J. Field Ornithol., 70(3):310–320

EFFECTS OF AREA, ISOLATION, AND LANDSCAPE ON THE AVIFAUNA OF CAROLINA BAYS

LISA B. MAMO AND ERIC G. BOLEN
The University of North Carolina at Wilmington
Department of Biological Sciences
601 South College Road
Wilmington, North Carolina 28403 USA

Abstract.—Using mist nets, we examined the distribution of resident and migratory birds in nine Carolina bays (<1.0 to >80 ha) in Bladen County, North Carolina. We analyzed the influence of bay area, isolation, and landscape on species richness and relative abundance. Area accounted for greater than 60% of the variation in species richness among bays. Adjacent habitat also strongly influenced species richness (R^2 = 0.47). When considered individually, adjacent landscape was the only variable that weakly influenced relative abundance (R^2 = 0.28). The situation of bays within a broad habitat matrix and uniqueness as forested wetland depressions attracted a diversity of species. This study establishes Carolina bays as breeding habitat for several Neotropical migrants regarded as interior specialists and experiencing population declines throughout their ranges.

EFECTOS DEL ÁREA, AISLAMIENTO, Y DEL PAISAJE EN LA AVIFAUNA DE LAS BAHÍAS DE CAROLINA

Sinopsis.—Examinamos la distribución de aves residentes y migratorias en nueve bahías en Carolina (<1.0 a 80.0 >ha) en el Condado de Bladen en Carolina del Norte utilizando redes de niebla. Analizamos la influencia del área de la bahía, del aislamiente, y el paisaje en la riqueza de especies y la abundancia relativa. El área explicó más del 60% de la variación en la riqueza de especies entre bahías. Los hábitats adyacentes también influenciaron grandemente la riqueza de especies (R^2 = 0.47). El paisaje adyacente fué la única variable influenciando débilmente la abundancia relativa (R^2 = 0.28) al considerarse individualmente. La condición de bahías dentro de una matriz amplia de habitats y la cualidad única de depresiones anegadas forestadas atrajeron una diversidad de especies. Este estudio establece las bahías de Carolina como un habitat de anidaje para varias especies de migrantes neotropicales considerados como especialistas interiores y experimentando reducciones poblacionales a través de toda su distribucion.

Carolina bays are non-tidal, palustrine wetlands found in shallow, elliptical depressions with distinct sand rims along the Atlantic Coastal Plain (Fig. 1). Although they are among the least studied natural wetlands in the United States, increased degradation of forested wetlands in the southeastern U.S. has renewed interest in Carolina bays as potentially critical nesting and stopover habitat for birds. Unfortunately, bird population research has been primarily limited to general surveys of pocosin (a vegetation community that may be found within Carolina bays) avifauna (Lee 1986). The U.S. Fish and Wildlife Service recommendations for these fragile areas include establishing, "As a first priority, basic lists, relative population sizes, and extent of utilization by the animal species associated with pocosins and Carolina bays . . . " as well as emphasizing long-term studies (Sharitz and Gibbons 1982). This research represents the first attempt at defining a species list and habitat use by birds of Carolina bays. There is also a need for studies examining the impact the

FIGURE 1. Aerial view of three Carolina bays (ovals at top) in Bladen County, North Carolina. The middle bay was among those sampled in this study (Floodgate Bay). Note partial view of a water-filled bay on the left margin of the photo and, in the field at lower right, the sandy southeastern rim of an obliterated bay. Photo courtesy of Weyerhaeuser Company.

loss of Carolina bays might have on populations of Neotropical migrants breeding in the southeastern U.S.

Therefore, the purpose of this paper is to quantify (1) the species of birds occupying Carolina bays; (2) the influence of bay area, isolation, and landscape on avian species richness and relative abundance; and (3) the role of Carolina bays as wetland habitat for resident and migratory birds. The premise that these communities are influenced by bay characteristics was investigated by determining species number and relative abundance of birds in bays varying in size, isolation, and adjacent habitat.

STUDY AREA AND METHODS

This research was conducted in a 108-km^2 area centered within Bladen Lakes State Forest, Bladen County, North Carolina (Fig. 2). Sites were selected based on the following criteria: 1) accessibility, both from major roads and among study site secondary trails; 2) met structural definition of Carolina bay (elliptical shape, distinct sand rim, and NW-SE orientation); 3) evergreen shrub-forest vegetation (High pocosin-Bay forest as defined below); 4) peat soil; 5) landowner permission; 6) size class (small <1.0–5.0 ha, medium 10–35 ha, large 40–100 ha); 7) no recent disturbance; and 8) adjacent habitat: pine plantation or clear-cut. Nine bays were selected in three size classes from aerial soil survey maps (1:24,000, Leab 1990) and measured by digital planimeter (Table 1). The number of bays selected for study was limited by the ability of a single researcher to access, properly sample and analyze in the course of this study. Because of the difficulty in locating bays in the study area that met all the criteria, both Norris and Chinquapin were selected despite the fact that they had shorter pocosin shrubs and fewer canopy species than the other study sites. Silvicultural and land-use practices were determined from Forest Service and county records.

Vegetation.—There is considerable disagreement concerning what defines a pocosin-bay community (Lee 1986; Richardson 1983, 1991). For the purposes of this research, High pocosin and Bay forest were considered almost indistinguishable and were defined as an assemblage of shrub understory species and dominant canopy species that are associated with peat soils, rare incidence of fire, and frequent standing water. Each type includes the dominant shrubs Titi (*Cyrilla racemiflora*), Coast Pepperbush (*Clethra alnifolia*), Zenobia (*Zenobia pulverulenta*), Fetterbush (*Lyonia lucida*), Holly (*Ilex* spp.), Wax Myrtle (*Myrica* spp.), and Sheep Laurel (*Kalmia angustifolia*) and the canopy species Sweetbay (*Magnolia virginiana*), Red Bay (*Persea borbonia*), Lobolly Bay (*Gordonia lasianthus*), Sweet Spires (*Itea virginica*), Loblolly Pine (*Pinus serotina*), Sour Gum (*Nyssa sylvatica*), Red Maple (*Acer rubrum*), and Bald Cypress (*Taxodium ascendens*) (Ashton and Ashton 1979, Sharitz and Gibbons 1982, Weakley and Scott 1982, Weakley and Schafale 1991).

Mist netting.—Birds were mist-netted using black, 2.5 × 12 m nylon nets (30-mm mesh) in lanes 1.5-m wide during an 18-mo period (Jan-

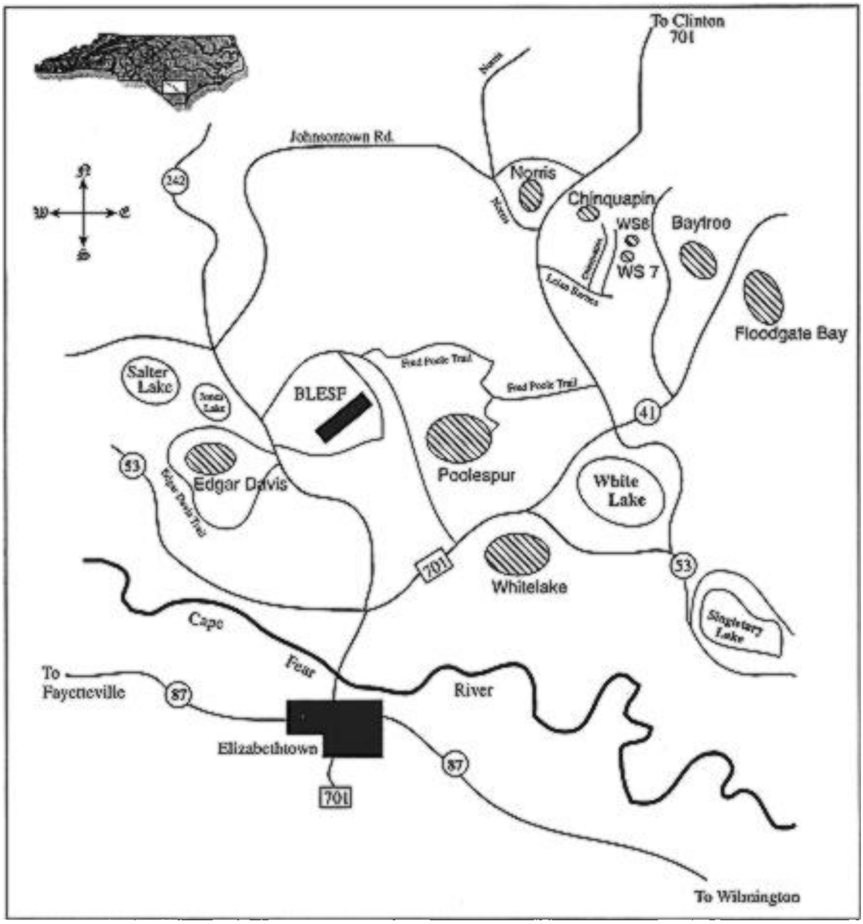

FIGURE 2. Cross-hatched ovals represent bays selected for study sites in Bladen County, North Carolina (not to scale).

uary 1995–July 1996). Net use was standardized (i.e., net effort (h) per area among sites, net dimensions, placement, arrangement, time of day, weather conditions) to minimize biases involved in using mist net data for measures of relative abundance (Jenni and Leuenberger 1996, Karr 1979, Mehlop and Lynch 1986, Ralph and Scott 1981, Remsen and Good 1996).

The total number of mist nets used was limited by the time required to access each bay, complete setup, and properly sample (remove birds, band, and release) three bays (small, medium, and large) in a single day. This schedule was necessary to sample the "same" migratory population in each size class. We were also limited by permit to five nets to be used

TABLE 1. Summary of independent and dependent variables measured for nine Carolina bays, Bladen Lakes State Forest, North Carolina.

Bay	Size (ha)	Species richness	Relative abundance (birds/m/net hour)	BAY[a] (km)	FOR[a] (km)	POCO[a] (km)	Land-use[a]
Floodgate	82.4	16	0.00038	0.20	0.00002	0	0
Whitelake	57.5	20	0.00046	0.29	2.35	1.33	0
Poolespur	49.4	18	0.00045	0.16	0.03	0.8	1
Edgar Davis	35.9	14	0.00046	0.13	1.72	0.64	1
Baytree	21.5	17	0.00018	0.10	1.41	1.60	0
Norris	10.9	7	0.00034	1.15	0.84	0.06	1
Chinquapin	2.8	10	0.00049	0.32	0.72	1.44	1
WS 7	0.85	10	0.00048	0.05	0.48	1.28	1
WS 6	0.82	8	0.00045	0.04	0.58	1.30	1

[a] See methods for definitions.

in a single banding period. Three nets were used in large bays, two in medium bays, and one in small bays (sampling effort proportional to area). After the first season, net operation (i.e., raising and lowering nets, removing birds) and banding improved, lanes were extended and the number of nets used increased by one (i.e., small 1–2, medium 2–3, large 3–4).

Nets were placed at the interior of the lane along a straight line. A two-hour sampling period was used in each bay. The first sampling period began 30 min after sunrise and the last period ended 1 h before sunset. The nets were checked approximately every 30 min. Birds that spend much of their time in the canopy, and that may have been excluded due to net height, were recorded for species list by vocalization or observation during the sample period. Each bay was sampled an equal number of times during periods of highest expected activity. During spring and summer, nets were closed during the hottest hours (1300–1500 h), and netting was not conducted on excessively windy or rainy days.

Nets were generally operated three consecutive days each week during migration and every 2 wk in mid-winter and late summer. As a result of varying water levels, total net hours among study sites were within an arbitrary 10%. This schedule was interrupted during the late winter and spring months when heavy rain and flooding made the bays inaccessible.

Captured birds were identified and banded with U.S. Fish and Wildlife Service aluminum bands. Sex and age were determined (where possible) by plumage and season. Breeding individuals exhibited evidence of cloacal protuberance or brood patch. Birds were categorized according to migratory status: long-distance Neotropical migrant (Neo), short-distance North American migrant (SD), stopover, non-breeding (en route) migrant (SO), Permanent resident (PR), winter resident (WR) and habitat specialization: edge (E)—nest and forage primarily along edge, edge-interior (EI)—territories within forest but utilize edge or more than one forest fragment and interior (I)—nesting within forest interior, rarely occurring near edge (Whitcomb et al. 1981, Freemark and Collins 1992) (Table 2). Raptors and scavengers were not included in the analysis because of their large territories, which often included several forest patches (Whitcomb et al. 1981). The avian community was defined to include only breeding species, whether permanent or migratory. Species that use bays as stopovers en route to breeding or wintering grounds, and winter residents are not considered in analyses of area-isolation effects, an approach consistent with previous research (Power 1972, Robbins et al. 1989).

We used the coefficient of determination (R^2) to determine all possible subsets of independent variables that best predict a dependent variable by linear regression. This selection method examines the model with the largest R^2 for each number of variables considered (SAS Institute Inc. 1985). Sample sizes were too small to consider individual species for statistical analysis. The dependent variables were (1) Species richness—total number of breeding species in each bay and (2) Relative abundance—number of birds per meter of net hour. Independent variables were (1) Area—bay size measured by planimeter in ha; (2) Isolation from Forest (FOR)—minimum distance (km) to nearest deciduous forest >10 ha (Robbins et al. 1989); (3) Isolation from Pocosin (POCO)—minimum distance (km) to nearest pocosin >50 ha outside of Carolina bays; (4) Isolation from Bay (BAY)—minimum distance (km) to nearest Carolina Bay; (5) Landscape composition—adjacent land-use practice (e.g., Best et al. 1995)—represented by dummy variable: 1 silvicultural, 0 if otherwise.

Edge effect was not directly tested in this study. Adequate indices to account for the nuances of landscape composition are not yet available. The landscape variable used in this research is meant to give some general indication of matrix influence.

We used correlation matrices to test for collinearity among variables. Residual plots validated constant variance assumption and normal distribution was tested by box plots.

RESULTS

Mist netting.—A total of 336 birds, of 51 species, was banded in 758 net hours. Thirty-six species were considered breeders. Long-distance Neotropical migrants composed 29% of all species recorded. Seventy percent of all species whose ranges and habitats include temperate forest in southeastern North Carolina were detected in Carolina bays (excluding those species whose ranges are very large and include other forest types, and whose habits preclude mist net capture). Area-sensitive interior specialists composed 40% of all recorded species. Of these species, those considered of priority status for Carolina bays by Partners in Flight included: Acadian Flycatcher (see Table 2 for Scientific names), Wood Thrush, American Redstart, Worm-eating Warbler, Hooded Warbler, and Swainson's Warbler. Several of the bays served as stopover habitat for nonbreeding migrants, including Veery, Magnolia Warbler, Black-throated Blue Warbler, and Ovenbird. Four Common Yellowthroats and Hooded Warblers, were captured in the same bay in successive years. The Hooded Warblers are considered a long-distance migrant species.

The majority of Neotropical migrants including such species as Wood Thrush and Red-eyed Vireo, were present only in the largest bays sampled. Two exceptions were the Great Crested Flycatcher, which may be more dependent on the availability of trees for cavity nesting, and the American Redstart, which was recorded in the smallest, but relatively unisolated (≤20 m) bays.

Species richness.—Among variables considered individually, area accounted for almost 60% of the variation in species richness among bays ($R^2 = 0.59$, $P = 0.01$). Adjacent habitat also exerted a relatively strong influence on species richness ($R^2 = 0.47$). The set of variables with the highest correlation coefficient, area and distance from pocosin habitat, provided the strongest relationship with species number ($R^2 = 0.89$, $P =$

0.007). Non-significant improvement occurred with the addition of remaining variables.

Relative abundance.—When considered individually, adjacent landscape was the only variable that weakly influenced relative abundance (R^2 = 0.28), P = 0.14. This improved with the addition of area (R^2 = 0.41).

DISCUSSION

The strength of the species-area relationship is well documented by earlier studies of habitat islands (Galli et al. 1976, Whitcomb et al. 1981, Ambuel and Temple 1983, Blake and Karr 1987, Robbins et al. 1989). Both bay area and distance to pocosin habitat worked together to influence species number in Carolina bays. Species apparently respond to pocosin located close by (<50 m) rather than strict recognition of Carolina bays as distinct habitat islands. Adjacent habitat played a large role in relative abundance. This seems reasonable considering those birds contributing greatest to abundance were edge and generalist species such as Carolina Wren, Northern Cardinal, Gray Catbird, and Common Yellowthroat.

Individual species.—We recorded the presence of many of the same edge-interior species one would expect from a shrub-dominated habitat. However, several stopover migrants known to be interior specialists (e.g., Black-throated Blue Warbler, Magnolia Warbler, Veery), as well as interior breeders (e.g., Swainson's Warbler, Wood Thrush, Worn-eating Warbler, Acadian Flycatcher), were recorded in several bays. Two Hooded Warbler individuals confirmed breeding site fidelity as well. Carolina bays have been delineated as priority habitat by Partners in Flight of North Carolina for species of special concern including moderate priority species: Gray Catbird, White-eyed Vireo; high priority: Prothonotary Warbler, Prairie Warbler, Great Crested Flycatcher, Yellow-billed Cuckoo, Acadian Flycatcher, Eastern Wood-Pewee, and very high priority: Worm-eating Warbler, Swainson's Warbler and Hooded Warbler (Boynton et al. 1995). All of these species were recorded in the study area.

The situation of Carolina bays in a broad habitat matrix as well as their uniqueness as wetland depressions, attracted a diversity of species. Pine warblers (*Dendroica pinus*) are considered interior-breeding species and depend upon pine forest (Whitcomb et al. 1981, Freemark and Collins 1989). The embedding of bays within longleaf and loblolly pine plantation offer excellent breeding habitat. Worm-eating Warblers demand protected interiors for breeding provided by large bays, while the edges formed by the xeric rims allow foraging (Whitcomb et al. 1981, Freemark and Collins 1989). More common species such as the Gray Catbird and Common Yellowthroat thrive in this shrub community.

Conservation.—Do Carolina bays serve an important regional role as habitat for birds? Our results suggest both large and small bays are used by a diversity of species. Previous studies have shown in regions with larger or less-isolated forest, habitat islands such as small bays studied here can serve important functions, whether stopover (e.g., Martin 1980, Blake

TABLE 2. Species and number of individuals of bird species recorded in Carolina bays, Bladen County, North Carolina.

Species[a]	Number netted	Migratory[a] status	Habitat[b] specialization
Ruby-throated Hummingbird (*Archilochus colubris*)	2	Neo	EI
Yellow-billed Cuckoo (*Coccyzus americanus*)	3, 1[c]	Neo	EI
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	0[c]	PR	E
Red-bellied Woodpecker (*Melanerpes carolinus*)	0[c]	PR	I[d]
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	0[c]	WR	U[e]
Downy Woodpecker (*Picoides pubescens*)	0[c]	PR	EI
Hairy Woodpecker (*Picoides villosus*)	1	PR	I[d]
Northern Flicker (*Colaptes auratus*)	0[c]	PR	U[e]
Pileated Woodpecker (*Dryocopus pileatus*)	0[c]	PR	I[d]
Acadian Flycatcher (*Empidonax virescens*)	1	Neo	I[d]
Eastern Phoebe (*Sayornis phoebe*)	1	WR	E
Eastern Wood-Pewee (*Contopus virens*)	0[c]	Neo	EI
Great Crested Flycatcher (*Myiarchus crinitus*)	1	Neo	EI
Eastern Kingbird (*Tyrannus tyrannus*)	0[c]	Neo	E
Blue Jay (*Cyanocitta cristata*)	0[c]	PR	EI
Carolina Chickadee (*Parus carolinensis*)	15	PR	EI
Tufted Titmouse (*Parus bicolor*)	7	PR	EI
Brown-headed Nuthatch (*Sitta pusilla*)	1	PR	U[e]
Carolina Wren (*Thryothorus ludovicianus*)	25	PR	EI
Winter Wren (*Troglodytes troglodytes*)	2	WR	EI
Golden-crowned Kinglet (*Regulus satrap*)	14	WR	I
Ruby-crowned Kinglet (*Regulus calendula*)	24	WR	I
Blue-gray Gnatcatcher (*Polioptila caerulea*)	1	SD	EI[d]
Gray Catbird (*Dumetella carolinensis*)	27	PR	EI
Northern Mockingbird (*Mimus polygottos*)	0[c]	PR	EI
American Robin (*Turdus migratorius*)	1	PR	EI
Brown Thrasher (*Toxostoma rufum*)	1	PR	E
Veery (*Catharus fuscescens*)	0[c]	SO	I[d]
Gray-cheeked Thrush (*Catharus minimus*)	1	WR	I
Swainson's Thrush (*Catharus ustulatus*)	7	WR	I
Hermit Thrush (*Catharus guttatus*)	10	WR	U[e]
Wood Thrush (*Hylocichla mustelina*)	1	Neo	I[d]
White-eyed Vireo (*Vireo griseus*)	24	SD	EI
Blue-headed Vireo (*Vireo solitarius*)	1	WR	U[e]
Red-eyed Vireo (*Vireo olivaceus*)	2	Neo	EI[d]
Orange-crowned Warbler (*Vermivora celata*)	3	WR	U[e]
Black-throated Blue Warbler (*Dendroica caerulescens*)	3	SO	I[d]
Yellow-rumped Warbler (*Dendroica coronata*)	1	WR	U[e]
Magnolia Warbler (*Dendroica magnolia*)	4	SO	I
Pine Warbler (*Dendroica pinus*)	1	PR	I
Prairie Warbler (*Dendroica discolor*)	14	Neo	E
American Redstart (*Setophaga ruticilla*)	5	Neo	I[d]
Prothonotary Warbler (*Protonotaria citrea*)	12	Neo	EI
Worm-eating Warbler (*Helmitheros vermivorus*)	1	Neo	I[d]
Swainson's Warbler (*Limnothlypis swainsonii*)	2	SD	I

TABLE 2. Continued.

Species[a]	Number netted	Migratory[a] status	Habitat[b] specialization
Ovenbird (*Seiurus aurocapillus*)	1	SO	I[d]
Common Yellowthroat (*Geothlypis trichas*)	41	SD	EI
Hooded Warbler (*Wilsonia citrina*)	18	Neo	I[d]
Yellow-breasted Chat (*Icteria virens*)	1	Neo	E
Brown-headed Cowbird (*Molothrus ater*)	0[c]	PR	E
Common Grackle (*Quiscalus quiscula*)	1	PR	E
Summer Tanager (*Piranga rubra*)	0[c]	Neo	EI[d]
Dark-eyed Junco (*Junco hyemalis*)	2	WR	U[e]
Northern Cardinal (*Cardinalis cardinalis*)	13	PR	EI
Eastern Towhee (*Pipilo erythophthalmus*)	26	PR	E
Chipping Sparrow (*Spizella passerina*)	0[c]	WR	E
Fox Sparrow (*Passerella iliaca*)	1	WR	E
Swamp Sparrow (*Melospiza georgiana*)	5	WR	E
White-throated Sparrow (*Zonotricha albicollis*)	6	WR	E

[a] Migratory status: Neo = long-distance Neotropical migrant, SD = short-distance North American migrant, PR = permanent resident, SO = stopover (en route) migrant, WR = winter resident (Peterson 1980).

[b] Habitat specialization: E = edge species, EI = edge-interior species, I = interior specialist (Whitcomb et al. 1981).

[c] Observed.

[d] Species considered area sensitive (Freemark and Collins 1992).

[e] Unknown.

1986), foraging or nesting territory. Thus, a range of different sized preserves, each serving specific functions may help to minimize the effects of loss of large, contiguous forest (Butcher et al. 1981, Whitcomb et al. 1981). Our study sites serve a role as breeding, foraging and stopover (non-breeders) habitat for several Neotropical migrant species. Many of these birds are interior species of special concern as a result of declining populations and habitat destruction throughout much of their range (Whitcomb et al. 1981, Robbins et al. 1989).

ACKNOWLEDGMENTS

We thank James Parnell and Martin Posey for their suggestions concerning the conduct of this research and William Powell and Thomas Padgett for their help with logistics and field techniques. Steven Jones, Daniel Singletary and Isabel Norris generously allowed us access to their property. Our work was supported, in part, by The Society of Wetland Scientists and a Cahill Research Award from the University of North Carolina at Wilmington.

LITERATURE CITED

AMBUEL, B., AND S. A. TEMPLE. 1983. Area-dependent changes in the bird communities and vegetation of southern Wisconsin forests. Ecology 64:1057–1068.

ASHTON, P. S., AND R. E. ASHTON. 1979. Biological survey of the Carolina bays of Bladen Lakes State Forest and Suggs Mill Pond, Bladen County, North Carolina. North Carolina Heritage Program and North Carolina Dept. of Parks and Recreation, Raleigh, North Carolina.

BEST, L. B., K. E. FREEMARK, J. J. DINSMORE, AND M. CAMP. 1995. A review and synthesis of habitat use by breeding birds in agricultural landscapes of Iowa. Am. Midl. Nat. 134:1–29.

BLAKE, J. G. 1986. Species-area relationship of migrants in isolated woodlots in east-central Illinois. Wilson Bull. 98:291–296.

———, AND J. R. KARR. 1987. Breeding birds of isolated woodlots: area and habitat relationships. Ecology 68:1724–1734.

BOYNTON, A., D. LEE, H. LEGRAND, M. LYNCH, AND H. VINSON. 1995. A management plan for neotropical migrant birds: 1995–2000. North Carolina Partners in Flight, North Carolina Wildlife Resources Commission, Raleigh, North Carolina.

BUTCHER, G. S., W. A. NEIRING, W. J. BARRY, AND R. H. GOODWIN. 1981. Equilibrium biogeography and the size of nature preserves: an avian case study. Oecologia 49:29–37.

FREEMARK, K., AND B. COLLINS. 1992. Landscape ecology of birds breeding in temperate forest fragments. Pp. 443–454, *in* J. M. Hagen III and D. W. Johnston, eds. Ecology and conservation of Neotropical migrant landbirds. Smithsonian Institution Press, Washington, D.C.

GALLI, A. E., C. F. LACK, AND R. T. T. FORMAN. 1976. Avian distribution patterns in forest islands of different sizes in central New Jersey. Auk 93:356–364.

JENNI, L., AND M. LEUENBERGER. 1996. Capture efficiency of mist nets with comments on their role in the assessment of passerine habitat use. J. Field Ornithol. 67:263–274.

KARR, J. R. 1979. On the use of mist nets in the study of bird communities. Inland Bird Band. 51:1–10.

LEAB, K. 1990. Bladen county soil survey. Soil Conservation Service, U.S. Dept. of Agric., Washington, D.C.

LEE, D. S. 1986. Pocosin breeding bird fauna. Am. Birds 40:1263–1273.

MARTIN, T. E. 1980. Diversity and abundance of spring migratory birds using habitat islands on the Great Plains. Condor 82:430–439.

MEHLOP, P., AND J. F. LYNCH. 1986. Bird/habitat relationships along a successional gradient in the Maryland coastal plain. Am. Midl. Nat. 116:225–239.

POWER, D. M. 1972. Number of bird species on the California islands. Evolution 26:451–463.

RALPH, C. J., AND J. M. SCOTT. 1981. Estimating numbers of terrestrial birds. Studies in Avian Biology No. 6.

REMSEN, J. V., JR. AND D. A. GOOD. 1996. Misuse of data from mist-net captures to assess relative abundance in bird populations. Auk 113:381–398.

RICHARDSON, C. J. 1983. Pocosins: vanishing wastelands or valuable wetlands? BioScience 33: 626-633.

———. 1991. Pocosins: an ecological perspective. Wetlands 11:335–353.

ROBBINS, C. S., D. K. DAWSON, AND B. A. DOWELL. 1989. Habitat area requirements of breeding forest birds of the middle Atlantic states. Wildl. Monogr. 103:1–34.

SAS INSTITUTE INC. 1985. SAS users's guide, version 6. SAS Institute Inc., Cary. 889 pp.

SHARITZ, R. R., AND J. W. GIBBONS. 1982. The ecology of southeastern shrub bogs (pocosins) and Carolina bays: a community profile. U.S. Fish and Wildlife Service, Div. of Biol. Sci., Washington, D.C.

WEAKLEY, A. S., AND S. K. SCOTT. 1982. Natural features summary and preserve design for Carolina bays in Bladen and Cumberland counties, North Carolina. Report submitted to the North Carolina Heritage Foundation, North Carolina Dept. of Natural Resources, and The North Carolina Nature Conservancy, Raleigh, North Carolina.

———, AND M. P. SCHAFALE. 1991. Classification of pocosins of the Carolina coastal plain. Wetlands 11:355–374.

WHITCOMB, R. F., C. S. ROBBINS, J. F. LYNCH, B. L. WHITCOMB, M. K. KLIMKIEWICZ, AND D. BYSTRAK. 1981. Effects of forest fragmentation on avifauna of deciduous forest. Pp. 123–205, *in* R. Burgess, and D. Sharpe, eds. Forest island dynamics in man-dominated landscapes. Springer-Verlag, New York.

Received 26 Mar. 1998; accepted 3 Nov. 1998.