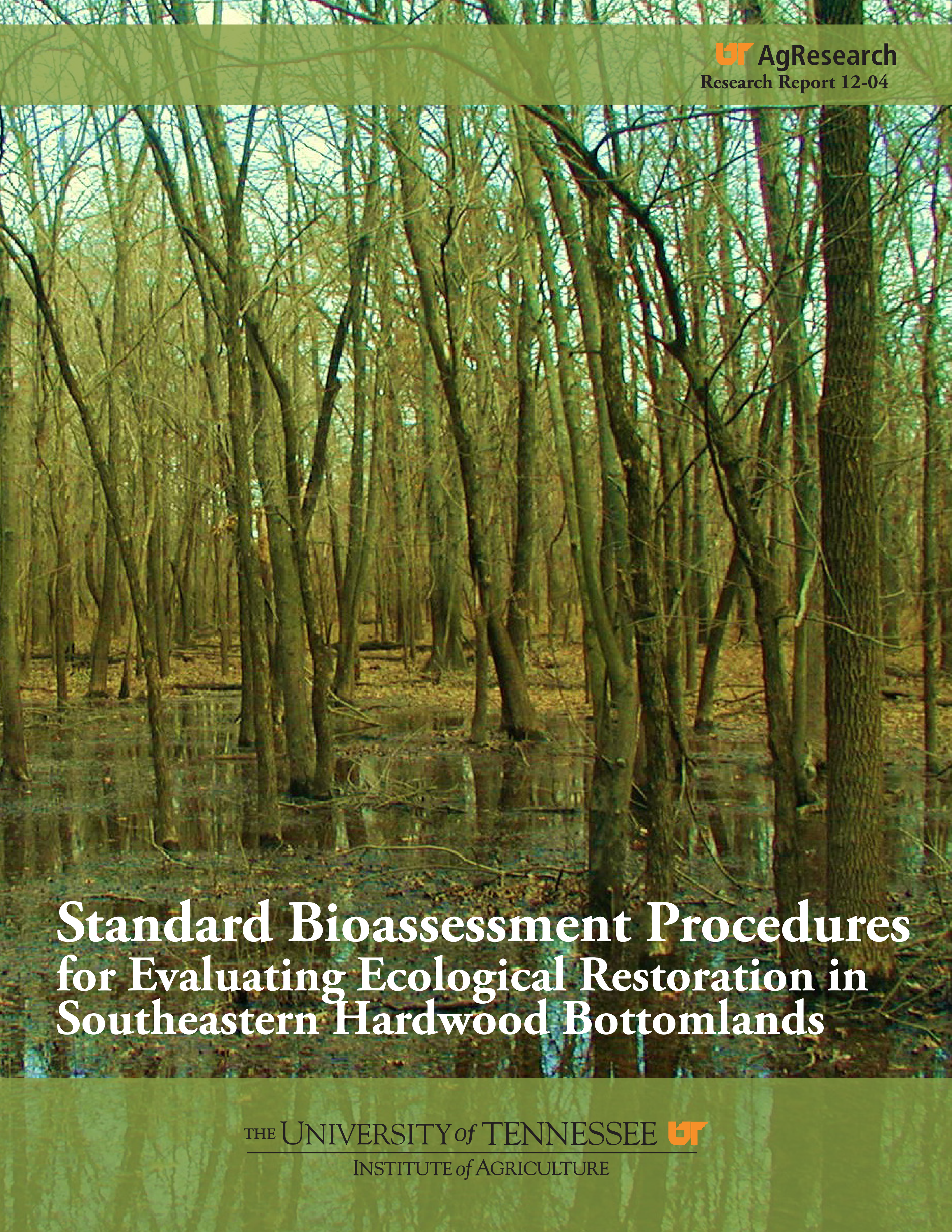

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Standard Bioassessment Procedures for Evaluating Ecological Restoration in Southeastern Hardwood Bottomlands

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Cover photo: Reference hardwood bottomland at the Hatchie National Wildlife Refuge, Haywood County, Tennessee.

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Introduction

Hardwood bottomlands are forested floodplain wetlands adjacent to riverine systems that afford a number of ecosystem services, including flood control, groundwater recharge, carbon sequestration, and providing habitat for wildlife (Taylor et al. 1990, Hyberg and Riley 2009). Historically, these wetlands covered about 25 million acres in the conterminous United States, with the greatest coverage in the Southeast (Sharitz 1992). Coverage of hardwood bottomlands has decreased substantially since European settlement due to deforestation and draining for production agriculture (Tiner 1984). In the 1970s, the Clean Water Act established protection for hardwood bottomlands, and subsequent legislation created several conservation programs in the United States that provide funds to landowners to restore floodplain wetlands (Stanturf et al. 2001). The U.S. Department of Agriculture (USDA) Wetlands Reserve Program (WRP) is the largest conservation program that provides cost-share incentives for wetland restoration (King et al. 2006). As of January 2011, 2.3 million acres had been enrolled in the WRP (J. Groves, USDA Natural Resources Conservation Service [NRCS], personal communication). Similarly, thousands of acres have been enrolled in the USDA Conservation Reserve Program for wetland restoration, and several state natural resource agencies and nongovernment organizations participate in bottomland restoration (King and Keeland 1999). To date, no monitoring protocol has been developed for evaluating ecological restoration in hardwood bottomland ecosystems (NRCS 2010).

Bioassessment models are one tool that can be used by natural resource practitioners to evaluate the state of ecological restoration. A bioassessment model uses several biological metrics to assign a site a numerical score, which is an indicator of overall ecological integrity and function (Karr 1981). Ecological integrity is defined as the ability of a site to support and maintain a balanced, adaptive community of organisms with a species composition and functional organization similar to undisturbed reference sites within a region (Karr and Dudley 1981). The process of developing a bioassessment model includes selection of sites along a disturbance or restoration gradient. Plant or animal assemblages are sampled at the sites, and biological metrics are chosen that show a predictable and empirical response to restoration (Karr 1981). Each metric is assigned an individual score (i.e., a subindex), and subindices are summed to yield an overall index that can be used to compare state of ecological restoration among wetlands of the same type (United States Environmental Protection Agency [EPA] 2002).

Our goal was to develop standard procedures for monitoring the state of ecological restoration in hardwood bottomlands in the southeastern United States. We developed bioassessment models by measuring the vegetation and bird communities at 17 restoration sites and four reference sites in western Tennessee, from March to August 2008. These sites were located in the Mississippi Alluvial Valley and Tennessee River Valley drainages, and they represented typical hardwood bottomlands in the southeastern United States (Summers 2010). We chose duration since enrollment in the WRP as the restoration/disturbance gradient, and identified six vegetation and three bird community metrics that were strongly correlated with this gradient. These metrics were used to construct vegetation and bird bioassessment models. In practice, biologists measure these metrics in the field and compare measurements to reference values. Sites can be assigned to one of four restoration categories: early restoration, mid-restoration, late restoration and reference (or restored) condition. Below, we describe the procedures for using these models to monitor ecological restoration in hardwood bottomlands. For more details, we refer readers to Summers (2010).

Bioassessment Model Components

We developed bioassessment models for the vegetation and bird communities. We recommend measuring both communities for the most comprehensive assessment of ecological restoration. Predictions of restoration state by vegetation and bird models were correlated (R^2= 0.73) at our sites (Summers 2010); thus if the expertise, time or resources do not exist to measure both communities, one community could be measured without losing substantial information. If one model is used, we recommend measuring the vegetation community, because sampling requires less expertise and time compared to measuring metrics in the bird model.

The vegetation bioassessment model includes density of logs, snags and overstory trees; basal area; and percent vertical cover of vegetation in two height strata (0 – 20 inches, 20 – 40 inches) measured using a profile board (Table 1). All vegetation metrics were positively correlated with site age (i.e., the restoration gradient) except percent vertical cover, which was negatively related with site age. The bird bioassessment model contained density of bark feeding, branch nesting, and twig nesting species (Table 2). All bird metrics were positively related with site age. The restoration scores in Tables 1 and 2 were determined by calculating quartiles (i.e., 25th, 50th and 75th percentiles) from our field data, which resulted in an ordinal ranking of 1 – 3 or 1 – 4 for the scores depending on the metric.

It is important to note that our models make predictions for conditions at typical bottomland sites, and they assume a linear (not nonlinear) relationship between the metrics and site age. Certain disturbances (e.g., flooding from beaver dams, tornadoes) could result in high values for snag and log density, which indicate restored conditions using our models. Thus, our bioassessment models may not perform accurately at sites with disturbance that causes extensive tree mortality.

Field Sampling Instructions

For both models, personnel should establish one permanent sampling plot at the approximate geometric center of the bottomland restoration site (Summers 2010). If the geometric center is not representative of site conditions, we recommend establishing the sampling plot at the approximate center of a representative portion of the site. Alternatively, more than one plot per site can be established at nonhomogeneous or large sites. Plots should be placed at least 275 yards apart if the bird community is measured to ensure that point count surveys are independent. Vegetation and bird community metrics should be averaged among plots at a site before assigning restoration scores using Tables 1 and 2.

Vegetation metrics should be measured once between May and August. We recommend that the bird community is sampled at least four times between March and August, with at least one week between surveys. Sampling for both communities should be repeated every 2 – 4 years at the same plot to monitor the state of ecological restoration. Below are details on sampling procedures for both communities.

Vegetation — Vegetation sampling occurs in two concentric plots located around the approximate geometric center of the site (Figure 1). Count the number of overstory trees within a 0.1-acre circular plot (radius, r = 37 feet). Overstory trees are defined for our model as live woody plants that are greater than 4.6 feet in height with greater than 4.5 inches DBH. Next, count the number of snags and logs in a 7.8-acre circular plot (r = 330 ft). If

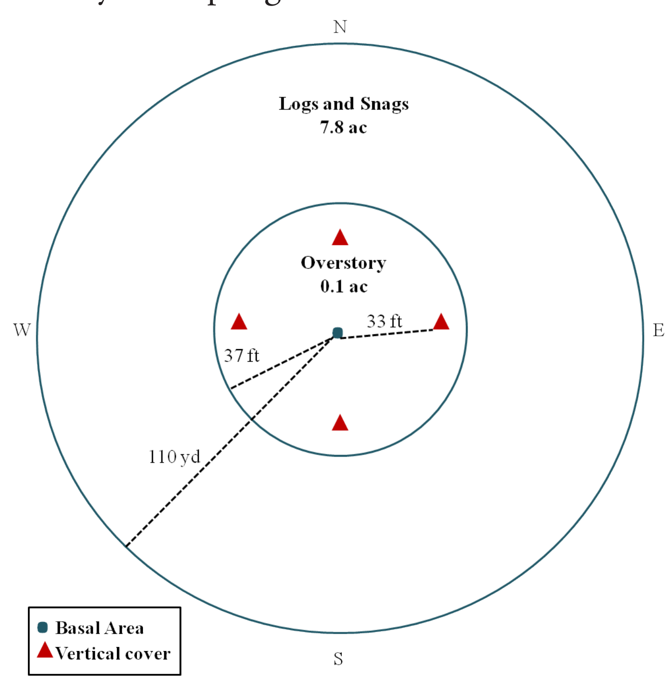

Figure 1. Schematic of vegetation plots for measuring density of overstory trees, logs and snags, tree basal area, and percent vertical cover of vegetation. Plots are located at the approximate geometric center of the restoration site.

the site is smaller than 7.8 acres, count all snags and logs within the site and convert the field measurement to a 7.8-acre plot. We defined snags as dead standing trees with greater than 4.5 inches DBH. Logs were dead fallen trees with diameter greater than 4.5 inches measured at 4.5 feet from the base of the trunk. Next, measure basal area at plot center using a 10 BAF prism (Figure 1); total number of trees counted is multiplied by 10 to calculate basal area. Finally, percent vertical cover of vegetation is measured using a graduated checkered profile board (Figure 2). This profile board is divided into two height strata (low = 0 – 20 inches, mid-level = 20 – 40 inches); each stratum contains 30 2-by-2-inch alternately colored boxes (Figure 2). Percent vertical cover is measured separately for each stratum by placing the board at plot center and inspecting the board from a kneeling position at 33 feet in each of the four cardinal directions (Figure 1). Esimate percent vertical cover by counting the number of boxes per stratum that are covered greater than or equal to 50 percent by vegetation, then divide the number of covered boxes by 30 for each stratum. Percent vertical cover should be averaged among the four cardinal sampling locations for the low- and mid-level strata.

Figure 2. Checkered profile board used for measuring percent vertical cover of vegetation in 0 – 20 inches (low) and 20 – 40 inches (mid-level) height strata. There are 30 2-by-2-inch boxes per stratum.

Avifauna — Bird community composition is measured using 10-minute, fixed-radius point count surveys extending from plot center to 165 feet (i.e., 1.95 acre plot, Ralph et al. 1993). Point counts should be performed between sunrise and five hours following sunrise on days with no rain and wind less than 7 mph (Ralph et al. 1993). After arriving to the site, stand at plot center for five minutes before beginning the bird survey. If vegetation measuring is planned also, perform the bird survey first. During the survey, do not move from plot center. All birds that are detected by sight or call less than or equal to 165 feet from plot center during the 10-minute point count survey are recorded to the species level. Birds that fly over plots are not included. To ensure birds beyond 165 feet are not included in the survey, we recommend using a rangefinder or tape measure to establish reference distances from plot center. In our previous work (Summers 2010), we determined that bird detection was similar among bottomland restoration sites within 165 feet of plot center, thus uncorrected bird density estimates from the field can be used in our bioassessment models (i.e., correction for detectability is unnecessary).

Post-processing of the bird data is necessary to use the bird bioassessment model. All detected birds need to be assigned to a feeding and nesting guild following Appendix I

(Summers 2010). If a detected bird is not in Appendix I, use DeGraaf and Chadwick (1984) or Ehrlich et al. (1988) for guild classification. Thereafter, sum the number of detected birds separately for the bark feeding, branch nesting and twig nesting guilds. Birds detected in other guilds are not needed for model predictions. If sampling occurred more than once, average the number of detected birds for each guild among sampling dates.

Table 1. Metric scoring for the vegetation bioassessment model that predicts the state of ecological restoration in hardwood bottomlands.

Metric	Field Measurement	Restoration Score
Logs	0	1
	1 – 2	2
	3 – 21	3
	>21	4
Snags	0	1
	1 – 2	2
	>2	3
Overstory trees	0	1
	1 – 5	2
	>5	3
Basal area	0	1
	1 – 30	2
	31 – 60	3
	>60	4
Mid-level vertical cover (%)	93.9 – 100	1
	80.5 – 93.8	2
	47.6 – 80.4	3
	0 – 47.5	4
Low vertical cover (%)	98.3 – 100	1
	85.1 – 98.2	2
	0 – 85	3

Table 2. Metric scoring for bird bioassessment model that predicts the state of ecological restoration in hardwood bottomlands.

Metric	Field Measurement	Restoration Score
Bark feeders	0	1
	0.1 – 0.3	2
	>0.3	3
Branch nesters	0 – 0.3	1
	0.4 – 1.0	2
	1.1 – 2.6	3
	>2.6	4
Twig nesters	0 – 0.1	1
	0.2 – 0.5	2
	0.6 – 1.0	3
	>1.0	4

Using and Interpreting Bioassessment Models

- Assign restoration scores by comparing vegetation or bird measurements from the field to reference values in Tables 1 and 2.
- For one or both models, sum the scores across the metrics to derive a total restoration score for the site and compare this value to the ranges below to categorize the state of ecological restoration.
- Interpretation of Vegetation Score: 6 – 9 = early restoration, 10 – 13 = mid restoration, 14 – 17 = late restoration, and 18 – 21 = reference condition.
- Interpretation of Bird Score: 3 – 4 = early restoration, 5 – 6 = mid restoration, 7 – 8 = late restoration, and 9 – 11 = reference condition.
- If both models are used, you can add vegetation and bird scores for a comprehensive multi-metric restoration score, and interpret it as follows:
    - » Interpretation of Multi-metric Score: 9 – 14 = early restoration, 15 – 20 = mid restoration, 21 – 26 = late restoration, and 27 – 32 = reference condition.
- A site is declared as ecologically restored when reference conditions are achieved.

Example — Suppose a site contained two logs, one snag and four overstory trees, tree basal area = 50, low vertical cover = 90 percent, and mid-level vertical cover = 50 percent in a sampling plot. Using Table 1, the respective vegetation scores would be 2, 2, 2, 3, 2 and 3, and the total vegetation restoration score = 14. Now, suppose bird point counts resulted in an average of 0.5 bark feeding, 1.5 branch nesting, and 0 twig nesting species per plot. The respective bird scores would be 3, 3 and 1 for a total bird restoration score = 7 (Table 2). Thus, the combined multimetric score would be 21 (14 + 7), which indicates the site is in late restoration based on the ranges provided above.

Conclusions

We present the first bioassessment models for use in monitoring ecological restoration in hardwood bottomlands in the southeastern United States. Given that our models were developed at 21 typical bottomland WRP sites across western Tennessee and that our restoration gradient followed a predictable successional gradient (Summers 2010), we anticipate that our models will produce robust predictions of ecological restoration in the southeastern United States. Moreover, metrics in our vegetation model were based on forest structure (i.e., density and percent cover), which tend to vary less spatially than metrics related to plant composition. Similarly, the bird model contained metrics for abundance of community guilds, which are less variable than species composition. Despite these promising attributes, it is important that researchers test the performance of our models in other regions of the Southeast. Summers (2010) outlined an approach to validate our bioassessment models among regions. Given that our models were developed at typical bottomland sites, they may not accurately predict restoration at sites that become invaded with exotic plant species or are exposed to atypical disturbance (e.g., excessive flooding from beavers, tornadoes).

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Appendix I. Commonly detected bird nesting and feeding guilds in Tennessee hardwood bottomlands and the corresponding habitat-use guilds (Summers 2010).

Species[a]	*Scientific Name*	*Nesting Guild*[b]	*Foraging Guild*[c]
Acadian flycatcher	*Empidonax virescens*	Twig	air
American crow	*Corvus brachyrhynchos*	Branch	ground
American goldfinch	*Carduelis tristis*	Twig	ground
American redstart	*Setophaga ruticilla*	Branch	canopy
American robin	*Turdus migratorius*	Branch	ground
bank swallow	*Riparia riparia*	Other	air
barn swallow	*Hirundo rustica*	Other	air
black and white warbler	*Mniotilta varia*	Ground	canopy
blue-gray gnatcatcher	*Polioptila caerulea*	Branch	canopy
brown-headed cowbird	*Molothrus ater*	Other	ground
blue grosbeak	*Passerina caerulea*	Shrub	ground
blue jay	*Cyanocitta cristata*	Branch	ground
blackpoll warbler	*Dendroica striata*	Branch	canopy
brown thrasher	*Toxostoma rufum*	Shrub	ground
blue-winged teal	*Anas discors*	Ground	other
blue-winged warbler	*Vermivora pinus*	Ground	canopy
Carolina chickadee	*Parus carolinensis*	Cavity	canopy
Carolina wren	*Thryothorus ludovicianus*	Cavity	ground
chimney swift	*Chaetura pelagica*	Cavity	air
cliff swallow	*Hirundo spilodera*	Other	air
common grackle	*Quiscalus quiscula*	Branch	ground
common snipe	*Gallinago gallinago*	Ground	ground
common yellowthroat	*Geothlypis trichas*	Ground	canopy
dickcissel	*Spiza americana*	Ground	ground
downy woodpecker	*Picoides tridactylus*	Cavity	bark
eastern bluebird	*Sialia sialis*	Cavity	air
eastern kingbird	*Tyrannus tyrannus*	Branch	air
eastern meadowlark	*Sturnella magna*	Ground	ground
eastern phoebe	*Sayornis phoebe*	Cavity	air
eastern towhee	*Pipilo erythrophthalmus*	Ground	ground
eastern wood-pewee	*Contopus virens*	Twig	air
fish crow	*Corvus ossifragus*	Branch	ground
field sparrow	*Spizella pusilla*	Ground	ground
fox sparrow	*Passerella iliaca*	Ground	ground
great blue heron	*Ardea herodias*	Branch	other
great-crested flycatcher	*Myiarchus crinitus*	Cavity	air

Appendix I (continued).

Species[a]	*Scientific Name*	*Nesting Guild*[b]	*Foraging Guild*[c]
golden-crowned kinglet	*Regulus satrapa*	Twig	canopy
gray catbird	*Dumetella carolinensis*	Shrub	ground
great egret	*Egretta alba*	Branch	other
green heron	*Butorides virescens*	Branch	other
hairy woodpecker	*Picoides villosus*	Cavity	bark
hermit thrush	*Catharus guttatus*	Ground	ground
indigo bunting	*Passerina cyanea*	Ground	canopy
killdeer	*Charadrius vociferous*	Ground	ground
least bittern	*Ixobrychus exilis*	Ground	other
marsh wren	*Cistothorus palustris*	Ground	ground
Mississippi kite	*Ictinia mississippiensis*	Branch	air
mourning dove	*Zenaida macroura*	Branch	ground
Nashville warbler	*Vermivora ruficapilla*	Ground	canopy
northern bobwhite	*Colinus virginianus*	Ground	ground
northern cardinal	*Cardinalis cardinalis*	Ground	ground
northern parula	*Parula americana*	Twig	Canopy
northern waterthrush	*Seiurus noveboracensis*	Ground	other
orchard oriole	*Icterus spurius*	Twig	canopy
palm warbler	*Dendroica palmarum*	Ground	ground
pileated woodpecker	*Dryocopus pileatus*	Cavity	bark
prairie warbler	*Dendroica discolor*	Shrub	canopy
prothonotary warbler	*Protonotaria citrea*	Cavity	bark
purple martin	*Progne subsis*	Cavity	air
red-bellied woodpecker	*Melanerpes carolinus*	Cavity	bark
ruby-crowned kinglet	*Regulus calendula*	Twig	canopy
red-eyed vireo	*Vireo olivaceus*	Shrub	canopy
red-shouldered hawk	*Buteo lineatus*	Branch	ground
ruby-throated hummingbird	*Archilochus colubris*	Branch	other
red-winged blackbird	*Agelaius phoeniceus*	Ground	ground
savanna sparrow	*Passerculus sandwichensis*	Ground	ground
song sparrow	*Melospiza melodia*	Ground	ground
summer tanager	*Piranga rubra*	Branch	canopy
swamp sparrow	*Melospiza georgiana*	Shrub	ground
Swainson's thrush	*Catharus ustulatus*	Branch	ground
Swainson's warbler	*Limnothlypis swainsonii*	Shrub	ground
Tennessee warbler	*Vermivora peregrina*	Ground	canopy
tree swallow	*Tachycineta bicolor*	Cavity	air
tufted titmouse	*Baeolophus bicolor*	Cavity	canopy

Appendix I (continued).

Species[a]	*Scientific Name*	*Nesting Guild*[b]	*Foraging Guild*[c]
white-breasted nuthatch	*Sitta carolinensis*	Cavity	bark
white-eyed vireo	*Vireo griseus*	Shrub	canopy
willow flycatcher	*Empidonax traillii*	Shrub	air
winter wren	*Troglodytes troglodytes*	Ground	Ground
wood duck	*Aix sponsa*	Cavity	other
wood thrush	*Hylocichla mustelina*	Branch	ground
white-throated sparrow	*Zonotrichia albicollis*	Ground	ground
yellow-breasted chat	*Icteria virens*	Shrub	canopy
yellow-billed cuckoo	*Coccyzus americanus*	Shrub	canopy
yellow-bellied sapsucker	*Sphyrapicus varius*	Cavity	bark
yellow-crowned night heron	*Nyctanassa violacea*	Branch	other
yellow-rumped warbler	*Dendroica coronata*	Branch	canopy
yellow-throated vireo	*Vireo flavifrons*	Twig	canopy
yellow-throated warbler	*Dendroica dominica*	Branch	canopy
yellow warbler	*Dendroica petechia*	Branch	canopy

[a]Species detected in a 1.95 acre (54.7-yard radius) plot during a 10-minute point count survey.

[b]Twig = species primarily nests on tree twigs, branch = species primarily nests on tree branches, ground = species primarily nests on ground or in low herbaceous vegetation, shrub = species primarily nests in shrubs, vines or brambles, cavity = species primarily nests in tree cavities or crevices, and other = species belongs to a nesting guild which was not commonly detected during model development (DeGraaf and Chadwick 1984).

[c]Air = species primarily forages aerially, ground = species primarily forages on the ground, canopy = species primarily forages in the canopy, and other = species belongs to a foraging guild which was not commonly detected during model development (DeGraaf and Chadwick 1984).

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