of Dry & Mesic Longleaf Pine Woodlands include splitbeard bluestem (*Andropogon ternarius*), Elliott's bluestem (*Andropogon gyrans var. gyrans*), broomsedge bluestem (*Andropogon virginicus*), pineywoods dropseed (*Sporobolus junceus*), rough dropseed (*Sporobolus clandestinus*), little bluestem (*Schizachyrium scoparium*), slender little bluestem (*Schizachyrium tenerum*), Indiangrass (*Sorghastrum nutans*), slender Indiangrass (*Sorghastrum elliottii*), and lopsided Indiangrass (*Sorghastrum secundum*). In the Wet Longleaf & Slash Pine Flatwoods & Savannas, Carolina wiregrass or pineland threeawn (*Aristida stricta*) or Southern wiregrass or Beyrich's threeawn (*Aristida beyrichiana*) often dominates, but toothache grass (*Ctenium aromaticum*), cutover muhly (*Muhlenbergia expansa*), little bluestem (*Schizachyrium scoparium*), Florida dropseed (*Sporobolus floridanus*), Carolina dropseed (*Sporobolus pinetorum*), wireleaf dropseed (*Sporobolus teretifolius*), chalky bluestem (*Andropogon capillipes*), other bluestems (*Andropogon* spp.), or other grasses may also dominate. In the Ozarks and Ouachitas (Interior Highlands), native warm season grasses include little bluestem (*Schizachyrum scoparium*), big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), bearded shorthusk (*Brachyelytrum erectum*), Elliott's bluestem (*Andropogon gyrans*), blackseed speargrass (*Piptochaetium avenaceum*), composite dropseed (*Sporobolus compositus*), and other grasses (Blaney et al. 2015, Farrington 2010, Nelson 1985). In open shortleaf pine woodlands in northern Mississippi, native warm season grasses include little bluestem (*Schizachyrum scoparium*), Bosc's witchgrass (*Dichanthelium boscii*) and broomsedge (*Andropogon virginicus*) (Brewer et al. 2015, Maynard and Brewer 2013).

Background: Grasses and grass-like plants provide much of the fine fuels which allow frequent low intensity fire to occur in southern open pine ecosystems (Kirkman et al. 2004). Fires are an important natural disturbance and process which helps maintain longleaf pine ecosystems. Native grasses and grass-like plants which provide the fine fuels in southern open pine are called pyrophytic graminoids. These are mostly native perennial warm season grasses, which can resprout fairly quickly following fire during the growing season. Native warm season grasses use the four Carbon, C_4 pathway in photosythesis (not the more common three Carbon C_3 pathway used by cool season grasses) and generally are associated with prairies and open woodlands. The C_4 pathway is more efficient for photosynthesis in warmer temperatures (Edwards et al. 2010). For most southern open pine ecosystems, there is broad overlap between native warm season grasses (using the C_4 pathway), and the plants measured in this metric, which have been called pyrophytic graminoids. Areas with good cover of native warm season grasses can be foraging areas for gopher tortoise (Hinderliter 2014), nesting and feeding areas for Bachman's sparrow, and bobwhite quail (McIntyre 2012, Richardson 2014a), and habitat for the eastern diamondback rattlesnake (NatureServe 2015). This metric has been useful in other assessments (FNAI and FFS 2014, NatureServe 2011). Maintenance condition class for herbaceous cover in longleaf pine woodlands is considered to be herbaceous cover >35% with native pyrogenic species present in stand (Longleaf Partnership Council 2014).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Grasses and grass-like plants provide much of the fine fuels which allow frequent low intensity fire to occur in southern open pine ecosystems (Kirkman et al. 2004). This metric has been useful in other assessments (FNAI and FFS 2014, NatureServe 2011).

Measurement Protocol: For the assessment area, estimate total foliar cover of all native warm season grass and grass-like species (FNAI and FFS 2014, NatureServe 2011). Examples from Florida include wiregrass (*Aristida stricta*), pineywoods dropseed (*Sporobolus junceus*), Florida dropseed (*Sporobolus floridanus*), Chapman's beaksedge (*Rhynchospora chapmanii*), cutover muhly (*Muhlenbergia capillaris* var. *trichopodes*), toothache grass (*Ctenium aromaticum*), little bluestem (*Schizachyrum scoparium*) and Florida toothache grass (*Ctenium floridanum*), **but not switchgrass (*Panicum virgatum*)**. Some typical wide ranging southern native warm season grasses of Dry & Mesic Longleaf Pine Woodlands include splitbeard bluestem (*Andropogon ternarius*), Elliott's bluestem (*Andropogon gyrans var. gyrans*), broomsedge bluestem (*Andropogon virginicus*), pineywoods dropseed (*Sporobolus junceus*), rough dropseed (*Sporobolus clandestinus*), little bluestem (*Schizachyrium scoparium*), slender little bluestem (*Schizachyrium tenerum*), Indiangrass (*Sorghastrum nutans*), slender Indiangrass (*Sorghastrum elliottii*), and lopsided Indiangrass (*Sorghastrum secundum*). In the Wet Longleaf & Slash Pine Flatwoods & Savannas, Carolina wiregrass or pineland threeawn (*Aristida stricta*) or Southern wiregrass or Beyrich's threeawn (*Aristida beyrichiana*) often dominates, but toothache grass (*Ctenium aromaticum*), cutover muhly (*Muhlenbergia expansa*), little bluestem (*Schizachyrium scoparium*), Florida dropseed (*Sporobolus floridanus*), Carolina dropseed (*Sporobolus pinetorum*), wireleaf dropseed (*Sporobolus teretifolius*), chalky bluestem (*Andropogon capillipes*), other bluestems (*Andropogon* spp.), or other grasses may also dominate. In the Ozarks and Ouachitas (Interior Highlands), native warm season grasses include little bluestem (*Schizachyrum scoparium*), big bluestem (*Andropogon gerardii*), Indian grass (*Sorghastrum nutans*), bearded shorthusk (*Brachyelytrum erectum*), Elliott's bluestem (*Andropogon gyrans*), blackseed speargrass (*Piptochaetium avenaceum*), composite dropseed (*Sporobolus compositus*), and other grasses (Blaney et al. 2015, Farrington 2010, Nelson 1985). In open shortleaf pine woodlands in northern Mississippi, native warm season grasses include little bluestem (*Schizachyrum scoparium*) Bosc's witchgrass (*Dichanthelium boscii*) and broomsedge (*Andropogon virginicus*) (Brewer et al. 2015, Maynard and Brewer 2013). Percent cover classes will be used. Note: Foliar cover is the ocular (visual) estimate of the percent of ground covered by foliage and branches. Spaces between leaves and stems do NOT count as cover.

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	*Dry & Mesic Longleaf Pine Woodlands*
EXCELLENT (A)	>25 to 97% foliar cover of all native warm season grasses
GOOD (B)	>15 to 25% or >97% foliar cover of all native warm season grasses
FAIR (C)	10-15% foliar cover of all native warm season grasses
POOR (D)	<10% foliar cover of all native warm season grasses

Metric Rating	*Mesic Longleaf Pine Flatwoods*
EXCELLENT (A)	>25 to 97% foliar cover of all native warm season grasses
GOOD (B)	>15 to 25% or >97% foliar cover of all native warm season grasses
FAIR (C)	10-15% foliar cover of all native warm season grasses
POOR (D)	<10% foliar cover of all native warm season grasses

Metric Rating	*Wet Longleaf & Slash Pine Flatwoods & Savannas*
EXCELLENT (A)	25-97% foliar cover of all native warm season grasses
GOOD (B)	>15 to <25% or >97% foliar cover of all native warm season grasses
FAIR (C)	10-15% foliar cover of all native warm season grasses
POOR (D)	<10% foliar cover of all native warm season grasses

Metric Rating	*Xeric Longleaf Pine Barrens*
EXCELLENT (A)	25-95% foliar cover of all native warm season grasses
GOOD (B)	15 to <25% or >95% foliar cover of all native warm season grasses
FAIR (C)	10 to <15% foliar cover of all native warm season grasses
POOR (D)	<10% foliar cover of all native warm season grasses

Metric Rating	*Dry & Mesic Highlands Pine Woodlands*
EXCELLENT (A)	>25 to 85% foliar cover of all native warm season grasses
GOOD (B)	>15 to 25% or >85% foliar cover of all native warm season grasses
FAIR (C)	10 -15% foliar cover of all native warm season grasses
POOR (D)	<10% foliar cover of all native warm season grasses

Metric Rating	*Dry & Mesic Highlands Pine Woodlands (Mountain Longleaf)*
EXCELLENT (A)	>25 to 85% foliar cover of all native warm season grasses
GOOD (B)	20 to 25% or >85% foliar cover of all native warm season grasses
FAIR (C)	10 to <20% foliar cover of all native warm season grasses
POOR (D)	<10% foliar cover of all native warm season grasses

Metric Rating	*Dry & Mesic Hilly Pine Woodlands*
EXCELLENT (A)	25- 100% foliar cover of all native warm season grasses
GOOD (B)	>15 to <25% foliar cover of all native warm season grasses
FAIR (C)	10-15% foliar cover of all native warm season grasses

POOR (D)	<10% foliar cover of all native warm season grasses

Metric Rating	***Upper Coastal Plain Pine Flatwoods***
EXCELLENT (A)	>25% foliar cover of all native warm season grasses
GOOD (B)	20 to 25% foliar cover of all native warm season grasses
FAIR (C)	10 to <20% foliar cover of all native warm season grasses
POOR (D)	<10% foliar cover of all native warm season grasses

Data for Metric Rating: Published data that support the basis for the metric rating

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Brewer, J. S., M.J. Abbott, and S. Moyer. 2015. Effects of oak-hickory woodland restoration treatments on native groundcover vegetation and the invasive grass Microstegium vimineum. Ecological Restoration 33(3): 256-265.

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Nelson, P. W. 1985. The terrestrial natural communities of Missouri. Missouri Natural Areas Committee, Jefferson City. 197 pp. Revised edition, 1987.

Nelson, P. 2010. The terrestrial natural communities of Missouri. Revised edition. Missouri Natural Areas Committee, Department of Natural Resources and the Department of Conservation, Jefferson City.

Richardson, D. 2014a. Fire Management Species Profile, Bachman's Sparrow (Peucaea aestivalis). Division of Strategic Resource Management & the Division of Fire Management, USFWS, Southeast Region, Atlanta, GA.

Scaling Rationale: This metric is based on live foliar cover, as observed looking down at the plants. For the data collection to be repeatable, include only live material foliar cover seen by looking down towards the ground.

Confidence that reasonable logic and/or data support the metric: High

RANK FACTOR: VEGETATION

Metric Name:

Invasive Plant Presence/Distribution

Definition: Invasive plant presence/distribution. Describes the extent and distribution of invasive exotic plants within or along the perimeter of the polygon; includes only Florida EPPC category I and II listed species. <http://www.fleppc.org/list/list.htm>

Background: Invasive exotic species are a major threat to biological integrity in a wide variety of ecosystems (Miller 2003). These species can out compete the native species, alter ecological functions (Bryson and Carter 1993, Lippincott 2000) and contribute to decline in biological integrity. For wetlands, NatureServe has used cover of invasive nonnative plants for rapid ecological integrity assessment (Faber-Langendoen et al. 2015). NatureServe's categories are excellent if absent or < 1% cover, good if sporadic or 1-3% cover, fair if somewhat abundant with 4-10% cover, between fair and poor if abundant with 11-30% cover, and poor if very abundant with >30% cover of invasive nonnative plants (Faber-Langendoen et al. 2015). Less than or equal to 1% cover of invasive exotic plant species or ongoing progress towards this indicates maintenance condition for longleaf pine woodlands (Longleaf Partnership Council 2014). The Florida Exotic Pest Plant Council reviews and updates their list of invasive exotic plants every two years. The distributions within Florida are listed for north, central, and south Florida (FLEPPC 2015). For areas outside of Florida, refer to those invasive exotic species listed for north Florida. Exotic subtropical grasses are a particular threat to longleaf pine ecosystems. Tallow tree (*Triadica sebifera*) and cogongrass (*Imperata cylindrica*) are threats to Wet Longleaf & Slash Pine Flatwoods & Savannas (Brewer 2008, Wang et al. 2011). Cogongrass is also a threat to other longleaf pine ecosystems. Japanese stiltgrass (*Microstegium vimineum*) and Japanese honeysuckle (*Lonicera japonica*) are threats during restoration of open woodlands in northern Mississippi, such as the Dry & Mesic Hilly Pine Woodlands (Brewer, Abbott and Moyer 2015).

Metric Type: Condition

Tier: 2 (rapid field measure)

Rationale for Selection of the Variable: Invasive exotic species are a major threat to biological integrity in a wide variety of ecosystems. The metric and scaling is based on the type detection likely on a cursory or rapid field visit to a site.

Measurement Protocol: Describe the extent and distribution of invasive exotic plants within or along the perimeter of the site. If time allows, GPS locations of invasive exotic plant species which are encountered. This can facilitate the prompt control of these plants and simplify their management. Determine the presence only of Florida EPPC category I and II listed species. For areas outside of Florida, refer to those invasive exotic species listed for north Florida. <http://www.fleppc.org/list/list.htm>

Metric Rating: Specify the narrative and numerical ratings for the metric, from excellent to poor.

Metric Rating	***All Southern Open Pine Ecosystems***
EXCELLENT (A)	Invasive nonnative plant species absent or cover in any stratum is very low ($\geq$1% absolute cover)
GOOD (B)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)
FAIR (C)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)
POOR (D)	Invasive nonnative plant species in any stratum common (>10% cover)

Data for Metric Rating: Published data that support the basis for the metric rating

Brewer, S. 2008. Declines in plant species richness and endemic plant species in longleaf pine savannas invaded by *Imperata cylindrica*. Biological Invasions 10:1257–1264.

Brewer, J. S., M. J. Abbott, and S. Moyer. 2015. Effects of oak-hickory woodland restoration treatments on native groundcover vegetation and the invasive grass *Microstegium vimineum*. Ecological Restoration 33(3): 256-265.

Bryson, C. T. and R. Carter. 1993. Cogongrass *Imperata cylindrica,* in the United States. Weed Technology 7:1005-1009.

Faber-Langendoen, D., W. Nichols, K. Strakosch Walz, J. Rocchio, J. Lemly, L. Gilligan, and G. Kittel. 2015. NatureServe Ecological Integrity Assessment Protocols: Wetland Rapid Assessment Method [revisions in progress]. NatureServe. Arlington, VA.

FLEPPC. 2015. List of Invasive Plant Species. Florida Exotic Pest Plant Council. http://www.fleppc.org/list/list.htm

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Miller J. H. 2003. Nonnative invasive plants of southern forests: a field guide for identification and control. Asheville, NC. Southern Research Station, USDA Forest Service. Revised General Technical Report SRS-62.

Miller, S. J. and D. H. Wardrop. 2006. Adapting the floristic quality assessment index to indicate anthropogenic disturbance in central Pennsylvania wetlands. Ecological Indicators 6(2): 313–326.

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Richardson, D. M., P. Pysek, M. Rejmánek, M. G. Barbour, F. D. Panetta, and C. J. West. 2000. Naturalization and invasion of alien plants: Concepts and definitions. Diversity and Distributions 6: 93–107.

Tierney, G. L., D. Faber-Langendoen, B. R. Mitchell, W. G. Shriver, and J. P. Gibbs. 2009. Monitoring and evaluating the ecological integrity of forest ecosystems. Frontiers in Ecology and the Environment 7: 308–316.

Wang, H., W. E. Grant, T. M. Swannack, J. Gan, W. E. Rogers, T. E. Koralewski, J. H. Miller and J.W. Taylor, Jr. 2011. Predicted range expansion of Chinese tallow tree (Triadica sebifera) in forestlands of the southern United States. Diversity and Distributions 17: 552–565.

Scaling Rationale: The scaling is based on the type of detection likely on a cursory or rapid field visit to a site. In order to detect invasive exotic plants, it is important to be familiar with those plants, and how to differentiate them from native plants. The metric can be applied to small assessment areas (fixed radius areas around points) or larger stands or conservation sites.

Confidence that reasonable logic and/or data support the metric: High

Appendix D. Participant list (including affiliations) for Meetings and Review

Name	Affiliation	State
Andy Vanderyacht	Center for Native Grasslands Management	TN
Brian Camposano	Florida Forest Service	FL
Bryan Rupar	Arkansas Natural Heritage Commission	AR
Carl Nordman	NatureServe	NC
Carol Denhof	Longleaf Alliance	AL
Catherine Rideout	USFWS	GA
Chris Oswalt	US Forest Service	TN
Chuck Hunter	USFWS	GA
Clarence Coffey	TWRA (Retired)	TN
Clay Ware	USFWS	GA
Dan Hipes	Florida Natural Areas Inventory	FL
Doug Zollner	TNC Arkansas	AR
Doyle Shook	Lower Miss JV	AR
Gary Burger	SCDNR	SC
Jim Guldin	USFS Research Station	AR
Joan Walker	USFS Research Station	SC
Joanne Baggs	US Forest Service	GA
Jon Scott	National Fish and Wildlife Foundation	DC
Kevin Mcintyre	Jones Center	GA
Lora Smith	Jones Center	GA
Martin Blaney	Arkansas Game and Fish	AR
Matt Hinderliter	USFWS	MS
McRee Anderson	TNC Arkansas	AR
Mike Black	Shortleaf Initiative	TN
Mike Conner	Jones Center	GA
Milo Pyne	NatureServe	NC
Randy Wilson	USFWS	MS
Rickie White	NatureServe	NC
Russ Walsh	USFWS	MS
Tom Foti	Arkansas Natural Heritage Program	AR
Wally Akins	Tennessee Wildlife	TN
Will McDearman	USFWS	MS

Appendix E: Associations and Alliances of the Southern Open Pine Groupings

The Associations of the United States National Vegetation Classification (USNVC) (Jennings et al. 2009) are plant community types that are based on field data (observations, plots of varying dimensions) taken by NatureServe, the state Natural Heritage Programs or by other plant community ecologists. Thanks to the work of Dr. Robert Peet and many others, the associations for Longleaf Pine communities in particular constitute a representative if not complete suite of types. Alliances and Vegetation Groups are successively broader USNVC units, with their own descriptions, including vegetation, habitat and geographic distribution attributes, into which the Associations nest. In the table below, the database code (e.g. CEGL007126) and colloquial name of the Association are given beneath their Alliance and Vegetation Group. These are presented below the related Southern Open Pine Grouping. More information is available at http://usnvc.org/.

Grouping/Group	Identifier	Association Colloquial Name
Xeric Longleaf Pine Barrens		
G154 - Xeric Longleaf Pine Woodland		
	A4074	**Pinus palustris / Quercus laevis / Aristida stricta Woodland Alliance**
	CEGL007126	Atlantic Coastal Plain Subxeric Sandy Longleaf Pine - Pond Pine Ecotonal Woodland
	CEGL003592	Longleaf Pine / Scrub Oak Sandhill (Northern Type)
	CEGL003577	Carolina Coastal Longleaf Pine Sandhill
	CEGL003589	Atlantic Coastal Plain Longleaf Sandhill Scrub
	CEGL003590	Atlantic Coastal Plain Xeric Sandhill Scrub
	CEGL007125	Wiregrass Gap Xeric Longleaf Pine Sand Woodland
	CEGL003591	Carolina Longleaf Pine / Mixed Scrub Oak Sandhill
	CEGL003586	Fall-line Sandhills Dry Longleaf Pine Woodland
	CEGL003584	Atlantic Coastal Plain Xeric Longleaf Pine Sand Woodland
	A3122	**Pinus palustris / Quercus incana Woodland Alliance**
	CEGL008566	West Gulf Coastal Plain Xeric Post Oak Woodland
	CEGL008571	West Gulf Coastal Plain Fire-Infrequent Mixed Longleaf Pine Forest/Woodland
	CEGL007513	West Gulf Coastal Plain Fire-Infrequent Xeric Sandhill
	CEGL003602	West Gulf Coastal Plain Xeric Longleaf Pine Sandhill
	CEGL008572	West Gulf Coastal Plain Subxeric Longleaf Pine Sandhill
	CEGL003580	Western Upland Longleaf Pine Forest (Stream Terrace Sandy Woodland Type)
	CEGL004957	Eastern Louisiana Xeric Longleaf Woodland
	A4076	**Pinus palustris / Quercus laevis - Quercus geminata Woodland Alliance**
	CEGL003604	Florida Panhandle Fire-Suppressed Sandhill
	CEGL007137	Northern Florida Peninsula Longleaf Pine Red Oak Woodland
	CEGL007133	Western Florida Panhandle Xeric Lowland Sandhill Woodland
	CEGL004490	South Atlantic Coastal Plain Dry Longleaf Pine Sandhill
	CEGL007132	Florida Peninsula Xeric Sandhills
	CEGL003583	Longleaf Pine / Turkey Oak Woodland
	CEGL007135	Florida Red Hills Submesic Longleaf Pine Woodland
	CEGL007141	Florida Panhandle Lowlands Subxeric Longleaf Pine Woodland
	CEGL007254	Florida Central Sand Ridge Ruderal Turkey Oak Woodland

CEGL004689	Ruderal Turkey Oak Xeric Sandhill Scrub
A4077	**Pinus palustris / Quercus laevis / Aristida condensata Woodland Alliance**
CEGL003587	East Gulf Coastal Plain Xeric Longleaf Pine Sandhill
CEGL003601	East Gulf Coastal Plain Subxeric Longleaf Pine Sandhill
CEGL003588	East Gulf Coastal Plain Longleaf Sandhill Woodland
A4075	**Pinus palustris / Quercus laevis / Schizachyrium scoparium Woodland Alliance**
CEGL004488	Atlantic Inner Coastal Plain Yellow Sand Longleaf Pine Woodland
CEGL004492	Georgia Dry Longleaf Pine - Scrub Oak Sand Woodland
CEGL007127	Georgia Xeric Fall-line Sandhills Longleaf Pine Woodland
CEGL007844	South Atlantic Dry Longleaf Pine Sandhill
CEGL003593	South Carolina Central Longleaf Woodland
CEGL007129	Southern Inner Coastal Plain Silty Longleaf Pine / Sand Post Oak Woodland
CEGL007842	South Atlantic Sandhills Subxeric Silty Longleaf Pine Woodland
CEGL004487	Georgia Outer Coastal Plain Subxeric Longleaf Pine Woodland
CEGL008491	Xeric Upper East Gulf Coastal Plain Longleaf Pine Woodland

Dry & Mesic Longleaf Pine Woodlands

G009 - Dry-Mesic Loamy Longleaf Pine Woodland

A3127	**Pinus palustris / Aristida spp. - Schizachyrium scoparium Southeastern Coastal Plain Woodland Alliance**
CEGL007738	Atlantic Coastal Plain Mesic Longleaf Pine / Little Bluestem Woodland
CEGL004774	East Gulf Coastal Plain Lorman Soil Longleaf Pine Woodland
CEGL003664	Longleaf Pine Savanna (Lumbee Type)
CEGL003570	Fall-line Mesic Longleaf Pine Woodland
CEGL004485	East Gulf Coast Dougherty Plain Dry-Mesic Longleaf Pine Woodland
CEGL004496	Mesic Atlantic Coastal Plain Longleaf Pine - Little Bluestem Woodland
CEGL004945	East Gulf Coastal Plain Clayhill Longleaf Pine Woodland
CEGL003575	East Gulf Coastal Plain Loamy Longleaf Pine Woodland
CEGL004084	Dry Atlantic Coastal Plain Longleaf Pine - Little Bluestem Woodland
CEGL007749	Tifton Uplands Submesic Longleaf Pine / Running Oak Woodland
CEGL004955	Western East Gulf Coastal Plain Silt Loam Longleaf Pine Woodland
CEGL008452	Upper East Gulf Coastal Plain Loamhill Longleaf Woodland
CEGL003573	Carolina Fall-line Mesic Longleaf Pine Terrace Woodland
A3124	**Pinus palustris / Schizachyrium scoparium West Gulf Coastal Plain Woodland Alliance**
CEGL003609	West Gulf Coastal Plain Fire-Suppressed Longleaf - Mixed Pine Forest
CEGL008482	Texas Upper West Gulf Coastal Plain Longleaf Pine Woodland
CEGL003576	West Gulf Coastal Plain Fire-Suppressed Longleaf Forest
CEGL003571	West Gulf Coastal Plain Mesic Upland Longleaf Pine Woodland
CEGL003572	West Gulf Coastal Plain Dry-Mesic Upland Longleaf Pine Woodland
CEGL003581	Western Upland Longleaf Pine Forest (Messer Pimple Mound Type)
A3125	**Pinus palustris / Quercus margarettiae / Aristida spp. Southeastern Coastal Plain Woodland Alliance**
CEGL007511	Fire-Suppressed Longleaf Sandhill

CEGL004263	Cumberland Island Dry Longleaf Pine - Oak Woodland
CEGL008586	Munson Sandhill, Bluejack Oak Phase
CEGL003578	Carolina Sandhills Loamy Longleaf Pine / Scrub Oak Woodland
CEGL007767	Sandstone/Gravel Longleaf Pine Woodland
CEGL004083	Outer Coastal Plain Subxeric Longleaf Pine / Little Bluestem Woodland
A3123	**Pinus palustris / Quercus marilandica / Schizachyrium scoparium West Gulf Coastal Plain Woodland Alliance**
CEGL007907	West Gulf Coastal Plain Dry Post Oak Woodland
CEGL008579	West Gulf Coastal Plain Clayey Longleaf Pine Forest
CEGL003579	West Gulf Coastal Plain Clayey Longleaf Pine Woodland (Dry Type)
CEGL008580	West Gulf Coastal Plain Clayey Longleaf Pine Woodland (Moist Type)
CEGL003596	West Gulf Coastal Plain Calcareous Clay Longleaf Pine Glade
CEGL003597	Louisiana Longleaf Pine Fleming Glade
A3126	**Pinus palustris / Quercus marilandica / Aristida spp. Southeastern Coastal Plain Clayhill Woodland Alliance**
CEGL004489	Altamaha Grit Longleaf Pine Woodland
CEGL003595	Atlantic Longleaf Pine - Blackjack Oak Woodland
CEGL003598	Mississippi Loam Hills Longleaf Forest
CEGL003599	Fall-line Sandhills Longleaf Pine - Blackjack Oak Woodland

Mesic Longleaf Pine Flatwoods

G596 - Mesic Longleaf Pine Flatwoods - Spodosol Woodland

A3160	**Pinus palustris / Serenoa repens / Aristida beyrichiana Woodland Alliance**
CEGL007714	Longleaf Pine / Slash Pine Scrubby Flatwoods
CEGL006658	Mid- to Late-Successional Slash Pine - Loblolly Pine Woodland
CEGL003650	Central Florida Slash Pine Flatwoods
CEGL004658	Maritime Slash Pine - Longleaf Pine Upland Flatwoods
CEGL004969	South Atlantic Wet Slash Pine Flatwoods
CEGL004680	East Gulf Coastal Plain Maritime Slash Pine Flatwoods
CEGL003643	Slash Pine Flatwoods
CEGL003656	East Gulf Coastal Plain Wet Longleaf Pine Flatwoods
CEGL004967	South Atlantic Outer Coastal Plain Wet Longleaf Pine Flatwoods
CEGL007750	Peninsular Florida Scrubby Flatwoods
CEGL004791	Wet Longleaf Pine - Pond Pine Flatwoods
CEGL003662	Southern Atlantic Barrier Island Spodosol Pine / Oak Woodland
CEGL003808	Florida Panhandle Fragipan Longleaf Pine / Running Oak Flatwoods
CEGL003653	Longleaf Pine / Saw Palmetto Flatwoods
CEGL004486	South Atlantic Coastal Plain Longleaf Flatwoods
CEGL003795	Central Florida Pond Pine Shrubby Flatwoods
A3161	**Pinus palustris / Vaccinium crassifolium / Aristida stricta Woodland Alliance**
CEGL003647	Wet Longleaf Pine Flatwoods (Northern Type)
CEGL003658	Longleaf Pine - Pond Pine Savanna (Wet Spodosol Type)
CEGL003661	Longleaf Pine Savanna (Wet Pleea Flat Type)

CEGL003648	Wet Longleaf Pine Flatwoods (Southern Type)
CEGL003649	Wet Pine Flatwoods (Leiophyllum Type)

Wet Longleaf & Slash Pine Flatwoods & Savannas

G190 - Wet-Mesic Longleaf Pine Open Woodland

A3305 **Pinus palustris - Pinus serotina Atlantic Coastal Plain Wet Open Woodland Alliance**

CEGL003659	Sandhill/Pocosin Ecotone
CEGL004085	Atlantic Coastal Plain / Wet Ultisol Longleaf Pine Savanna (Curtis' Dropseed Type)
CEGL004790	South Atlantic Coastal Plain Wet Pine Flatwoods
CEGL004497	Longleaf Pine - Slash Pine Wet Swale Woodland
CEGL004498	Longleaf Pine - Pond Pine Wet Swale Woodland
CEGL003660	Longleaf Pine - Pond Pine Savanna (Wet Ultisol Type)
CEGL004499	South Atlantic Coastal Plain Wet Longleaf Pine - Pond Pine Woodland
CEGL004500	Mid-Atlantic Coastal Plain Very Wet Loamy Longleaf Pine Savanna
CEGL004501	Atlantic Coastal Plain Wet Ultisol Longleaf Pine Savanna
CEGL004502	Atlantic Coastal Plain Very Wet Clay Longleaf Pine Savanna
CEGL003663	Lower Piedmont Wet Longleaf Pine Woodland
CEGL004495	Mid-Atlantic Coastal Plain Wet Silty Longleaf Pine Savanna
CEGL004086	Atlantic Coastal Plain / Wet Ultisol Longleaf Pine Savanna
CEGL004814	Atlantic Coastal Plain Longleaf Pine Clay Savanna

A3306 **Pinus palustris West Gulf Coastal Plain Wet Open Woodland Alliance**

CEGL003646	West Gulf Coastal Plain Wet Longleaf Pine Savanna (High Terraces Type)
CEGL007802	Western Wet Longleaf Pine Savanna (Prairie Terraces Acidic Silt Loam Type)
CEGL003654	Western Wet Longleaf Pine Savanna (Prairie Terraces Sodic Silt Loam Type)

A4104 **Pinus palustris - Pinus elliottii East Gulf Coastal Plain Wet Open Woodland Alliance**

CEGL003673	East Gulf Coastal Plain Wet Pine Flatwoods
CEGL004556	Gulf Coast Wet Slash Pine Flatwoods
CEGL003645	East Gulf Coastal Plain Wet Longleaf Pine Savanna
CEGL004792	Southern Mississippi Claypan Flatwoods
CEGL003860	Southern Fall-line Sandhills Wet Longleaf Pine - Pond Pine Woodland
CEGL004956	Florida Parishes Coastal Terrace Longleaf Pine Flatwoods
CEGL003797	East Gulf Coastal Plain Pond Pine / Herbaceous Woodland

Dry & Mesic Highland Pine Woodlands

G012 - Shortleaf Pine - Oak Forest & Woodland (in part)

A3271 **Pinus echinata - Quercus stellata - Quercus velutina Ozark-Ouachita Woodland Alliance**

CEGL004444	Ouachita Shortleaf Pine - Oak Forest
CEGL007489	Interior Highlands Shortleaf Pine - Oak Dry-Mesic Forest
CEGL002394	Shortleaf Pine - Oak Dry-Mesic Woodland
CEGL002393	Ozark-Ouachita Shortleaf Pine - Oak Dry Woodland
CEGL002401	Interior Highlands Shortleaf Pine - Black Oak Forest
CEGL002402	Interior Highland Shortleaf Pine Woodland

CEGL007815	Ouachita Shortleaf Pine Savanna
CEGL002400	Interior Highlands Shortleaf Pine / Blueberry Forest

A3272 **Pinus palustris - Pinus echinata - Quercus prinus Interior Woodland Alliance**

CEGL007029	Pine Mountain Georgia Oak Woodland
CEGL003606	Montane Longleaf Pine - Heath Bluff Woodland
CEGL004432	Pine Mountain Georgia Longleaf Pine Woodland
CEGL008437	Montane Mixed Longleaf Woodland
CEGL003608	Georgia Piedmont Longleaf Pine Serpentine Woodland
CEGL007018	Georgia Piedmont Longleaf Pine Basic Woodland
CEGL004060	Southern Ridge and Valley Chestnut Oak - Longleaf Forest

Dry & Mesic Hilly Pine Woodlands

G012 - Shortleaf Pine - Oak Forest & Woodland (in part)

A3270 **Pinus echinata - Quercus falcata Upper Coastal Plain Alliance**

CEGL004834	Mixed Pine - Cherrybark Oak Forest
CEGL008493	East Gulf Coastal Plain Shortleaf Pine - Loblolly Pine Forest
CEGL004050	East & Upper East Gulf Coastal Plains Shortleaf Pine - Mesic Oak Forest
CEGL004052	East Gulf Coastal Plain Shortleaf Pine - Southern Red Oak Forest
CEGL004054	Interior Low Plateau Shortleaf Pine - Oak Forest
CEGL004053	East Gulf Coastal Plain Shortleaf Pine - Post Oak Forest
CEGL007919	Crowley's Ridge Shortleaf Pine Forest

G013 - Western Gulf Coastal Plain Pine - Oak Forest & Woodland

A3129 **Pinus echinata - Pinus taeda - Quercus stellata Forest Alliance**

CEGL007947	West Gulf Coastal Plain Dry Shortleaf Pine Forest
CEGL004713	West Gulf Coastal Plain Shortleaf - Loblolly - Mixed Oak Forest
CEGL007499	West Gulf Coastal Plain Shortleaf Pine - Post Oak Forest
CEGL007798	West Gulf Coastal Plain Calcareous Pine - Oak Woodland
CEGL007800	West Gulf Coastal Plain Shortleaf Pine - Post Oak Woodland
CEGL007528	West Gulf Coastal Plain Dry Loblolly Pine - Hardwood Forest
CEGL002112	West Gulf Coastal Plain Upland Loblolly Pine - Post Oak Woodland
CEGL007868	East Texas Catahoula Barrens Post Oak Woodland
CEGL007900	West Gulf Coastal Plain Acidic Clay Post Oak - Blackjack Oak Woodland

A0386 **Quercus incana - Quercus arkansana - Pinus echinata Woodland Alliance**

CEGL007973	Upper West Gulf Coastal Plain Xeric Sand Barrens
CEGL007507	West Gulf Coastal Plain Xeric Upland Shortleaf Pine - Oak Woodland
CEGL007946	West Gulf Coastal Subxeric Shortleaf Pine - Oak Woodland
CEGL003559	West Gulf Coastal Plain Xeric Stream Terrace Shortleaf Pine Woodland
CEGL007972	Upper West Gulf Coastal Plain Xeric Sandhill Complex (Mixed Oak Type)
CEGL003693	Upper West Gulf Coastal Plain Xeric Sandhill Complex (Arkansas Oak Type)

A3130 **Pinus taeda - Quercus alba / Viburnum spp. Forest Alliance**

CEGL008410	Upper West Gulf Coastal Plain Shortleaf - Loblolly Pine Naturally Mixed Forest
CEGL003855	West Gulf Coastal Plain Shortleaf Pine - Oak Rich Mesic Forest

CEGL008582	Neches Bluff Pine / Swamp Chestnut Oak Forest
CEGL007955	West Gulf Coastal Plain Subcalcareous Loblolly - Water Oak/Palmetto Riparian Forest
CEGL007524	West Gulf Coastal Plain Subcalcareous Pine - Hardwood Slope and Stream Bottom Forest

Upper Coastal Plain Pine Flatwoods

G130 - Hardwood - Loblolly Pine Nonriverine Wet Flatwoods

A4189	**Quercus laurifolia - Quercus phellos - Quercus michauxii Atlantic Coastal Plain Wet Flatwoods Forest Alliance**
CEGL004228	South Atlantic Willow Oak Flatwoods Forest
CEGL004831	South Atlantic Mixed Oak-Pine Calcareous Flatwoods Forest
A3445	**Quercus stellata - Quercus falcata Wet Flatwoods Forest Alliance**
CEGL008587	West Gulf Coastal Plain Post Oak - Loblolly Flatwoods
A4190	**Pinus taeda - Quercus laurifolia - Quercus phellos West Gulf Coastal Plain Wet Flatwoods Forest Alliance**
CEGL004534	Louisiana Wet Spruce Pine - Hardwood Flatwoods Forest
CEGL007069	West Gulf Coastal Plain Pine - Oak Nonriverine Flatwoods
CEGL007715	Louisiana Pleistocene Prairie Terrace Mixed Hardwood-Loblolly Flatwoods Forest

References cited

Jennings, M. D., D. Faber-Langendoen, O. L. Loucks, R. K. Peet, and D. Roberts. 2009. Standards for Associations and Alliances of the U.S. National Vegetation Classification. Ecological Monographs 79(2): 173-199.

Appendix F: Representative Species Pool for Coastal Plain Open Pine Woodland and Savanna (GCPO LCC), with Priority Species in bold

Scientific Name	Common Name	Taxon	Pine
Ambystoma bishopi	Flatwoods Salamander	Amphibians	x
Ambystoma talpoideum	Mole Salamander	Amphibians	x
Ambystoma tigrinum	Tiger Salamander	Amphibians	x
Anaxyrus (*Bufo*) *quercicus*	Oak Toad	Amphibians	x
Eurycea cf. quadridigitata	Bog Dwarf Salamander	Amphibians	x
Eurycea quadridigitata	Dwarf Salamander	Amphibians	x
Hyla andersonii	Pine Barrens Treefrog	Amphibians	x
Rana areolata areolata	Southern Crawfish Frog	Amphibians	x
Rana capito	Gopher Frog	Amphibians	x
Rana sevosa	Mississippi Gopher Frog	Amphibians	x
Aimophila aestivalis	**Bachman's Sparrow**	**Birds**	**x**
Ammodramus henslowii	Henslow's Sparrow	Birds	x
Caprimulgus carolinensis	Chuck-will's-widow	Birds	x
Caprimulgus vociferus	Whip-poor-will	Birds	x
Coccyzus americanus	Yellow-billed Cuckoo	Birds	x
Colinus virginianus	**Northern Bobwhite**	**Birds**	**x**
Dendroica discolor	**Prairie Warbler**	**Birds**	**x**
Dendroica dominica	Yellow-throated Warbler	Birds	x
Dendroica pinus	**Pine Warbler**	**Birds**	**x**
Dryocopus pileatus	Pileated Woodpecker	Birds	x
Falco sparverius paulus	Southeastern American Kestrel	Birds	x
Geococcyx californianus	Greater Roadrunner	Birds	x
Grus canadensis pulla	Mississippi Sandhill Crane	Birds	x
Melanerpes erythrocephalus	Red-headed Woodpecker	Birds	x
Meleagris gallopavo	Wild Turkey	Birds	x
Picoides borealis	**Red-cockaded Woodpecker**	**Birds**	**x**
Picoides villosus	Hairy Woodpecker	Birds	x
Pipilo erythrophthalmus	Eastern Towhee	Birds	x
Sitta pusilla	**Brown-headed Nuthatch**	**Birds**	**x**
Geomys pinetis	**Southeastern Pocket Gopher**	**Mammals**	**x**
Sciurus niger niger	Southeastern Fox Squirrel	Mammals	x
Cemophora coccinea	Scarlet Snake	Reptiles	x
Crotalus adamanteus	**Eastern Diamondback Rattlesnake**	**Reptiles**	**x**
Drymarchon couperi	Eastern Indigo Snake	Reptiles	x
Gopherus polyphemus	**Gopher Tortoise**	**Reptiles**	**x**
Lampropeltis getula	Common Kingsnake	Reptiles	x
Masticophis flagellum	Eastern Coachwhip	Reptiles	x
Micrurus fulvius	Coral Snake	Reptiles	x
Micrurus tener tener	Texas Coral Snake	Reptiles	x
Pituophis melanoleucus	**Northern Pine Snake**	**Reptiles**	**x**
Pituophis ruthveni	**Louisiana Pine Snake**	**Reptiles**	**x**
Sistrurus miliarius	Pygmy Rattlesnake	Reptiles	x
Tantilla coronata	Southeastern Crowned Snake	Reptiles	x

Appendix G: Priority Species of Open Pine Woodlands of the GCPO LCC

Common name	Scientific name	Project area states where it occurs	States where listed as Species of Greatest Conservation Need (SGCN) in 2005 State Wildlife Action Plan	Open Pine Groupings
Red-cockaded Woodpecker	*Picoides borealis*	All project area states, except MO (Extirpated)	AL, AR, FL, GA, KY (Extirpated) , LA, MD, MO (Extirpated), MS, NC, OK, SC, TX, VA	All?
Louisiana Pine Snake	*Pituophis ruthveni*	LA, TX	LA, TX	Xeric Longleaf Pine Barrens
Black Pine Snake	*Pituophis melanoleucus lodingi*	AL, LA, MS	AL, LA, MS	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands
Florida Pine Snake	*Pituophis melanoleucus mugitus*	AL, FL, GA, SC	AL, FL, GA, SC	Xeric Longleaf Pine Barrens
Brown-headed Nuthatch	*Sitta pusilla*	All project area states, except MO (Extirpated)	AR, DE, FL, LA, MD, MO (Extirpated), MS, NC, OK, SC, TN, TX, VA	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands, Mesic Longleaf Pine Flatwoods, Wet Longleaf & Slash Pine Flatwoods & Savannas, Dry & Mesic Hilly Pine Woodlands (East Gulf), Dry & Mesic Hilly Pine Woodlands (West Gulf), Upper Coastal Plain Pine Flatwoods
Bachman's Sparrow	*Peucaea (Aimophila) aestivalis*	All project area states	AL, AR, FL, GA, KY, LA, MD, MO, MS, NC, OH (Extirpated), OK, SC, TN, TX, VA, WV	All?
Northern Bobwhite	*Colinus virginianus*	All project area states	AR, CT, DC, DE, FL, GA, IA, IL, KS, KY, LA, MA, MD, MI, MS, NC, NE, NJ, NY, OH, OK, PA, RI, SC, TX, VA, WI, WV	All?
Pine Warbler	*Setophaga pinus*	All project area states	NJ, OH	All?
Gopher Tortoise	*Gopherus polyphemus*	AL, FL, GA, LA, MS, SC	AL, FL, GA, LA, MS, SC	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands, Mesic Longleaf Pine Flatwoods
Prairie Warbler	*Setophaga discolor*	All project area states	AR, CT, DE, IL, KY, LA, MA, MD, ME, MI, MS, NC, NJ, NY, OH, OK, PR, RI, SC, TN, TX, VA, VI, VT, WV	All?
Eastern Diamondback Rattlesnake	*Crotalus adamanteus*	AL, FL, GA, LA, MS, NC, SC	AL, FL, GA, LA, MS, NC	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands, Mesic Longleaf Pine Flatwoods
Southeastern Pocket Gopher	*Geomys pinetis*	AL, FL, GA	AL, FL, GA	Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands
Baird's Pocket Gopher	*Geomys breviceps*	LA, TX		Xeric Longleaf Pine Barrens, Dry & Mesic Longleaf Pine Woodlands, Dry & Mesic Hilly Pine Woodlands (West Gulf)
Plains Pocket Gopher	*Geomys bursarius*	AR (Izard County), MO	IN, WY	Dry & Mesic Highlands Pine Woodlands
Ozark Pocket Gopher	*Geomys bursarius ozarkensis*	AR	AR	Dry & Mesic Highlands Pine Woodlands

Pinus palustris

Field Manual for Rapid Assessment Metrics for Wildlife and Biodiversity in Southern Open Pine Ecosystems

May 6, 2016

Prepared by:
Rickie White & Carl Nordman
NatureServe
601-A Foster Street
Durham, NC 27701

Based on work originated by:
F. Joseph Rocchio
Washington Natural Heritage Program
Washington Department of Natural Resources
Olympia, Washington 98504-7014

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1.0 Introduction

This document describes a new, highly flexible, rapid, efficient approach to assessment of open pine ecosystems that can be applied by a wide range of landowners, land managers, wildlife technicians, biologists, and other natural resource scientists to help them understand their land's contribution to biodiversity and target species' wildlife habitat.

Specifically, the protocols describe a way to apply field-based desired forest condition metrics within Southern Open Pine Ecosystems **specifically for those managers whose primary goal is maintenance of biodiversity or enhancement of wildlife habitat for species dependent on open pine ecosystems**. The metrics in this protocols document are based directly on Nordman et al. 2016, and more exhaustive descriptions of each metric can be found there. Discussion of the concepts behind this type of assessment, which is often referred to as an ecological integrity assessment, can be found in Rocchio and Crawford (2011) and Faber-Langendoen et al. (2006, 2012, and 2014).

What is Southern Open Pine?

In the southeastern United States, there are several large-scale (or formerly large-scale) ecosystems dominated by an open canopy of pine trees that are used by a great variety of game and non-game wildlife species and plants. Due to changes in land use and lack of fire, these open pine ecosystems have undergone extensive declines over the last 100 years and continue to be threatened with further decline. These ecosystems are found from the West Gulf Coastal Plain and Ozark and Ouachita Mountains to the Southern Appalachians, Piedmont, Atlantic and East Gulf Coastal Plains, and south into the Florida Peninsula.

In the past, these ecosystems have consisted of open pine stands with a diverse ground cover composed of native warm season grasses and forbs, often with some low shrubs and only sparse tall shrubs. These open conditions were historically maintained by natural processes, including fire and grazing. Today, these ecosystems require active management to maintain or to restore the open herbaceous conditions preferred by many species of wildlife (for a fuller discussion of the wildlife targeted in this assessment, please refer to Nordman et al. 2016).

While these ecosystems occur across the southeastern United States, this current project more specifically focuses on southern open pine wildlife systems dominated by southern yellow pines, particularly longleaf pine (*Pinus palustris*) and shortleaf pine (*Pinus echinata*), which occur in the southern coastal plains and the Ozark and Ouachita mountains. We also focus on natural stands of slash pine (*Pinus elliottii*) and loblolly pine (*Pinus taeda*).

Who is the intended user for these protocols?

This protocols document can be utilized by anyone who is working within the geographic range of our project. The protocols have been specifically developed for landowners and land managers on **lands where conservation and/or restoration of open pine ecosystems and their associated wildlife is the highest priority.**

How do these protocols help users meet conservation goals?

After years of steady decline in acreage and quality, the remaining examples of southern open pine ecosystems are a patchwork of existing and restored tracts. In order to restore the function of this formerly grand ecosystem and to fully protect the species that rely on the ecosystem, we must first understand the amount of land that is currently providing high quality habitat to our target species. These protocols help us at two different scales:

- At the finest scale, these protocols give land managers with a conservation focus a powerful, efficient tool that allows them to collect data and quickly understand whether stands are in good or excellent condition (providing priority wildlife species' habitat) or not.
- At larger scales, these protocols can contribute to our understanding of the overall condition of open pine ecosystems regionally and allow us to more precisely plan for a better future for this ecosystem.

2.0 Applying Rapid Assessment Metrics in Southern Open Pine Ecosystems

Below are general guidelines for applying the desired forest condition metrics to southern open pine occurrences.

Step 1: **Determine the assessment area, determine your target Southern Open Pine Groupings (community type(s)), and choose your sampling strategy.** Look at a map of your study area and determine the extent and size of the southern open pine occurrences or stands on your site and any stands that you wish to manage as southern open pine but that are currently other community types (for example, an old field or low quality hardwood stand that you are managing to become open pine in the future). Using the guidance in Section 2.2 below, delineate boundaries of the occurrences or stands of the different southern open pine groupings and choose a sampling strategy that best fits your needs.

Step 2: **Conduct the field assessment and enter data collected on field datasheet.** Assess point or polygon. Assessment will consist of walking stands or visits to sets of random points within stands, and can be completed as data collection added to an ongoing natural resource inventory or timber cruise procedure. Use the sample field data sheet provided, or create your own.

Step 3: **Complete metric assessment scores to calculate a score for the canopy, midstory, ground layer, and an overall score** using the worksheet provided in this document.

Step 4: **Enter/upload results** into a database. Our Ecology Observation Database for open pine is currently under development, but should be available later in 2016.

2.1 Determine the Assessment Area and Determine the Target Southern Open Pine Groupings (based on Faber-Langendoen et al. 2012, Rocchio 2015).

The assessment area is "the entire area, subarea, or point of an occurrence of an ecosystem type with a relatively homogeneous ecology and condition" (Faber-Langendoen et al. 2012). In other words, it is the area where the desired forest condition metrics will be applied. There are different approaches for determining the assessment area boundaries. The approach used depends on natural resource management goals, project objectives, southern open pine ecosystem restoration targets, etc. The approaches for assessment area delineation are generally of two categories: (1) point-based and (2) polygon-based.

A single point-based approach typically defines a relatively small area (.1 hectare, for example) around a point, where the assessment is conducted. This could be a circle of a certain radius for most metrics, and basal area could be measured with a prism from the center.

A point based approach in which a fixed area is sampled around a point offers some advantages and disadvantages (Fennessy et al. 2007, Stevens and Jensen 2007):

- simple sampling design
- no mapped boundary of ecosystem type is required for assessment unit
- limited practical difficulties in the field of assessing the entire area, as the area is typically relatively small (.1-1 hectare); long-term monitoring programs often use a point-based approach because of these advantages
- Flexible so user can take one point per stand or can take multiple points per stand depending upon goals and resources available for sampling.
- For collection of multiple points, can take a large amount of sampling time as compared to the polygon approach.

A polygon approach is based on a specific southern open pine ecosystem extent or stand that is delineated to create a mapped area. The polygon approach is used when a more comprehensive assessment of ecological integrity is desired. Its advantages and disadvantages are:

- Mapping boundaries facilitates whole ecosystem and landscape interpretations
- Decision-makers and managers are often more interested in "stands" or "occurrences," rather than points
- Involves assessing the polygon as a whole with one sample, which can speed up the process of data collection but can also lead to spurious conclusions if area sampled is not truly characteristic of polygon as a whole. In areas that turn out to be more heterogeneous than originally intended, there may still need to be some assessment of multiple distinct patches to come up with an average score for the polygon.

How to determine your assessment area (regardless of polygon or point-based approach):

1. Estimate Southern Open Pine Boundaries/assessment area*:* The first action needed is to map (formally or informally) the southern open pine ecosystem assessment area, if there isn't already a useable map of the area. Readily observable ecological criteria such as vegetation, soil, and hydrological characteristics can all be used to define the assessment area where it is most appropriate to apply the rapid assessment protocols (i.e. areas that are either currently in southern open pine or where managers wish to manage for a future with open pine. This map could be as simple as a hand drawing (preferably to scale) or could be a remotely sensed map with a GIS environment.

2. Classify your Southern Open Pine Observations: The Southern Open Pine Groupings themselves represent an ecosystem classification, which is an important tool in assessing the ecological integrity of the observations. Ecosystem classifications help fieldworkers to better cope with natural variability within and among types of ecosystems, and allow differences between observations with excellent, good, fair or poor condition to be more clearly recognized. Ecological classifications are also important in establishing "ecological equivalency," for example, in providing guidance on how an impacted Mesic Longleaf Pine Flatwoods can be restored to a Mesic Longleaf Pine Flatwoods with improved condition.

Within the target assessment area mapped in action 1, determine the Southern Open Pine Grouping(s) present using the dichotomous key in **Appendix A**. Under the ideal scenario, the assessment area will only consist of one ecological "grouping" to minimize confusion in how to apply the final rapid assessment metrics (and if you encounter other open pine groupings, consider treating them as a separate assessment area). The specific place where an ecosystem type is found can be referred to as an "ecological observation", "assessment area", "sample point", "field site," or "occurrence". The term "observation" is sometimes used as a generic, flexible term applied to any kind of place or unit where an ecosystem is identified and described (Stevens and Jensen 2007), and is increasingly used as a term for all species or ecosystem field records (Lapp et al. 2011).

3. Modify Boundaries of Observations Based on Variation in Land Use: Significant differences in management or land use can result in distinct ecological differences across an observation boundary. If such changes result in strong differences in condition, they should be considered separate stands or occurrences, rather than the same observation/assessment area. Some examples follow:

- Heavily grazed Wet Longleaf & Slash Pine Flatwoods & Savannas on one side of a fence line and ungrazed Wet Longleaf & Slash Pine Flatwoods & Savannas on the other could result in separate stands or occurrences (Figure 1).
- Altered hydrology including, ditches, water diversions, tiling, or roadbeds that substantially alter a site's hydrology relative to adjacent areas could result in separate stands or occurrences (Figure 1).

4. Choose best sampling strategy for Assessment Areas: Occurrences of southern open pine can be very large. For such occurrences/observations, it may be necessary to sample more than one area to best capture the variability within the observed area. A random or stratified random sampling design is a useful way to accomplish this goal. The

Generalized Random Tessellation Stratified (GRTS) survey design can be used to create a spatially balanced random sample of points within the AA. This method allows for some points to be dropped while maintaining spatially balanced random sampling. The R statistics software package called spsurvey, can be used for GRTS survey design. Details are available online at:

https://science.nature.nps.gov/im/datamgmt/statistics/r/advanced/grts.cfm

http://www.inside-r.org/packages/cran/spsurvey/docs/grts

https://cran.r-project.org/web/packages/spsurvey/index.html

Alternatively, subdivide large occurrences based on ecological or practical criteria and delineate such that they provide a practical assessment area for rapid assessment application.

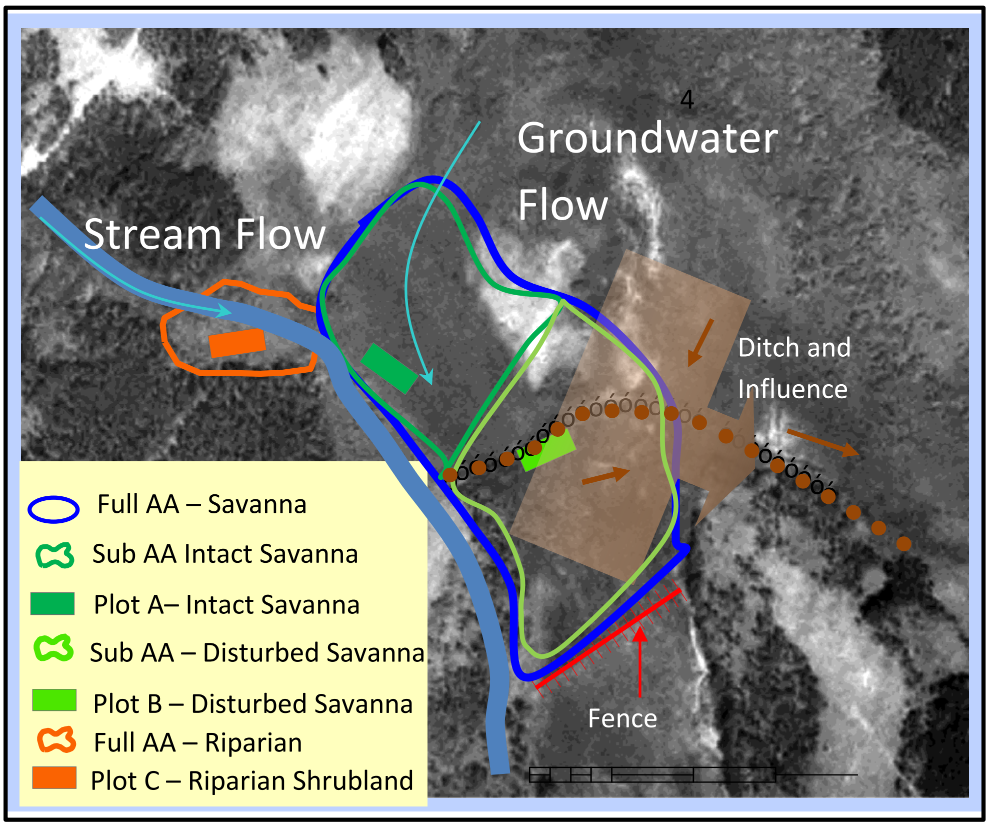

Figure 1. Example of delineated Assessment Areas (AAs). Although contiguous with each other, the savanna and riparian shrubland were delineated as distinct AAs because they were distinct wetland types (e.g., savanna vs. riparian shrubland). The savanna was divided into sub-AAs due to a human-induced disturbance (e.g., ditching) which could significantly alter a large portion of an otherwise contiguous wetland type (e.g., intact vs. disturbed savanna). A decision as to whether to formally recognize two sub assessment areas within a larger assessment area or

to simply incorporate the variation into a single evaluation depends on the observed differences in integrity and the size of the main assessment area versus sub-AAs (adapted from Rocchio 2007).

2.2 Conduct the field assessment and enter data collected on fieldsheet.

The great advantage to our methodology is that it is both fast and flexible. Users can apply the methodology as rigorously or loosely as is possible using their available resources. Similarly, users may choose to either apply all metrics or just a subset depending upon the amount of time and resources they feel they can spare.

Assessment can consist of simply walking through the stands using a polygon-based assessment, visits to sets of random points within stands using a point-based approach, or can be completed as data collection added to an ongoing natural resource inventory or timber cruise procedure. **Use the sample field data coversheet provided in Appendix B to document your entire assessment area and choose the appropriate field form from Appendix C to take specific data for each point or polygon within your assessment area.** *Since this is the first version of this document, we encourage input and feedback on these forms so that we can improve them for the next iteration of this protocols document.*

At the beginning of your project, choose the metrics that you wish to apply. Under the ideal scenario, users would collect data on all metrics suggested in the document for the open pine grouping that is applicable. If time is a major factor, at a minimum choose at least 1-2 metrics per strata (for a total of 3-6 metrics) to ensure that you have metrics representing the canopy, midstory, and ground layer.

Also for canopy layer, keep in mind that users may use the yellow pine stand density index measurement INSTEAD OF yellow pine canopy cover and yellow pine basal area. The stand density index is still in early development stages, so we are allowing users to consider this as an optional alternative where they feel comfortable applying it.

We highly recommend that users that have the resources to do so collect exact measurements in the field. In this way, we can potentially look back at the raw data to better understand how far measurements were from cutoffs between categories of excellent, good, fair, poor. However, if time is highly limited, then simply marking the excellent/good/fair/poor category on the datasheet without recording the actual specific measure is acceptable.

2.3 Complete metric assessment scores to calculate a score for the canopy, midstory, ground layer, and an overall score.

Once all data is filled in for an assessment area (**see appendix C for data sheet templates**), it is time to score each point or polygon assessed. If only scoring one sample, convert any raw data to a score using the metric cutoffs on the data sheet. Add up all metrics for a particular strata and follow instructions on sheet for developing a score for that strata. Finally, add up all three strata scores and divide by 3 to obtain the final total score.

Scores can be useful in two ways:

- Scores for each strata can help users better understand which strata are in good condition vs. which strata are in poor/fair condition. These results may help users understand which strata need the most "help" to improve condition in the future, thereby potentially focusing future management.
- Overall scores can help users understand how their stand is performing overall and can be rolled up and used at a large stand or regional scale to better quantify larger scale wildlife habitat and biodiversity contributions at these larger scales.

2.4 Enter/upload Results.

Enter/upload results into database. The Ecology Observation Database for open pine is not yet available, but we hope for a release in late 2016.

3.0 Definitions of key fields on data sheets

This section provides guidance on how to populate the field form. The first four sections address basic site-level data. Thereafter, protocols for each metric are described. They are organized by Rank Factor categories. The majority of protocols used for the WA wetland/riparian Level 2 EIAs are the same as outlined by Faber-Langendoen et al. (2012. We occasionally use regional language for some of the metric ratings.

Site / Assessment Area Information

Date: the date of the survey

Project: name of field data collection project

Site ID: unique ID of site

Field Crew Team Members

Leader: leader of the field team, with first and last name

Assistants: field team assistants, with first and last names

Photographer: name of the photographer
Photos of Site: descriptions of each photo (in order, separated by commas). A brief description of each photo's content should be documented in a previous image taken of the top of that field form, or (1) a field notebook or (2) file name; or (3) in the photo's metadata.
Photo filenames: filenames of photos, these ideally should have the photographer's initials and a number (e.g., fjr_001), or siteID and a number (e.g., Black_Creek_stand12_1).
Assessment Area Shape: shape of assessment area, such as circle, rectangle or polygon
Bearing: compass bearing of length of rectangle or polygon assessment area
Assessment Area Dimensions: radius of circle, or width and length of rectangle or polygon
State: State in which the assessment area occurs.
County: County in which the assessment area occurs.
Twp: Township, only for areas where TRS (Township, Range, Section) land designations are used
Range: Range, only for areas where TRS (Township, Range, Section) land designations are used
Section: Section, only for areas where TRS (Township, Range, Section) land designations are used
USGS 7.5' Quad: 7.5 Minute Quadrangle map name from US Geological Survey
Landowner/Managed Area Name:
Contact Person: name of contact person associated with the site
Stand Name: name of stand where assessment area is, could be a stand code or name.
Permit Required? Yes/No, if a permit is required the field team should always carry it in the field.
Locked Gate? Yes/No, the field team should leave locked gates as they are instructed to by contact person. If there is a series of locks, be careful to relock as found when team is done working beyond gate.
Access Difficulties? (describe): Any particular access difficulties should be clearly noted, on an extra sheet if needed. These notes will enable future visits to be efficient.
Site Description: General description of the site, provide a written description of the site's characteristics with details appropriate for project needs. Focus on the setting in which the site occurs, ecological and vegetation patterns both within and adjacent to the site, notable stressors or human activity, signs of wildlife, etc. A drawing may also be helpful.
General Drawing (Optional): A clear drawing is optional but can be useful.

Location

Assessment Area CENTRUM (check one) Original Moved (why? how far?)
GPS Unit: GPS make, model and number (if numbered)
GPS Filename: filename of saved new GPS point at assessment area
Projection: projection of GPS data
UTM Zone: UTM zone, which is the same for most project areas.
UTM X Easting: Easting of field recorded new GPS point
UTM Y Northing: Northing of field recorded new GPS point

Datum: Circle either NAD83 or WGS84, or write in other datum
LAT (decimal degree): Latitude of field recorded new GPS point
LONG (decimal degree): Longitude of field recorded new GPS point
GPS Accuracy: reported accuracy, such as from a Garmin GPS (e.g. 5 feet)
PDOP: PDOP is reported for Trimble GPS units
# of Sats: number of satellites used by GPS for recorded point
Original (e.g. GRTS): original random, stratified random, or GRTS random point location which was navigated to with GPS
Post-processed: values if GPS point taken in the field was post-processed to improve accuracy

Classification

Southern Open Pine Grouping: use the key provided to determine Southern Open Pine Grouping
Other Community Classification Reference: optional other classification reference used, such as Eyre 1980 (SAF), Florida Natural Areas Inventory 2010, Edwards, Ambrose & Kirkman 2013, etc.
Name: optional name of other open pine community name following classification reference
USNVC Association (Optional): the US National Vegetation Classification Plant Association name is optional, and can be added if known.
Classification Comments: any comments on classification of assessment area
Notes: any notes, specify which field or topic they pertain to

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Appendix A. Key to Southern Open Pine Habitat Groupings

This key should help determine which southern open pine habitat grouping desired forest condition metrics are most appropriate for particular lands. A map of states and USDA Forest Service sections (Cleland et al. 2007), is provided (see Figure A-1, below). Some of the southern open pine habitat groupings occur within the range of longleaf pine (*Pinus palustris*) as defined by Little (1971). This general range is not precise in all places, so it is possible that a stand of a longleaf pine grouping could be found outside this range. In the vast majority of cases, a user should be able to place a stand in a southern open pine grouping, then chose the appropriate set of metric values for that grouping.

The key is specifically designed for use within the boundaries of the Gulf Coast Plains and Ozarks Landscape Conservation Cooperative (GCPOLCC), which includes the Missouri and Arkansas highlands of the Ozark, Boston and Ouachita mountain ranges, and the Gulf Coastal Plains, which extend from eastern Texas to the Florida panhandle. It also applies to stands dominated by Longleaf Pine (*Pinus palustris*) throughout the range of this species, but makes no attempt to accommodate other related vegetation east and north of the GCPOLCC footprint.

The key will lead a user through a series of choices ("couplets") related to the geographic location of the area under consideration, as well as choices about stand composition and environment. At its higher levels, the key is constructed around these Forest Service regions. Further into the key, the choices related to stand composition and environment come into play. A user should read both statements and see which one best applies to the area and stands under question. If an obviously incorrect answer is obtained, it may be necessary to repeat the exercise.

Common terms rather than highly technical ones are used (wet, dry, sandy, upland, seasonally, etc.). One term that may be unfamiliar to some users is "mesic". This is a kind of shorthand for an environment that is neither very dry nor very wet (i.e. "in the middle" of a broad ecological moisture continuum). It is most frequently applied to species-rich hardwood stands ("coves"), but in this context it would refer to stands that are not "wet", i.e. without standing water), but have enough available soil moisture to support diverse and possibly dense herbaceous layers. Similarly "dry-mesic" refers to stands that are on the dry side of mesic, but not notably dry. These terms may roughly correlate with soil texture, in that under similar hydrological conditions, coarser-textured soils are more likely to be drier that those with finer particle size.

Following the key, a table of distributions of the open pine groupings by state and region (Table A-1), a map of the relevant USDA Forest Service Sections (Figure A-1), and a table of USDA Forest Service Provinces and Sections referred to in the key (Table A-2) are provided to assist in its use.

Key to Open Pine Groupings

1a. Forests and woodlands in the coastal plains (Outer Coastal Plains Mixed Forest Province 232; Southeastern Mixed Forest Province 231, southern parts of Sections 231B, 231E and 231H within the range of Longleaf Pine [*Pinus palustris*] as defined by Little [1971]), typically dominated by Longleaf Pine (*Pinus palustris*) and/or Slash Pine (*Pinus elliottii*), habitat ranging from very dry sandy uplands, mesic finer-textured soils, and seasonally wet or saturated flatwoods and savannas......................... 2

1b. Forests and woodlands landward of the coastal plains (Southeastern Mixed Forest Province 231, Sections 231A, 231C, 231D, 231G, 231I; also Central Interior Broadleaf Forest Province 223, Section 223A; Ozark Broadleaf Forest Province M223, and Ouachita Mixed Forest-Meadow Province M231); or in the inner portions of the coastal plains landward of the range of Longleaf Pine (Southeastern Mixed Forest Province 231, most of Sections 231B, 231E, lowland parts of Section 231G, 231H) dominated by Shortleaf Pine (*Pinus echinata*) and/or Loblolly Pine (*Pinus taeda*), OR dominated by Longleaf Pine (*Pinus palustris*) and found landward of the coastal plains as mentioned above.......... 3

2a. Longleaf Pine / Slash Pine Woodlands (wet and mesic flatwoods and savannas); the wet examples found on poorly drained, somewhat poorly drained, and seasonally saturated mineral soils with seasonally high water tables; the mesic examples found on flat sites with a spodosol soil which has a hardpan (spodic horizon) impeding drainage which can cause sites to be wet in the winter and dry in the summer 4

2b. Stands of longleaf pine (*Pinus palustris*) on sandy to loamy soils on upland sites ranging from gently rolling lands, broad ridgetops to steeper side slopes, and in mesic swales and terraces.. 5

3a. Stands with Longleaf Pine (*Pinus palustris*) in combination with Shortleaf Pine (*Pinus echinata*) and dry Oak (*Quercus*) species, found landward of the coastal plains (Southeastern Mixed Forest Province 231, Sections 231A, 231C, 231D, 231I) .... "**Mountain Longleaf"**

.... **Dry & Mesic Highlands Pine Woodlands, in part; [part of US NVC GROUP G012]**

3b. Forests and woodlands dominated by Shortleaf Pine (*Pinus echinata*) and/or Loblolly Pine (*Pinus taeda*) found landward of the coastal plains (Southeastern Mixed Forest Province 231, Sections 231E, 231G); and in the inner portions of the coastal plains landward of the range of Longleaf Pine (Southeastern Mixed Forest Province 231, most of Sections 231B, 231E and 231H); also west of the Mississippi River in the Central Interior Broadleaf Forest Province 223, Section 223A; Ozark Broadleaf Forest Province M223, and Ouachita Mixed Forest-Meadow Province M231, as well as the Crowley's Ridge Subsection 234Db) 6

4a. Mesic Longleaf Pine flatwood woodlands found on flat sites with spodic horizons (Spodosols) or some factor impeding drainage which can cause sites to be wet in the winter and dry in the summer..

....**Mesic Longleaf Pine Flatwoods [US NVC GROUP G596]**

4b. Wet Longleaf Pine / Slash Pine flatwoods and savannas found on poorly drained, somewhat poorly drained, and seasonally saturated mineral soils with seasonally high water tables ....

.... **Wet Longleaf & Slash Pine Flatwoods & Savannas [US NVC GROUP G190]**

5a. Stands of longleaf pine (*Pinus palustris*) on deep sandy soils, in the fall-line sandhills (Subsection 232Bq) as well as on other sandy sites in the outer coastal plains, typically with scrub oaks (Turkey Oak, Bluejack Oak, Sand Post Oak) in the subcanopy ....

....**Xeric Longleaf Pine Barrens [US NVC GROUP G154]**

5b. Other stands of longleaf pine (*Pinus palustris*) on sandy to loamy soils on upland sites ranging from gently rolling lands, broad ridgetops to steeper side slopes, and in mesic swales and terraces. Subcanopy oaks include White Oak, Southern Red Oak, Black Oak, Blackjack Oak ....

....**Dry & Mesic Longleaf Pine Woodlands [US NVC GROUP G009]**

6a. Dry and dry-mesic forests and woodlands dominated by Shortleaf Pine (*Pinus echinata*) found west of the Mississippi River in the Central Interior Broadleaf Forest Province 223, Section 223A; Ozark Broadleaf Forest Province M223; Ouachita Mixed Forest-Meadow Province M231; Southeastern Mixed Forest Province 231, Section 231G ....**"Shortleaf-Loblolly Woodlands"**

.... **Dry & Mesic Highlands Pine Woodlands, in part; [part of US NVC GROUP G012]**

6b. Forests and woodlands, including flatwoods, dominated by Shortleaf Pine (*Pinus echinata*) and/or Loblolly Pine (*Pinus taeda*) found in the inner portions of the coastal plains landward of the range of Longleaf Pine (Southeastern Mixed Forest Province 231, most of Sections 231B, 231E, 231H), as well as in portions of the Mississippi River Alluvial Basin Section 234A. [this Grouping would also apply to the lower/outer parts of the Piedmont (Sections 231A, 231I but this area is not within the GCPOLCC footprint] 7

7a. Dry and dry-mesic forests and woodlands dominated by Shortleaf Pine (*Pinus echinata*) and/or Loblolly Pine (*Pinus taeda*) found in the inner portions of the coastal plains landward of the range of Longleaf Pine (Southeastern Mixed Forest Province 231, most of Sections 231B, 231E, 231H), as well as the Crowley's Ridge Subsection 234Db (Lower Mississippi Riverine Forest Province 234) [this

Grouping would also apply to the lower/outer parts of the Piedmont (Sections 231A, 231I) but this area is not within the GCPOLCC footprint]..

.... **Dry and Mesic Hilly Pine Woodlands [US NVC GROUP G013, part of G012]**

7b. Flatwoods (nonriverine wetland or seasonally wet pine-hardwood forests) in the coastal plains (Outer Coastal Plains Mixed Forest Province 232; Southeastern Mixed Forest Province 231, most of Sections 231B, 231E, 231H) and the Lower Mississippi Riverine Forest Province 234 ....

.... **Upper Coastal Plain Flatwoods [US NVC GROUP G130]**

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States	Region	Dominant Pines	Site	Southern Open Pine Grouping
AR, MO, OK	Ozark and Ouachita Highlands	Shortleaf Pine	Dry & Mesic Uplands	Dry & Mesic Highlands Pine Woodlands
AR, LA, TX	Coastal Plain	Shortleaf Pine, Loblolly Pine	Dry & Mesic Uplands	Dry & Mesic Hilly Pine Woodlands
AR, LA, TX	Coastal Plain	Shortleaf Pine, Loblolly Pine	Wet-Mesic to Wet Flats	Upper Coastal Plain Pine Flatwoods
LA, TX	Coastal Plain	Longleaf Pine	Xeric Uplands on deep sandy soils	Xeric Longleaf Pine Barrens
LA, TX	Coastal Plain	Longleaf Pine	Dry & Mesic Uplands	Dry & Mesic Longleaf Pine Woodlands
LA, TX	Coastal Plain	Longleaf Pine	Wet Flats	Wet Longleaf & Slash Pine Flatwoods & Savannas
AL, GA, NC, SC	Appalachians and Piedmont	Longleaf Pine	Dry Uplands, on ridges and upper slopes	Dry & Mesic Highlands Pine Woodlands
AL, GA, NC, SC	Piedmont	Shortleaf Pine, Loblolly Pine	Dry & Mesic Uplands	Dry & Mesic Hilly Pine Woodlands
AL, GA, FL, MS, NC, SC	Coastal Plain	Shortleaf Pine, Loblolly Pine	Dry & Mesic Uplands	Dry & Mesic Hilly Pine Woodlands
AL, GA, MS, NC, SC	Coastal Plain	Longleaf Pine	Xeric Uplands on deep sandy soils	Xeric Longleaf Pine Barrens
AL, GA, MS, NC, SC	Coastal Plain	Longleaf Pine	Dry & Mesic Uplands	Dry & Mesic Longleaf Pine Woodlands
AL, GA, MS, NC, SC	Coastal Plain	Longleaf Pine, Slash Pine	Mesic to Wet Flats, Spodosols	Mesic Longleaf Pine Flatwoods
AL, GA, MS, NC, SC	Coastal Plain	Longleaf Pine, Slash Pine	Wet Flats	Wet Longleaf & Slash Pine Flatwoods & Savannas
FL	Coastal Plain	Longleaf Pine	Dry & Mesic Uplands	Dry & Mesic Longleaf Pine Woodlands
FL	Coastal Plain	Longleaf Pine	Xeric Uplands on deep sandy soils	Xeric Longleaf Pine Barrens
FL	Coastal Plain	Longleaf Pine, Slash Pine, South Florida Slash Pine	Mesic to Wet Flats, Spodosols	Mesic Longleaf Pine Flatwoods
FL	Coastal Plain	Longleaf Pine, Slash Pine, South Florida Slash Pine	Wet Flats	Wet Longleaf & Slash Pine Flatwoods & Savannas

Table A-1. States, Regions, and Southern Open Pine Groupings

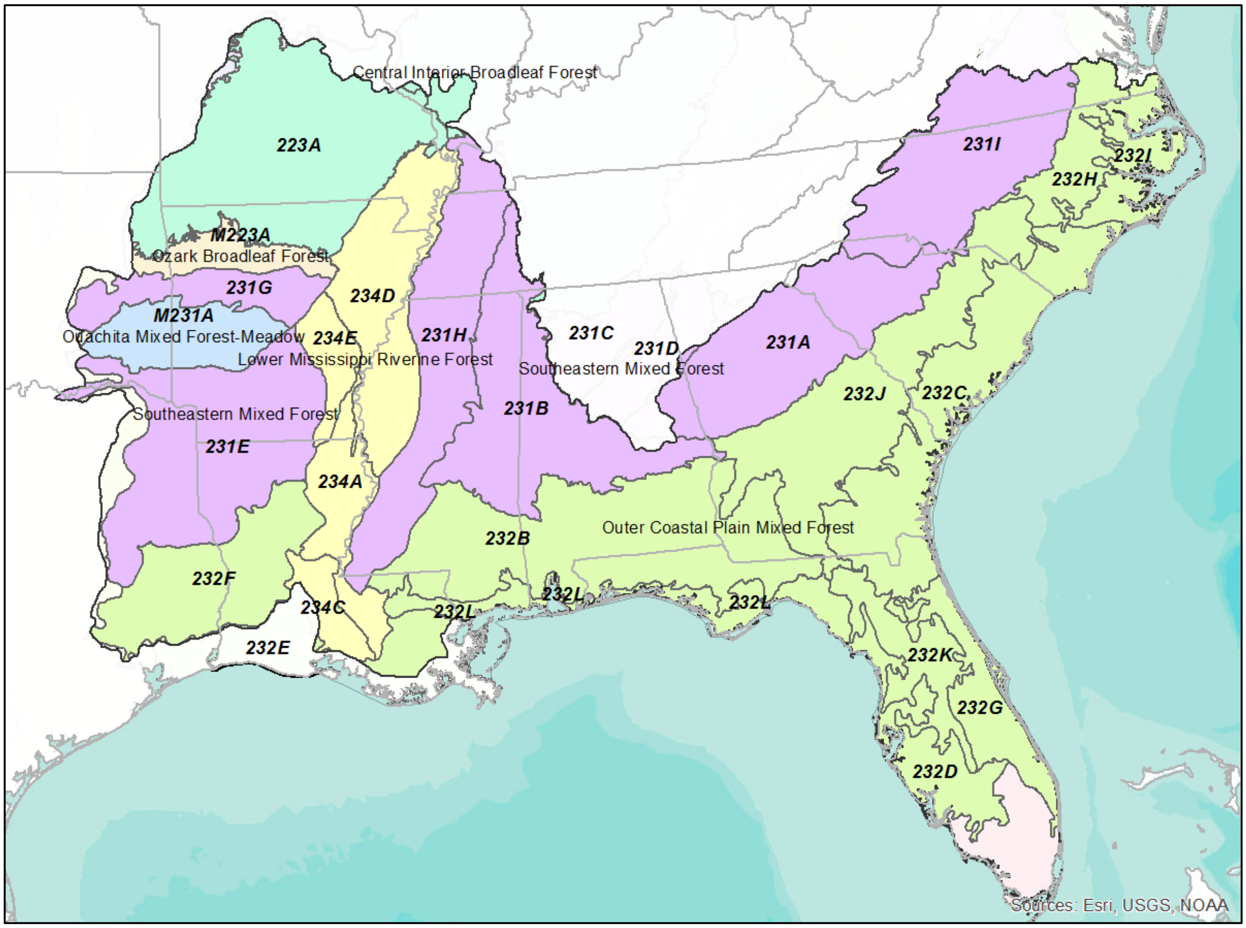

Figure A-1. USDA Forest Service Provinces and Sections (from Cleland et al. 2007)

PROVINCE /SECTION	**PROVINCE**/SECTION_NAME
223	**Central Interior Broadleaf Forest**
223A	Ozark Highlands
M223	**Ozark Broadleaf Forest**
M223A	Boston Mountains
231	**Southeastern Mixed Forest**
231A	Southern Appalachian Piedmont
231B	Coastal Plains-Middle

231C	Southern Cumberland Plateau
231D	Southern Ridge and Valley
231E	Mid Coastal Plains-Western
231G	Arkansas Valley
231H	Coastal Plains-Loess
231I	Central Appalachian Piedmont
M231	**Ouachita Mixed Forest-Meadow**
M231A	Ouachita Mountains
232	**Outer Coastal Plain Mixed Forest**
232B	Gulf Coastal Plains and Flatwoods
232C	Atlantic Coastal Flatwoods
232D	Florida Coastal Lowlands-Gulf
232F	Coastal Plains and Flatwoods-Western Gulf
232G	Florida Coastal Lowlands-Atlantic
232H	Middle Atlantic Coastal Plains and Flatwoods
232I	Northern Atlantic Coastal Flatwoods
232J	Southern Atlantic Coastal Plains and Flatwoods
232K	Florida Coastal Plains Central Highlands
232L	Gulf Coastal Lowlands
234	**Lower Mississippi Riverine Forest**
234A	Southern Mississippi Alluvial Plain
234C	Atchafalaya and Red River Alluvial Plains
234D	White and Black River Alluvial Plains
234E	Arkansas Alluvial Plains

Table A-2. USDA Forest Service Provinces and Sections referred to in the Key

Notes on Some Ambiguous or Confusing Habitats

There are some possible situations related to open pine habitats in the southeastern United States which are ambiguous or may present uncertainties in terms of which habitat is best managed for in a particular locale.

1. Sites found landward of the coastal plains (Southeastern Mixed Forest Province 231, Sections 231A, 231C, 231D) with Longleaf Pine as a dominant or codominant should be treated as examples of "Mountain Longleaf". These could be proximal to, or interfingered with, stands dominated by Shortleaf Pine without Longleaf Pine. The issue here is that "Mountain Longleaf" would be evaluated with the metrics for the Dry & Mesic Highlands Pine Woodlands Grouping, and the adjacent Shortleaf Pine stands would be evaluated with the metrics for the Dry & Mesic Hilly Pine Woodlands Grouping. In this area, both of these Groupings are related to US NVC GROUP G012. A distinction may need to be made between stands dominated by Shortleaf Pine without Longleaf Pine which are landward of the coastal plain and do **not** have loblolly pine or are outside the range of loblolly pine, then their grouping would be Dry & Mesic Highlands Pine Woodlands, otherwise. Stands that are within the range of Loblolly Pine would be part of the Dry & Mesic Hilly Pine Woodlands Grouping.

2. In a portion of the inner coastal plain (Section 231B), there are quite rugged landforms found north of the black belt region and southwest of the southern end of the Ridge and Valley (this is within the ranges of both Longleaf Pine and Chestnut Oak [*Quercus prinus*]). Using our key to Open Pine Groupings, this would be part of the Dry & Mesic Longleaf Pine Woodlands, but has some characteristics of the "Mountain Longleaf" discussed above. This area includes the Oakmulgee District of the Talladega National Forest in Bibb, Hale, Perry, and Tuscaloosa counties of Alabama. It is not clear which metrics are better applied in this area.

3. The third exception or anomaly would be stands dominated by Shortleaf Pine found within the range of Longleaf Pine in the inner or outer coastal plains (Provinces 231 and 232). This type of stand would have been far less common in the outer coastal plain, and more likely in the inner coastal plain. More information is needed about this vegetation and its characteristics and environment. One example is Shortleaf Pine vegetation of the Red Hills of Florida and Georgia. In this case, the metrics for Dry & Mesic Hilly Pine Woodlands [US NVC GROUP G012] would apply.

Appendix B. Rapid Assessment Field Cover Sheet

Field Form for Rapid Assessment Metrics for Wildlife and Biodiversity in Southern Open Pine Ecosystems

Date: Project: Site ID:

Field Crew Team Members:

Leader: ______________________________ Assistants:____

Photographer: _______________________ Photos of Site: __ *AA Centrum out:* _N _E_ S _W ; __*Buffer in*: _N _E _S _W; Add'l: Y / N

Photo filenames: ____

Assessment Area Shape: Circle, Rectangle, Square, Polygon Bearing: __________

Assessment Area Dimensions: radius 18m, 40m, ______ m/ft. or rectangle ______ m/ft wide x ______m/ft long (fill in values, units)

State:_____County:____________________ Twp:____Range:____Section:____USGS 7.5' Quad:_____________________________

Landowner/Managed Area Name:______________________________ Contact Person: ___________________________________

Stand Name: _____________ Permit Required? ___ Locked Gate? ___ Access Difficulties? (describe)___________________________

SITE DESCRIPTION:

GENERAL DRAWING (Optional): Provide a drawing of the assessment area, including its boundaries, either aerial view or transect view.

LOCATION: Assessment Area CENTRUM (check one) ___ ORIGINAL ___ MOVED (why? how far?)				
GPS Unit:	GPS Filename:		Projection:	
UTM Zone:	Datum: NAD83 WGS84	GPS Accuracy: ___ m/ ft	PDOP:	# of Sat's:
UTM X Easting: __ __ __ __ __ __	LAT: decimal degree	*Original (GRTS):*	Field:	Post-processed:
UTM Y Northing: __ __ __ __ __ __ __	LONG: decimal degree			

Classification (use to select appropriate Southern Open Pine Metrics Datasheet for page 2 of field form)

Southern Open Pine Grouping: ____

Other Community Classification Reference: ______________________ Name: ____

USNVC Association (Optional):____

Classification Comments:

Notes:

Appendix C. Rapid Assessment Metrics Data/Scoring Sheets (By Habitat Grouping)

Dry & Mesic Highlands Pine Woodlands (Mountain Longleaf) Metrics Data Sheet					Recorded Measured Value of Metric	Recorded Metric Score (1.0-4.0)
Canopy Metrics	If the optional Stand Density Index metric is used, then Canopy Southern Pine Basal Area and Southern Yellow Pine Canopy Cover do not need to be used as metrics					
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft²/acre basal area of longleaf & shortleaf pine	30 to 35 or >75 to 90 ft²/acre basal area of longleaf & shortleaf pine	10 to <30 or >90 to 110 ft²/acre basal area of longleaf & shortleaf pine	<10 or >110 ft²/acre basal area of longleaf & shortleaf pine	**ft²/acre BA**	**x0.25**
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of longleaf & shortleaf pine	20-25% or >70 to 80% canopy cover of longleaf & shortleaf	10 to <20% or >80 to 90% canopy cover of longleaf & shortleaf	<10% or >90% canopy cover of longleaf & shortleaf pine	**% cover**	**x0.25**
Southern Yellow Pine Stand Age Structure	BA ≥20 ft²/acre of flat-top longleaf pine of any diameter and/or longleaf or shortleaf pine trees ≥14" DBH class	BA ≥10 ft²/acre of longleaf or shortleaf pine trees ≥14" DBH class	Longleaf or shortleaf pine trees ≥14" DBH class are present, but at<10 ft²/acre BA	No longleaf or shortleaf pine trees ≥14" DBH or flat-top longleaf pine are present	**ft²/acre BA**	**x0.25**
Canopy Hardwood Basal Area	≤20 ft²/acre BA of hardwood trees	>20 to 40 ft²/acre BA of hardwood trees	>40 to 50 ft²/acre BA of hardwood trees	>50 ft²/acre BA of hardwood trees	**ft²/acre BA**	**x0.25**
Stand Density Index (applies to longleaf pine)	SDI = 55 – 120 (14 - 30% of Maximum SDI of 400)	SDI = 40 – 55 or 120 - 160 (10-14% or 30-40% of Maximum SDI of 400)	SDI = 15 – 40 or 160 - 200 (4-10% or 40-50% of maximum SDI)	SDI <15 or >200 (<4% or >50%, 240 is 60% of Maximum SD of 400)	**SDI value**	**x0.5**
Midstory/Shrub Metrics					**Canopy Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-30% cover of midstory fire tolerant hardwoods	>30 to 40% cover of midstory fire tolerant hardwoods	>40% cover of midstory fire tolerant hardwoods	**% cover**	**x0.25**
Midstory Overall Cover	<20% cover of woody midstory	≥20 to 25% cover of woody midstory	>25 to 35% cover of woody midstory	>35% cover of woody midstory	**% cover**	**x0.25**
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20- 25% cover	Short shrubs average >25 to 40% cover	Short shrubs average >40% cover	**% cover**	**x0.25**
Tall Shrub (3-10 ft) Cover	Tall shrubs average < 15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.	**% cover**	**x0.25**
Ground Layer Metrics					**Midstory Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Overall Native Herbaceous Ground Cover	>45 to 80% herbaceous cover	30-45% or >80% herbaceous cover	15 to <30% herbaceous cover	<15% herbaceous cover	**% cover**	**x0.25**
Longleaf Pine Regeneration	Longleaf pine regeneration cover is >1% of stand (Good and Excellent)	Longleaf pine regeneration cover is >1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand	**% of stand Regen?** **Cones?**	**x0.25**
Native Warm Season Grass Cover	>25 to 85% foliar cover of all native warm season grasses	20-25% or >85% foliar cover of all native warm season grasses	10 to <20% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses	**% foliar cover**	**x0.25**
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5% cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)	**% cover**	**x0.25**
Final Score is : **Canopy Score _______x0.33 + Midstory Score________x0.33 + Ground Layer Score________x0.33 =** **Evaluation Scale: 4.0 to 3.5 = Excellent, 3.5 to 2.5 = Good, 2.5 to 1.5 = Fair, 1.5 to 1.0 = Poor**					**Ground Layer Score =**	

Dry & Mesic Highlands Pine Woodlands Metrics Data Sheet					**Recorded Measured Value of Metric**	**Recorded Metric Score (1.0-4.0)**
Canopy Metrics	If the optional Stand Density Index metric is used, then Canopy Southern Pine Basal Area and Southern Yellow Pine Canopy Cover do not need to be used as metrics					
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Canopy Southern Yellow Pine Basal Area	>35 to 75 ft^2/acre basal area of shortleaf pine	30 to 35 or >75 to 90 ft^2/acre basal area of shortleaf pine	10 to <30 or >90 to 110 ft^2/acre basal area of shortleaf pine	<10 or >110 ft^2/acre basal area of shortleaf pine	**ft^2/acre BA**	**x0.25**
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of shortleaf pine	20-25% or >70 to 80% canopy cover of shortleaf pine	10 to <20% or >80 to 90% canopy cover of shortleaf pine	<10% or >90% canopy cover of shortleaf pine	**% cover**	**x0.25**
Southern Yellow Pine Stand Age Structure	Basal area ≥20 ft^2/acre of shortleaf pine trees ≥14" DBH class	Basal area ≥10 ft^2/acre of shortleaf pine trees ≥14" DBH class	Shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No shortleaf pine trees ≥14" DBH are present	**ft^2/acre BA**	**x0.25**
Canopy Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 40 ft^2/acre BA of hardwood trees	>40 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees	**ft^2/acre BA**	**x0.25**
Stand Density Index (applies to shortleaf pine)	SDI = 65 – 135 (14 - 30% of Maximum SDI of 450)	SDI = 45 – 65 or 135 - 180 (10-14% or 30-40% of Maximum SDI of 450)	SDI = 20 – 45 or 180 - 225 (4-10% or 40-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)	**SDI value**	**x0.5**
Midstory/Shrub Metrics					**Canopy Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-30% cover of midstory fire tolerant hardwoods	>30 to 40% cover of midstory fire tolerant hardwoods	>40% cover of midstory fire tolerant hardwoods	**% cover**	**x0.25**
Midstory Overall Cover	<20% cover of woody midstory	20-25% cover of woody midstory	>25 to 35% cover of woody midstory	>35% cover of woody midstory	**% cover**	**x0.25**
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 25% cover	Short shrubs average >25 to 40% cover	Short shrubs average >40% cover	**% cover**	**x0.25**
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average < 15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.	**% cover**	**x0.25**
Ground Layer Metrics					**Midstory Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Overall Native Herbaceous Ground Cover	>45 to 80% herbaceous cover	30-45% or >80% herbaceous cover	15 to <30% herbaceous cover	<15% herbaceous cover	**% cover**	**x0.33**
Native Warm Season Grass Cover	>25 to 85% foliar cover of all native warm season grasses	>15 to 25% or >85% foliar cover of native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses	**% foliar cover**	**x0.33**
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)	**% cover**	**x0.33**
Final Score is : **Canopy Score _______x0.33 + Midstory Score________x0.33 + Ground Layer Score________x0.33 =** **Evaluation Scale: 4.0 to 3.5 = Excellent, 3.5 to 2.5 = Good, 2.5 to 1.5 = Fair, 1.5 to 1.0 = Poor**					**Ground Layer Score =**	

Dry & Mesic Hilly Pine Woodlands Metrics Data Sheet					Recorded Measured Value of Metric	Recorded Metric Score (1.0-4.0)
Canopy Metrics	If the optional Stand Density Index metric is used, then Canopy Southern Pine Basal Area and Southern Yellow Pine Canopy Cover do not need to be used as metrics					
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Canopy Southern Yellow Pine Basal Area	30-85 ft^2/acre basal area of loblolly or shortleaf pine	20 to <30 or >85 to 100 ft^2/acre basal area of loblolly or shortleaf pine	10 to <20 or >100 to 115 ft^2/acre basal area of loblolly or shortleaf pine	<10 or >115 ft^2/acre basal area of loblolly or shortleaf pine	**ft^2/acre BA**	**x0.25**
Southern Yellow Pine Canopy Cover	>25 to 75% canopy cover of loblolly or shortleaf pine	>15 to 25% canopy cover or >75 to 85% canopy cover of loblolly or shortleaf pine	10-15% canopy cover or >85 to 95% canopy cover of loblolly or shortleaf pine	<10% cover or >95% cover of loblolly or shortleaf pine	**% cover**	**x0.25**
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	BA ≥10 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	Loblolly and/or shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No loblolly and/or shortleaf pine trees ≥14" DBH are present	**ft^2/acre BA**	**x0.25**
Canopy Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 30 ft^2/acre BA of hardwood trees	>30 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees	**ft^2/acre BA**	**x0.25**
Stand Density Index (applies to shortleaf pine)	SDI = 55 – 155 (12 - 34% of Maximum SDI of 450)	SDI = 35 – 55 or 155 - 205 (8-12% or 34-45% of Maximum SDI of 450)	SDI = 20 – 35 or 205 - 225 (4-8% or 45-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)	**SDI value**	**x0.5**
Midstory/Shrub Metrics					**Canopy Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-20% cover of midstory fire tolerant hardwoods	>20 to 35% cover of midstory fire tolerant hardwoods	>35% cover of midstory fire tolerant hardwoods	**% cover**	**x0.25**
Midstory Overall Cover	<20% cover of woody midstory	≥20 to 30% cover of woody midstory	>30 to 50% cover of woody midstory	>50% cover of woody midstory	**% cover**	**x0.25**
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 - 30% cover	Short shrubs average >30 to 45% cover	Short shrubs average >45% cover	**% cover**	**x0.25**
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 to 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.	**% cover**	**x0.25**
Ground Layer Metrics					**Midstory Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Overall Native Herbaceous Ground Cover	35-80% herbaceous cover	20 to <35% or >80% herbaceous cover	10 to <20% herbaceous cover	<10% herbaceous cover	**% cover**	**x0.33**
Native Warm Season Grass Cover	25-100% foliar cover of all native warm season grasses	>15 to <25% foliar cover of all native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses	**% foliar cover**	**x0.33**
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)	**% cover**	**x0.33**
Final Score is : **Canopy Score _______x0.33 + Midstory Score________x0.33 + Ground Layer Score________x0.33 =** **Evaluation Scale: 4.0 to 3.5 = Excellent, 3.5 to 2.5 = Good, 2.5 to 1.5 = Fair, 1.5 to 1.0 = Poor**					**Ground Layer Score =**	

Dry & Mesic Longleaf Pine Woodlands Metrics Data Sheet					Recorded Measured Value of Metric	Recorded Metric Score (1.0-4.0)
Canopy Metrics	If the optional Stand Density Index metric is used, then Canopy Southern Pine Basal Area and Southern Yellow Pine Canopy Cover do not need to be used as metrics					
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Canopy Southern Yellow Pine Basal Area	30-80 ft^2/acre basal area of longleaf pine	20 to <30 or >80 to 90 ft^2/acre basal area of longleaf pine	10 to <20 or >90 to 105 ft^2/acre basal area of longleaf pine	<10 or >105 ft^2/acre basal area of longleaf pine	**ft^2/acre BA**	**x0.25**
Southern Yellow Pine Canopy Cover	30-65% canopy cover of longleaf pine	>20 to <30% or >65 to 75% canopy cover of longleaf	10-20% canopy cover or >75 to 85% canopy cover of longleaf pine	<10% cover or >85% cover of longleaf pine	**% cover**	**x0.25**
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf pine of any diameter and/or longleaf pine trees ≥14" DBH class	BA ≥10 ft^2/acre of longleaf pine trees ≥14" DBH class	Longleaf pine trees ≥ 14" DBH class are present, but at <10 ft^2/acre BA	No longleaf pine trees ≥14" DBH or flat-top longleaf pine are present	**ft^2/acre BA**	**x0.25**
Canopy Hardwood Basal Area	<20 ft^2/acre BA of hardwood trees	≥20 to 25 ft^2/acre BA of hardwood trees	>25 to 35 ft^2/acre BA of hardwood trees	>35 ft^2/acre BA of hardwood trees	**ft^2/acre BA**	**x0.25**
Stand Density Index (applies to longleaf pine)	SDI = 60 – 125 (15 - 31% of Maximum SDI of 400)	SDI = 40 – 60 or 125 - 160 (10-15% or 31-40% of Maximum SDI of 400)	SDI = 20 – 40 or 160 - 200 (5-10% or 40-50% of maximum SDI)	SDI <20 or >200 (<5% or >50%, 240 is 60% of Maximum SD of 400)	**SDI value**	**x0.5**
Midstory/Shrub Metrics					**Canopy Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Midstory Fire Tolerant Hardwood Cover	<15% cover of midstory fire tolerant hardwoods	15 to <20% cover of midstory fire tolerant hardwoods	20-25% cover of midstory fire tolerant hardwoods	>25% cover of midstory fire tolerant hardwoods	**% cover**	**x0.25**
Midstory Overall Cover	<20% cover of woody midstory	20 to <30% cover of woody midstory	30-40% cover of woody midstory	>40% cover of woody midstory	**% cover**	**x0.25**
Short Shrub (<3 ft tall) Cover	Short shrubs average <30% cover	Short shrubs average 30 to 35% cover	Short shrubs average >35 to 45% cover	Short shrubs average >45% cover	**% cover**	**x0.25**
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <20% cover.	Tall shrubs average 20 to 30% cover.	Tall shrubs average >30 to 40% cover.	Tall shrubs average >40% cover.	**% cover**	**x0.25**
Ground Layer Metrics					**Midstory Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Overall Native Herbaceous Ground Cover	40-98% herbaceous cover	30 to <40% or >98% herbaceous cover	20 to <30% herbaceous cover	<20% herbaceous cover	**% cover**	**x0.25**
Longleaf Pine Regeneration	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand	**% of stand Regen?** **Cones?**	**x0.25**
Native Warm Season Grass Cover	>25 to 97% foliar cover of all native warm season grasses	>15 to 25% or >97% foliar cover of native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses	**% foliar cover**	**x0.25**
Invasive Plant Presence / Distribution	Invasive nonnative plant species cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present, but sporadic (1-5% cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)	**% cover**	**x0.25**
Final Score is : **Canopy Score _______x0.33 + Midstory Score________x0.33 + Ground Layer Score________x0.33 =** **Evaluation Scale: 4.0 to 3.5 = Excellent, 3.5 to 2.5 = Good, 2.5 to 1.5 = Fair, 1.5 to 1.0 = Poor**					**Ground Layer Score =**	

Mesic Longleaf Pine Flatwoods Metrics Data Sheet

Mesic Longleaf Pine Flatwoods Metrics Data Sheet					Recorded Measured Value of Metric	Recorded Metric Score (1.0-4.0)
Canopy Metrics	If the optional Stand Density Index metric is used, then Canopy Southern Pine Basal Area and Southern Yellow Pine Canopy Cover do not need to be used as metrics					
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Canopy Southern Yellow Pine Basal Area	30-80 ft^2/acre basal area of longleaf or slash pine	20 to <30 or >80 to 90 ft^2/acre basal area of longleaf or slash pine	10 to <20 or >90 to 105 ft^2/acre basal area of longleaf or slash pine	<10 or >105 ft^2/acre basal area of longleaf or slash pine	**ft^2/acre BA**	**x0.25**
Southern Yellow Pine Canopy Cover	30 to 65% canopy cover of longleaf or slash pine	20 to <30% canopy cover or >65 to75% canopy cover of longleaf or slash pine	10 to <20% canopy cover or >75 to 85% canopy cover of longleaf or slash pine	<10% cover or >85% cover of longleaf or slash pine	**% cover**	**x0.25**
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf or slash pine of any diameter and/or longleaf or slash pine trees ≥14" DBH class	BA ≥10 ft^2/acre of longleaf or slash pine trees ≥ 4" DBH class	Longleaf or slash pine trees ≥14" DBH class are present, but at < 10 ft^2/acre BA	No longleaf or slash pine trees ≥14" DBH or flat-top slash or longleaf pine	**ft^2/acre BA**	**x0.25**
Canopy Hardwood Basal Area	<20 ft^2/acre BA of hardwood trees	≥20 to 25 ft^2/acre BA of hardwood trees	>25 to 35 ft^2/acre BA of hardwood trees	>35 ft^2/acre BA of hardwood trees	**ft^2/acre BA**	**x0.25**
Stand Density Index (applies to longleaf pine)	SDI = 60 – 125 (15 - 31% of Maximum SDI of 400)	SDI = 40 – 60 or 125 - 160 (10-15% or 31-40% of Maximum SDI of 400)	SDI = 20 – 40 or 160 - 190 (5-10% or 40-48% of maximum SDI)	SDI <20 or >190 (<5% or >48%, 240 is 60% of Maximum SD of 400)	**SDI value**	**x0.5**
Midstory/Shrub Metrics					**Canopy Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10 to <20% cover of midstory fire tolerant hardwoods	20 to 25% cover of midstory fire tolerant hardwoods	>25% cover of midstory fire tolerant hardwoods	**% cover**	**x0.25**
Midstory Overall Cover	<20% cover of woody midstory	20 to <30% cover of woody midstory	30-40% cover of woody midstory	>40% cover of woody midstory	**% cover**	**x0.25**
Short Shrub (<3 ft tall) Cover	Short shrubs average <30% cover	Short shrubs average 30 to <40% cover	Short shrubs average 40-45% cover	Short shrubs average >45% cover	**% cover**	**x0.25**
Tall Shrub (3-10 ft) Cover	Tall shrubs average <20% cover.	Tall shrubs average 20 to <30% cover.	Tall shrubs average 30-35% cover.	Tall shrubs average >35% cover.	**% cover**	**x0.25**
Ground Layer Metrics					**Midstory Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Overall Native Herbaceous Ground Cover	40-98% herbaceous cover	30 to <40% or >98% herbaceous cover	20 to <30% herbaceous cover	<20% herbaceous cover	**% cover**	**x0.25**
Longleaf Pine Regeneration	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand	**% of stand Regen?** **Cones?**	**x0.25**
Native Warm Season Grass Cover	>25 to 97% foliar cover of all native warm season grasses	>15 to 25% or >97% foliar cover of native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses	**% foliar cover**	**x0.25**
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5% cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)	**% cover**	**x0.25**
Final Score is : **Canopy Score _______x0.33 + Midstory Score________x0.33 + Ground Layer Score________x0.33 =** **Evaluation Scale: 4.0 to 3.5 = Excellent, 3.5 to 2.5 = Good, 2.5 to 1.5 = Fair, 1.5 to 1.0 = Poor**					**Ground Layer Score =**	

Upper Coastal Plain Pine Flatwoods Metrics Data Sheet					Recorded Measured Value of Metric	Recorded Metric Score (1.0-4.0)
Canopy Metrics	If the optional Stand Density Index metric is used, then Canopy Southern Pine Basal Area and Southern Yellow Pine Canopy Cover do not need to be used as metrics					
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Canopy Southern Yellow Pine Basal Area	30-80 ft^2/acre basal area of loblolly or shortleaf pine	20 to <30 or >80 to 90 ft^2/acre basal area of loblolly or shortleaf pine	10 to <20 or >90 to 110 ft^2/acre basal area of loblolly or shortleaf pine	<10 or >110 ft^2/acre basal area of loblolly or shortleaf pine	**ft^2/acre BA**	**x0.25**
Southern Yellow Pine Canopy Cover	>25 to 70% canopy cover of loblolly or shortleaf pine	>15 to 25% canopy cover or >70 to 80% canopy cover of loblolly or shortleaf pine	10-15% canopy cover or >80 to 90% canopy cover of loblolly or shortleaf pine	<10% cover or >90% cover of loblolly or shortleaf pine	**% cover**	**x0.25**
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	BA ≥10 ft^2/acre of loblolly and/or shortleaf pine trees ≥14" DBH class	Loblolly and/or shortleaf pine trees ≥14" DBH class are present, but <10 ft^2/acre basal area of those large trees	No loblolly and/or shortleaf pine trees ≥14" DBH are present	**ft^2/acre BA**	**x0.25**
Canopy Hardwood Basal Area	≤20 ft^2/acre BA of hardwood trees	>20 to 30 ft^2/acre BA of hardwood trees	>30 to 50 ft^2/acre BA of hardwood trees	>50 ft^2/acre BA of hardwood trees	**ft^2/acre BA**	**x0.25**
Stand Density Index (applies to shortleaf pine)	SDI = 55 – 145 (12 - 32% of Maximum SDI of 450)	SDI = 35 – 55 or 145 - 180 (8-12% or 32-40% of Maximum SDI of 450)	SDI = 20 – 35 or 180 - 225 (4-8% or 40-50% of maximum SDI of 450)	SDI <20 or >225 (<4% or >50%, 270 is 60% of Maximum SD of 450)	**SDI value**	**x0.5**
Midstory/Shrub Metrics					**Canopy Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10 to 20% cover of midstory fire tolerant hardwoods	>20 to 35% cover of midstory fire tolerant hardwoods	>35% cover of midstory fire tolerant hardwoods	**% cover**	**x0.25**
Midstory Overall Cover	<20% cover of woody midstory	20-30% cover of woody midstory	>30 to 50% cover of woody midstory	>50% cover of woody midstory	**% cover**	**x0.25**
Short Shrub (<3 ft tall) Cover	Short shrubs average <20% cover	Short shrubs average 20 to 30% cover	Short shrubs average >30 to 45% cover	Short shrubs average >45% cover	**% cover**	**x0.25**
Tall Shrub (3-10 ft tall) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 - 20% cover.	Tall shrubs average >20 to 30% cover.	Tall shrubs average >30% cover.	**% cover**	**x0.25**
Ground Layer Metrics					**Midstory Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Overall Native Herbaceous Ground Cover	35-80% herbaceous cover	20 to <35% or >80% herbaceous cover	10 to <20% herbaceous cover	<10% herbaceous cover	**% cover**	**x0.33**
Native Warm Season Grass Cover	>25% foliar cover of all native warm season grasses	20-25% foliar cover of all native warm season grasses	10 to <20% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses	**% foliar cover**	**x0.33**
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5 % cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)	**% cover**	**x0.33**
Final Score is : **Canopy Score _______x0.33 + Midstory Score________x0.33 + Ground Layer Score________x0.33 =** **Evaluation Scale: 4.0 to 3.5 = Excellent, 3.5 to 2.5 = Good, 2.5 to 1.5 = Fair, 1.5 to 1.0 = Poor**					**Ground Layer Score =**	

Wet Longleaf & Slash Pine Flatwoods & Savannas Metrics Data Sheet					Recorded Measured Value of Metric	Recorded Metric Score (1.0-4.0)
Canopy Metrics	If the optional Stand Density Index metric is used, then Canopy Southern Pine Basal Area and Southern Yellow Pine Canopy Cover do not need to be used as metrics					
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Canopy Southern Yellow Pine Basal Area	20-80 ft^2/acre basal area of longleaf or slash pine	10 to <20 or >80 to <90 ft^2/acre basal area of longleaf or slash pine	5 to <10 or 90 to <100 ft^2/acre basal area of longleaf or slash pine	<5 or ≥100 ft^2/acre basal area of longleaf or slash pine	**ft^2/acre BA**	**x0.25**
Southern Yellow Pine Canopy Cover	20-65% canopy cover of longleaf or slash pine	15 to <20% canopy cover or >65-75% canopy cover of longleaf or slash pine	10 to <15% canopy cover or >75-85% canopy cover of longleaf or slash pine	<10% cover or >85% cover of longleaf or slash pine	**% cover**	**x0.25**
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf or slash pine of any diameter and/or longleaf or slash pine trees ≥14" DBH class	BA ≥10 ft^2/acre of longleaf or slash pine trees ≥14" DBH class	Longleaf or slash pine trees ≥14" DBH class present, but at <10 ft^2/acre BA	No longleaf or slash pine trees ≥14" DBH or with flat-top slash or longleaf pine	**ft^2/acre BA**	**x0.25**
Canopy Hardwood Basal Area	<20 ft^2/acre BA of hardwood trees	≥20 to 25 ft^2/acre BA of hardwood trees	>25 to 35 ft^2/acre BA of hardwood trees	>35 ft^2/acre BA of hardwood trees	**ft^2/acre BA**	**x0.25**
Stand Density Index (applies to longleaf pine)	SDI = 35 – 120 (9 - 30% of Maximum SDI of 400)	SDI = 20 – 35 or 120 - 155 (5-9% or 30-39% of Maximum SDI of 400)	SDI = 10 – 20 or 155 - 180 (2.5-5% or 39-45% of maximum SDI)	SDI <10 or >180 (<2.5% or > 45%, 240 is 60% of Maximum SD of 400)	**SDI value**	**x0.5**
Midstory/Shrub Metrics					**Canopy Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-15% cover of midstory fire tolerant hardwoods	>15 to 25% cover of midstory fire tolerant hardwoods	>25% cover of midstory fire tolerant hardwoods	**% cover**	**x0.25**
Midstory Overall Cover	<20% cover of woody midstory	20-30% cover of woody midstory	>30 to 40% cover of woody midstory	>40% cover of woody midstory	**% cover**	**x0.25**
Short Shrub (<3 ft tall) Cover	Short shrubs average <30% cover	Short shrubs average 30 to <40% cover	Short shrubs average 40-45% cover	Short shrubs average >45% cover	**% cover**	**x0.25**
Tall Shrub (3-10 ft) Cover	Tall shrubs average < 15% cover.	Tall shrubs average 15 to <25% cover.	Tall shrubs average 25-35% cover.	Tall shrubs average >35% cover.	**% cover**	**x0.25**
Ground Layer Metrics					**Midstory Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Overall Native Herbaceous Ground Cover	40-100% herbaceous cover	30 to <40% herbaceous cover	20 to <30% herbaceous cover	<20% herbaceous cover	**% cover**	**x0.25**
Longleaf Pine Regeneration	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand	**% of stand Regen?** **Cones?**	**x0.25**
Native Warm Season Grass Cover	25-97% foliar cover of all native warm season grasses	>15 to <25% or >97% foliar cover of native warm season grasses	10-15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses	**% foliar cover**	**x0.25**
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5% cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)	**% cover**	**x0.25**
Final Score is : **Canopy Score _______x0.33 + Midstory Score________x0.33 + Ground Layer Score________x0.33 =** **Evaluation Scale: 4.0 to 3.5 = Excellent, 3.5 to 2.5 = Good, 2.5 to 1.5 = Fair, 1.5 to 1.0 = Poor**					**Ground Layer Score =**	

Xeric Longleaf Pine Barrens Metrics Data Sheet					Recorded Measured Value of Metric	Recorded Metric Score (1.0-4.0)
Canopy Metrics	If the optional Stand Density Index metric is used, then Canopy Southern Pine Basal Area and Southern Yellow Pine Canopy Cover do not need to be used as metrics					
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Canopy Southern Yellow Pine Basal Area	25-80 ft^2/acre basal area of longleaf pine	>15 to <25 or >80 to 90 ft^2/acre basal area of longleaf pine	10 to 15 or >90 to <100 ft^2/acre basal area of longleaf pine	<10 or ≥100 ft^2/acre basal area of longleaf pine	**ft^2/acre BA**	**x0.25**
Southern Yellow Pine Canopy Cover	>20 to 55% canopy cover of longleaf pine	>15 to 20% canopy cover or >55 to 70% canopy cover of longleaf pine	5-15% canopy cover or >70 to 80% canopy cover of longleaf pine	<5% cover or >80% cover of longleaf pine	**% cover**	**x0.25**
Southern Yellow Pine Stand Age Structure	BA ≥20 ft^2/acre of flat-top longleaf pine of any diameter and/or longleaf pine trees ≥12" DBH class	BA ≥10 ft^2/acre of longleaf pine trees ≥12" DBH class	Longleaf pine trees ≥12" DBH class are present, but at <10 ft^2/acre BA	No longleaf pine trees ≥12" DBH or flat-top longleaf pine are present	**ft^2/acre BA**	**x0.25**
Canopy Hardwood Basal Area	<20 ft^2/acre BA of hardwood trees	≥20 to 25 ft^2/acre BA of hardwood trees	>25 to 35 ft^2/acre BA of hardwood trees	>35 ft^2/acre BA of hardwood trees	**ft^2/acre BA**	**x0.25**
Stand Density Index (applies to longleaf pine)	SDI = 50 – 120 (13 - 30% of Maximum SDI of 400)	SDI = 30 – 50 or 120 - 160 (8-13% or 30-40% of Maximum SDI of 400)	SDI = 20 – 30 or 160 - 180 (5-8% or 40-45% of maximum SDI)	SDI <20 or >180 (<5% or >45%, 240 is 60% of Maximum SD of 400)	**SDI value**	**x0.5**
Midstory/Shrub Metrics					**Canopy Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Midstory Fire Tolerant Hardwood Cover	<10% cover of midstory fire tolerant hardwoods	10-20% cover of midstory fire tolerant hardwoods	>20 to 25% cover of midstory fire tolerant hardwoods	>25% cover of midstory fire tolerant hardwoods	**% cover**	**x0.25**
Midstory Overall Cover	<20% cover of woody midstory	20 to <30% cover of woody midstory	30-40% cover of woody midstory	>40% cover of woody midstory	**% cover**	**x0.25**
Short Shrub (<3 ft tall) Cover	Short shrubs average <25% cover	Short shrubs average 25 - 35% cover	Short shrubs average >35 to 45% cover	Short shrubs average >45% cover	**% cover**	**x0.25**
Tall Shrub (3-10 ft) Cover	Tall shrubs average <15% cover.	Tall shrubs average 15 to <25% cover.	Tall shrubs average 25-30% cover.	Tall shrubs average >30% cover.	**% cover**	**x0.25**
Ground Layer Metrics					**Midstory Score=**	
	Excellent = 4.0	**Good = 3.0**	**Fair = 2.0**	**Poor = 1.0**		
Overall Native Herbaceous Ground Cover	40-100% herbaceous cover	>25 to <40% herbaceous cover	>15 to 25% herbaceous cover	0-15% herbaceous cover	**% cover**	**x0.25**
Longleaf Pine Regeneration	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regeneration cover is ≥1% of stand (Good and Excellent)	Longleaf pine regen cover is present but is <1% of stand, or no regen seen, but cone producing longleaf pine are present	Longleaf pine regen cover is apparently absent, and no cone producing longleaf pine are present in the stand	**% of stand Regen?** **Cones?**	**x0.25**
Native Warm Season Grass Cover	25-95% foliar cover of all native warm season grasses	15 to <25% or >95% foliar cover of native warm season grasses	10 to <15% foliar cover of all native warm season grasses	<10% foliar cover of all native warm season grasses	**% foliar cover**	**x0.25**
Invasive Plant Presence / Distribution	Invasive nonnative plant species absent or cover is very low (≤1% cover)	Invasive nonnative plant species in any stratum present but sporadic (1-5% cover)	Invasive nonnative plant species in any stratum uncommon (5-10% cover)	Invasive nonnative plant species in any stratum common (>10% cover)	**% cover**	**x0.25**
Final Score is : **Canopy Score _______x0.33 + Midstory Score________x0.33 + Ground Layer Score________x0.33 =** **Evaluation Scale: 4.0 to 3.5 = Excellent, 3.5 to 2.5 = Good, 2.5 to 1.5 = Fair, 1.5 to 1.0 = Poor**					**Ground Layer Score =**	

From:	Tirpak, John
To:	Smith, Patrick W CIV USARMY CEMVN (USA)
Cc:	Breaux, Catherine; Soileau, Karen; Paille, Ronald; Kelso, LeeAnn
Subject:	[URL Verdict: Neutral][Non-DoD Source] Re: [EXTERNAL] RCW - Geographic Range of Applicability
Date:	Monday, August 8, 2022 9:29:10 AM
Attachments:	OpenPineMetrics_Final Report_051216.pdf

Patrick-

Following up on the call from last Thursday. Here is the requested info:

1. BCR Shapefiles - they can be downloaded from this page: https://www.birdscanada.org/bird-science/nabci-bird-conservation-regions/
2. Publication on pine communities of the Southeast - attached. This document demonstrates the consistency in pine communities in the East and West Gulf Coastal Plains and the applicability of RCW to all.
3. As co-author of the HSI model for RCW, my professional opinion is the model is applicable within any of the open pine ecosystems of the coastal plains. Indeed, Table 2 on page 11 denotes that RCW is a priority species with habitat relationships that are robust in all open pine groupings.

Please let me know if you require additional information or documentation.

-John

John Tirpak, PhD
Deputy Assistant Regional Director, Ecological Services
South Atlantic-Gulf and Mississippi Basin
U.S. Fish and Wildlife Service
Department of the Interior
1875 Century Boulevard
Atlanta, GA 30345
404-679-7311 (office)
601-630-7010 (mobile)

From: Tirpak, John <John_Tirpak@fws.gov>
Sent: Tuesday, August 2, 2022 1:41 PM
To: Smith, Patrick W CIV USARMY CEMVN (USA) <Patrick.W.Smith@usace.army.mil>
Cc: Breaux, Catherine <catherine_breaux@fws.gov>; Soileau, Karen <karen_soileau@fws.gov>; Paille, Ronald <ronald_paille@fws.gov>; Kelso, LeeAnn <leeann_kelso@fws.gov>
Subject: Re: [EXTERNAL] RCW - Geographic Range of Applicability

Patrick-

Happy to help. Having a quick conversation to understand specifically what you are looking for would likely be the most efficient way to address your needs. Can you work with LeeAnn, copied here, to find 30 minutes on our calendar for that discussion? Throwing a few options out there for her to consider would be a great start; I am tied up until at least noon on Wednesday.

Thanks for reaching out. I hope I can be of help here.

-John

John Tirpak, PhD
Deputy Assistant Regional Director, Ecological Services
South Atlantic-Gulf and Mississippi Basin
U.S. Fish and Wildlife Service
Department of the Interior
1875 Century Boulevard
Atlanta, GA 30345
404-679-7311 (office)
601-630-7010 (mobile)

From: Smith, Patrick W CIV USARMY CEMVN (USA) <Patrick.W.Smith@usace.army.mil>
Sent: Tuesday, August 2, 2022 11:40 AM
To: Tirpak, John <John_Tirpak@fws.gov>
Cc: Breaux, Catherine <catherine_breaux@fws.gov>; Soileau, Karen <karen_soileau@fws.gov>; Paille, Ronald <ronald_paille@fws.gov>
Subject: [EXTERNAL] RCW - Geographic Range of Applicability

Dr. Tirpak,

I'm a biologist with the Corps who is helping the STP team with model selection and approval. Cathy Breaux suggested I reach out to you directly.

We are hoping to use your RCW model to estimate negative impacts and mitigation planning for pine savannah habitats. I believe all impacts associated with the STP on pine savannah habitats are in Southeastern Coastal Plain (BCR 27). Part of the USACE approval process is to document the model's geographic range of applicability. To do this I need two things.

1. A general understanding of habitat use/preference across its range.
2. Specific information related to habitat use/preferences for RCW between BCR 27, BCR 24, and BCR 25.

Any assistance on this would be very helpful.

Thanks,
Patrick

Patrick Smith, PhD
Biologist, Environmental Studies Section
Regional Environmental Planning Division, South
USACE, New Orleans District
(o): (504) 862-1583
(c): (706) 799-2277

Mississippi Valley Division,
Regional Planning and Environment Division South

Annex M Modeling
Riparian Habitat

Mile Branch St Tammany Project
Methodology and Assumptions for Determining Desktop Estimates for Impacts

The proposed deepening and widening of 2 miles of Mile Branch would impact approximately 3 acres of riverine stream bottom habitat and 33 acres of riparian habitat. It is anticipated that the impacts to 3 acres of stream bottom would be offset by replacement of three acres of water bottom habitat through the establishment of backwater areas connecting the existing stream. The backwater area(s) would be a part of the nature-based design that would be further fleshed out during the Planning, Engineering and Design (PED) phase of the study once project authorization and funding are received.

Due to time, lack of access and lack of an adequate riparian community model, it was determined that a desktop estimate could be conducted utilizing riparian habitat data from a similar project of similar habitat, specifically for the East Baton Rouge (EBR) Project, as well as the limited data collected in the Mile Branch riparian zone. The Mile Branch riparian zone is dominated by a pine/hardwood mix. However, due to limited access to collect data, the data that was collected is more representative of dry bottomland hardwood habitat (BLH) and may not fully account for the intermixture of pine habitat. The EBR project sites have similar bottomland hardwood habitat to Mile Branch but this does not include an intermixture of pine habitat. It will be important to reanalyze the Mile Branch riparian habitat once a riparian and stream community model is fully developed during PED.

Acres of riparian zone (Pine/BLH) and stream (Water) impacted can be seen in table 1.

Table 1. Riparian zone (Pine/BLH) and stream (water) impact acres.

Mile Branch			Totals
Habitat	Permanent Acres	Temporary Acres	Acres
Pine/Hardwood	31.4	1.3	32.7
Developed	5.4	1.9	7.3
Water	3.0	0.0	3.0

Figure 1. Mile Branch project area.

East Baton Rouge Riparian Bottomland Hardwood WVA

Data from three EBR project sites that seemed to be most similar to the habitat of Mile Branch based on the limited field data collected were utilized for the desktop estimate. The EBR sites included EBR 8, EBR 10, and EBR 20 (see Table 2). WVAs were conducted for the EBR sites and the Average Annual Habitat Units per acre (AAHU/ac) calculated are shown in Table 2.

Table 2. East Baton Rouge (EBR) Average Annual Habitat Unit (AAHU) per acres for sites similar to the Mile Branch riparian habitat.

East Baton Rouge Project (similar sites)				AAHU/ac
EBR8	sycamore dominant			-0.73
EBR10	sycamore dominant			-0.66
EBR20	cottonwood dominant			-0.74
Average				-0.71

Mile Branch Limited Data

Bottomland Hardwood Wetland Value Assessment

We then evaluated the limited Mile Branch data in a Bottomland Hardwood (BLH) WVA.

<u>Methods used to determine BLH impacts</u>

The WVA operates under the assumption that optimal conditions for general fish and wildlife habitat within a given coastal wetland type can be characterized, and that existing or predicted conditions can be compared to that optimum to provide an index of habitat quality. Habitat quality is estimated or expressed through the use of a mathematical model developed specifically for each wetland type. Each model consists of 1) a list of variables that are considered important in characterizing fish and wildlife habitat, 2) a Suitability Index graph for each variable, which defines the assumed relationship between habitat quality (Suitability Index) and different variable values, and 3) a mathematical formula that combines Suitability Index (SI) for each variable into a single value for wetland habitat quality; that single value is referred to as the Habitat Suitability Index, or HSI.

The assumptions for assessing the direct impacts associated with construction activities of the Mile Branch Riparian Zone and the assumptions used to determine BLH baseline, FWOP, and FWP projections for the proposed Project area are described below:

Changes in each variable are predicted for future without-project and future with-project scenarios over a 50-year project life. The latest (2018) USACE Civil Works versions of the BLH (v1.2) WVA was used.

The BLH WVA consists of seven variables:

1. Tree species composition;
2. Stand maturity;
3. Understory/midstory;
4. Hydrology;
5. Size of contiguous forested area;
6. Suitability and traversability of surrounding land uses; and
7. Disturbance.

General Assumptions

The period of analysis expands from 2031 (TY0) to 2082 (TY50), with TY0 representing baseline conditions. In determining future with-project conditions, all project-related direct (construction) impacts were assumed to occur in Target Year 1. Target Years (TYs) for FWOP and FWP include TY0, TY1, and TY50.

The HET assumed the habitat within the temporary staging areas would be lost permanently due to repeated use over time, compression and compaction as well as lack of plans to restore the areas to match pre-existing conditions. All temporary impacts, therefore, were included in the permanent impacts assessment.

Relative Sea Level Rise (RSLR) was assumed to not impact the Mile Branch Riparian zone because it is high in elevation and too far inland.

Data Collected from Mile Branch Site Visits

Limited baseline data (1 plot) for riparian habitat was collected from site visits in December 2021. This will be helpful for determining the rough order of magnitude (ROM) estimates but more data will need to be collected to get a better representation of the impacted habitat.

One tenth acre (37.2 ft radius) size plot was used. Parameters such as diameter at breast height (dbh), stand structure, and hydrology was taken. The site was directly on the proposed construction footprint.

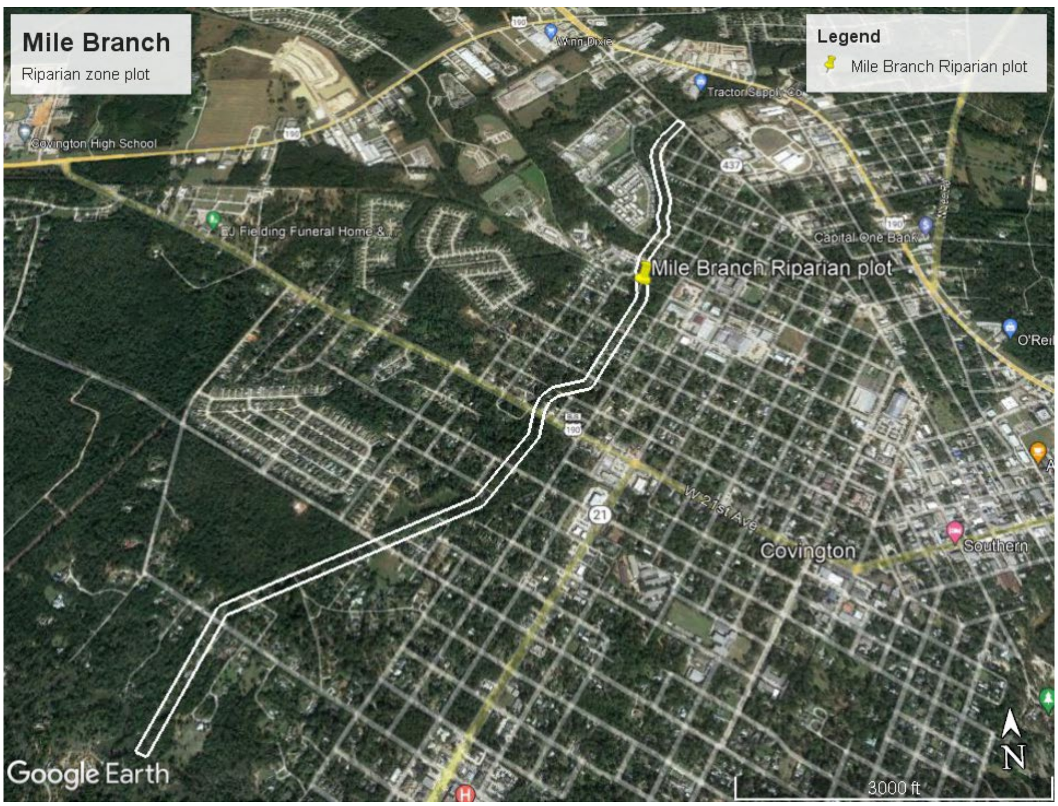

Figure 2. WVA site visit plot location.

In-growth spreadsheets

In-growth spreadsheets were used to predict tree growth for individual trees from the plot's data. This spreadsheet grows individual tree dbh and field site basal area over time. Outputs from the plot's in-growth spreadsheets including tree composition (Variable V1), stand maturity (Variable V2), and understory/midstory (Variable V3) for each target year. The plot data had notes on the condition of individual trees and the overall site conditions including water levels at the time of the data collection. In general the site was considered to be medium quality based on the tree types and the size and conditions of the trees. Initial growth rates were based on dominant trees and site conditions of each plot. A growth factor for BLH was used to project tree growth of typical BLH species (Putnam et al. 1960).

Recruitment was addressed by allowing saplings to grow into the population over time. Sapling sizes were either measured or estimated in the plot and became a part of the plot when they reached 6” dbh or greater. Plots with very small saplings were entered as 0.1 (when marked as < 0.5”), 0.5 (when marked as <1”) or 1.5 (when marked as <2”) inch dbh depending on field notes and/or measurements. Saplings with a 2” or greater dbh were measured and recorded.

Trees in each plot were grown in for 50 years and included BLH mortality which was factored into the basal area calculations. The mortality values used are seen in Table 3.

Table 3. Mortality rate of bottomland hardwood.

0 - 1.9 DBH	**20%/yr**	0.150
2 - 3.9 DBH	**10%/yr**	0.075
≥ 4 DBH	**1.9%/yr**	0.014

Variable V1 Tree Species Association

Wildlife species that utilize bottomland hardwoods depend heavily on mast, other edible seeds, and tree buds as primary sources of food. The basic assumptions for this variable are: 1) more production of mast (hard and/or soft) and other edible seeds is better than less production, and 2) because of its availability during late fall and winter and its high energy content, hard mast is more critical than soft mast, other edible seeds, and buds. Table 4 shows the class values based on tree species.

Table 4. BLH Variable V1 Tree Species Association Class descriptions.

Class 1:	Less than 25% of overstory canopy consists of mast or other edible-seed producing trees or more than 50% of soft mast present but no hard mast.
Class 2:	25% to 50% of overstory canopy consists of mast or other edible-seed producing trees, but hard mast producers constitute less than 10% of the canopy
Class 3:	25% to 50% of overstory canopy consists of mast or other edible-seed producing trees, and hard mast producers constitute more than 10% of the canopy.
Class 4:	Greater than 50% of overstory canopy consists of mast or other edible-seed producing trees, but hard mast producers constitute less than 20% of the canopy.
Class 5:	Greater than 50% of overstory canopy consists of mast or other edible-seed producing trees, and hard mast producers constitute more than 20% of the canopy.

<u>FWOP</u>

TY0, TY1, and TY50 - Class 4.

The canopy was made up of trees that provide either hard (water oak) or soft (cottonwood) mast. We estimated about 25% hard mast for this plot. However, we reduced the estimate to less than 20% hard mast overall because sites not samples would have more pine.

FWP Permanent

Habitat would be removed for structure footprint.

Variable V2 Stand Maturity

The production of mast and other edible seeds is expected to begin at about Age 10, increase with age, and reach maximum potential by approximately Age 50. In addition to increased production of hard mast, soft mast, other edible seeds, and buds, older stands provide important wildlife requisites such as tree snags, nesting cavities, and the medium for invertebrate (wildlife food) production. Also, as the stronger trees establish themselves in the canopy, weaker trees are outcompeted and eventually die, forming additional snags and downed treetops that would not be present in younger stands. Because the average age of canopy-dominant and canopy-codominant trees is usually unknown, average tree diameter at breast height (dbh) can be used to determine the Suitability Index for this variable.

Data was collected from the site visit for baseline estimates. Projections for the site was processed through the WVA Site-Ingrowth spreadsheets. The results of the In-growth spreadsheets can be seen in Table 5 which show the FWOP dbh and basal area (BA) for TY0, TY1, and TY50. FWP permanent habitat would be removed for structure footprint.

Table 5. Diameter at breast height and basal area from Mile Branch.

ROE 4 Mile Branch BLH plot							
Year 0.0			Year 1.0			Year 50.0	
DBH	BA		DBH	BA		DBH	BA
10.5	84.0		10.4	94.0		32.3	1346.4
11.0			12.8			23.3	

Variable V3 Understory / Midstory

The understory and midstory components of bottomland hardwoods provide resting, foraging, breeding, nesting, and nursery habitat. The understory and midstory provide soft mast, other edible seeds, and vegetation as sources of food. The understory and midstory also provide the medium for invertebrate production, an additional food source.

Data was collected from the site visit for baseline estimates.

FWOP

TY	0	TY	1	TY	50
Class/Value	SI	Class/Value	SI	Class/Value	SI
Understory %		Understory %		Understory %	
60		60		20	
Midstory %		Midstory %		Midstory %	
40	1.00	40	1.00	30	0.85

FWP Permanent

Habitat would be removed for structure footprint.

Variable V4 Hydrology

The hydrology variable considers the flooding duration and amount of water flow or exchange in forested wetlands using eight categories (Table 6).

Table 6. BLH Variable V4 Hydrology

		Flow/Exchange			
		High	Moderate	Low	None
Flooding Duration	Temporary	1.00	0.85	0.70	0.50
	Seasonal	0.85	0.75	0.65	0.40
	Semi-Permanent	0.75	0.65	0.45	0.25
	Permanent/Dewatered	0.65	0.45	0.30	0.10

Baseline hydrology was primarily based on knowledge of the area and best professional judgment. Mile Branch is a tributary of the Tchefuncte River and receives rain water and drainage from the surrounding city of Covington. Field visits confirmed water levels varying from shallow to potentially over topping its banks (based on increase berm by residents).

TY	0	TY	1	TY	50
Class/Value	SI	Class/Value	SI	Class/Value	SI
Flow/Exchange		Flow/Exchange		Flow/Exchange	
Moderate		Moderate		Moderate	
Flooding Duration		Flooding Duration		Flooding Duration	
Temporary	0.85	Temporary	0.85	Temporary	0.85

Variable V5, V6, and V7 General

To estimate Variables V5 Contiguous forest, V6 Surrounding Land Uses, and V7 Disturbance.

Variable V5 Size of Contiguous Forested Area

Although edge and diversity, which are dominant features of small forested tracts, are important for certain wildlife species, it is important to understand four concepts: 1) species which thrive in edge habitat are highly mobile and presently occur in substantial numbers, 2) because of forest fragmentation and ongoing timber harvesting by man, edge and diversity are quite available, 3) most species found in "edge" habitat are "generalists" in habitat use and are quite capable of existing in larger tracts, and 4) those species in greatest need of conservation are "specialists" in habitat use and require large forested tracts. Therefore, the basic assumption for this variable is that larger forested tracts are less common and offer higher quality habitat than smaller tracts. For this model, tracts greater than 500 acres in size are considered large enough to warrant being considered optimal. See Table 7.

Table 7. Variable V5 Size of Contiguous Forested Area.

Class 1.	0 to 5 acres
Class 2.	5.1 to 20 acres
Class 3.	20.1 to 100 acres
Class 4.	100.1 to 500 acres
Class 5.	> 500 acres

For this variable, USGS 2008 National Wetlands Inventory (NWI) and 2019 imagery were used to determine sizes of contiguous forested areas. Corridors less than 75 feet wide do not constitute a break in the forested area contiguity.

The Mile Branch has extensive forest connecting to the southern portion of the project area. Further north Mile Branch is surrounded by the city of Covington with some smaller forest (Figure 3). The HET estimated 1/3 of the area would be optimal (Class 1 - connected to over 500acres of forest) and 2/3 of the area categorized as a Class 3. Using a weighted average we estimated V5 to be a 0.73 for all target years.

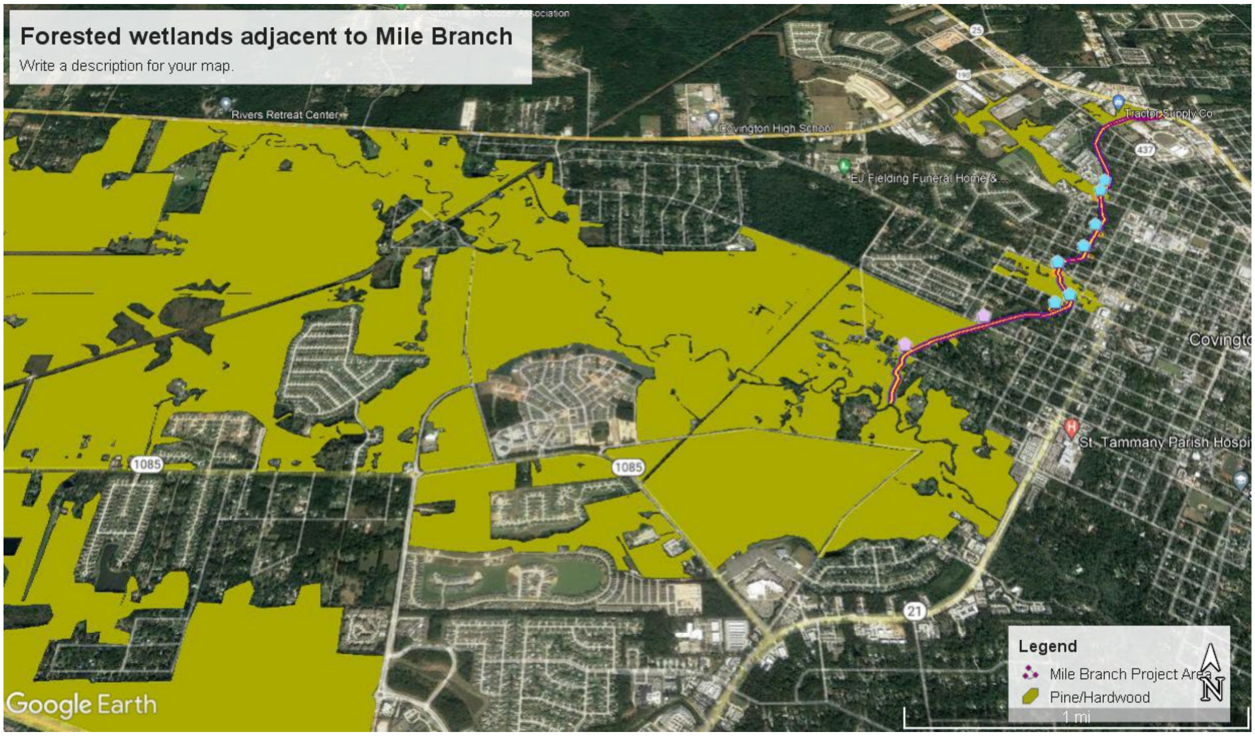

Figure 3. Variable 5 Mile Branch surrounding forest.

Variable V6 Suitability and Traversability of Surrounding Land Uses

Many wildlife species commonly associated with bottomland hardwoods will often use adjacent areas as temporary escape or resting cover and seasonal or diurnal food sources. Surrounding land uses which meet specific needs can render a given area of bottomland hardwoods more valuable to a cadre of wildlife species. Additionally, the type of surrounding land use may encourage, allow, or discourage wildlife movement between two or more desirable habitats. Land uses which allow such movement essentially increase the amount of habitat available to wildlife populations.

For the quick desktop estimates, an ocular review of the area was performed. Based on this review we categorized all habitat as either forest (50%) or developed (50%) for all target years.

Variable V7 Disturbance

Human-induced disturbance can displace individuals, modify home ranges, interfere with reproduction, cause stress, and force animals to use important energy reserves. The effect of disturbance is a factor of the distance to, and the type of, disturbance (Table 8).

Note: Linear and/or large project sites may be exposed to various types of disturbances at various distances. The SI for this variable should be weighted to account for those variances.

Table 8. Variable V7 Disturbance Classes.

Distance Classes	Type Classes
Class 1. 0 to 50 ft.	**Class 1.** Constant/Major. (Major highways, industrial, commercial, majornavigation.)
Class 2. 50.1 to 500 ft.	**Class 2.** Frequent/Moderate. (Residential development, moderately used roads, waterways commonly used by small to mid-sized boats).
Class 3. > 500 ft.	**Class 3.** Seasonal/Intermittent.(Agriculture, aquaculture.)
	Class 4. Insignificant. (Lightly Used roads and waterways, individual homes, levees, rights of way).

The USGS 2008 NWI habitat/land classification overlaid on 2019 aerial photographs of the area was viewed to estimate the disturbance categories. It was estimated that the class type was moderate (residential) or Class 2 and the distance was within 50ft or Class 1 and is expected to remain the same for 50 years.

Results of Bottomland Hardwood WVA

A summary of resulting AAHUs and acres impacted for all direct BLH impacts for the Mile Branch Project are shown in Table 9.

Table 9. Mile Branch Estimated Bottomland Hardwood Impacts.

	Initial Acres	Net Acres	AAHUs	AAHUs/acre
Mile Branch Riparian Zone	32.73	-32.73	-21.43	-0.65

Literature Cited

ELOS. 2018. Wetland Delineation Report for the Mid-Breton Sediment Diversion Project in Plaquemines Parish, LA.

Putnam, J.A., G.M. Furnival, and J.S. McKnight. 1960. Management and inventory of southern hardwoods. Agricultural Handbook No. 181. U.S. Department of Agriculture, Forest Service publication. 102pp.

Summary of the Mile Branch Desktop Estimates
For Impacts to the Riparian Zone

Taking the average of the 3 EBR sites and the BLH desktop WVA an average AAHUs per acre was used and applied to the impacted acres of Mile Branch Riparian Zone (Table 10).

Table 10. Summary of Mile Branch Impacts based on Desktop Estimates.

	AAHUs	Acres	AAHU/ac
Minimal data Mile Branch WVA	-21.43	-32.73	-0.65
EBR Average	-23.31	-32.73	-0.71
	AAHUs	**Acres**	**AAHU/ac**
Mile Branch Desktop Impacts Estimate	-22.37	-32.73	-0.68

Mississippi Valley Division,
Regional Planning and Environment Division South

Annex M Modeling
WVA Assumptions

Intermediate Marsh WVA

For determining marsh impacts for the St. Tammany Parish (Project), the Intermediate Marsh WVA methodology was selected as the most appropriate evaluation tool. Described below are the assumptions used to determine fresh and intermediate marsh baseline and FWOP and FWP projections for the proposed project area for direct and indirect impacts.

Fresh and intermediate marsh consists of six variables:

1. Percent of wetland area covered by emergent vegetation;
2. Percent of open water area covered by aquatic vegetation;
3. Marsh edge and interspersion;
4. Percent of open water area < 1.5 feet deep, in relation to marsh surface:
5. Mean high salinity during the growing season (March through November): and
6. Aquatic organism access

General Assumptions

The period of analysis expands from 2031 (TY0) to 2082 (TY50), with TY0 representing baseline conditions. In determining future with-project conditions, all project-related direct (construction) impacts were assumed to occur in Target Year 1.

Marsh impacts evaluated included direct permanent impacts to the project features (Figure 1). Note direct temporary (staging) areas were assumed to be permanent impacts because they would be reused for multiple lift. Impacts to Big Branch Marsh National Wildlife Refuge (BBMNWR) were evaluated separately from other impacts. Direct impacts to BBMNWR were evaluated for completeness. However, the Service requires any direct impacts associated with the project that occur on refuge lands to be swapped for the lands that are not impacted. With a land swap for direct impacts, BBMNWR will only have indirect impacts to pine savannah since there were no indirect impacts to marsh as determined by the hydraulics and hydrology (H&H) modeling.

Figure 1: St Tammany Project Features.

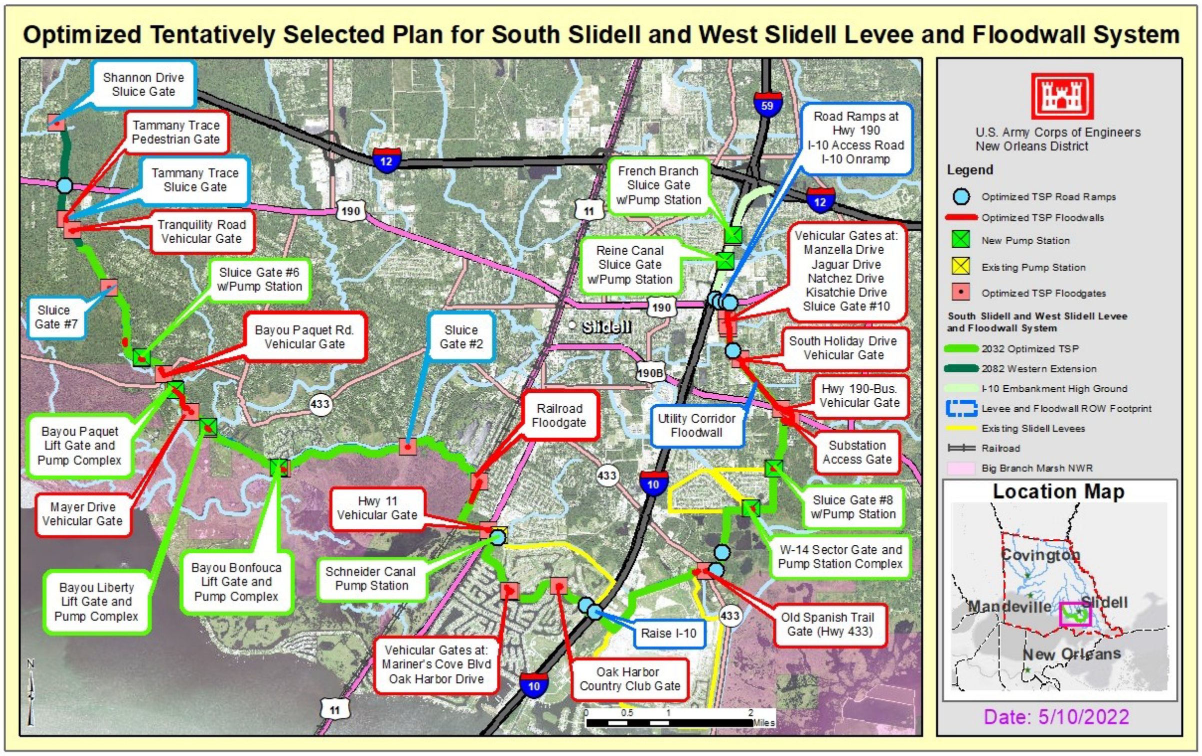

Table 1 and Table 2 list the marsh WVAs developed for all impacts.

Table 1. Table List of Total Direct Impact Wetland Value Assessments.

MARSH PRIVATE Lands			
Impact Area	**Habitat Type Impacted**	**WVA Model**	**Number of models**
Direct Permanent	Marsh	Intermediate	1
BBMNWR Direct Permanent	Marsh	Intermediate	1
Total Number of Model Runs with 3 RSLR			**6**

Temporary impacts are assumed to initially last approximately 5 years, though some areas may be restored earlier. For simplicity we will assume impacts for the full 5 years. The area is assumed to be cleared at the start of construction. After use for construction laydown and staging areas the area would be allowed to re-seeded naturally from surrounding marsh vegetation. After the 5 year use of temporary areas, it is assumed that temporary areas would be reused for future levee lifts. Thus with the expected re-occurring use to temporary areas, the

HET assumed the temporary staging areas would be lost permanently due to use over time and to compression and compaction and because they would not be restored to match pre-existing marsh conditions. All temporary marsh impacts, therefore, were included in the permanent impacts assessment.

Target Years (TYs) for Permanent impacts for FWOP and FWP include TY0, TY1, TY40, and TY50. TY40 represents RSLR impacts for both FWOP and FWP.

Target years are as follows:
FWOP Permanent Direct Impacts TYs – TY0, TY1, TY40, and TY50
FWP Permanent Direct Impacts TYs – TY0, TY1, TY40, and TY50

Land Loss/ Sea level Rise Effects
Land loss rates estimated by the Service were adjusted by the projected effects of the low, intermediate, and high relative sea level rise (RSLR) scenario for these analyses. The land loss rate for the North Shore Marshes was used (-0.46% per year for the period 1985-2016) based on USGS data for the extended project boundary (North shore marshes, total 1 11,383.9 acres). An average accretion rate of 0.75 mm/year was used for this site (0.75 mm/yr from Tchefuncte River, Nyman et al., 2006).

Sea level rise (SLR) estimates were calculated using the USACE's Sea-Level Calculator (SLC). The closest long-term (Aug 1957 to July 2002) gauge to the project area is Gauge 85575: Lake Pontchartrain at Mandeville. The USACE curves are computed using criteria in EC 1165-2-212 for high, intermediate, and low rates. The low, intermediate, and high SLR curve (gauge 85575) was used as appropriate for all SLR estimates.

Based on the USACE's SLC, an estimated subsidence rate of 4.9 mm/yr from the Lake Pontchartrain at Mandeville (gauge 85575) was used for RSLR estimates. The eustatic sea level rise was assumed to be 1.7 mm/yr.

Variable V1 Percent Emergent Marsh

Direct Permanent Impacts:
Persistent emergent vegetation (i.e., emergent marsh) plays an important role in coastal wetlands by providing foraging, resting, and breeding habitat for a variety of fish and wildlife species; and by providing a source of detritus and energy for lower trophic organisms that form the basis of the food chain. An area with no emergent vegetation (i.e., shallow open water) is assumed to have minimal habitat suitability in terms of this variable, and is assigned an SI of 0.1. Optimal vegetative coverage (i.e., percent marsh) is assumed to occur at 60-80 percent (SI=1.0).

Assume all water acres are associated with marsh habitat.

FWOP

Future percent marsh acres were determined using the Marsh Impact Mitigation (MIM) spreadsheet as is the standard procedure. MIM calculates loss of marsh while accounting for RSLR and accretion.

Variable V2 Submerged Aquatic Vegetation

Few standard conventions have been adopted for V2 FWOP and FWP projections. SAV cover is generally assumed to decrease under FWOP conditions as marsh loss continues, areas become deeper, and fetch increases as open water areas become larger.

<u>Direct Permanent Impacts:</u>
FWOP
Marsh site visits were conducted in mid July 2021 just prior to when Submerged Aquatic Vegetation (SAV) coverage would be at its peak density. It can be assumed that maximum coverage is achieved at the end of a growing season (late summer-early fall). A visual estimate of SAV coverage was taken at each transect line. Conditions are expected to remain constant through target years TY0 and TY1. Coverage is expected to decrease by TY40 by half with a continued decrease in coverage by TY50 based on the change in shallow open water to deeper water and increased wave fetch. In addition, sea level rise predications and a slight increase in salinity could result in degradation of SAV.

TY0 and TY1 – 23% SAV
TY40 – 12% SAV
TY50 – 5% SAV RSLR deepening water.

Variable V3 Marsh edge and interspersion
This variable takes into account the relative juxtaposition of marsh and open water for a given marsh**:**water ratio.

<u>Direct Permanent Impacts:</u>
FWOP- Interspersion classes were determined utilizing aerial imagery (see Figures 1-3 for examples) and site data collected during site visits. With minimal land loss expected in this area even with SLR, baseline is a class 1 and reduces to a class 2 in 50 years.

FWOP
TY0 and TY1 is a class 1
TY40 and TY50 is a class 2

FWP
Habitat would be removed for structure footprint

Figure 1. Marsh interspersion on St Tammany Project Big Branch Marsh National Wildlife Refuge land. Blue lines represent levee footprint and orange lines represent staging areas.

Figure 2. Marsh interspersion on St. Tammany Project Bid Branch Marsh National Wildlife Refuge land. Blue lines represent levee footprint and orange lines represent staging areas.

Figure 3. Marsh Interspersion on St. Tammany Project Private lands. Blue lines represent levee footprint and orange and purple lines represent staging areas.

Variable V4 Percent Open Water ≤ 1.5 ft

Direct Permanent and Temporary Impacts:
FWOP- Marsh site visits were conducted on 15 July 2021. Water depths were measured using a water depth staff gauge and recorded to a tenth of a foot. Water elevations were adjusted to the CRMS0006 hydrostation datum (NAVD88; Geoid 12A). Using the adjusted field data, the percent of open water less than or equal to 1.5 feet was calculated for TY0.

Using the CWPRRA standard procedure for calculating shallow open water projections, TY40 and TY50 bottom elevations were estimated by applying 40 and 50 years of subsidence (-0.8ft at TY40 and -0.6ft at TY50) to all TY0 bottom elevations. Subsidence of 4.9 mm/yr was determined by using the USACE's Sea-Level Calculator, Lake Pontchartrain at Mandeville gauge 85575. The subsidence rate (4.9mm/yr) was converted to the TY40 and TY50 values in ft.

Baseline (TY0) shallow open water was 11% and was applied to both TY0 and TY1. With SLR and marsh loss, the percent was assumed to decrease to 0% by TY40, and remained 0% through TY50.

Direct Permanent Impacts

FWOP
TY0 and TY1 – 11% SOW
TY40 and TY50 – 0% SOW

FWP
Habitat would be removed for structure footprint

Variable V5 Salinity

Existing or Baseline Salinity
The project features are located north of Lake Pontchartrain where the primary influence is freshwater from residing downstream of local rivers and bayous as well as saltier tidal influence coming from Lake Pontchartrain. Lake Pontchartrain salinities are increased through the Rigolets which is an outlet to Lake Borgne and Chandeleur Sound. Previously there were additional openings that were closed to help prevent saltwater intrusion and storm surge. These included the Mississippi River Gulf Outlet (MRGO), closed in 2009; the Inner Harbor Navigation Canal-Lake Borgne Surge Barrier (surge barrier), closed in 2010; and the Seabrook floodgate complex, completed in 2012. Since these closures, average salinities and salinity spikes have been reduced in the Pontchartrain basin and the project area. Salinities seemed to have leveled out by 2014. Therefore baseline salinity estimates were based on nearby Coastwide Reference Monitoring System (CRMS) station salinities from 2014-2021.

The area of impact presently contains fresh and intermediate marsh, which will be permanently impacted by project construction. See Figure 5 for referenced CRMS station locations. The closest CRMS station to the project features is CRMS 3667. This station was compromised by an adjacent CWPPRA marsh creation site that breached its containment dikes and flooded the CRMS gauge with sediment making the station's readings unreliable for recent years. CRMS 0006 was thought to be too greatly influenced by lake Pontchartrain while all the project features were further inland. CRMS 4406 and 4407 were also reviewed but had higher salinities due to the bayou Rigolets connection to Lake Borgne. In all 11 surrounding CRMS stations were evaluated to determine the most appropriate stations for salinity.

CRMS 2854 was used as the main station for determining average growing season salinities and salinity projections. CRMS 2854 has been collecting continuous hourly salinities since September 2007 to the present and is in close proximity to the project area. Salinity data from March 2014 to October 2021 was analyzed to determine the mean salinity during growing season (March to November). The analysis yielded **1.3 ppt**. This data was projected forward to year 2031 to represent the TY0 baseline salinity. See below for an explanation on salinity projections. TY0 salinity, projected forward to 2032, is **1.47ppt**.

Table 2. CRMS 2854 Growing Season Average Salinity from 2014 to 2021.

Growing Season Average Salinity	
Year	**Salinity (ppt)**
2014	**1.8**
2015	**2.4**
2016	**0.9**
2017	**0.8**
2018	**1.1**
2019	**0.7**
2020	**1.2**
2021	**1.2**
Overall Avg	**1.3**

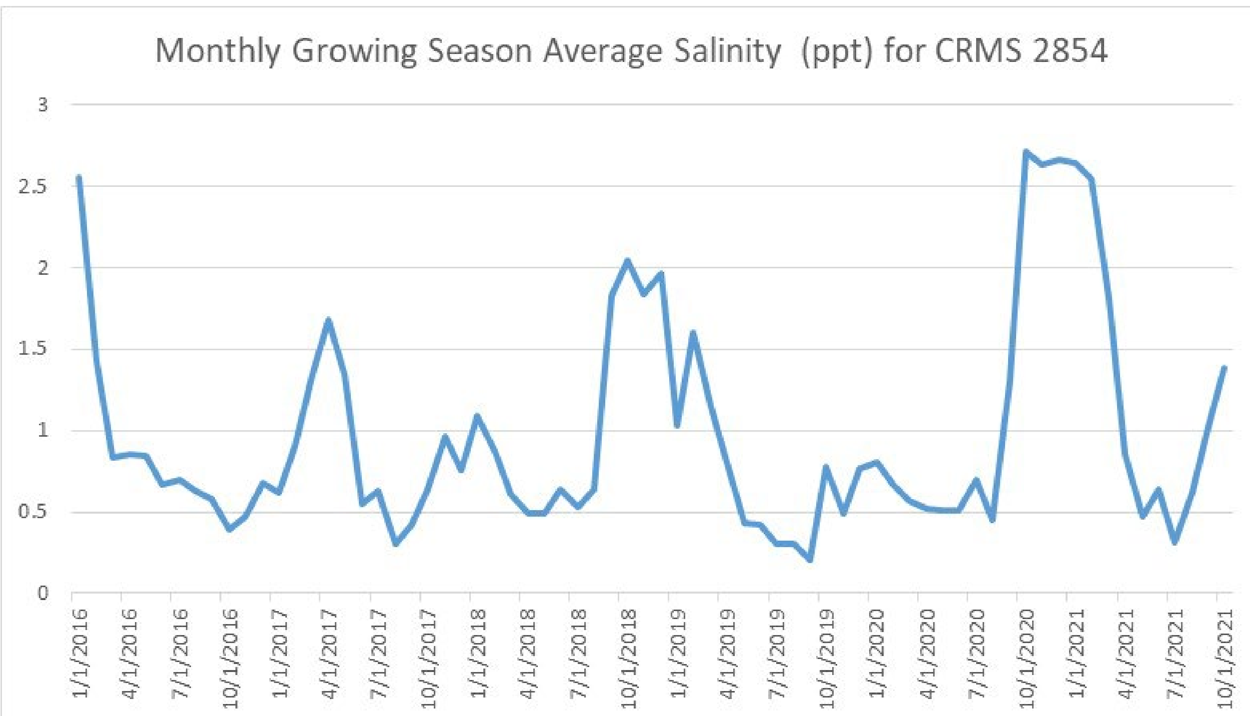

Figure 4. CRMS 2854 Monthly Growing Season Average Salinity (ppt) from 2014 to 2021.

<u>Future Salinity Projections:</u>
In the future, saltwater increases are expected due to continued land loss associated with RSLR. One may get a sense of future salinities by looking at Gulfward salinity monitoring sites as a proxy for future salinities at a more inland site. To project the salinity values the HET used the data from CRMS 0006 as the Gulfward gauge (figure 5).

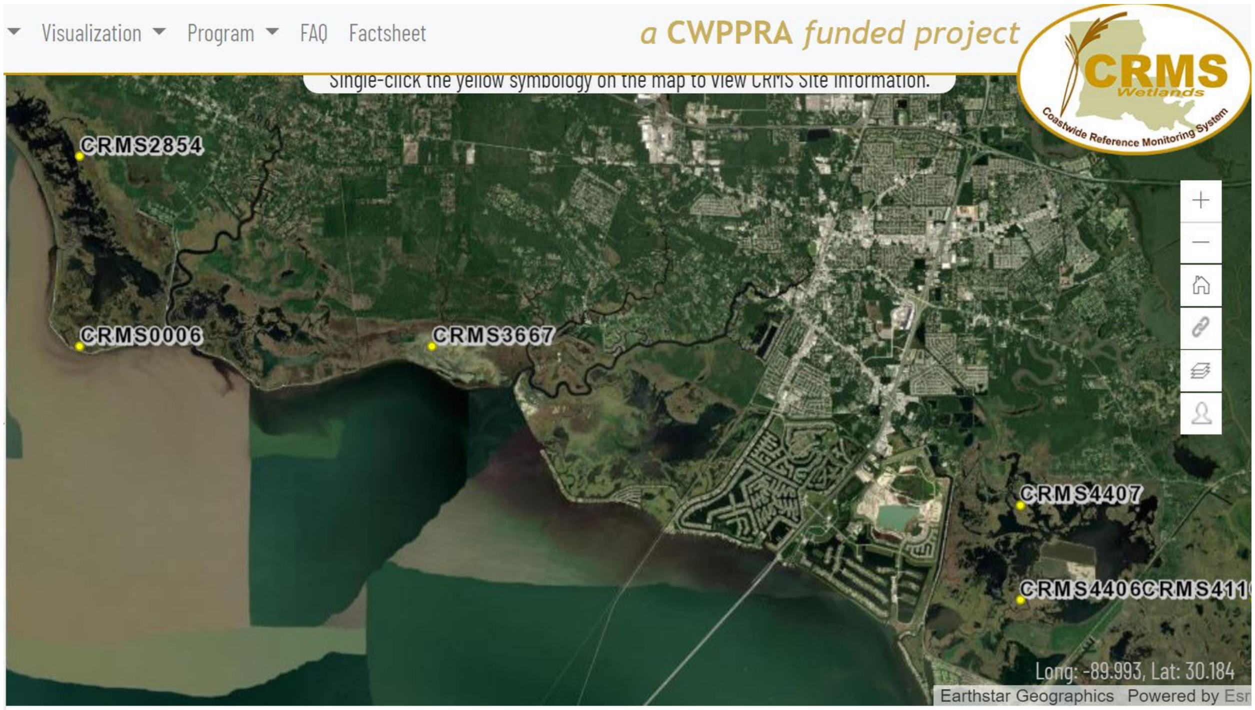

Figure 5. CRMS stations reviewed for St. Tammany Project.

Sea level rise (SLR) estimates were calculated using the USACE's Sea-Level Calculator (SLC). The closest long-term (Aug 1957 to July 2002) gauge to the project area is Gauge 85575: Lake Pontchartrain at Mandevilee. The USACE curves are computed using criteria in EC 1165-2-212 for high, intermediate, and low rates. The intermediate SLR curve (gauge 85575) was used for future salinity projections.

By using the CRMS Gulfward salinity data and the USACE's SLC (gauge 85575) future salinity projections were estimated to increase to **1.68 ppt** by TY50.

<u>Direct Permanent Impacts:</u>
FWOP
TY0 – 1.47 ppt
TY1 –1.48 ppt
TY40 – 1.66 ppt
TY50 – Salinity will increase to 1.68 ppt.

FWP
Habitat would be removed for structure footprint.

Variable V6 Fish Access

<u>Direct Permanent Impacts:</u>
FWOP – The project area are not currently impounded or hydrologically controlled by any structures. It is assumed that aquatic organisms have full access to sites. All FWOP scenarios

were assumed to have an "A" structure rating (open system), and it was assumed that 100% of the wetland would be accessible by all access points.

FWP - Habitat would be removed for project footprint.

Intermediate Marsh WVA Results

See Table 4 for a summary of resulting Annual Average Habitat Unit (AAHUs) and net acres direct and indirect impacts at the end of the period of analysis (year 50) for the three RSLR scenarios for the Intermediate marsh of the St. Tammany Parish Project.

Table 3. St Tammany Parish Project Annual Average Habitat Unit (AAHUs) and Net Marsh acres for the Intermediate Marsh Direct and Indirect Impact areas for the Low, Intermediate, and High Relative Sea Level Rise (RSLR).

LOW RSLR		
FRESH/INTERMEDIATE MARSH	Acres	AAHUS
Private Direct Permanent	-23.9	-21.4
BBMNWR Direct Permanent	-50.8	-40.18
Total	-51	-40
INTERMEDIATE RSLR		
FRESH/INTERMEDIATE MARSH	Acres	AAHUS
Private Direct Permanent	-11.1	-14.4
BBMNWR Direct Permanent	-28.8	-33.13
Total	-40	-48
HIGH RSLR		
FRESH/INTERMEDIATE MARSH	Acres	AAHUS
Private Direct Permanent	0.0	-10.6
BBMNWR Direct Permanent	0.0	-19.77
Total	0	-30