CONTRIBUTIONS OF INTENSIVELY MANAGED FORESTS TO THE SUSTAINABILITY OF WILDLIFE COMMUNITIES IN THE SOUTH

T. Bently Wigley , William M. Baughman, Michael E. Dorcas, John A. Gerwin, J. Whitfield Gibbons, David C. Guynn, Jr., Richard A. Lancia, Yale A. Leiden, Michael S. Mitchell, Kevin R. Russell

ABSTRACT

Wildlife communities in the South are increasingly influenced by land use changes associated with human population growth and changes in forest management strategies on both public and private lands. Management of industry-owned landscapes typically results in a diverse mixture of habitat types and spatial arrangements that simultaneously offers opportunities to maintain forest cover, address concerns about fragmentation, and provide habitats for a variety of wildlife species. We report here on several recent studies of breeding bird and herpetofaunal communities in industry-managed landscapes in South Carolina. Study landscapes included the 8,100-ha GilesBay/Woodbury Tract, owned and managed by International Paper Company, and 62,363-ha of the Ashley and Edisto Districts, owned and managed by Westvaco Corporation. Breeding birds were sampled in both landscapes from 1995-1999 using point counts, mist netting, nest searching, and territory mapping. A broad survey of herpetofauna was conducted during 1996-1998 across the Giles Bay/Woodbury Tract using a variety of methods, including: searches of natural cover objects, time-constrained searches, drift fences with pitfall traps, coverboards, automated recording systems, minnow traps, and turtle traps. Herpetofaunal communities were sampled more intensively in both landscapes during 1997-1999 in isolated wetland and selected structural classes. The study landscapes supported approximately 70 bird and 72 herpetofaunal species, some of which are of conservation concern. Habitat structure at both the stand and landscape scale had an important influence on relative abundance of many bird species, while many herpetofaunal species were associated with isolated wetlands. Pine plantations and other habitats within the landscapes appeared to act as population sources for some Neotropical migratory birds. In general, industry-managed forests can provide important habitats for many species and opportunities to consider landscape design, and thereby contribute to sustaining wildlife communities in the South.

National Council for Air and Stream Improvement, Inc., PO Box 340362, Clemson, SC, 29634-0362 (TBW); Westvaco Corporation, PO Box 1950, Summerville, SC, 29484 (WMB); Biology Department, Davidson College, PO Box 1719, Davidson, NC, 28036-1719 (MED); State Museum of Natural Sciences, 11 West Jones Street, Raleigh, NC 27601-1029 (JAG); Savannah River Ecology Lab, Drawer E, Aiken, SC, 29802 (JWG); Deptartment of Forest Resources, Clemson University, P.O. Box 341003, Clemson, SC, 29634-1003 (DCG); The Wildlife Program, Departments of Forestry and Zoology, North Carolina State University, Box 8002, Raleigh, NC, 27695-8002 (RAL); Savannah River Ecology Lab, Drawer E, Aiken, SC, 29802 (YAL); Alabama Cooperative Fish and Wildlife Research Unit, 108 M. White Smith Hall, Auburn University, AL 36849 (MSM); Willamette Industries, Inc., PO Box 488, Dallas, OR, 97339-0488 (KRR).

Citation: Wigley, T. Bently, William M. Baughman, Michael E. Dorcas, John A. Gerwin, J. Whitfield Gibbons, David C. Guynn, Jr., Richard A. Lancia, Yale A. Leiden, Michael S. Mitchell, and Kevin R. Russell. 2000. Contributions of intensively managed forests to the sustainability of wildlife communities in the South. In: Sustaining Southern Forests: the Science of Forest Assessment. Southern Forest Resource Assessment. http://www.srs.fs.fed.us/sustain/conf/

INTRODUCTION

Wildlife communities in the South are influenced by changes in land use and forest management. In the United States, the human population is expected to increase (at a mid-level estimate of immigration) from 275.3 million in 2000 to 377.3 million by 2040 (U.S. Census Bureau 2000). If past trends continue, the South's share of that population will increase (U.S. Department of Commerce 1992). Because of this population growth, forest habitats in the South are increasingly being converted to residential, urban, and agricultural uses (Alig and Wear 1992). Thus, landscapes dominated by contiguous areas of forest are increasingly important as habitats for many wildlife species.

In the eastern United States, the forest products industry often owns large contiguous blocks of forest that are embedded in a matrix of agriculture, urban areas, and small woodlots. In 13 southern states, the forest products industry owns or manages about 40 million acres or about 20 percent of the commercial forestland in the region (USDA Forest Service 2000). Much of this industry-owned land in the South is concentrated in the Gulf and Atlantic Coastal Plains where soils are productive and the growing season is favorable (Figure 1).

These large industry-owned forests are particularly important in the South because of the paucity of large public ownerships. Currently in 13 southern states, only 5.8 percent of commercial forest is in national forests, and only 4.9 percent is held by other public entities. Thus, significant wildlife conservation opportunities exist on industry lands, and conservation strategies to sustain wildlife communities in the South will not be complete unless private lands, including industry ownerships, are considered.

Management of industry-owned landscapes typically results in a diverse mixture of forest types and spatial arrangements that simultaneously offers opportunities to maintain forest cover, address concerns about fragmentation, and provide habitats for wildlife species. Far from being monotypic landscapes, large blocks of industry land generally are composed of multiple forest types and stand structures. Regionally, a significant proportion of industrial land is softwood forest, particularly loblolly-shortleaf pine (*Pinus taeda-P. echinata*) (Table 1). However, about 45 percent of industry land in 13 southern states is hardwood forest, e.g., oak-pine (*Quercus* spp.-*Pinus* spp.), oak-hickory (*Q.* spp.-*Carya* spp.), and oak-gum-cypress (*Quercus* spp.-*Taxodium* spp.) (Table 1).

Herein, we report on several recent studies of wildlife communities in 2 industry-managed landscapes in South Carolina. The projects were supported and conducted through the cooperative efforts of International Paper Company, Westvaco Corporation, National Audubon Society, USDA Forest Service Center for Forested Wetlands, National Fish and Wildlife

Foundation, North Carolina State University, North Carolina State Museum of Natural Science, Clemson University, University of Georgia's Savannah River Ecology Laboratory, National Science Foundation, and National Council for Air and Stream Improvement, Inc. Our research also was aided by Financial Assistance Award Number DE-FC09-96SR18546 from the U.S. Department of Energy to the University of Georgia Research Foundation. The studies, which were conducted to support the implementation of sustainable forestry within an industrial context, were designed to:

- evaluate the composition and productivity of bird communities in industry-managed landscapes;
- document herpetofaunal communities in industry-managed landscapes;
- examine the contribution of key abiotic features (i.e., isolated wetlands) to herpetofaunal diversity within the study landscapes; and
- explore relationships between habitat features (forest structure, abiotic considerations) and the bird community in order to provide information useful for development of models of habitat suitability.

Thus, we will describe the diversity of bird, reptile, and amphibian species identified on large industry-managed landscapes, discuss productivity of selected bird species, identify habitat variables correlated with presence of selected bird species, and explain contributions of abiotic factors (specifically isolated wetlands) to the maintenance of herpetofaunal communities.

STUDY AREAS

Our study landscapes included the 8,100-ha GilesBay/Woodbury Tract, owned and managed by International Paper Company, and 62,363-ha of the Ashley and Edisto Districts, owned and managed by Westvaco Corporation. As is the case for many industry ownerships, both study landscapes were complex mosaics of habitats.

The Woodbury/Giles Bay landscape is located at the confluence of the Pee Dee and Little Pee Dee rivers in Marion County, South Carolina. The landscape consisted of bottomland hardwood forests and sandhill ridges dominated by planted loblolly (*Pinus taeda*) and longleaf (*P. palustris*) pine forests that ranged from recently clearcut stands to mature stands >50 years old. The tract also had extensive bottomland hardwood forests (sweetgum [*Liquidambar styraciflua*], green ash [*Fraxinus pennsylvanica*], red maple [*Acer rubrum*], American sycamore [*Platanus occidentalis*], laurel oak [*Quercus laurifolia*]) and numerous isolated wetlands interspersed among the sandhill ridges (Leiden et al. 1999). Forested stands were managed using a variety of rotation lengths and harvesting techniques, depending upon the forest type. Pine plantations were on 20-year rotations (harvest by clearcutting followed by site preparation) (Peters 1999).

The Ashley/Edisto landscape is located in Charleston, Colleton, and Dorchester counties, South Carolina, approximately 24 km west of Charleston. It is about 135 km southwest of the Woodbury/Giles Bay landscape. The Ashley/Edisto landscape consisted primarily of stands of loblolly pine mixed with bottomland hardwood hummocks and gumponds (dominated by black gum [*Nyssa sylvatica*], bald cypress [*Taxodium distichum*], red maple and green ash). The landscape also contained linear habitats in the form of streamside zones adjacent to perennial and intermittent streams (50-100 m wide on each side) and "habitat diversity zones," which formed a network of 100-m-wide corridors across the study area. Rotations for forested stands on the Ashley/Edisto landscape were 20 years for pine plantations, 40-60 years for corridors, and 60 years for hardwoods. Gum ponds typically were excluded from management. In intensively managed stands, timber was harvested primarily by clearcutting followed by site preparation (Turner 1998).

METHODS

Breeding Birds

We sampled breeding birds in both landscapes during 1996-1999 using point counts, mist netting, nest searching, and territory mapping. To estimate relative breeding bird abundance, we sampled about 350 fixed-radius (50 m) plots per year in the Ashley/Edisto landscape and about 235 fixed-radius (50 m) plots per year in the Woodbury/Giles Bay landscape. Plots were allocated to each major habitat type approximately in proportion to their abundance on each landscape, although rotation-age pines stands were somewhat oversampled. Most plots were >25 m from edges and >250 m from adjacent plots to ensure as much independence among samples as possible.

To estimate productivity in selected habitats, we conducted constant-effort mist netting each year on each study area. On the Woodbury/Giles Bay landscape, mistnet-units were located in pine stands (aged 11-16 and 16-20), hardwood stands regenerated through shearing, and hardwoods regenerated without shearing. On the Ashley/Edisto landscape, we located mistnet units predominantly in 16- to 20-year-old pine stands. We used 20-net arrays each morning on the Ashley/Edisto landscape and 10 each morning on the Woodbury/Giles Bay landscape. The nets were located parallel to designated roads, a minimum of 50 m from road edges, in a semi-elliptical (horseshoe-shaped) pattern. The distance between neighboring nets ranged between 50 and 100 m.

In 1996, we sampled each mist-net array on a 3-day rotation; during 1997-1999, we used a 2-day rotation. Nets were opened at first light and closed between 1000 and 1100 hours. Each net was checked every 40-45 minutes, and we made morphological measurements for all individual birds that we captured (weight, unflattened wing length, cloacal protuberance, brood patch). Each bird received a standard United States Fish and Wildlife (USFW) aluminum band.

Age was classified as hatching year (HY) or after hatching year (AHY), based on breeding condition, plumage, and skull ossification. Male birds with a medium or large cloacal protuberance, and females with a partially or fully vascularized brood patch were classified as adults in breeding condition. For the Woodbury/Giles bay landscape, we calculated the ratio of juveniles to adults as a measure of productivity and the percentage of juveniles in the population [HY/(HY+AHY)]. We assumed that Hatch Year (HY) birds recorded at a site originated there or nearby (Peters 1999).

During this study, Swainson's warbler (scientific names of birds are in Appendix A) was a focal species on the Woodbury/Giles Bay landscape (Peters 1999). Thus, we mapped territories of Swainson's warblers, and searched for and monitored their nests on that landscape. Playback tapes were used to capture territorial males that were located outside of the constant-effort sampling area. We fitted adult Swainson's warblers that we captured with unique combinations of plastic color bands.

Acadian flycatchers and hooded warblers were focal species on the Ashley/Edisto landscape. Thus, we searched for and monitored their nests in 16- to 20-year-old pine stands on that study area. We also monitored nests of other species when we found them. Once an active nest was located, it was checked immediately to determine its status (i.e., building phase, eggs, hatchlings). Nests were monitored every 3-4 days if they were in the building or incubation stages, and more frequently as the hatching and fledging dates approached. A nest was considered successful if $\geq$1 young fledged. For failed nests, we attempted to identify the cause of failure, such as predation or parasitism by brown-headed cowbirds.

We collected microhabitat data at 202 bird sampling plots on the Woodbury/Giles Bay and about 400 plots on the Ashley/Edisto landscapes. At the center of each plot, we measured percent canopy closure (using a spherical densiometer), mean overstory and midstory height (using a clinometer), and diameter at breast height for the nearest 5 trees. We also counted the number of snags within 50 m of each plot center. Mean basal area was calculated for hardwoods and pines separately. We used a 2.5-m-tall coverboard to estimate vertical density of vegetation at 2 heights: 0-1.5 m (low vertical density) and 1.5-2.5 m (high vertical density). We also estimated indices for vine abundance (1=low, through 5=high) and presence of switch cane (*Arundinaria gigantea*; 1=present, 0=absent) within 10 m of the center of each plot (Peters 1999).

Because we were uncertain about the spatial scale at which landscape features influenced habitat selection, we calculated landscape-level variables at multiple spatial scales around each sampling point. Landscape-scale variables were based on simple summary statistics of forest age and forest type (percent landscape in pine overstory) calculated for areas of different size around each point sampled for birds. To reflect fine-scale habitat assessment by birds, we measured landscape characteristics for circular areas with 80-m (2 ha) and 160-m (8 ha) radii, centered on each bird sampling point. To reflect a coarser scale of assessment by birds, we measured landscape characteristics for radii ranging from 250-m (20 ha) to 3000-m (2,827 ha) at 250-m intervals. We then calculated the mean, standard deviation, and spatial continuity (covariance of neighboring values indexed using the Moran's *I* statistic, Cliff and Ord 1981) of forest age and percent pine for pixels contained within each circle, and used Idrisi GIS to calculate distance to nearest water for each sampling point.

We used stepwise logistic regression (SAS Institute 1990) to explore relationshps between the presence of selected bird species and variables describing microhabitat and landscape-scale habitat. We used significance thresholds of P=0.01 for variable entry and retention in models that included only microhabitat variables and P=0.001 for models that included landscape-scale variables (i.e., landscape-level variables only and a combination of microhabitat and landscape-scale variables). We assessed the explanatory power of all models using percent concordance (*C*; the number of times a bird was present and the probability of presence estimated by the model was greater than the probability of absence, divided by total observations) and Somer's *D* (*C* adjusted for the number of nonconcordant predictions, ranging from -1 to 1, indicating complete disagreement to complete agreement between predictions and observations; SAS Institute 1990). We qualitatively compared model fit for all species across the microhabitat, landscape, and combined microhabitat/landscape models to evaluate their relative explanatory power.

Herpetofauna

In order to compile a list of herpetofaunal species inhabiting an industry-managed landscape, we conducted a broad survey during 1996-1998 across the Woodbury/Giles Bay landscape (Leiden et al. 1999). Because the study area contained a variety of habitat types, we used a variety of methods, including time-constrained searches, drift fences with pitfall traps, coverboards, automated recording systems, minnow traps, and turtle traps. More details on some of these techniques are provided below. We also searched natural cover objects such as tree stumps, logs, and leaf litter in all available habitats and made additional observations during road travel.

Herpetofauna Associated with Specific Habitat Types

In order to evaluate the relative contribution of several common habitat types on the Woodbury/Giles Bay landscape to herpetofaunal diversity, we also sampled herpetofaunal communities more intensively during 1997 in selected habitat types. We used drift fences (Gibbons and Semlitsch 1981) to sample 4 stands each of 3 upland forest types/structural classes: 0- to 3-year-old pine plantations, 10- to 15-year-old pine plantations, and 25- to 40-year-old mixed pine-hardwood stands. We also sampled herpetofaunal communities in 4 isolated upland wetlands (i.e., Carolina bays) and 4 bottomland wetlands using turtle traps, minnow traps, and coverboards placed at the wetland edge.

Drift fences were constructed of silt-fence material (Department of Transportation grade) in the shape of an "X", with each wing being 15 m long. Each wing had 6 pitfall traps (19-liter plastic buckets), 3 on each side of the fence, and 4 double-ended funnel traps (2 per side). We placed a snake box trap (60-cm^3 boxes made of plywood with a hinged lid and a plastic funnel in each vertical side) at the center of each drift fence array. In the upland habitats, we checked the drift fence arrays in 2 of 3 habitat types for 4 consecutive days at bi-weekly intervals, resulting in 24 fence checks per week (624 for year). We sampled each wetland habitat for 15 days (5-day periods, 3 times per year).

We used analysis of dissimilarity (Clarke 1993, Smith 1998, Philippi et al. 1998) to compare herpetofaunal community composition between the upland and wetland habitat types on the Woodbury/Giles Bay landscape, and among the 3 upland habitat types. We computed Bray-Curtis and Jaccard dissimilarities in species composition between all pairs of samples. The magnitudes of the dissimilarities for between versus within pairs were tested using a Kruskal-Wallis nonparametric t-test, with significance determined by a Mantel test permuting the habitat labels on the samples. With 4 samples within each habitat type, a given comparison has 4*4=16 between-habitat and 2*(3+2+1)=12 within-habitat dissimilarities. However, there were only 35 unique label permutations. So even for the strongest possible result (all between-habitat dissimilarities are larger than the largest within-habitat dissimilarity), the most significant result would be P = 0.029 (1/35).

In a separate study on the Ashley/Edisto landscape (Baughman 2000), we characterized herpetofaunal assemblages in four 19-year-old pine plantations before and after stands were regenerated through clearcutting. In each plantation, we established 2 Y-shaped drift fence arrays as described by Bury and Corn (1987) and a square enclosure that was 100 x 100 m (1 ha) in size. Fences were constructed of 60–cm-high aluminum flashing buried 10–15 cm in the ground. Pitfall traps were 7.5-liter plastic buckets. For the enclosure, pitfall traps were paired on opposite sides of the fence at 20-m intervals, and funnel traps were located at each corner (again on both sides of the fence). Traps were open for 8 days each month and checked daily during that time. We used Analysis of Variance to compare abundance of amphibians and reptiles in different orders (e.g., Anura, Caudata) before and after the plantations were regenerated.

Intensive Study of Isolated Wetlands

We used another 5 isolated wetlands located in the upland sandhills portion of the Woodybury/Giles Bay to intensively study herpetofaunal diversity associated with these landscape features and relationships between diversity and wetland size. The small isolated wetlands were 0.38 ha, 0.47 ha, 0.59 ha, 0.72 ha, and 1.06 ha in size. Distances between the 5 wetlands range from 402-1,509 m.

In order to capture herpetofauna as they entered and exited the wetlands, we completely encircled each wetland with a continuous drift fence (Gibbons and Semlitsch 1981, Dodd 1992). The drift fences were located just above the anticipated high water mark in the ecotone between the isolated wetland and the surrounding upland stands. Fences were constructed of 60–cm-high aluminum flashing or silt fencing buried 10–15 cm in the ground. The drift fences for each pond were 192 m, 226 m, 271 m, 302 m, and 366 m in circumference. Paired pitfall traps (19-liter plastic buckets) were buried on each side of the fences at 10–m intervals.

To sample the adjacent upland forests, we used 3 arrays of individually numbered plywood coverboards (0.61 m X 1.22 m; Grant et al. 1992). The 3 arrays, each of which contained 20 boards, were equally spaced around each wetland and radiated out from the wetland into the upland. We placed the first board in each array at the wetland periphery and subsequent boards extended linearly into the upland stand at 10-m intervals. We checked pitfall traps and coverboards daily between 0700 and 1000 hours (depending on season) from September 1996–August 1998 (0.38-ha, 0.47-ha, and 0.72-ha wetlands) and April 1997–August 1998 (0.59-ha and 1.06-ha wetlands).

For all animals captured, we identified the species, sex (when possible), and age-class (e.g., larvae, recent metamorph, juvenile, sub-adult, adult). Salamanders, anurans (frogs and toads), and lizards were marked by toe clipping (Ferner 1979), but not for individual recognition. Snakes and turtles were transported to a field station at the study area and individually marked with 14-mm PIT tags (Russell and Hanlin 1999) and shell notching (Cagle 1939), respectively. We released marked individuals at least 5 m from the point of capture and on the opposite side of drift fences to minimize the probability of immediate recapture. All capture, handling, and marking protocols were approved by the research institutions participating in these studies (Clemson University, North Carolina State University, Savannah River Ecology Laboratory).

RESULTS

Birds

We identified 113 bird species that were breeding or foraging in the 2 study landscapes. We identified 72 species in the Woodbury/Giles Bay landscape and 105 in the Ashley/Edisto landscape. Many of the species found only on the Ashley/Edisto landscape (e.g., white ibis, belted kingfisher, Canada goose, laughing gull, European starling) likely were present due to the proximity of that landscape to coastal wetlands and a large urban area (Charleston, SC). Also, some of the additional species were migrants encountered by chance.

Although their relative abundances differed, many bird species were found in both landscapes (Table 2). Blue-gray gnatcatchers were the most common bird in both landscapes. Five species (blue-gray gnatcatchers, northern parulas, Acadian flycatchers, northern cardinals, and white-eyed vireos) were among the 10 most common species on both areas. The percentages of bird species in both landscapes in selected habitat associations and migratory categories also were similar (Table 3).

Almost 20 percent of the bird species in the study landscapes were of moderate to high conservation priority from a national and/or regional perspective (Table 4). We identified 20 species in both study landscapes that had Partners In Flight conservation scores >20 for PIF physiographic region 3 (Atlantic Coastal Plain). Nine species were on the national "Watch List" (Muether 1998). High-priority species were not rare in the landscapes. Three of the 10 most common species on the Woodbury/Giles Bay landscape (prothonotary warbler, northern parula, Acadian flycatcher) and 3 on the Ashley/Edisto landscape (Acadian flycatcher, northern parula, hooded warbler) were of some conservation interest at the national and/or regional level.

Swainson's Warbler

One bird species of special conservation interest in the Southeast is Swainson's warbler. Because of their rarity, they are one of the least understood North American avian species. Many researchers have spent entire field seasons searching for nests of Swainson's warblers with little or no success. In 50 years of fieldwork, Brooke Meanley discovered the most active nests on record (n = 30) (Peters 1999).

We found relatively large numbers of Swainson's warblers inhabiting hardwood stands on the Woodbury/Giles Bay landscape. During 1997-1999, we banded 165 Swainson's warblers, mapped 73 territories, and discovered 36 active nests. We found more Swainson's warblers (two-tailed Fisher's exact test, $P = 0.02$) in point-count plots in hardwood stands that had been regenerated using shearing than in plots where shearing had not been used. Furthermore, we found 26 territories (1998 only) and 39 nests (1997 and 1998) in sites where shearing had been used, versus 8 territories and 5 nests in sites that had not been sheared (1998 only; Peters 1999).

At the microhabitat level, we identified percent cover of switch cane and vines (greenbriar [*Smilax* spp.], crossvine [*Bignonia carpeolata*], Virginia creeper [*Parthenocissus quincefolia*], trumpet creeper [*Campsis radicans*], wild grape [*Vitis* spp.]) as characteristics influencing the presence of Swainson's warbler (Figure 2) (Peters 1999). When both vegetative components were prevalent on a plot, the probability of detecting a bird was high (59 percent) (Figure 2). However, vine cover and canopy closure were selected through logistic regression as the most important explanatory variables at this scale (Table 5).

We developed a second-generation logistic regression model for Swainson's warblers based on variables identified in initial models (Table 5) and other variables that have been suggested in the literature as being important to this species. This second-generation model indicated that the presence of Swainson's warblers was negatively associated with stand age and its spatial continuity at relatively small scales (2 ha and 20 ha, respectively), but positively associated with stand age and its spatial continuity at large spatial scales (2,827 ha and 491 ha, respectively). Other landscape variables included in this second-generation model were spatial continuity of species composition (negative relationship at 2,827 ha) and distance to water (negative relationship). The landscape-scale relationships identified in this second-generation model, particularly those related to stand age, strongly coincide with observations by others that Swainson's warblers inhabit openings in mature forests (Peters 1999). Yet, the logistic regression model (which was developed using data from the Woodbury/Giles Bay landscape) had a very high predictive capability (Somer's D = 94 percent) on the intensively managed forests of the Ashley/Edisto landscape.

Bird Habitat Associations

As has been found in studies elsewhere (e.g., Hagan et al. 1997), each habitat type/structural class within the study landscapes, including early successional stages, contributed to landscape-level diversity of bird communities. For example, on the Woodbury/Giles Bay landscape 2 or more bird species reached peak abundance (detections/point) in each habitat type (Tables 6 and 7). On that landscape, more bird species (12 species) reached peak abundance in hardwoods that had been regenerated using shearing than in other habitat type/structural class (Tables 6 and 7). Early successional pine stands (0-5 years old) ranked second. Pine stands 16-20 years old had the fewest species (2 species) reaching maximum abundance. However, one of those 2 species was the ovenbird, which often is characterized as a forest-interior species associated with dry upland hardwood habitats.

On the Ashley/Edisto landscape, many bird species (59 species) were identified in both hardwood and pine stand types, and similar bird communities were found in harvest-aged (i.e., 14-30 years) pine stands and hardwood stands (Turner 1998). Hardwood stems within the midstory of older pine stands and small hardwood stands scattered throughout the landscape seemed to facilitate the presence of some bird species normally categorized as "forest-interior" species. Thus, hardwood stands supported the greatest densities of all birds and of Neotropical migratory species (Turner 1998). However, older loblolly pine stands contained many forest-interior species typically associated with hardwood habitats. Thus, the red-eyed vireo, Acadian flycatcher, northern parula, and hooded warbler were relatively common on the Ashley/Edisto landscape. Other examples of "hardwood-associated" species that we found breeding in pine-dominated stands were worm-eating warbler, black-and-white warbler, and yellow-billed cuckoo. Some of these hardwood associates (e.g., hooded warbler) were found in pine stands as young as 11 years old.

On the Ashley/Edisto landscape some pine stands hosted significantly higher densities of resident species and early-successional Neotropical migrants than did hardwood stands. Several species (e.g., indigo bunting, painted bunting, blue grosbeak, orchard oriole, prairie warbler) preferred young, regenerating pine stands. For example, the prairie warbler appeared in pine plantations as young as 2 years old, and peaked in numbers when pine stands were 3-6 years old. By age 10, when canopy closure in pine plantations began to occur, the prairie warbler and most of the other species mentioned dropped significantly in numbers.

Using logistic regression, we found that habitat structure at the stand level was important to many bird species (Mitchell et al. *in review*). Stand-level variables identified as important predictors of presence for at least 1 species included overstory height, midstory height, low vertical density, high vertical density, pine basal area, hardwood basal area, number of vine stems, and canopy closure (Table 5). For most bird species, only 2-3 variables were selected through a stepwise process as predictors of presence. Somer's *D* for the models based on microhabitat features ranged from 0.47-0.91 across all species.

Landscape-scale measures of habitat (e.g., average stand age and forest type) also were related to probability of presence for some species (Table 5). In general, logistic regression models based only on landscape-level measures of habitat (Somer's $D = 0.61 \pm 0.16$ SD) were as robust as models using only microhabitat variables ($D = 0.61 \pm 0.14$). Combining the 2 types of variables in one model provided only a slight improvement in the explanatory ability of the models ($D = 0.62 \pm 0.18$). Models for Neotropical and short-distance migrants had the highest fit to field data, whereas models for resident species had relatively poor fit.

Our landscape models provided insights into the spatial scales at which birds select habitat (Mitchell et al., *in review*) (Table 5). Some species (e.g., hooded warbler, northern parula, wood thrush) selected habitat at relatively moderate to large spatial scales). Other species (e.g., American redstart, indigo bunting) selected habitat on relatively small scales. Some (e.g., northern parula) appeared to respond to habitat on a single landscape scale, while others responded to habitat on more than one scale (e.g., pine warbler). We calculated the mean scale of landscape variables in the models for each species and then compared the means across various groups of species. Mean scale was unrelated to successional stages ($P = 0.4085$), migratory classes ($P = 0.9945$), or degree of habitat specialization ($P = 0.9801$).

Bird Productivity

We did not monitor nests on the Woodbury/Giles Bay landscape; rather, we based estimates of productivity on ratios of HY:AHY birds. Using this approach, sheared hardwoods supported higher breeding rates than did unsheared hardwoods and rotation-aged aged pines, at least for species that utilized the lower vegetative strata (Figure 3). Breeding rates in the unsheared hardwoods and rotation-aged pine plantations appeared similar. Across all habitats, success of monitored nests in the Ashley/Edisto landscape ranged from 0.34 for northern cardinal to 0.69 for summer tanager (Table 8).

The largest sample size of nests was for Acadian flycatcher, one of our focal species. We determined nest outcome for a subsample of 84 of their nests. Two of the 84 nests failed due to abandoned eggs, 4 failed due to unknown causes, 35 nests were depredated, and 43 successfully fledged young (Hazler 1999). There were no instances of brood parasitism by cowbirds. Mayfield estimates of daily survival rates of nests ranged from 0.93 to 0.98, and did not differ between the nestling and incubation stages. At the stand scale, probability of nest success was negatively correlated with core area and positively correlated with tree canopy height (Hazler 1999). Typical nest trees for Acadian flycatchers were sweetgum, oaks, ashes, and hickories.

Hooded warblers generally located their nests in switch cane, sweet pepperbush (*Clethra alnifolia*), red bay (*Persea borbonia*), wax myrtle (*Myrica cerifera*), and other shrubs. Nest sites had lower hardwood basal area and greater shrub cover than did randomly selected sites. We determined the outcome for a subsample of 32 nests (Hazler 1999). Cowbirds parasitized 7 of the 32 nests, but only 2 of these failed as a result of parasitism. Daily survival of nests was 0.9331, and did not differ between the nestling and incubation stages.

Cowbirds were relatively low in abundance in our landscapes (Table 2). Based on all locations of cowbirds (including those outside the 50-m radius plots), they ranked twentieth and twenty-seventh (0.05 and 0.03 detections/point, respectively) in relative abundance on the Woodbury/Giles Bay and Ashley/Edisto landscapes, respectively. Thus, cowbirds appeared to have a relatively low impact on breeding birds in these 2 landscapes.

Herpetofauna

Based on broad-scale geographic ranges (Conant and Collins 1991), we estimated that 102 species of amphibians and reptiles potentially occurred on the Woodbury/Giles Bay landscape. Our broad-scale survey confirmed the presence of 73 of these species (Table 9). This represents the highest recorded richness of amphibians and reptiles in South Carolina, with the exception of the Savannah River Site, where continuous sampling has occurred since the 1950's (Leiden et al. 1999).

Some reptiles and amphibians species captured on the Woodbury/Giles Bay landscape have been identified as species of conservation priority. The South Carolina Department of Natural Resources lists 16 amphibians and 15 reptiles as Species of Special Concern, of which 16 potentially occurred on the Woodbury/Giles Bay landscape. We recorded 7 (1 amphibian and 6 reptiles) of the 16 species (Table 10) on our study landscape. The canebrake rattlesnake (scientific names of herpetofauna are presented in Appendix B), which we found on the landscape, is a Species of Special Concern in the mountains of South Carolina, but not on the Coastal Plain where the Woodbury/Giles Bay landscape is located.

Several other findings of conservation interest emerged during this survey of an industry-managed landscape. The population of river frogs recorded on the Woodbury/Giles Bay landscape represents the northern-most population currently known for this species (Leiden et al.

1999). We often found mud turtles crossing roads; eastern mud turtle and striped mud turtle, which are Species of Special Concern in South Carolina, are presumed to occur in high numbers on the Woodbury/Giles Bay landscape because suitable habitats (Ernst et al. 1994) are common there. We also recorded the first verifiable specimen of the southern hognose snake from Marion County, South Carolina. This is an important finding because a recent survey of museum specimens and literature indicate that populations have become extirpated in major portions of its range (Turbeville et al. 1999). Although the hognose snake historically occurred in the Coastal Plain from Mississippi to North Carolina (Mount 1975), no records of the species have been reported in some states (e.g., Alabama) for more than 15 years (Alabama Natural Heritage Program 1997).

Herpetofauna Habitat Relationships

As with bird communities, herpetofaunal communities sometimes differed among habitats within the Woodbury/Giles Bay landscape (Table 9). Thus, different habitats contributed to overall herpetofaunal diversity within the landscape. Preliminary analyses indicate that the herpetofaunal communities in the isolated wetland and bottomland wetland habitats were statistically dissimilar from those in the 3 upland habitat types ($P < 0.0001$) (Ryan et al., *in preparation*), largely because pond-breeding salamanders were present in the wetland habitats. Preliminary analyses (Ryan et al., *in preparation*) also suggest that species compositions in the 3 upland habitats were not statistically dissimilar at $\alpha = 0.05$ in the pairwise comparisons (pine 0-5 years versus mixed pine-hardwood [$P = 0.0571$]; pine 0-5 years versus pine 10-15 years [$P = 0.0571$]; mixed pine-hardwood versus pine 10-15 years [$P = 0.0857$]. However, because the level of probability in our statistical tests had a lower boundary of $P = 0.029$, as opposed to infinity, P-values of 0.06 - 0.09 may indicate some level of biological significance.

These potentially significant differences in herpetofaunal communities in the 3 upland habitats are evident in Figure 4, which is a non-metric multidimensional scaling from the pairwise Bray-Curtis dissimilarities. The 2 dimensions in Figure 4 were determined by undefined factors, which likely included environmental and microgeographic variables such as aspect, slope, proximity to water, and distance to edge of the habitat. Nonetheless, the 3 upland habitats were generally not distinctive with respect to reptile and amphibian communities present, and the overlap among species captured among the 3 upland habitats was high. We identified at least 3 species in each of the 3 upland habitats that were not found in the other two upland habitats. However, because many species were represented by as few as 1 or 2 observations, the ecological significance must be viewed cautiously. Detailed understanding of the dynamics and interactions within and among species associated with the different upland habitats and management regimes will require further long-term field studies.

Although we did not conduct a broad-scale survey of the Ashley/Edisto landscape, we sampled herpetofauna in 19-year-old pine plantations before and after regeneration through clearcutting (Baughman 2000). We captured 59 species of herpetofauna in the study plots (Baughman 2000). Using Analysis of Variance, we found no difference in average number of Anurans or Caudates captured in late-rotation pine plantations and in the same locations following regeneration. Anurans constituted 84 percent of all individual animals captured, followed by Caudata (10 percent), Lacertilla (3 percent), Serpentes (2 percent), and Testudines (1 percent). Because of small sample sizes, we could not subject numbers of Lacertilia, Serpentes, or Testudines to statistical analysis. However, there was a decreasing trend in numbers of Lacertilia in harvested areas and increasing trend for Serpentes. Potential changes in species composition have not yet been examined.

Isolated Wetlands

Isolated wetlands were a key habitat for many of the herpetofaunal species identified on the Woodbury/Giles Bay landscape. We captured 56 species of herpetofauna (20 amphibians, 36 reptiles) from the 5 isolated wetlands that we studied intensively (Table 11) (Russell 2000). This represents almost 77 percent of the species identified in the broad-scale survey. Four of the 56 species (pickerel frog, spotted turtle, striped mud turtle, black swamp snake) were classified by the South Carolina Department of Natural Resources as Species of Special Concern (Tables 11 and 12). We documented use of the isolated wetlands or adjacent upland stands for reproduction, as determined by the presence of larvae, recent metamorphs, hatchlings, or juveniles, for 15 amphibian species and 23 reptile species (52 percent of the total species assemblage on the Woodbury/Giles Bay landscape).

Although differences in herpetofaunal community measures were found among wetlands, there were no consistent trends in the richness, evenness, or diversity of herpetofauna with respect to wetland size (Table 12). Sorenson Coefficients of Similarity indicated a high degree of overlap in herpetofaunal species among all 5 wetlands (Table 13). The 2 largest wetlands (0.72-ha and 1.06-ha) exhibited the highest degree of community similarity and the 0.47-ha and 0.59-ha wetlands exhibited the lowest degree of similarity (Table 13).

Anurans were the dominant amphibians at all 5 wetlands (Table 11). The leopard frog was captured most often and composed 37 percent of all amphibian captures, followed by the southern toad (27 percent), southern cricket frog (15 percent), green frog (8 percent), eastern narrow-mouthed toad (4 percent), and carpenter frog (4 percent). Of the 5 species of salamanders captured, only the mud salamander was relatively common (2 percent of captures; Table 11) around these 5 isolated wetlands (2 percent of captures; Table 11), although aquatic adults of broken-striped newts were abundant in other wetlands that held water for most of the year. Lizards were the most abundant reptiles at all sites except the 0.59-ha wetland, where snakes dominated reptile captures (Table 9). Ground skink was the most abundant lizard (24 percent of all reptile captures), followed by worm snake (13 percent), green anole (11 percent), southeastern five-lined skink (7 percent), broad-headed skink (6 percent), and the racer (4 percent).

DISCUSSION

Species inventories provide the essential foundation for conserving biological diversity (Dodd 1992, Oliver and Beattie 1993) and even acquiring data on species perceived to be common is an important aspect of conservation efforts (Dodd and Franz 1993, Gibbons et al. 1997). The industry-managed landscapes that we studied supported large and diverse communities of birds and herpetofauna, and appeared to provide habitat for a large proportion of the species in these taxa that potentially occur in forested habitats of the region. Furthermore, a significant number of bird and herpetofauna species in the landscapes were of moderate to high conservation priority. Thus, our results suggest that high levels of diversity are possible in landscapes under intensive forest management (Leiden et al. 1999). Interestingly, the study landscapes have been under active forest management for many years, and have a prior history of agricultural use since colonial times.

The current diversity of habitat types within the landscapes likely enhanced diversity of the wildlife communities. The presence of multiple structural classes of loblolly pine forest was important to many resident bird species as well as early-successional Neotropical migrants. The large number of small, mature hardwood stands scattered throughout the matrix of pine stands and hardwood midstory in pine stands facilitated the presence of "hardwood associates" and forest-interior bird species within structurally similar pine stands. Isolated depressional wetlands were a key feature for many herpetofauna species.

Active forest management practices such as shearing may be useful tools for creating suitable habitat for some species of high conservation priority (e.g., Swainson's warbler). Of course habitat preferences of the Swainson's warbler undoubtedly was influenced by other factors such as moisture regime, soil properties and associated understory vegetation particularly vines and cane. However, shearing did apparently promote habitat structures (e.g., vines) attractive to this species. Unfortunately, because of their relative rarity, it is sometimes difficult to study the use of management to enhance habitat for species of high conservation priority or potential adverse impacts of management practices. For example, the full range of stand ages and structures that are suitable for Swainson's warblers remains unknown. The sheared stands sampled in this study were about 15-25 years old, and all received approximately equal use by Swainson's warblers. We suggest that this silvicultural technique should be evaluated more fully in our study landscapes and others as a technique to potentially increase the breeding habitat for this species.

Industry-managed landscapes, including those with significant amounts of loblolly pine plantations, have the potential to serve as viable breeding habitat for many forest birds, including some that are categorized as associates of deciduous forest. We studied reproductive success of 2 species (Acadian flycatcher and hooded warbler) that often are categorized as forest-interior or area-sensitive species (e.g., Whitcomb et al. 1981, Hamel 1992). Preliminary analyses of source-sink dynamics suggested that plantations in our study landscapes serve as population sources for hooded warblers under conditions of moderate survivorship (Hazler 1999). For Acadian flycatchers, stands >20 years old should act as population sources under conditions of low to moderate survival. Stands <20 years old likely will act as population sinks for Acadian flycatchers (Hazler 1999).

Our results suggest that, at least for bird communities, intensively managed landscapes do not exhibit characteristics associated with fragmentation such as decreased abundance of Neotropical migrants or reduced nest success rates. In our study area, stand-level vegetative structure seemed to be a more important driving factor in territory establishment and nesting success of birds than patch shape or edge effects. Landscape attributes, however, were important factors influencing presence of many species. Habitat generalists were relatively insensitive to landscape characteristics, but specialists appeared to respond to them strongly. In general, coarse landscape characteristics were most important to migratory bird species that were limited in the number of habitats they could use for breeding. Average forest age and forest type, and variability in these parameters at multiple spatial scales, were important to many of these species. Interestingly, landscape characteristics were equally important to both mature forest specialists and pioneering opportunists.

The spatial scale of landscape variables important to bird species was unrelated to successional class, migratory status, or degree of habitat specialization. This suggests that the scale at which a bird perceives habitat is a function of its unique natural history, and perhaps is an emergent property of the environmental parameters that define its niche. Based on our results, it is unlikely that any single spatial scale can be used to assess landscape characteristics for coarse ecological groupings of bird species (much less all birds or for other taxa). This also calls into question relationships that often are assumed between forest-interior species and area sensitivity, at least in the landscape context we examined. And, it brings into question efforts to use landscape metrics at any single spatial scale as surrogates for landscape "health" or biological diversity.

Our study demonstrates that small isolated wetlands are important habitat features for herpetofauna in commercially managed forests, potentially influencing the landscape far from their edge. For example, toads from an inconspicuous 1-ha isolated wetland conceivably could support a population of hognosed snakes occupying over 1000-ha of upland habitats (Moler and Franz 1987). Clearly, our results indicate that size alone is not an adequate index of wetland values and functions (Gibbs 1993, Semlitsch and Bodie 1998). Small isolated wetlands, while superficially similar with respect to dominant species, support variable levels of herpetofaunal diversity and abundance that can only be conserved by protecting a range of sites. However, in order to determine which sites to protect, more knowledge is needed on the variability of these unique communities (Dodd 1992). We strongly urge additional characterization of small isolated wetland herpetofaunal communities in managed forests and the determinants of among-wetland variability. Continued monitoring of herpetofaunal communities in isolated wetlands would strengthen our understanding of their response to management practices throughout a rotation or multiple rotations, and their response to alternative management strategies for wetlands (e.g., various buffer designs, prescribed fire within wetlands). Particularly valuable would be studies that explicitly examine the influences of upland habitat conditions and the need for adjacent terrestrial buffers (Semlitsch and Bodie 1998).

Several factors should be considered in interpreting and applying results of our research. Our results are most directly applicable to forested landscapes on the lower Coastal Plain. Because we did not sample in other types of landscapes (e.g., those dominated by unmanaged forests, agriculture, or urbanization), we cannot directly compare our results with data from those types of habitats. Furthermore, species habitat relationships and responses to forest management may differ in other physiographic regions. Although we identified many species residing in our study landscapes, our data do not describe landscape-level population trends. Nor do we understand levels of diversity before the landscapes were placed under agriculture several centuries ago or forest management in more recent decades. Continued monitoring would strengthen our understanding of natural fluctuations in abundances of herpetofauna and the influence of management on population trends, particularly for species that were relatively rare within the study landscapes.

CONCLUSION

The American Forest and Paper Association's Sustainable Forestry Initiative^{SM} commits member forest products companies to "manage the quality and distribution of wildlife habitats and contribute to the conservation of biological diversity" (American Forest and Paper Association 2000). Although our data measure only current levels of diversity, our results indicate that there are significant opportunities for industry-managed landscapes to contribute to the support of biological diversity in the southeastern United States. Furthermore, industry landscapes can potentially complement conservation efforts on other ownerships if industry-owned lands are kept in forest cover under management stewardship similar to that which we studied. Further research would assist industry in further understanding potentially negative impacts of management practices on sensitive taxa and in developing management approaches that minimize those impacts. Newly emerging computer-based tools (e.g., the harvest scheduler HabPlan [Van Deusen 1999]) also offer industry managers an opportunity to actively consider habitat relationships of high-priority and other species while planning timber harvests. Efforts to manage and monitor biological diversity in industry-managed landscapes should consider the variability of wildlife communities among different habitats, and the disproportionate value of selected habitats (e.g., small, isolated wetlands, breeding habitat for Swainson's warblers) to some taxa.

LITERATURE CITED

Alabama Natural Heritage Program. 1997. Rare upland snakes of south Alabama. Herp Atlas News 2:2.

Alig, R. J., and D. N. Wear. 1992. Changes in private timberland: statistics and projections for 1952 to 2040. J. For. 90(5):31-36.

American Forest and Paper Association. 2000. Sustainable Forestry Initiative^{SM} Standard: Principles and objectives (SFI—2000). American Forest and Paper Association. Washington, DC. 5pp.

Baughman, W. M. 2000. The effects of corridors on herpetofauna assemblages in intensively managed forests. Ph.D. Dissert. Clemson Univ., Clemson, SC. 68pp.

Bury, R. B., and P. S. Corn. 1987. Evalution of pitfall trapping in northwestern forests: Trap arrays with drift fences. J. Wildl. Manage. 51:112-119.

Cagle, F. R. 1939. A system for marking turtles for future identification. Copeia 1939:170-173.

Colorado Bird Observatory. 1998. Partners In Flight scores by physiographic regions. http://www.cbobirds.org/pif/index.html

Clarke, K.R., 1993. Non-parametric multivariate analysis of changes in community structure. Australian Journal of Ecology 18:117-143.

Cliff, A. D., and J. K. Ord. 1981. Spatial processes: models and applications. Pion Ltd., London, UK.

Conant, R., and J. T. Collins 1991. A field guide to the reptiles and amphibians of eastern and central North America. Houghton Mifflin. New York. 450 pp.

DeGraaf, R. M., and J. H. Rappole. 1995. Neotropial migratory birds: natural history, distribution, and population change. Cornell University Press, Ithaca, NY. 676pp.

Dodd, C. K., Jr. 1992. Biological diversity of a temporary pond herpetofauna in north Florida sandhills. Biodiversity and Conservation 1:125-142.

Dodd, C. K., Jr., and R. Franz. 1993. The need for status information on common herpetofaunal species. Herpetological Review 24:47-50.

Ernst, C. H., J. E. Lovich, and R. W. Barbour. 1994. Turtles of the United States and Canada. Smithsonian Institution Press. Washington, D.C. 578 p.

Ferner, J. W. 1979. A review of marking techniques for amphibians and reptiles. Society for the Study of Amphibians and Reptiles, Herpetofaunal Circular 9.

Gibbons, J. W., and R. D. Semlitsch. 1981. Terrestrial drift fences with pitfall traps: an effective technique for quantitative sampling of animal populations. Brimleyana 7:1–16.

Gibbons, J. W., V.J. Burke, J.E. Lovich, R.D. Semlitsch, T.D. Tuberville, J.R. Bodie, J. L. Greene, P.H. Niewiarowski, H.H. Whiteman, D.E. Scott, J.H.K. Pechmann, C.R. Harrison, S.H. Bennett, J. D. Krenz, M.S. Mills, K.A. Buhlmann, J.R. Lee, R.A. Seigel, A.D. Tucker, T.M. Mills, T. Lamb, M.E. Dorcas, N.B. Frazer, J.D. Congdon, M. H. Smith, D.H. Nelson, M.B. Dietsch, H.G. Hanlin, J.A. Ott, and D.J. Karapatakis. 1997. Perceptions of species abundance, distribution, and diversity: Lessons from four decades of sampling on a government-managed reserve. Env. Mgt. 21:259-268.

Gibbs, J. P. 1993. Importance of small isolated wetlands for the persistence of local populations of wetland-associated animals. Wetlands 13:25-31.

Grant, B. W., A. D. Tucker, J. E. Lovich, A. M. Mills, P. M. Dixon, and J. W. Gibbons. 1992. The use of coverboards in estimating patterns of reptile and amphibian biodiversity. Pp. 379-403 *in* D. R. McCullough and R. H. Barrett (eds.), Wildlife 2001: Populations. Elsevier Applied Science, New York.

Hagan, J. M., III, and D. W. Johnston, eds. 1992. Ecology and conservation of neotropical migrant landbirds. Smithsonian Institution Press, Washington, DC. 609pp.

Hagan, J. M., P. S. McKinley, A. L. Meehan, and S. L. Grove. 1997. Diversity and abundance of landbirds in a northeastern industrial forest. J. Wildl. Manage. 61(3):718-735.

Hamel, P. B. 1992. The land manager's guide to the birds of the South. The Nature Conservancy, Chapel Hill, NC and USDA Forest Service, Southern Region, Atlanta, GA. 366pp.

Hazler, K. R. 1999. An assessment of pine plantations as breeding habitat for Acadian flycatchers and hooded warblers. M.S. Thesis. North Carolina State University, Raleigh. 91pp.

Leiden, Y. A., M. E. Dorcas, and J. W. Gibbons. 1999. Herpetofaunal diversity in Coastal Plain communities of South Carolina. J. of the Elisha Mitchell Scientific Society 115(4):270-280.

Mitchell, M. S., R. A. Lancia, and J. A. Gerwin. *In review*. Using landscape-level data to predict the distribution of birds on a managed forest: effects of scale. Ecological Applications.

Moler, P. E., and R. Franz. 1987. Wildlife values of small, isolated wetlands in the Southeastern coastal plain. Pages 234-241 *in* R. R. Odom, K. A. Riddleberger, and J. C. Ozier, eds. Proceedings of the Third Nongame and Endangered Wildlife Symposium. Georgia Department of Natural Resources, Social Circle, Georgia.

Mount, R. H. 1975. The Reptiles and Amphibians of Alabama. Auburn Univ. Agriculture Experiment Station. Auburn, AL. 347p.

Muehter, V. R. (ed.). 1998. WatchList website, Version 97.12. National Audubon Society, New York, NY. <http://www.audubon.org/bird/watch/>

Oliver, I., and A. J. Beattie. 1993. A possible method for the rapid assessment of biodiversity. Conservation Biology 7:562-568.

Peters, K. A. 1999. Swainson's warbler (*Limnothlypis swainsonii*) habitat selection in a managed bottomland hardwood forest in South Carolina. M. S. Thesis. North Carolina State Univ., Raleigh. 89pp+appendices.

Philippi, T. E., P. M. Dixon, and B. E. Taylor. 1998. Detecting trends in species composition. Ecological Applications 8:300-308.

Russell, K. R., and H. G. Hanlin. 1999. Aspects of the ecology of worm snakes (*Carphophis amoenus*) associated with small isolated wetlands in South Carolina. Journal of Herpetology 33:343-347.

Russell, K. R. 2000. Effects of upland forest management on small isolated wetland herpetofauna in the Coastal Plain of South Carolina. Ph.D. Dissertation. Clemson University, Clemson, SC. 110pp.

Ryan, T. J., T. Philippi, Y. A. Leiden, M. E. Dorcas, T. B. Wigley, AND J. W. Gibbons. In preparation. Monitoring herpetofauna in a managed forest landscape: Effects of habitat types and census techniques.

SAS Institute. 1990. SAS/STAT user's guide. Version 6. SAS Institute, Cary, North Carolina, USA.

Semlitsch, R. D., and J. R. Bodie. 1998. Are small, isolated wetlands expendable? Conservation Biology 12:1129-1133.

Smith, E.P. 1998. Randomization methods and the analysis of multivariate ecological data. Environmetrics 9:37-51.

Tuberville, T. D., J. R. Bodie, J. Jensen, L. LaClaire, and J. W Gibbons. 2000. Apparent decline of the southern hog-nosed snake (*Heterodon simus*). Journal of the Elisha Mitchell Scientific Society 116: 19-40.

Turner, J. C. 1998. Influences of hardwood stand size and adjacency on breeding bird communities in an intensively managed pine landscape in the South Carolina Lowcountry. M.S. Thesis, North Carolina State University, Raleigh. 126pp.

U.S. Census Bureau. 2000. National population projections. <http://www.census.gov/population/www/projections/natproj.html>

U.S. Department of Commerce. 1992. Statistical abstract of the United States. 112th edition. U.S. Government Printing Office, Washington, DC.

USDA Forest Service. 2000. Southern Region Forest Inventory and Analysis Home Page. USDA Forest Service, Southern Research Station. <http://www.srsfia.usfs.msstate.edu/Fiab.htm>

Van Deusen, P.C. 1999. Multiple solution harvest scheduling. Silva Fennica 33(3): 207–216.

Whitcomb, R. F., C. S. Robbins, J. F. Lynch, B. L. Whitcomb, M. K. Klimkiewicz, and D. Bystrak. 1981. Effects of forest fragmentation on the avifauna of the eastern deciduous forest. Pages 125-205 *in* R. L. Burgess and D. M. Sharpe, eds. Forest island dynamics in man-dominated landscapes. Springer-Verlag, New York.

Table 1. Area of industry ownership (thousands of acres) by forest type in 13 southern states[1] (from data in USDA Forest Service 2000).

Forest type	Total forest area	Area of industry ownership	Percent of industry ownership	Percent of total forest area
Softwood	64247.6	21896.1	54.7	34.1
White-red-jack pine	691.9	27.3	0.1	3.9
Spruce-fir	13.1	0.0	0.0	0.0
Longleaf-slash	13541.9	5118.7	12.8	37.8
Loblolly-shortleaf	50000.7	16750.1	41.8	33.5
Hardwood	136133.4	18068.1	45.1	13.3
Oak-pine	29973.8	5568.9	13.9	18.6
Oak-hickory	74201.8	6279.0	15.7	8.5
Oak-gum-cypress	28481.3	5945.9	14.9	20.9
Elm-ash-cottonwood	2420.0	260.0	0.6	10.7
Maple-beech-birch	1056.6	14.3	0.0	1.4
Nontyped	354.7	62.8	0.2	17.7
Total	200735.7	40027	100.0	19.9

[1]States include Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Mississippi, Oklahoma, North Carolina, South Carolina, Tennessee, Texas, and Virginia.

Table 2. Relative abundance (detections/point) of the 70 most common bird species identified in each study landscape.

Ashley/Edisto landscape		Woodbury/Giles Bay landscape	
Species[1]	Relative abundance	Species	Relative abundance
Blue-gray gnatcatcher	0.32	Blue-gray gnatcatcher	0.38
Red-eyed vireo	0.26	Prothonotary warbler	0.27
Acadian flycatcher	0.25	Acadian flycatcher	0.25
Pine warbler	0.25	Northern parula	0.24
White-eyed vireo	0.24	Carolina wren	0.20
Northern parula	0.21	Northern cardinal	0.18
Great crested flycatcher	0.19	White-eyed vireo	0.18
Northern cardinal	0.18	Carolina chickadee	0.15
Common yellowthroat	0.17	Eastern tufted titmouse	0.10
Hooded warbler	0.17	Red-eyed vireo	0.09
Eastern tufted titmouse	0.17	Yellow-billed cuckoo	0.09
Eastern towhee	0.16	Indigo bunting	0.08
Carolina wren	0.15	Summer tanager	0.08
Yellow-breasted chat	0.11	Common grackle	0.08
Carolina chickadee	0.10	American redstart	0.08
Summer tanager	0.10	Great crested flycatcher	0.07
Prairie warbler	0.09	Pine warbler	0.07
Yellow-billed cuckoo	0.08	Prairie warbler	0.06
Red-bellied woodpecker	0.07	Yellow-breasted chat	0.06
Prothonotary warbler	0.06	Brown-headed cowbird	0.05
Yellow-throated vireo	0.06	Common yellowthroat	0.05
Eastern wood-pewee	0.05	Hooded warbler	0.05
Kentucky warbler	0.05	Eastern towhee	0.11
Worm-eating warbler	0.05	Red-bellied woodpecker	0.05
Downy woodpecker	0.04	Ovenbird	0.04
American crow	0.03	Swainson's warbler	0.04
Brown-headed cowbird	0.03	Yellow-throated vireo	0.03
Bluejay	0.03	Yellow-throated warbler	0.03
Indigo bunting	0.03	Downy woodpecker	0.03
Ovenbird	0.03	Mourning dove	0.03
Yellow-throated warbler	0.03	Blue grosbeak	0.03
Brown-headed nuthatch	0.02	Blue jay	0.02
Gray catbird	0.02	Eastern wood-peewee	0.02
Myrtle warbler	0.02	Great egret	0.02
Pileated woodpecker	0.02	Orchard oriole	0.02
Red-headed woodpecker	0.02	Eastern kingbird	0.02
White-breasted nuthatch	0.02	American crow	0.01
Wood thrush	0.02	Chimney swift	0.01
American goldfinch	0.01	Brown-headed nuthatch	0.01
American redstart	0.01	Kentucky warbler	0.01
American robin	0.01	Little blue heron	0.01
American woodcock	0.01	Pileated woodpecker	0.01
Bachman's sparrow	0.01	Brown thrasher	0.01
Barred owl	0.01	Eastern bluebird	0.01

Table 2.Continued.

Ashley/Edisto landscape		Woodbury/Giles Bay landscape	
Species[1]	Relative abundance	Species	Relative abundance
Black-and-white warbler	0.01	Wood thrush	0.01
Blue grosbeak	0.01	Fish crow	0.01
Brown thrasher	0.01	Northern mockingbird	0.01
Black-throated blue warbler	0.01	Ruby-throated hummingbird	0.01
Black-throated green warbler	0.01	Wood duck	0.01
Chipping sparrow	0.01	Black-and-white warbler	<0.01
Common grackle	0.01	Field sparrow	<0.01
Common tern	0.01	Green heron	<0.01
Chuck-will's-widow	0.01	Hairy woodpecker	<0.01
Eastern bluebird	0.01	Northern bobwhite	<0.01
Eastern kingbird	0.01	Great blue heron	<0.01
Fish crow	0.01	Red-shouldered hawk	<0.01
Gray-cheeked thrush	0.01	Wild turkey	<0.01
Great horned owl	0.01	Barred owl	<0.01
Green heron	0.01	Bachman's sparrow	<0.01
Hairy woodpecker	0.01	Blackpoll warbler	<0.01
Hermit thrush	0.01	Brown creeper	<0.01
House wren	0.01	Common nighthawk	<0.01
Little blue heron	0.01	Gray catbird	<0.01
Mourning dove	0.01	Louisiana waterthrush	<0.01
Northern bobwhite	0.01	Swainson's thrush	<0.01
Northern mockingbird	0.01	Tree swallow	<0.01
Northern waterthrush	0.01	Turkey vulture	<0.01
Orchard oriole	0.01	Worm-eating warbler	<0.01
Painted bunting	0.01	Yellow-crowned night heron	<0.01
Rose-breasted grosbeak	0.01	Yellow-shafted flicker	<0.01

[1] Scientific names are presented in Appendix A

Table 3. The percentages of bird species in each study landscape by migratory status and habitat association.

Migratory/habitat status[1]	Ashley/ Edisto	Woodbury/ Giles Bay
Long-distance migrants	54[2]	58
Short-distance migrants	20	14
Residents	26	27
Forest interior species	20	20
Cavity/snag users	27	31

[1]Status based on information in DeGraaf and Rappole (1995), Hagan and Johnston (1992), Hamel (1992).
[2]Percentage of 70 most common species.

Table 4. Bird species found within the 2 study landscapes that have Partners In Flight scores ≥20 for Physiographic Region 3 (Atlantic Coastal Plain) or are on the national "watch list."

Species[1]	Regional Score[2]	Watch List Score
Acadian flycatcher	20	
Bachman's sparrow	30	24
Brown-headed nuthatch	27	21
Chimney swift	20	
Chuck-will's-widow	21	19
Eastern towhee	20	
Hooded warbler	23	
Kentucky warbler	20	19
Louisiana waterthrush	21	
Northern bobwhite	22	
Northern parula	23	
Painted bunting	23	
Prairie warbler	23	20
Prothonotary warbler	22	21
Swainson's warbler	27	24
White ibis	20	
Wood thrush	24	20
Worm-eating warbler	23	21
Yellow-billed cuckoo	21	
Yellow-throated warbler	22	

[1]Scientific names are presented in Appendix A.
[2]Scores taken from Colorado Bird Bird Observatory (1998).

Table 5. Relationships between presence of selected bird species in managed forest landscapes in South Carolina and microhabitat and landscape variables as determined through logistic regression (adapted from Mitchell et al., *in review*).

		Microhabitat[1] model				Landscape model					Combined model				
Species[2]	*n*[3]	Slope	Variable[4]	*C*	*D*	slope	Variable	Scale[5] (m)	*C*	*D*	Slope	Variable	Scale (m)	*C*	*D*
Long-distance Migrants															
ACFL	104	+	overht	76.5	0.55	+	mean age	79	83.1	0.67	+	mean age	79	83.1	0.67
						-	% pine	8			-	% pine	8		
AMRE	32	+	overht	91.7	0.84	-	% pine	8	82.8	0.73	-	% pine	8	82.8	0.73
		-	vdl												
		-	pba												
BAWW	3	+	vines	95.6	0.91	X	X	X	X	X	X	X	X	X	X
		+	pba												
BGGN	114	+	overht	73.2	0.47	-	% pine	79	57.9	0.34	-	% pine	79	57.9	0.34
		-	vdh												
HOWA	47	+	overht	78.1	0.57	-	% pine	491	81.1	0.62	+	vines		88.6	0.77
		+	vines								-	% pine	491		
											+	SD age	20		
INBU	68	-	overht	80.3	0.61	-	mean age	8	88.0	0.76	-	CC		85.2	0.71
		-	CC			+	SD age	20			-	mean age	8		
KEWA	10	X	X	X	X	+	SD age	177	79.2	0.60	+	SD age	177	79.2	0.60
NOPA	120	+	overht	78.1	0.60	+	mean age	962	84.7	0.70	+	mean age	962	84.7	0.70
		-	pba												
OVEN	37	-	vines	77.9	0.63	-	MI age	314	86.9	0.74	+	pba		86.2	0.73
		+	pba			+	% pine	2			+	dh2o			
						+	dh2o				-	MI age	2		

Table 5. Continued.

		Microhabitat[1] model				Landscape model					Combined model				
Species[2]	*n*[3]	Slope	Variable[4]	*C*	*D*	slope	Variable	Scale (m)	*C*	*D*	Slope	Variable	Scale (m)	*C*	*D*
PRAW	58	-	overht	84.5	0.69	+	MI type	2827	82.2	0.65	-	overht		83.2	0.67
		-	vines			-	mean age	20			+	% pine	20		
		+	vdh			+	% pine	8							
PROW	93	+	overht	86.7	0.74	+	mean age	8	94.2	0.89	+	mean age	8	94.2	0.89
		-	midht			-	% pine	79			-	% pine	79		
		+	hwba												
		-	pba												
REVI	78	+	overht	80.8	0.62	+	mean age	8	72.6	0.48	+	overht		80.8	0.62
		-	vdl								-	vdl			
SWWA	32	+	vines	78.8	0.58	-	mean age	2	79.0	0.60	+	CC		90.6	0.81
		+	CC			-	% pine	20			-	mean age	2		
											-	MI age	79		
											-	% pine	20		
WOTH	23	X	X	X	X	+	% pine	1963	69.8	0.41	+	% pine	1963	69.8	0.41
YBCH	39	-	overht	85.3	0.71	+	MI age	314	93.3	0.87	-	overht		92.4	0.85
		-	hwba			-	mean age	2			+	MI age	314		
						-	mean age	1257			-	mean age	1257		
Short-distance Migrants															
COYE	69	+	vdl	84.7	0.70	+	% pine	2	67.0	0.51	-	CC		83.1	0.67
		-	CC								+	% pine	2		
		-	hwba												
PIWA	56	X	X	X	X	+	mean age	2376	85.6	0.72	+	mean age	2376	85.6	0.72
						+	% pine	2			+	% pine	2		

Table 5. Continued.

		Microhabitat[1] model				Landscape model					Combined model				
Species[2]	*n*[3]	Slope	Variable[4]	*C*	*D*	slope	Variable	Scale (m)	*C*	*D*	Slope	Variable	Scale (m)	*C*	*D*
Residents															
CACH	94	+	overht	71.9	0.44	X	X	X	X	X	-	vdl		62.1	0.25
		-	vdl												
NOCA	183	+	CC	62.5	0.37	-	MI age	1590	75.1	0.51	-	MI age	1590	75.1	0.51
RBWO	118	X	X	X	X	+	mean age	2827	68.2	0.37	+	mean age	3000	68.2	0.37

[1]Model fit is indicated by percent concordance (*C*; the number of times a bird was present and the probability of presence estimated by the model was greater than the probability of absence, divided by total observations) and Somer's *D* (*C* adjusted for the number of nonconcordant predictions, ranging from -1 to 1, indicating complete disagreement to complete agreement between predictions and observations).

[2] Species abbreviations are defined in Appendix A.

[3] *n*=number of sample points where species was present.

[4]Variable names included in the model are defined as follows. Mean age = mean forest age, % pine = percent pine overstory, MI = Moran's I statistic of spatial continuity (-1=highly fragmented, 1=homogenous), SD = standard deviation, dh2o = distance to nearest water, overht=overstory height, vines=#vines, cane=percent cane, vdl=low vertical density, vdh=high vertical density, midht=midstory height, CC=canopy closure, hwba=hardwood basal area, pba=pine basal area, X = no model generated.

[5]Scale = area (ha) of a circle centered on the sampling point in which the variable was measured.

Table 6. Density (number of birds/plot) of bird species among major habitat types on the Woodbury/Giles Bay landscape, 1996-1999.

Species[1]	Pine 0-5 yrs	Pine 6-15 yrs	Pine 16-20 yrs	Hdwd	Sheared Hdwd	Hdwd-Pine
Number of plots	116	148	173	147	60	74
Acadian flycatcher	0.086	0.243	0.272	0.306	0.400	0.230
American redstart	0.017	0.047	0.000	0.109	0.467	0.014
Blue-gray gnatcatcher	0.147	0.385	0.249	0.537	0.800	0.419
Brown-headed cowbird	0.095	0.027	0.058	0.048	0.017	0.041
Carolina chickadee	0.017	0.155	0.069	0.279	0.350	0.149
Carolina wren	0.078	0.270	0.197	0.082	0.383	0.311
Common grackle	0.017	0.034	0.035	0.034	0.617	0.000
Common yellowthroat	0.078	0.115	0.040	0.007	0.000	0.027
Downy woodpecker	0.000	0.068	0.012	0.034	0.017	0.027
Eastern towhee	0.095	0.135	0.150	0.054	0.033	0.162
Eastern tufted titmouse	0.009	0.095	0.127	0.150	0.150	0.095
Great crested flycatcher	0.009	0.122	0.087	0.054	0.100	0.068
Green egret	0.112	0.000	0.006	0.000	0.000	0.000
Hooded warbler	0.043	0.027	0.012	0.027	0.200	0.122
Indigo bunting	0.284	0.101	0.040	0.000	0.067	0.027
Mourning dove	0.060	0.034	0.023	0.014	0.000	0.027
Northern cardinal	0.052	0.216	0.162	0.163	0.367	0.257
Northern parula	0.060	0.399	0.052	0.395	0.467	0.149
Ovenbird	0.000	0.034	0.133	0.014	0.000	0.014
Pine warbler	0.000	0.088	0.139	0.027	0.000	0.108
Prairie warbler	0.138	0.074	0.058	0.020	0.017	0.054
Prothonotary warbler	0.026	0.459	0.029	0.435	0.717	0.122
Red-bellied woodpecker	0.009	0.074	0.046	0.027	0.117	0.027
Red-eyed vireo	0.017	0.108	0.052	0.136	0.133	0.135
Summer tanager	0.009	0.081	0.098	0.088	0.083	0.176
Swainson’s warbler	0.026	0.034	0.000	0.014	0.267	0.027
White-eyed vireo	0.069	0.196	0.214	0.088	0.383	0.270
White ibis	0.422	0.000	0.000	0.000	0.000	0.000
Yellow-breasted chat	0.172	0.122	0.012	0.000	0.017	0.000
Yellow-billed cuckoo	0.026	0.061	0.139	0.061	0.167	0.108
Yellow-throated vireo	0.009	0.054	0.017	0.054	0.050	0.014
Yellow-throated warbler	0.017	0.068	0.006	0.061	0.033	0.000
Total Density	2.802	4.155	2.780	3.463	6.533	3.392

[1]Includes only species with >20 detections; scientific names are presented in Appendix A.

Table 7. Species reaching maximum abundance (detections/point) in different habitats on Woodbury/Giles Bay landscape, 1996-1999.

Habitat type	No. points	Species[1]
Pine 0-5 years	116	Brown-headed cowbird
		Indigo bunting
		Mourning dove
		Prairie warbler
		White ibis
		Yellow-breasted chat
Pine 6-15 years	148	Common yellowthroat
		Downy woodpecker
		Great-crested flycatcher
		Yellow-throated vireo
Pine 16-20 years	173	Ovenbird
		Pine warbler
Hardwood (Not sheared)	147	Red-eyed vireo
		Eastern tufted titmouse
		Yellow-throated vireo
Hardwood (Sheared)	60	Acadian flycatcher
		American redstart
		Blue-gray gnatcatcher
		Carolina chickadee
		Carolina wren
		Common grackle
		Northern cardinal
		Northern parula
		Prothonotary warbler
		Red-bellied woodpecker
		Swainson's warbler
		Eastern tufted titmouse
Hardwood-pine	74	Eastern towhee
		Hooded warbler
		Summer tanager
		White-eyed vireo

[1]Scientific names of bird species are presented in Appendix A.

Table 8. Nest success for selected bird species in the Ashley/Edisto landscape, 1996-2000.

Species	Total nests	No. fledged	Percent fledged
Summer tanager	23	16	0.6957
Red-eyed vireo	10	5	0.5000
White-eyed vireo	34	17	0.5000
Indigo bunting	13	6	0.4615
Hooded warbler	52	23	0.4423
Acadian flycatcher	141	59	0.4184
Eastern towhee	24	9	0.3750
Northern cardinal	65	22	0.3385
Total	362	157	0.4337

[1]Scientific names are presented in Appendix A.

Table 9. Herpetofaunal species identified in major habitat types on the Woodbury/Giles Bay, 1996-1998.

Species	Upland wetland	Bottomland wetland	Mixed pine-hardwood	Pine plantation (10-15 yrs)	Pine plantation (0-3 yrs)
Anurans					
Acris gryllus	X		X		
Bufo quercicus	X		X	X	X
Bufo terrestris	X	X	X	X	X
Gastrophryne carolinensis	X		X	X	X
Hyla chrysoscelis	X	X		X	X
Hyla cinerea	X	X		X	X
Hyla femoralis	X	X	X	X	
Hyla gratiosa	X				
Hyla squirella	X				X
Pseudacris crucifer	X	X	X		
Pseudacris ocularis	X		X		
Rana catesbeiana	X	X			X
Rana clamitans	X	X		X	
Rana heckscheri		X			
Rana utricularia	X	X	X	X	X
Rana virgatipes	X			X	
Rana spp.	X				
Scaphiopus holbrooki				X	X
Salamanders					
Ambystoma mabeei	X			X	
Ambystoma opacum	X			X	X
Amphiuma means	X				
Eurycea longicauda		X			
Eurycea quadridigitata	X	X			
Notophthalmus viridescens	X	X		X	
Pseudotriton montanus					
Siren lacertina	X	X			
Crocodillians					
Alligator mississippiensis				X	
Turtles					
Chelydra serpentina	X	X			
Clemmys guttata	X	X	X		
Deirochelys reticularia	X				
Kinosternon bauri	X				
Kinosternon subrubrum	X	X	X	X	X
Pseudemys concinna		X			
Sternotherus odoratus	X	X		X	X
Terrapene carolina	X			X	
Trachemys scripta	X	X	X	X	X

Table 9. Continued.

Species	Upland wetland	Bottomland wetland	Mixed pine-hardwood	Pine plantation (10-15 yrs)	Pine plantation (0-3 yrs)
Lizards					
Anolis carolinensis	X		X	X	
Cnemidophorus sexlineatus	X		X	X	X
Eumeces fasciatus					
Eumeces inexpectatus	X		X	X	X
Eumeces laticeps			X	X	
Ophisaurus ventralis	X				
Scincella lateralis	X	X	X	X	X
Snakes					
Agkistrodon contortrix		X		X	X
Agkistrodon piscivorus	X				
Carphophis amoenus	X		X	X	X
Cemophora coccinea			X	X	X
Coluber constrictor	X		X	X	X
Crotalus horridus				X	
Diadophis punctatus	X			X	
Elaphe guttata	X				
Elaphe obsoleta	X		X	X	
Farancia abcura					X
Farancia erytrogramma	X				
Heterodon platirhinos					X
Heterodon simus					X
Lampropeltis getula	X	X	X		X
Lampropeltis triangulum	X		X	X	
Masticophis flagellum			X	X	X
Nerodia erythrogaster	X	X	X		X
Nerodia fasciata	X	X			X
Nerodia taxispilota		X			
Nerodia spp.	X				
Opheodrys aestivus		X			
Pituophis melanoleucus			X		
Seminatrix pygaea	X				
Storeria dekayi					
Thamnophis sauritus		X			
Thamnophis sirtalis					
Virginia striatula	X				
Virginia valeriae		X			

Table 10. South Carolina herpetofaunal Species of Special Concern on the Woodbury/Giles Bay landscape (adapted from Leiden et al. 1999).

Species Recorded	Potentially Occurring But Not Found
Pickerel frog (*Rana palustris*)	Flatwoods salamander (*Ambystoma cingulatum*)
Spotted turtle (*Clemmys guttata*)	Northern cricket frog (*Acris crepitans*)
Striped mud turtle (*Kinosternon baurii*)	Striped chorus frog (*Pseudacris triseriata*)
Southern hognose snake (*Heterodon simus*)	Pine barrens treefrog (*Hyla andersonii*)
Pine snake (*Pituophis melanoleucus*)	Gopher frog (*Rana capito*)
Black swamp snake (*Seminatrix pygaea*)	Mimic glass lizard (*Ophisaurus mimicus*)
Timber rattlesnake (*Crotalus horridus*)[1]	Island glass lizard (*Ophisaurus compressus*)
	Eastern green water snake (*Nerodia floridana*)
	Eastern coral snake (*Micrurus fulvius*)
	Eastern diamondback rattlesnake (*Crotalus adamanteus*)

[1]*Crotalus horridus* is a South Carolina Species of Special Concern only in mountain regions.

Table 11. The total number of amphibians and reptiles captured at 5 small isolated wetlands on the Woodbury/Giles Bay landscape, 1996-1998 (from Russell 2000). The first and second numbers represent unmarked individuals and recaptures, respectively.

	Wetland area (ha)					
Species	0.38	0.47	0.59	0.72	1.06	Total
AMPHIBIANS						
Salamanders						
Ambystoma mabeei[a]	6/0	3/0	0/0	0/0	0/0	9/0
Ambystoma opacum[a]	0/0	1/0	0/0	1/1	0/0	2/1
Eurycea quadidigitata	0/0	2/0	0/0	0/0	0/0	2/0
Notophthalmus viridescens[a]	2/0	10/2	0/0	6/0	1/0	19/2
Pseudotriton montanus[a]	95/5	12/1	25/0	2/1	11/1	145/8
Anurans						
Acris gryllus[a]	249/6	65/0	465/15	201/4	318/12	1298/37
Bufo quercicus[a]	52/12	5/3	7/0	2/0	21/1	87/16
Bufo terrestris[a]	336/82	329/57	557/117	241/78	535/112	1998/446
Gastrophryne carolinensis[a]	29/3	53/6	67/3	26/0	172/14	347/26
Hyla chrysocelis	1/0	1/0	1/0	0/0	1/0	4/0
Hyla cinerea[a]	1/0	1/0	1/0	1/0	2/0	6/0
Hyla femoralis[a]	10/0	1/0	1/0	4/0	3/0	19/0
Hyla squirella	1/0	1/0	1/0	0/0	1/0	4/0
Pseudacris crucifer	2/0	2/0	1/0	2/0	3/0	10/0
Rana catesbeiana[a]	4/1	4/0	17/4	3/0	7/1	35/6
Rana clamitans[a]	73/15	145/15	212/20	46/5	179/26	655/81
Rana palustris[a, b]	0/0	3/1	22/12	2/0	4/5	31/18
Rana utricularia[a]	324/16	1274/65	246/21	93/3	1267/43	3204/148
Rana virgatipes[a]	30/6	20/8	194/37	29/0	34/6	307/57
Scaphiopus holbrookii	1/1	0/0	2/0	1/0	2/0	6/1
Total Amphibians	1216/147	1932/158	1819/229	660/92	2561/221	8188/847
REPTILES						
Turtles						
Chelydra serpentina[a]	5/6	3/0	0/0	2/3	2/0	12/9
Clemmys guttata[a, b]	12/7	0/0	2/1	2/0	8/5	24/13
Deirochelys reticularia[a]	0/0	0/0	2/1	0/0	0/0	2/1
Kinosternon baurii[a, b]	1/0	0/0	3/0	0/0	0/0	4/0
Kinosternon subrubrum[a]	8/2	1/1	8/0	1/0	18/4	36/7
Sternotherus odoratus[a]	1/1	2/0	12/0	3/0	6/0	24/1
Terrapene carolina	0/0	9/0	3/0	5/4	2/1	19/5
Trachemys scripta[a]	1/2	0/0	6/0	0/0	8/8	15/10

Table 11. Continued.

Species	Wetland area (ha)					Total
	0.38	0.47	0.59	0.72	1.06	
Lizards						
Anolis carolinensis[a]	19/0	18/1	21/0	7/0	51/1	116/2
Cnemidophorus sexlineatus	0/0	6/0	2/0	27/1	1/0	36/1
Eumeces fasciatus[a]	1/0	3/0	2/0	2/0	1/0	9/0
Eumeces inexpectatus[a]	10/1	19/1	3/0	36/2	3/0	71/4
Eumeces laticeps[a]	12/1	12/1	6/0	21/1	14/0	65/3
Ophisaurus attenuatus	0/0	1/0	0/0	0/0	0/0	1/0
Ophisaurus ventralis	0/0	0/0	1/1	0/0	0/0	1/1
Scincella lateralis[a]	91/0	77/0	16/0	36/1	28/0	248/1
Snakes						
Agkistrodon contrortrix	0/0	0/0	0/0	0/0	1/0	1/0
Carphophis amoenus[a]	34/3	15/0	16/1	45/4	24/0	134/8
Cemophora coccinea[a]	1/0	6/0	8/0	10/2	3/2	28/4
Coluber constrictor[a]	4/0	10/0	14/0	3/0	13/1	44/1
Elaphe obsoleta[a]	0/0	0/0	0/0	2/0	0/0	2/0
Farancia abacura[a]	1/0	0/0	0/0	3/0	3/1	7/1
Heterodon platyrhinos	0/0	1/0	2/0	0/0	1/0	4/0
Lampropeltis getula	1/0	1/1	0/0	1/0	0/0	3/1
Lampropeltis triangulum	0/0	0/0	0/0	1/0	2/0	3/0
Masticophis flagellum	0/0	0/0	0/0	1/0	0/0	1/0
Nerodia erythogaster[a]	0/0	3/0	5/1	3/0	2/0	13/1
Nerodia fasciata[a]	4/0	1/0	1/0	2/0	1/0	9/0
Nerodia taxispilota[a]	3/0	2/1	2/0	1/0	2/0	10/1
Opheodrys aestivus	2/0	2/1	0/0	2/0	0/0	6/1
Seminatrix pygaea[a, b]	0/0	1/0	0/0	0/0	0/0	1/0
Storeria dekayi	0/0	1/0	0/0	1/0	2/0	4/0
Storeria occipitomaculata[a]	7/0	4/0	5/0	3/0	10/0	29/0
Thamnophis sauritus	0/0	0/0	2/0	1/0	0/0	3/0
Thamnophis sirtalis[a]	0/0	3/0	2/0	2/0	3/0	10/0
Virginia valeriae	1/0	2/0	0/0	0/0	0/0	3/0
Total Reptiles	219/23	203/7	144/5	223/18	209/23	998/76
Grand Total	1435/170	2135/165	1963/234	883/110	2770/244	9186/923

[a]Reproduction documented by the presence of larvae, hatchlings, recent metamorphs, or juveniles.

[b]South Carolina Department of Natural Resources Species of Special Concern (1995).

Table 12. Number of species captured, evenness index (*J'*), and Shannon diversity index (*H'*) for amphibian, reptile, and combined herpetofaunal communities from 5 small isolated wetlands and adjacent upland stands on the Woodbury/Giles Bay landscape (from Russell 2000).

Wetland area (ha)	Community	Species Captured	*J'*	*H'*[1]
0.38	Amphibians	17	0.651	0.801[a]
	Reptiles	21	0.686	0.907[a]
0.47	Amphibians	19	0.398	0.509[b]
	Reptiles	25	0.730	1.02[b]
0.59	Amphibians	16	0.649	0.781[a]
	Reptiles	24	0.884	1.22[d]
0.72	Amphibians	16	0.597	0.719[c]
	Reptiles	27	0.755	1.08[b,c]
1.06	Amphibians	17	0.523	0.644[d]
	Reptiles	25	0.794	1.11[c]

[1] Different letters within columns denote significant differences in communities of same type among wetlands ($p \leq 0.05$).

Table 13. Sorenson Coefficient of Community Similarity for herpetofaunal communities from 5 small isolated wetlands and adjacent upland stands on the Woodbury/Giles Bay landscape, 1996-1998 (from Russell 2000). Values closer to 1.0 indicate greater community similarity between wetlands.

	Wetland (ha)			
Wetland (ha)	0.38	0.47	0.59	0.72
0.38				
0.47	0.805			
0.59	0.795	0.786		
0.72	0.790	0.828	0.795	
1.06	0.825	0.837	0.878	0.871

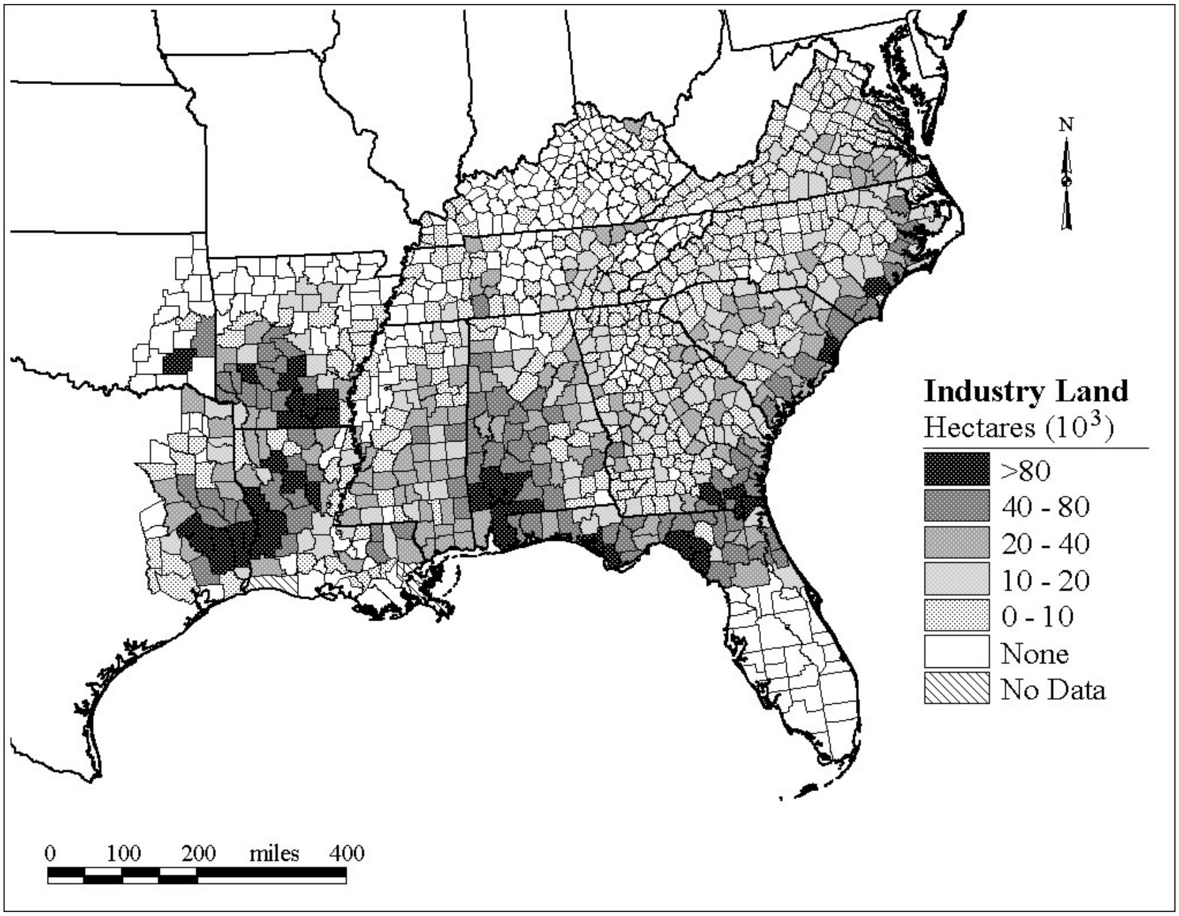

Figure 1. Area of industry ownership by county in 13 southeastern states (data derived from USDA Forest Service 2000).

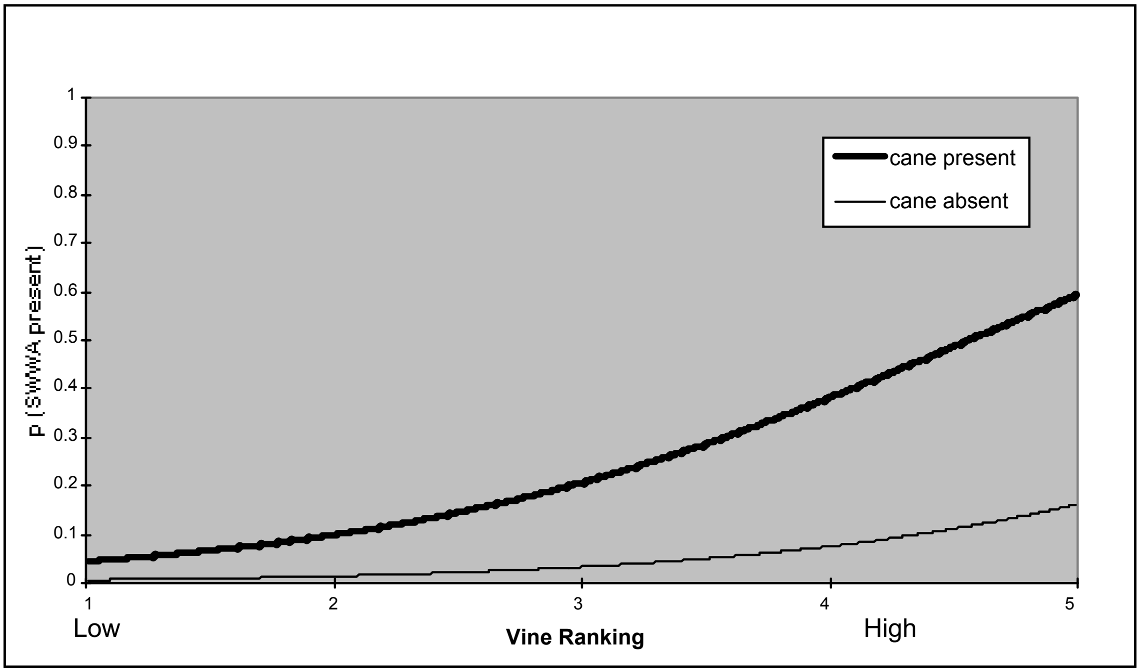

Figure 2. Probability of Swainson's warbler detection based on vine rankings and presence of switch cane (from Peters 1999).

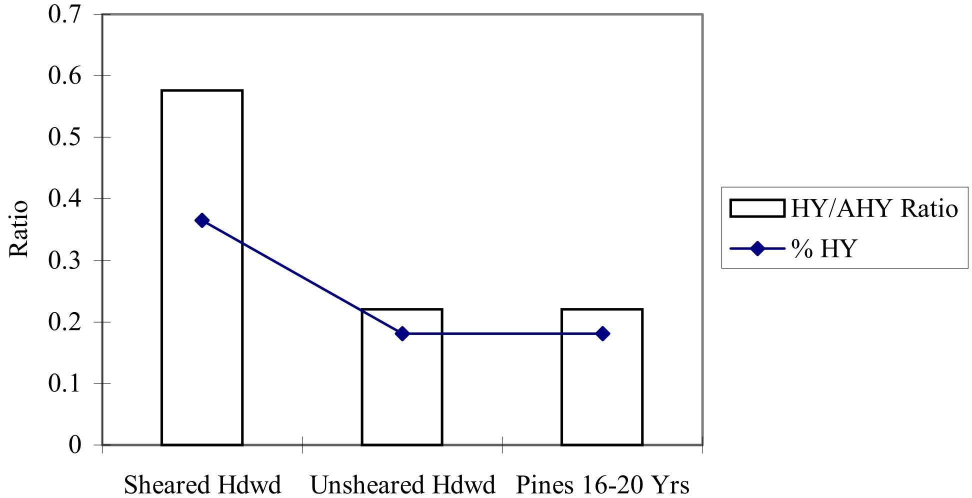

Figure 3. Hatching Year / After Hatching Year ratios and percent Hatching Year ratio for birds captured in 3 habitat types during the 1996-1998 breeding seasons on the Woodbury/Giles Bay landscape.

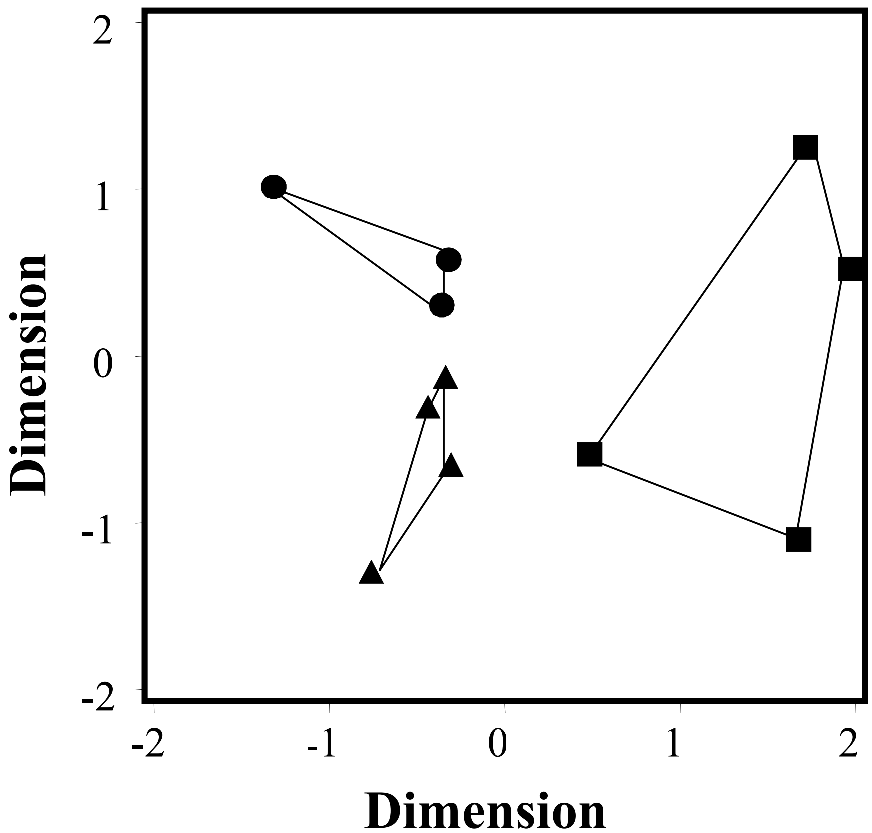

Figure 4. Herpetofaunal communities associated with the 3 upland habitat types on the Woodbury/Giles Bay landscape during 1997 in a two-dimensional nonmetric multidimensional scaling representation of the Bray-Curtis distances (adapted from Ryan et al., *in review*). Symbols are as follows: squares = pine stands 10-15 years old; circles = pine stands 0-5 years old; triangles = mixed pine-hardwood forests.

Appendix A. Scientific names and abbreviations for bird species referenced in the text and tables.

Species	Abbreviation	Scientific name
Acadian flycatcher	ACFL	*Empidonax virescens*
American crow	AMCR	*Corvus brachyrhynchos*
American goldfinch	AMGO	*Carduelis tristis*
American redstart	AMRE	*Setophaga ruticilla*
American robin	AMRO	*Turdus migratorius*
American woodcock	AMWO	*Scolopax minor*
Bachman's sparrow	BASP	*Aimophila aestivalis*
Barred owl	BAOW	*Strix varia*
Belted kingfisher	BEKI	*Ceryle alcyon*
Black-and-white warbler	BAWW	*Mniotilta varia*
Blackpoll warbler	BPWA	*Dendroica striata*
Black-throated blue warbler	BTBW	*Dendroica caerulescens*
Black-throated green warbler	BTNW	*Dendroica virens*
Blue grosbeak	BLGR	*Guiraca caerulea*
Blue jay	BLJA	*Cyanocitta cristata*
Blue-gray gnatcatcher	BGGN	*Polioptila caerulea*
Brown creeper	BRCR	*Certhia americana*
Brown thrasher	BRTH	*Toxostoma rufum*
Brown-headed cowbird	BHCO	*Molothrus ater*
Brown-headed nuthatch	BHNU	*Sitta pusilla*
Canada goose	CAGO	*Branta canadensis*
Carolina chickadee	CACH	*Poecile carolinensis*
Carolina wren	CARW	*Thryothorus ludovicianus*
Chimney swift	CHSW	*Chaetura pelagica*
Chipping sparrow	CHSP	*Spizella passerina*
Chuck-will's-widow	CWWI	*Caprimulgus carolinensis*
Common grackle	COGR	*Quiscalus quiscula*
Common tern	COTE	*Sterna hirundo*
Common yellowthroat	COYE	*Geothlypis trichas*
Downy woodpecker	DOWO	*Picoides pubescens*
Eastern bluebird	EABL	*Sialia sialis*
Eastern kingbird	EAKI	*Tyrannus tyrannus*
Eastern wood-pewee	EAWP	*Contopus virens*
European starling	EUST	*Sturnus vulgaris*
Field sparrow	FISP	*Spizella pusilla*
Fish crow	FICR	*Corvus ossifragus*
Gray catbird	GRCA	*Dumetella carolinensis*
Gray-cheeked thrush	GCTH	*Catharus minimus*
Great blue heron	GBHE	*Ardea herodias*
Great crested flycatcher	GCFL	*Myiarchus crinitus*
Great egret	GREG	*Ardea alba*
Great horned owl	GHOW	*Bubo virginianus*
Green heron	GRHE	*Butorides virescens*
Hairy woodpecker	HAWO	*Picoides villosus*
Hermit thrush	HETH	*Catharus guttatus*

Appendix A. Continued.

Species	Abbrev-iation	Scientific name
Hooded warbler	HOWA	*Wilsonia citrina*
House wren	HOWR	*Troglodytes aedon*
Indigo bunting	INBU	*Passerina cyanea*
Kentucky warbler	KEWA	*Oporornis formosus*
Laughing gull	LAGU	*Larus atricilla*
Little blue heron	LBHE	*Egretta caerulea*
Louisiana waterthrush	LOWA	*Seiurus motacilla*
Mourning dove	MODO	*Zenaida macroura*
Myrtle warbler	MYWA	*Dendroica coronata*
Northern bobwhite	NOBO	*Colinus virginianus*
Northern cardinal	NOCA	*Cardinalis cardinalis*
Northern mockingbird	NOMO	*Mimus polyglottos*
Northern parula	NOPA	*Parula americana*
Northern waterthrush	NOWA	*Seiurus noveboracensis*
Orchard oriole	OROR	*Icterus spurius*
Ovenbird	OVEN	*Seiurus aurocapillus*
Painted bunting	PABU	*Passerina ciris*
Pileated woodpecker	PIWO	*Dryocopus pileatus*
Pine warbler	PIWA	*Dendroica pinus*
Prairie warbler	PRAW	*Dendroica discolor*
Prothonotary warbler	PROW	*Protonotaria citrea*
Red-bellied woodpecker	RBWO	*Melanerpes carolinus*
Red-eyed vireo	REVI	*Vireo olivaceus*
Red-headed woodpecker	RHWO	*Melanerpes erythrocephalus*
Red-shouldered hawk	RSHA	*Buteo lineatus*
Rose-breasted grosbeak	RBGR	*Pheucticus ludovicianus*
Ruby-crowned kinglet	RCKI	*Regulus calendula*
Ruby-throated hummingbird	RTHU	*Archilochus colubris*
Eastern towhee	EATO	*Pipilo erythrophthalmus*
Summer tanager	SUTA	*Piranga rubra*
Swainson's thrush	SWTH	*Catharus ustulatus*
Swainson's warbler	SWWA	*Limnothlypis swainsonii*
Tree swallow	TRSW	*Tachycineta bicolor*
Eastern tufted titmouse	ETTI	*Baeolophus bicolor*
Turkey vulture	TUVU	*Cathartes aura*
White ibis	WHIB	*Eudocimus albus*
White-breasted nuthatch	WBNU	*Sitta carolinensis*
White-eyed vireo	WEVI	*Vireo griseus*
Wild turkey	WITU	*Meleagris gallopavo*
Wood duck	WODU	*Aix sponsa*
Wood thrush	WOTH	*Hylocichla mustelina*
Worm-eating warbler	WEWA	*Helmitheros vermivorus*
Yellow-billed cuckoo	YBCU	*Coccyzus americanus*
Yellow-breasted chat	YBCH	*Icteria virens*
Yellow-crowned night heron	YCNH	*Nyctanassa violacea*

Appendix A. Continued.

Species	Abbrev-iation	Scientific name
Yellow-shafted flicker	YSFL	*Colaptes auratus*
Yellow-throated vireo	YTVI	*Vireo flavifrons*
Yellow-throated warbler	YTWA	*Dendroica dominica*

Appendix B. Scientific names for amphibian and reptile species referenced in the text and tables.

Species	Scientific name
Anurans	
southern cricket frog	*Acris gryllus*
oak toad	*Bufo quercicus*
southern toad	*Bufo terrestris*
eastern narrow-mouthed toad	*Gastrophryne carolinensis*
gray treefrog	*Hyla chrysoscelis*
green treefrog	*Hyla cinerea*
pine woods treefrog	*Hyla femoralis*
barking treefrog	*Hyla gratiosa*
squirrel treefrog	*Hyla squirella*
spring peeper	*Pseudacris crucifer*
little grass frog	*Pseudacris ocularis*
bullfrog	*Rana catesbeiana*
green frog	*Rana clamitans*
river frog	*Rana heckscheri*
pickerel frog	*Rana palustris*
trug frogs	*Rana spp.*
southern leopard frog	*Rana utricularia*
carpenter frog	*Rana virgatipes*
eastern spadefoot	*Scaphiopus holbrooki*
Salamanders	
Mabee's salamander	*Ambystoma mabeei*
marbled salamander	*Ambystoma opacum*
two-toed amphiuma	*Amphiuma means*
long-tailed salamander	*Eurycea longicauda*
dwarf salamander	*Eurycea quadridigitata*
broken-striped newt	*Notophthalmus viridescens*
mud salamander	*Pseudotriton montanus*
greater siren	*Siren lacertina*
Crocodillians	
American alligator	*Alligator mississippiensis*
Turtles	
snapping turtle	*Chelydra serpentina*
spotted turtle	*Clemmys guttata*
chicken turtle	*Deirochelys reticularia*
striped mud turtle	*Kinosternon bauri*
eastern mud turtle	*Kinosternon subrubrum*
river cooter	*Pseudemys concinna*
stinkpot	*Sternotherus odoratus*
eastern box turtle	*Terrapene carolina*
pond slider	*Trachemys scripta*

Appendix B. Continued.

Lizards	
green anole	*Anolis carolinensis*
racerunner	*Cnemidophorus sexlineatus*
five-lined skink	*Eumeces fasciatus*
southeastern five-lined skink	*Eumeces inexpectatus*
broad-headed skink	*Eumeces laticeps*
slender glass lizard	*Ophisaurus attenuatus*
eastern glass lizard	*Ophisaurus ventralis*
ground skink	*Scincella lateralis*
Snakes	
copperhead	*Agkistrodon contortrix*
cottonmouth	*Agkistrodon piscivorus*
worm snake	*Carphophis amoenus*
northern scarlet snake	*Cemophora coccinea*
racer	*Coluber constrictor*
canebrake rattlesnake	*Crotalus horridus*
ringneck snake	*Diadophis punctatus*
corn snake	*Elaphe guttata*
rat snake	*Elaphe obsoleta*
mud snake	*Farancia abcura*
rainbow snake	*Farancia erytrogramma*
eastern hognose snake	*Heterodon platirhinos*
southern hognose snake	*Heterodon simus*
common kingnake	*Lampropeltis getulus*
milk snake	*Lampropeltis triangulum*
coachwhip	*Masticophis flagellum*
plain-bellied water snake	*Nerodia erythrogaster*
southern water snake	*Nerodia fasciata*
brown water snake	*Nerodia taxispilota*
water snakes	*Nerodia spp.*
rough green snake	*Opheodrys aestivus*
pine snake	*Pituophis melanoleucus*
swamp snake	*Seminatrix pygaea*
brown snake	*Storeria dekayi*
redbelly snake	*Storeria occipitomaculata*
eastern ribbon snake	*Thamnophis sauritus*
eastern garter snake	*Thamnophis sirtalis*
rough earth snake	*Virginia striatula*
smooth earth snake	*Virginia valeriae*