Studies in Avian Biology No. 21:18–31, 2000.

EARLY AVIAN RESEARCH AT THE SAVANNAH RIVER SITE: HISTORICAL HIGHLIGHTS AND POSSIBILITIES FOR THE FUTURE

J. MICHAEL MEYERS AND EUGENE P. ODUM

Abstract. Avian biology and collection of baseline population data was a major part of the first decade (1951–1961) of field research at the Savannah River Site (SRS). Baseline inventories involving organisms and land-use types were part of the mission in the early contracts between the Atomic Energy Commission (now the Department of Energy) and the University of Georgia prior to the establishment of the Savannah River Ecology Laboratory (SREL) as a National Environmental Research Park Laboratory. About 27% of the SREL publications during this first decade dealt with birds. Since that time, research on the SRS landscape has expanded and broadened with less than 10% of the publications dealing with birds. SRS changed also from an agriculturally dominated area with ca. 40% open areas (fields, crops, pastures) to a timber-managed area with ca. 80% forests, 12% open areas, and 2% open water impoundments. Baseline breeding bird populations of the SRS in the 1950s were typical for the region with avian species richness and density increasing with the age and succession of the vegetation (0–26 species and densities of 0–741 pairs/km^2 for the habitats surveyed). During the first decade at the SRS, the resident game bird population of Northern Bobwhites (*Colinus virginianus*) increased and the Mourning Dove (*Zenaida macroura*) population, a migratory upland game bird, remained stable. Current avian research efforts, as well as new opportunities to reexamine the breeding bird populations and the landscape of SRS, will provide a better understanding of the potential causes of declines of neotropical migratory birds, declines of resident and migratory game birds, and how habitat influences invasions and extinctions of breeding birds in the region. Emphasis for future research and monitoring should be on neotropical migratory bird populations in decline (Yellow-billed Cuckoo, *Coccyzus americanus;* Eastern Wood-Pewee, *Contopus virens*; Wood Thrush, *Hylocichla mustelina*; Prairie Warbler, *Dendroica discolor*; and Painted Bunting, *Passerina ciris*), resident species in decline (e.g., Loggerhead Shrike, *Lanius ludovicianus*), certain species groups (e.g., waterfowl and wading birds), important habitat, and recent invasions and extinctions of breeding species. Old growth forested wetlands should be monitored because of the large number of neotropical migratory birds that depend on this habitat in the southeastern United States. A variety of survey techniques will be needed to determine population trends: line transects, call or song playbacks, roadside point surveys (call counts for game birds), aerial surveys, and presence or absence of species within stratified areas of SRS. The SRS provides opportunity for avian research at the landscape level with the potential to solve problems important to the survival of many bird populations as well as to increase our knowledge on how to manage and conserve our avian natural resources for the future.

Key Words: abundance, bird community, breeding, census, game, habitat, history, landscape, Neotropical migrants, species richness.

In 1951 a proposal for ecological studies on the Savannah River Site (SRS) submitted by Dr. Eugene P. Odum was approved by the U.S. Atomic Energy Commission (AEC). The AEC at that time was in the process of acquiring a 315-mi^2 (780-km^2) tract on the South Carolina side of the Savannah River just below Augusta, Georgia, for the construction of the Savannah River Plant (SRP) to produce weapons-grade nuclear material. Thus began a very long contract between the University of Georgia and the federal energy agency (now called the Department of Energy) for ecological research on SRS that continues to this day. In 1958 a permanent University of Georgia laboratory facility, now known as the Savannah River Ecology Laboratory (SREL), was established on the site. An account of the first proposals and the first decade of work by the University of Georgia team has been published (Odum 1987).

Research emphasis during the first decade was on (1) ecological succession on the abandoned farmland (about 40% of the area), (2) inventories of selected species or species groups as a basis for assessing the effects of plant operations and future changes that would come with the expected extensive land-use changes, and (3) radioecology, especially use of radionuclide tracers for elucidating ecological processes such as energy flow and food chain dynamics.

Bird censuses and the preparation of a detailed annotated checklist became a major part of the inventory phase of the program because Odum, three graduate students, and the first University of Georgia resident ecologist, Dr. Robert Norris, were competent field ornithologists. John Hatcher, Director of the SRS U.S. Forest Service program (the "Savannah River Project"), then engaged in large-scale pine tree planting on the abandoned agricultural fields, was an avid bird-

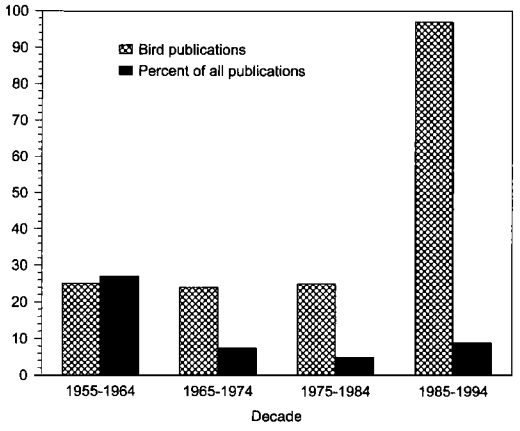

FIGURE 1. Trends in bird publications in comparison with all publications of the Savannah River Ecology Laboratory, Savannah River Site, South Carolina, 1955–1994.

watcher whose contributions are acknowledged in Norris (1963). In addition, the late Dr. Fred Denton, then a University of Georgia Medical School professor and leading authority on birds of the Augusta region, Dr. David Johnston (another Odum graduate student), and Gordon Hight, an amateur bird-bander from Rome, Georgia, contributed a great deal to the early bird studies.

An inventory of breeding birds conducted by Robert Pearson from 1952–1953 covered successive stages of ecological succession from old fields to mature forests (E. P. Odum, unpubl. report to AEC, 1953–1954). Robert Norris's censuses of floodplain and hammock broad-leaved forests followed in 1956–1957 (Norris 1963). Pearson was a student of S. Charles Kendeigh of the University of Illinois and was a research associate at SRS from 1952–1953. Norris obtained his M.S. with Odum at the University of Georgia and his Ph.D. with Dr. Joseph Grinnell at the University of California, Berkeley. He was the University of Georgia's first resident ecologist and worked full time on SRS from 1956–1958.

About 27% of the University of Georgia papers published during the first decade dealt with birds (Fig. 1), compared with <10% during the next three decades, as interests of the SREL staff shifted to other taxonomic groups such a cold-blooded vertebrates, and other research interests such as wetland ecology, biogeochemistry, ecotoxicology, and population genetics. Of the current SREL senior staff, only Dr. I. Lehr Brisbin has published extensively in ornithology, with waterfowl being a special interest because of the concern that migratory species might transport radioactive substances off the site (Brisbin 1991a). Among campus staff, Dr. H. Ronald Pulliam and his students and post-doctoral associates have recently completed an important study of the relationships between Bachman's Sparrow (considered to be a species of concern; see Appendix for scientific names of all species mentioned in text or tables) and alternative timber harvest programs (Pulliam et al. 1992, Dunning et al. 1995). Their models show how sparrow populations can be sustained with an economically feasible management program that includes both short- and long-rotation timber harvesting (Liu et al. 1995). Dr. David Krementz of the USGS Patuxent Wildlife Research Center and his students have recently completed research on survival and habitat relations of shrub-scrub birds of the SRS. In the last decade, Dr. Malcolm Coulter and Larry Bryan (see *this volume*) have published extensively on Wood Stork biology and management, which provided information for the recovery of this endangered bird. Recently, a new group of avian researchers from the Savannah River Institute and Warnell School of Forest Resources, The University of Georgia, and the Department of Biological Sciences, Clemson University, have published their work on breeding birds at the SRS (Kilgo et al. 1997,1998; Savannah River Site, SC, breeding bird censuses in Supplement to *Journal of Field Ornithology* from 1993–1997). As with bird studies everywhere, amateurs have contributed observations on the SRS, including Christmas Bird Counts.

To put all this in perspective of the 45-year history of SRS, we have prepared Table 1, which shows the distribution of the 171 SREL bird papers (out of 2,100 total, or 8%) published between 1955 and 1994 by the SREL. Most papers deal with single species or groups of related species of waterbirds, passerines, and game birds. Breeding birds censuses of the SRS have been published recently (not included above) and are valuable information for determining changes in SRS avian populations and communities since the 1950s.

EARLY AVIAN STUDIES AT THE SAVANNAH RIVER SITE

Detailed descriptions of the environment of the SRS may be found in White and Gaines (*this volume*). Much of the avian research at the SRS centered on avian populations and census methods, especially in the first years (see below). Ecological studies require good baseline data on the animal populations involved, which was the first objective of the research team under the direction of Odum. After completion of these studies, avian research branched into studies on

TABLE 1. DISTRIBUTION OF SAVANNAH RIVER ECOLOGY LABORATORY (SREL) PUBLICATIONS ON BIRDS (171 OR 8%) OUT OF 2,100 TOTAL PUBLICATIONS FROM 1953–1996

Publication groups	Number of publications (%)
By hierarchical levels	
Single species	112 (66)
Multiple species (usually families or related groups)	43 (25)
Population level (censuses)	5 (3)
Avian radioecology (see Brisbin 1991a)	10 (6)
Savannah River Site and region (Norris 1963)	1 (<1)
By taxonomic or ecological group	
Waterfowl	50
Passerines	30
Storks	16
Herons	10
Game birds	11
Birds of prey	9
Experimental birds	9
Woodpeckers	3
Avian Radioecology	10

physiology, energy flow, predation, radiation biology, and territoriality. Researchers concentrated on the old fields that developed after the abandonment of thousands of agricultural fields. These areas were simple systems that could be studied easily and that would provide an ecological understanding of the SRS. Two major research projects, energy flow through old-field consumers and selective predation of Savannah Sparrows, provided in-depth information on the old field habitat in relation to bird populations (Norris 1960, Odum et al. 1962).

OLD FIELD EMBERIZID STUDIES

The Savannah Sparrow population dominated the winter bird community of old fields at the SRS during in the 1950's (Norris 1963). Avian research concentrated on this species and provided important information for one of the major consumers in old fields (Johnston 1956, Norris and Hight 1957, Odum and Hight 1957; Norris 1960, 1961a,b; Odum 1960, Odum et al. 1962). Some of the methods developed and improved upon during this study are still in use today. For example, Norris (1961b) significantly improved the aging of birds using skull development (modified from Miller 1946) by eliminating cutting of the skin to view the skull. Most bird banders use this important method today. Investigators also demonstrated that effective use of mist nets could provide valuable data on bird populations, especially during winter (Odum and Hight 1957). However, it was Norris's intensive research of Savannah Sparrows that provided some fascinating results of the effects of predation on races of this species, as well as a novel method of studying birds confined in the wild under semi-natural conditions (Norris 1960).

Five geographical races of Savannah Sparrows co-existed in old field 3–412 of the SRS and intermingled in the same areas and habitat (Norris and Hight 1957, Odum and Hight 1957, Norris 1960). Norris (1960) enclosed a circular area (0.4 ha) of the old field and studied an experimental population of wing-clipped Savannah Sparrows from January to May, 1957. He called this beta-confinement in comparison to alpha-confinement, which he described as birds confined in small cages. Heavy predation began in early March and continued for weeks. Norris attributed the mortality mainly to owl predation, because of field signs and because an index of predation intensity was high on moonlit nights. It seemed also that a density-dependant relationship was apparent in the beta-confined population; however, this relationship was not a simple one when affected by the intensity of moonlight and on the particular method used to analyze the intensity of predation. Other observations by Norris indicated that the confined sparrow population was more vulnerable during nights of migratory unrest. During this time, flying sparrows gathered in the fields in preparation for their presumable northerly, nocturnal departure. Large fluttering flocks of sparrows may have attracted predators. Norris supported this with further evidence that remains of wing-clipped birds were found more than expected at the northern edge of the enclosure.

Norris's Savannah Sparrow study also demonstrated evidence of selective predation. A darker race of the Savannah Sparrow (*P. s. labradorius*), declined at a much slower rate than the other four races for the wing-clipped birds. One possible explanation of this was that dark races remained longer in the spring of 1956 (Norris and Hight 1957); however, in the spring of 1957, this was not true for *labradorius,* which migrated northward at the same period as other races (Norris 1960). Therefore delays in migratory unrest were not responsible for lower mortality. Although *labradorius* is darker than other races, it's doubtful that color had much effect on predation since it occurred at night. Comparison of dorsal coloration also provided no difference in protective coloration between the races. The *labradorius* race was the heaviest and most socially dominant of the five sparrow races. Its status, size, and moderate conspicuousness probably provided *labradorius* with increased ability to survive the winter.

Odum et al. (1962) contributed a functional

approach, through energy flow, to an ecological study by using the population level to elucidate the systems ecology of old fields. The three most important consumer groups of the fields were studied: old field mice (*Peromyscus polionotus*), Savannah Sparrows, and grasshoppers and crickets (*Melanoplus femur-rubrum, M. biliterous,* and *Oecanthus nigricornis*). The granivores, Savannah Sparrows and old field mice, required 10–50% of the annual seed crop in the fields to survive. In contrast, the herbivorous orthopterans required only 2–7% of the energy of the annual above ground standing crop. Energy flow in kilocalories m^{-2} yr^{-1}, however, was only 3.6 for the sparrows, almost double at 6.7 for the mice, and eight times at 25.6 for the orthoptera. Very little energy was channeled into production (2% for mice, 15% for grasshoppers, and very small amounts for sparrows in the form of fat deposits); most of the energy flow was required in the form of respiration to maintain the standing crop. Therefore, food was more likely to be limiting to granivores than to foliage-consuming herbivores in the old-field ecosystem. Odum et al. (1962) concluded that granivores in terrestrial ecosystems were intermediate between herbivores and carnivores in terms of density and energy flow.

Premigratory Fat and Departure of Hummingbirds

Norris et al. (1957) research on migration physiology was another important contribution of the 1950s avian studies. The opportunistic investigators studied a notable concentration of migrating Ruby-throated Hummingbirds on the SRS by marking, observing, and measuring fat gained during September and prior to their southerly departure. Mass, and particularly fat content, increased significantly after mid-September (Fig. 2). At the time of this study many doubted that birds, and especially hummingbirds, traveled nonstop across the Gulf of Mexico, but believed instead that they followed the coast. The heaviest hummingbirds in this study carried about 2 g of fat, which was calculated to be enough to migrate nonstop for 1,333 km, more than the distance across the Gulf of Mexico to Central America.

Territorial and Home Range Studies

Odum and Kuenzler (1955) developed methods of measuring home range and territory characteristics in birds, which was important to development of the concepts in home range and territory today. They followed singing males and plotted territories, the quantitative aspect of which had been relatively unexamined at that time. A result of the study was the concept of maximum territory versus utilized territory in birds. Its development used the observational-area curve, which was refined from the species-area curve used by ecologists. In all three species of birds studied they found that territory size was much smaller while adults were engaged in feeding nestlings than when the pair was engaged in nest building and incubation. This finding refuted the idea that territories are defended only for food resources.

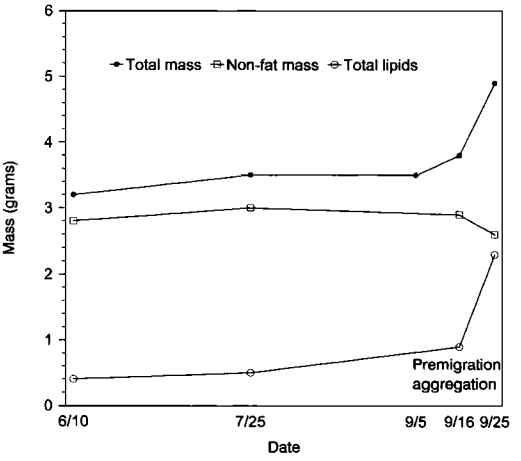

FIGURE 2. Changes in weight and fat deposition in Ruby-throated Hummingbirds in late summer and fall (redrawn from Norris et al. 1957).

Early Avian Radiation Study

Radiation effects on wildlife at the SRS provided some idea of the potential effects on humans. Norris (1958) conducted one of many of these studies on nesting Eastern Bluebirds. Birds were exposed to X-irradiation at a high dosage rate of 23.5 r/min while incubating in nest boxes. Most received 200 to 600 r. Although the sample size was small, adults and nestlings were suspected of having a much greater resistance to radiation. Embryos, however, were deemed more vulnerable to radiation.

BASELINE AVIAN STUDIES

An important component of the avian research conducted on SRS consisted of a series of censuses designed to develop baseline information on bird species abundances and distribution. Researchers selected avian study areas to represent all available successional habitat types in 1950 (Table 2), which are described in detail with photographs in Norris (1963). They surveyed 15 habitat types (N = 76 areas, total of 729 ha) with compass, tape, or pacing, and made maps for locating the positions of birds. Avian surveys were conducted from just before dawn for 2–5

TABLE 2. BREEDING BIRD DENSITIES BY HABITATS, SAVANNAH RIVER SITE, SOUTH CAROLINA, 1951–1953[a]

Habitats	N	Total area (ha)	Number of species	Mean density of breeding birds (pairs/km²)
Cultivated fields				
Corn	8	38	1	3
Cotton	6	31	0	0
Other	4	30	0	0
Uncultivated fields				
Horseweed	1	12	1	7
Aster	11	174	4	10
Broomsedge	11	136	1	22
Carolina bays	3	80	8	44
Forests				
Pine (young)	6	30	6	74
Pine-scrub oak	4	47	11	103
Scrub oak	2	16	9	136
Oak	4	24	16	170
Deciduous (no oak)	2	23	26	452
Creek flood plain	2	74	11	227
River swamp	1	10	23	682
Fence rows/house sites	11	4	11	741

[a] R. Pearson's unpublished data, as recorded in E. P. Odum's annual report to the Atomic Energy Commission, 1953–1954.

hr, depending on the habitat. In most habitats, observers spot-mapped singing males in the established area according to Williams's method (1936); however, in the swamp forest, surveyors established a line transect and mapped singing males within 100 m of the line (200-m strip). All areas were visited for five or more times, depending on habitat type, to establish the number of surveys necessary to account for 90% of the total observed bird populations. Thereafter for open fields, with sparse bird populations, only two surveys were necessary to meet the 90% rule, but four to five surveys were necessary in forested areas with relatively high avian densities.

Initially, observers conducted avian surveys from 1951–1953 (E. P. Odum, unpubl. report to AEC, 1952, 1953). Later, some additional surveys were conducted in swamp forests and Carolina bays by spot-mapping singing males (Norris 1957a,b) and in oak hammocks and swamp forests by recording singing birds along a transect (Norris 1963). Norris also compiled avian information into an annotated list (Norris 1963).

For game birds (e.g., Mourning Doves and Northern Bobwhite), road-side surveys were conducted along 32-km routes with stops every 1.6 km (Golley 1962). At each stop, up to four observers counted the number of calls independently for each species. Surveys began 30 min before sunrise and lasted 2 hr. Three routes were surveyed for 8 yr from 1952–1959.

These baseline studies revealed that breeding bird species richness (total number of species) and densities increased with succession of the plant community (Table 2). Below, we present breeding bird census results for plant successional stages arrayed from young to old.

FIELDS

Cultivated areas lacked any bird community. Of the 18 areas investigated during two years, only one, a corn field, was occupied by a Mourning Dove, which probably nested along the field edge (Table 3). Considerably more species (range 1–8) occupied uncultivated fields (N = 23) at low densities ($\bar{x}$ range from 7–22 pairs/km²; Table 2). Eastern Meadowlarks, Field Sparrows, and Prairie Warblers dominated uncultivated fields at relatively low densities (3–9 pairs/km²). Other birds, such as the Eastern Kingbird, Eastern Bluebird, and Orchard Oriole were found nesting in uncultivated fields; however, their home ranges extended well beyond the field boundary (Table 3).

BAYS

Species richness and breeding pair density of bay communities were relatively low (8 species and $\bar{x}$ = 44 pairs/km²) but higher than fields (Table 4). As would be expected, both terrestrial and aquatic species occupied Carolina bays. Eastern Meadowlarks (as in uncultivated fields), Red-winged Blackbirds, and Killdeer dominated bay habitat in 1952–1953 (Table 4). Least Bitterns, Purple Gallinules, King Rails, and Virginia Rails occurred at lower densities (1–4 pairs/km²) and frequencies (1 of 2 yr), and their presence probably depended on the amount of standing water during the breeding season. Later in 1957, Norris (1957b) found no change in breeding densities of bitterns, no breeding rails, and gallinules present but not breeding (Table 4). Norris also found much higher densities of Red-winged Blackbirds and much lower densities of Eastern Meadowlarks 5 yr later.

PINE AND PINE-OAK SCRUB FORESTS

Species richness and breeding bird density increase with the height and layering of the vegetation, which is true for most bird community changes associated with plant succession. Consequently, pine and pine-oak forests contained more breeding species and higher densities than early successional fields (Table 2). Pine-oak habitats (N = 4) with an additional vegetative layer contained higher species richness (11) and densities of breeding birds ($\bar{x}$ = 103 pairs/km²) than pine habitat that lacked the scrub oak layer (N

TABLE 3. BREEDING BIRD POPULATION DENSITIES (PAIRS/KM^2) BY SPECIES FOR CULTIVATED FIELDS, UNCULTIVATED FIELDS, AND PINE AND PINE-OAK SCRUB HABITATS, SAVANNA RIVER SITE, SOUTH CAROLINA, 1951–1953[a]

Species common name	Cultivated fields[b]	Uncultivated fields[c]		Pine and pine-oak scrub[d]	
	1951–1952	1952	1953	1952	1953
Mourning Dove	*[e]	*		*	*
Red-headed Woodpecker			*	*	
Eastern Wood-Pewee					3.5
Great Crested Flycatcher				*	*
Eastern Kingbird		*	*		
Blue Jay				*	*
Caroline Chickadee					+[f]
Tufted Titmouse					5.2
Brown-headed Nuthatch				4.0	3.5
Blue-gray Gnatcatcher				+	
Eastern Bluebird		*		*	
White-eyed Vireo				+	
Pine Warbler				23.7	30.4
Prairie Warbler		3.0	+	21.0	16.1
Summer Tanager				2.1	+
Northern Cardinal				5.2	12.3
Eastern Towhee				4.0	3.5
Bachman's Sparrow				11.9	10.6
Chipping Sparrow				2.7	+
Field Sparow		5.2	3.7		
Eastern Meadowlark		9.1	7.4		
Orchard Oriole			*		

[a] R. Pearson's unpublished data, as recorded in E. P. Odum's annual report to the Atomic Energy Commission, 1953–1954.
[b] Three sites totaling 99 ha.
[c] 23 sites totaling 302 ha in 1952 and 304 ha in 1953.
[d] 10 sites totaling 76 ha in 1952 and 8 sites totaling 56 ha in 1953 (pine trees harvested on two sites).
[e] Species nesting on the site but territory or home range extends beyond the site for an undetermined distance.
[f] Species with territories but <1.2 pairs/km^2.

= 6, species richness = 6, $\bar{x}$ = 74 pairs/km^2). Species common to southern pine forest dominated pine and pine-oak scrub (Table 3). Pine Warblers, a species dependent on southern pine forests, dominated the bird community in these habitats (23–30 pairs/km^2). Another parulid and neotropical migrant, the Prairie Warbler, was also common (16–21 pairs/km^2). The Bachman's Sparrow, which is also limited to southern pine forest, occurred at lower densities (11–12 pairs/km^2). Most of the species breeding in pine habitat were residents (e.g., Pine Warbler, Bachman's Sparrow, Carolina Chickadee, Tufted Titmouse, Brown-headed Nuthatch, Northern Cardinal, Eastern Towhee, and Chipping Sparrow). Only a few other neotropical migratory birds, such as the White-eyed Vireo and Summer Tanager, occurred in pine forests, and then at much lower densities (<3 pairs/km^2) than in other forests (Tables 3 and 5).

TABLE 4. BREEDING BIRD POPULATION DENSITIES (PAIRS/KM^2) BY SPECIES FOR CAROLINA BAYS, SAVANNAH RIVER SITE, SOUTH CAROLINA, 1952, 1953, AND 1957

Species	Carolina bays[b]		
	1952	1953	1957
Pied-billed Grebe		*[c]	
Least Bittern	3.7	4.9	5.2
King Rail	2.5		
Virginia Rail	1.2		
Purple Gallinule	2.5	3.7	+[d]
Killdeer	4.9	8.6	
Eastern Kingbird			6.9
Red-winged Blackbird	9.9	13.8	63.8
Eastern Meadowlark	22.5	18.8	3.5
Others (upland passerines)	1.2		6.9

[a] R. Pearson's unpublished data, as recorded in E. P. Odum's annual report to the Atomic Energy Commission and published surveys (Norris 1957b).
[b] Three bays totaling 80 ha in 1952–1953 and same 3 totaling 58 ha in 1957.
[c] Species nesting on the site but territory or home range extends beyond the site for an undetermined distance.
[d] Species with territories but <1.2 pairs/km^2.

OLD HOME SITES AND FENCE ROWS

Using 10 as the most abundant indicator for a species' density, the following breeding birds were ranked for residential areas and along fence row vegetation: Northern Mockingbird 10, Orchard Oriole 7, Northern Cardinal 6.5, Eastern Kingbird 5.5, Brown Thrasher 4.5, Blue Jay 3, Eastern Bluebird 2.5, Yellow-breasted Chat 2.5, House Sparrow 2, Indigo Bunting 1.5, Northern Bobwhite 1, Purple Martin 1, Painted Bunting 1, and European Starling 1. Breeding

TABLE 5. BREEDING BIRD POPULATION DENSITIES (PAIRS/KM^2) OF DECIDUOUS FOREST HABITATS, SAVANNAH RIVER SITE, SOUTH CAROLINA, 1952–1953

Group[b]	1952	1953
Group A (occurred in all wetland and upland forests)		
Mourning Dove	*[c]	*
Yellow-billed Cuckoo	8.4	6.7
Red-bellied Woodpecker	*	*
Downy Woodpecker	*	*
Hairy Woodpecker	*	*
American Crow	*	
Carolina Chickadee	3.5	15.3
Tufted Titmouse	10.1	8.4
Carolina Wren	20.5	24.2
Blue-gray Gnatcatcher	27.2	22.0
Red-eyed Vireo	54.4	30.6
Northern Cardinal	34.1	22.0
Eastern Towhee	8.4	3.5
Group B (occurred in upland oak and deciduous forests)		
Northern Flicker	*	
Eastern Wood-Pewee	6.9	4.4
Great Crested Flycatcher	*	*
Eastern Kingbird	*	
Blue Jay	*	*
Brown Thrasher		*
Pine Warbler	+[d]	4.4
Summer Tanager	11.6	9.4
Blue Grosbeak	*	*
Indigo Bunting	*	*
Orchard Oriole	*	
Group C (occurred in all forests except oak)		
Turkey Vulture	*	
Broad-winged Hawk	*	*
Ruby-throated Hummingbird	2.7	5.7
Acadian Flycatcher	31.1	50.9
Wood Thrush	22.7	14.1
White-eyed Vireo	45.5	39.5
Yellow-throated Vireo	8.4	8.4
Northern Parula	62.5	57.1
Yellow-throated Warbler	8.4	19.8
Kentucky Warbler	14.1	8.4
Hooded Warbler	24.7	19.8
Group D (confined to flood plain and swamp forests)		
Yellow-crowned Night Heron	*	
Wood Duck	*	
Barred Owl	*	
Chimney Swift		*
Pileated Woodpecker		*
American Redstart		*
Prothonotary Warbler	49.4	61.8
Swainson's Warbler		6.2
Louisiana Waterthrush	12.3	6.2

[a] R. Pearson's unpublished data, as recorded in E. P. Odum's annual report to the Atomic Energy Commission, 1953–1954.
[b] Group A was 9 sites totaling 57 ha; Group B was 6 sites totaling 42 ha; Group C was 5 sites totaling 35 ha; Group D was 3 sites totaling 16 ha.
[c] Species nesting on the site but territory or home range extends beyond the site for an undetermined distance.
[d] Species with territories but <1.2 pairs/km^2.

species occurring at the lowest relative density (0.5) in this habitat were Loggerhead Shrike, Red-bellied Woodpecker, Blue Grosbeak, Summer Tanager, Chipping Sparrow, Mourning Dove, and Common Yellowthroat. Painted Buntings and Yellow-breasted Chats were found only in lowland fence rows. House Sparrows, Purple Martins, and European Starlings were confined to old home sites.

DECIDUOUS FORESTS

Both wetland and upland deciduous forests contained relatively high avian species richness and densities (Table 2). Available SRS data were categorized initially by birds that were found in Group A = all deciduous forests (wetland and upland), Group B = upland oak and other upland deciduous forests, Group C = all deciduous forests except oak, and Group D = only in flood plain and swamp forests (Table 5). Neotropical migratory species were commonly found at higher species richness and densities in deciduous than pine forests (Tables 3 and 5).

Group A (all deciduous forests—wetland and upland)

The Red-eyed Vireo dominated in all deciduous forests and occurred most frequently of all the neotropical migratory birds (Table 5). The most frequent resident, the Northern Cardinal, co-dominated deciduous forests with the Carolina Wren and other residents (Carolina Chickadee, Tufted Titmouse, and Eastern Towhees), and the Blue-gray Gnatcatcher, another neotropical migrant. Yellow-billed Cuckoos were also found frequently at lower densities.

Group B (upland oak and other upland forests)

Species in this group are commonly referred to as "woodland edge species" and most are neotropical migrants (Table 5). Summer Tanagers and Eastern Wood-Pewees dominated this habitat type. All other species' densities were low or the species were using other habitat for most of their home range (e. g., Brown Thrasher and Orchard Oriole).

Group C (all deciduous forests except oak)

Almost all species of this group were neotropical migrants (Table 5). Northern Parula, Acadian Flycatcher, and White-eyed Vireo dominated all deciduous forest habitat except oak. Other common breeding species in this habitat were Hooded Warbler, Wood Thrush, Yellow-throated Warbler, Kentucky Warbler, and Ruby-throated Hummingbird.

Group D (floodplain and swamp forests only)

Important breeding birds of wetland forests were all neotropical migratory birds (Table 5).

TABLE 6. BREEDING BIRD POPULATION DENSITIES (PAIRS/KM^2) OF OLD GROWTH FOREST HABITATS, SAVANNAH RIVER SITE, SOUTH CAROLINA, 1956–1957

Species	Upper Three Runs Creek-flood plain forest		Steel Creek-oak hammock forest
	1956[a]	1957[b]	1956[a]
Yellow-billed Cuckoo	25	30	25
Barred Owl		10	
Ruby-throated Hummingbird		12	10
Red-bellied Woodpecker	10	+[c]	17
Pileated Woodpecker	5		10
Acadian Flycatcher	62	82	62
Great Crested Flycatcher		+	7
Fish Crow		+	
Carolina Chickadee	20	10	
Tufted Titmouse	37	+	40
Carolina Wren	20	40	22
Wood Thrush	5	10	12
Blue-gray Gnatcatcher	15	40	12
White-eyed Vireo	47	49	47
Yellow-throated Vireo	10	10	10
Red-eyed Vireo	136	111	74
Pine Warbler		+	
Northern Parula	49	30	96
Prothonotory Warbler	12	20	32
Swainson's Warbler	17	10	10
Kentucky Warbler	12	30	32
Louisiana Waterthrush		10	
Hooded Warbler	32	69	54
Summer Tanager		20	7
Northern Cardinal	22	49	40

[a] Strip census of singing males (total area unknown), Norris 1963.
[b] Area spot-mapping of singing males (5-ha survey), Norris 1957a.
[c] Species with territories but <10 pairs/km^2.

Prothonotary Warblers dominated forested wetlands with standing water during the breeding season. Less frequent and at much lower densities were Louisiana Waterthrush and Swainson's Warbler.

Four to five years later

Norris (1957a,b, 1963) recensused breeding birds in deciduous forests for the floodplain and oak hammock sites during 1956 and 1957 at Upper Three Runs Creek and Steel Creek (Table 6). Areas censused were smaller than prior censuses. He found similar species richness (19–23) and breeding bird densities (573–662 pairs/km^2) in these forests when compared to earlier censuses by Pearson. Red-eyed Vireos still dominated both forests. Six other neotropical migratory birds (Yellow-billed Cuckoo, Acadian Flycatcher, White-eyed Vireo, Northern Parula, Kentucky Warbler, and Hooded Warbler) codominated these forests. Blue-gray Gnatcatchers, another migrant, occurred at slightly lower densities. Norris found fewer Prothonotary Warblers and a new breeding bird, Yellow-throated Vireo, 5 yr later. Other neotropical migratory birds occurred at similar densities censused 5 yr earlier (Tables 5 and 6).

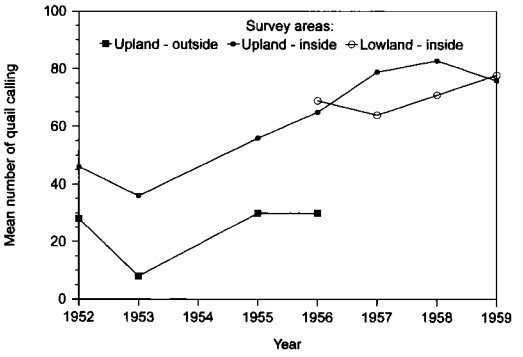

FIGURE 3. The mean number of Northern Bobwhite calling on three survey routes located inside and outside of the Savannah River Site, 1952–1959 (redrawn from Golley 1962).

Northern Cardinals remained the most abundant resident breeding bird 5 years later, while others, e.g., the Carolina Wren and Tufted Titmouse, occurred at similar low densities after 5 yr. Norris found considerably more Downy Woodpeckers in 1956–1957 than 5 yr earlier.

GAME BIRDS

Eight years of Northern Bobwhite roadside surveys revealed a significant positive trend in relative population within the SRS and no change outside the SRS (Fig. 3; Golley 1962). Relative densities of Mourning Doves remained fairly constant inside and outside the SRS from 1952–1959 (Fig. 4; Golley 1962). Establishment of the SRS created thousands of fallow fields, which are considered excellent habitat for bob-

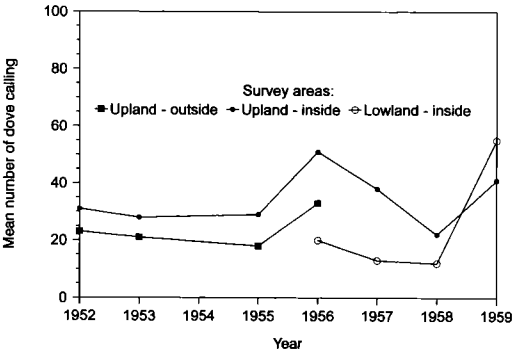

FIGURE 4. The mean number of Mourning Dove calling on three survey routes located inside and outside of the Savannah River Site, 1952–1959 (redrawn from Golley 1962).

whites, especially during the first 3–4 yr (Stoddard 1931:362). Bird hunting was not allowed on the SRS after 1951.

DISCUSSION

Breeding Bird Communities of the Savannah River Site

Species richness within the successional seres of the SRS during the 1950s were similar to other areas in the southeastern United States (Johnston and Odum 1956, Meyers and Johnson 1978, Meyers and Odum 1991). Compared to other southeastern areas, SRS breeding bird densities were considerably lower in Carolina bays and young pine forests. Breeding bird densities in fields, oak forests, and forested wetlands varied within the ranges for those found in the southeast (up to 750 pairs/km^2).

The SRS's ephemeral grasslands provided little structural diversity for a rich breeding bird community. The fields changed rapidly during the first years, from 1 to 4 and sometimes up to 7 yr, when shrubs and trees began to dominate the grassland. Densities of <100 pairs/km^2 and ≤ 8 breeding species are expected in this habitat (Johnston and Odum 1956). Although breeding bird populations are low in uncultivated fields, they do provide substantially more habitat for breeding birds than cultivated fields, which provide little to no habitat.

Carolina bays provided habitat for few breeding birds species with low densities. Species richness (7–8) in the bays equaled that found in three similar habitats of the Okefenokee Swamp, Georgia (Meyers and Odum 1991). Breeding bird density, however, was considerably lower in the SRS bays than in similar Okefenokee wetland habitats, which were two- to eight-times higher in densities. Compared to other wetland habitats in the eastern United States, Carolina bay breeding bird densities were from 25% of the densities found in the southeast to only 5% of densities found in similar wetlands of the northeast (Meyers and Odum 1991). One explanation for large differences in breeding bird density between Carolina bays and other similar wetland habitat may be an energetic relationship. Unlike other swamps with inputs from rivers, Carolina bays on the SRS receive very little nutrient input from outside the system. They are also deficient in available nutrients, with precipitation as the main external source of nutrients (Sharitz and Gibbons 1982).

Shrub or young forest habitat provides more habitat layers than grasslands, and therefore more niches, for species of breeding birds (MacArthur et al. 1962). Young pine forest habitat, however, with a closed canopy and little spatial heterogeneity, provides less (Johnston and Odum 1956, Odum and Kroodsma 1977). Both statements were true for these habitats on the SRS during the 1950s. However, breeding bird densities were 30–50% lower than those found in similar pine forests of the Piedmont and Coastal Plain of Georgia (Johnston and Odum 1956, Meyers and Johnson 1978, Meyers and Odum 1991). We offer no clear explanation for this, but suspect that low nutrient availability or lack of moisture (especially in the sandhills) on these habitats may reduce the breeding bird densities. Similar habitats in southeastern Georgia with much higher breeding bird densities were prescription burned every 4–5 yr, which releases nutrients to the soil, and were much wetter than the sandhill habitat on the SRS.

Older upland and wetland forests on the SRS supported a species richness (19–23) and breeding bird density (300–750 pairs/km^2) similar to other forests in the southeast with few exceptions (Johnston and Odum 1956, Meyers and Johnson 1978, Meyers and Odum 1991). Older upland pine-hardwood and hardwood forest habitat investigated in Arkansas, Louisiana, and North Carolina provided habitat for 900–1940 pairs/km^2 of breeding birds, which is 36–190% higher than those on the SRS (maximum of 662 pairs/km^2) in the 1950s (Meyers and Johnston 1978). However, a 10-year breeding bird census in the same old growth pine forest in Savannah, Georgia, revealed that densities can vary widely, from 300–900 pairs/km^2 in any given year (Meyers and Johnston 1978). Therefore, it is likely that breeding bird densities in older upland forests of the SRS may be higher or lower than 700 pairs/km^2 in certain years. Breeding bird densities (900 pairs/km^2) of black gum swamp forests in the Okefenokee Swamp were only slightly higher than those found in river swamp forest on the SRS, while species richness was slightly lower in the Okefenokee Swamp habitats, which could be related to the phenomenon that fewer bird species breed at southern than at more northern latitudes in the eastern United States (Figs. 5 and 6; Meyers and Odum 1991).

Game Birds

Migratory game bird populations are monitored by the state of South Carolina in cooperation with the federal government, but not on the SRS. Mourning Dove roadside survey routes should be repeated on the SRS to determine changes since the 1950s (Golley 1962). South Carolina's dove population is the only one that has declined under hunting regulations in the southeastern United States (J. Berdin, pers. comm.). Some comparisons have been made of

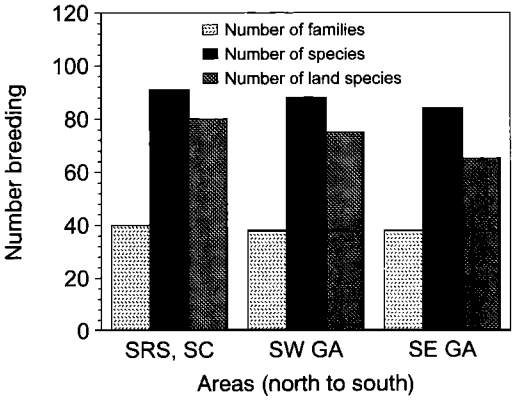

FIGURE 5. The regional diversity of breeding bird families and species for the southeastern U. S. (from Norris 1951, 1963; Laerm et al. 1980). Demonstrates the "reverse latitudinal gradient" from north to south (left to right on graph).

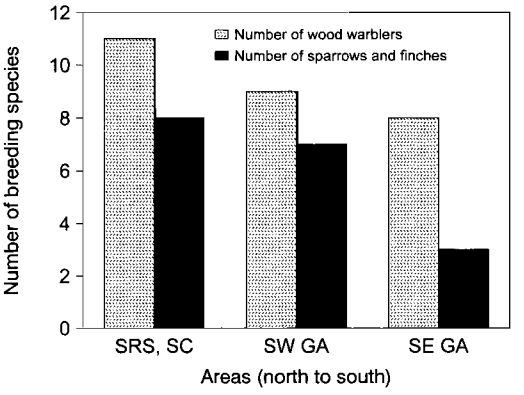

FIGURE 6. The regional diversity of breeding wood warblers, sparrows, and finches for the southeastern U. S. (from Norris 1951, 1963; Laerm et al. 1980). Demonstrates the "reverse latitudinal gradient" from north to south (left to right on graph).

Mourning Dove and Northern Bobwhite surveys on and off the site with counts higher off the SRS (Kilgo et al. 1997; J. Kilgo, pers. comm.). It is possible that recent and repeated investigations may provide valuable information in managing doves, because dove hunting is not allowed on most the SRS.

Declines of Northern Bobwhites have also been of concern in the South recently (Brennan 1991). Although bobwhites increased in the first decade after establishment of the SRS, expected declines occurred after 1950s as forests gradually replaced abandoned farmland (Golley 1962). By investigating if these declines have continued, we should be able to hypothesize causes for decline throughout the range of the bobwhite by looking at land use changes, use of pesticides, and other factors inside and outside the boundary of the SRS. Statistically designed quail call counts (same method as Golley 1962) should be repeated at least every 3 years for at least 2 consecutive years (if possible, annually), so that these hypotheses can be investigated.

Future Research, Questions of Breeding Status, and What to Monitor?

Breeding bird reinvasions and range expansions in the southeastern U.S.

Of great importance in the study of breeding bird communities in the eastern United States, though it is usually overlooked, is the relationship that fewer species of birds breed at southern latitudes (Cook 1969). Unlike in the western United States, where the number of breeding bird species increases with decreasing latitude, a "reverse latitudinal gradient" is present in the east, even over relatively short distances from South Carolina to Georgia (Figs. 5 and 6). From the SRS to southeastern Georgia the number of breeding wood warblers and finches declines by eight species (Figs. 5 and 6). This relationship must be taken into account when comparing regional avifauna in the South. More specifically, it is important to monitor species at the SRS that have ranges in the entire eastern range as well as the southeastern region. Breeding bird species of the southeastern region may have a wider range of habitats, which could translate into more available habitat for the species (MacArthur 1972, Tramer 1974, Odum et al. 1993).

Invasions of new breeding birds into the SRS are possible and more than likely are occurring now. Fewer breeding birds in the South may mean more habitat available for breeding birds, which could invade from northern or western U.S. Since the 1940s in Georgia, many new breeding species have established southern extensions or recolonizations of their ranges, which may have been accelerated by habitat changes (Odum et al. 1993). For example, breeding Song Sparrows can be found in abundance in central Georgia now, whereas during the 1940s they were not known to breed south of Georgia's mountain valleys (Odum et al. 1993). Residential areas with water nearby seem to be the first breeding habitat occupied by invading Song Sparrows in Georgia. However, most of the residential habitat at SRS has declined since 1951, so we would not predict range extensions by this species into the SRS. Many other species, however, may be expanding their ranges into the SRS and South Carolina (see Savannah River Site, SC, sites in 1993–1997 *Journal of Field Ornithology* Supplements; Kilgo et

al. 1997, 1998). These recent surveys revealed that Black-and-White Warblers, Ovenbirds, and American Redstarts are uncommon breeding birds in the 1990s, whereas they were absent in the 1950s. Invasions are more likely to come from the north or west than from the south (Odum et al. 1993).

Neotropical migratory birds in decline

"Neotropical migratory birds" has become popular term in the last decade because of bird population declines. Unfortunately, many people have different ideas on what species or groups actually are declining, and surveys can be biased (Geissler and Link 1988). Thus the question has become: are neotropical migratory birds really declining?

Peterjohn et al. (1995) highlighted patterns of population trends for neotropical migratory birds based on the Breeding Bird Survey (BBS, 1966–1991), a road-side 50-stop survey of 3 min/stop at 0.8 km intervals. Peterjohn et al. used a binomial test: does the percentage of the species that have positive trends differ from 50%? Early during the survey period (1966–1979), 78% ($P < 0.01$) of all neotropical migratory birds in the eastern region had increasing trends, but more recently (1980–1991) only 36% ($P < 0.01$) of the species were increasing. Over the entire period (1966–1991), no trend was evident, with 58% of the neotropical migratory species increasing ($P > 0.10$) in the eastern region. It is possible that the current downward trend (from 78% increasing to 36% increasing) will reverse itself in the next decade. However, continued declines both for those species already in a 30-year decline and for additional species will mean more populations at risk of extirpation or extinction.

It is evident that monitoring all breeding birds at the SRS may not answer questions about declining populations and how to reverse these trends. Also, intensive monitoring only can be cost effective by using trained volunteers, e.g., the BBS, which may or may not be possible at the SRS. It may be more reasonable or cost effective to emphasize groups of breeding birds, specific habitats, and absence or presence of rarer birds (e.g., breeding invaders or local extinctions) that usually can not be surveyed in a way that provides reliable population trends (Geissler and Link 1988).

What populations of breeding bird species may be declining at SRS?

In the eastern United States from 1966–1991 the following breeding birds, which also occur on the SRS, have had significant annual declines (%/yr): Yellow-billed Cuckoo (-1.7%, $P < 0.01$), Eastern Wood-Pewee (-1.3%, $P < 0.01$), Wood Thrush (-2.9%, $P < 0.01$), Prairie Warbler (-2.2%, $P < 0.01$), and Painted Bunting (-2.8%, $P < 0.01$) (Peterjohn et al. 1995). Most of these species occurred on the SRS at numbers >5–10 pairs/km^2. We recommend a selected habitat/species approach to monitor declining populations that have densities >5 pairs/km^2. Habitats to include in the surveys are older growth pine forests with an open canopy, clear cut pine forests, bottomland forests, and swamp forests.

Prairie Warblers and Eastern Wood-Pewees should be surveyed over a long term (20 yr) to determine possible causes for their decline. This might be accomplished in cooperation with current and future research of Bachman's Sparrow at the SRS. The survey should be designed to sample an adequate number of pewee's since this species is the least common of the three (Droge et al. 1993a,b). Other species, especially the common residents (e.g., Pine Warblers), also could be included in the survey to provide additional information on potential causes for declines. Declining populations of Wood Thrushes and Yellow-billed Cuckoos should be monitored by surveying breeding populations in mature bottomland hardwood forests, oak hammocks, and swamp forests. Other species that would be important to monitor in these forests, because they are common and because populations are stable or increasing (Peterjohn et al. 1995), might include Red-eyed Vireo, White-eyed Vireo, Prothonotary Warbler, Northern Parula, and Hooded Warbler. Long-term information on breeding bird populations of bottomland and swamp forests is also an excellent way to monitor many neotropical migratory birds, which are found at higher densities and species richness in these forests than in most pine forests (Meyers and Odum 1991). Pre-1950s losses of southern pine forests, particularly the longleaf pine community, as well as recent losses of forested wetlands in the South may affect bird populations (Sharitz and Mitsch 1993, Ware et al. 1993). These losses as well as the changes in landscape structure complicate the scientists' and managers' tasks of developing management plans for the conservation of birds (Freemark et al. 1995). Long-term monitoring of the avian community may provide managers with results that benefit biodiversity management (multi-species approaches) on the SRS (Block et al. 1995). The SRS's large land area provides excellent opportunities to monitor bird populations. Experimentation or modeling also may be required to further explain the causes of declines in neotropical migratory birds on SRS or in the region.

TABLE 7. BIRD SPECIES THAT ARE LIKELY INDICATORS OF CHANGE AND WHERE CURRENT STATUS SHOULD BE COMPARED TO THAT REPORTED IN THE 1950s (NORRIS 1963)

Species	1950s status
Pied-billed Grebe	breeding bird in Carolina bays and ponds
Herons and egrets	none found breeding with possible exception of Green-backed Heron
Least Bittern	breeding bird in Carolina bays
Canada Goose	not breeding
Hooded Merganser	not found breeding
Broad-winged Hawk	rare breeding bird
American Kestrel	uncommon breeding bird
Northern Bobwhite	common resident, need to repeat 1950s call counts
King Rail	breeding bird in Carolina bays
Purple Gallinule	breeding bird in Carolina bays
American Woodcock	rare breeding bird in 1950s
Mourning Dove	common breeding bird, need to repeat 1950s call counts
Common Ground-Dove	rare, occasional visitor near fields and Carolina bays
Yellow-billed Cuckoo	common breeding bird in floodplain and hammock forests
Great Horned Owl	uncommon resident
Short-eared Owl	common winter visitor in old fields
Common Nighthawk	common breeding bird in open-canopy pine forests
Red-headed Woodpecker	common breeding bird near wooden power poles
Red-cockaded Woodpecker	infrequent permanent resident
Great Crested Flycatcher	fairly common breeding bird in pine-hardwood forests
Barn Swallow	not breeding
House Wren	winter resident only, not breeding
Bewick's Wren	fairly common winter resident
Marsh Wren	breeding bird in Carolina bays
Wood Thrush	fairly common breeding bird in floodplain hardwoods
Eastern Bluebird	common resident in fields or open woodlands
Blue-gray Gnatcatcher	common breeding bird of hammocks and floodplain forests
Loggerhead Shrike	common resident in fields and shrub-scrub habitat
White-eyed Vireo	common breeding bird in broadleaf forests and scrub
Red-eyed Vireo	most common breeding bird in broadleaf forests
Northern Parula	abundant breeding bird in broadleaf forests
Yellow-throated Warbler	uncommon, probable breeding bird in swamp forests
Prairie Warbler	common breeding bird in fields, scrub, and young forests
American Redstart	suspected rare breeding bird in broadleaf forests
Prothonotary Warbler	common breeding bird in swamp forests and along streams
Swainson's Warbler	fairly common breeding bird in swamp and broadleaf forests
Kentucky Warbler	fairly common breeding bird in moist broadleaf and floodplain forests
Hooded Warbler	common breeding bird in broadleaf forests and bottomland near swamp forests
Yellow-breasted Chat	common breeding bird in fields, scrub, and young forests
Orchard Oriole	common breeding bird at old home sites and hedgerows
Brown-headed Cowbird	not detected as breeding bird
Summer Tanager	fairly common breeding bird in open pine-hardwood forests
Painted Bunting	fairly common breeding bird along lower terraces of river
Eastern Towhee	common permanent resident of shrubby pine-hardwood forests
Savannah Sparrow	abundant winter resident of old fields
Grasshopper Sparrow	uncommon winter visitor, regular occurrence
Bachman's Sparrow	fairly common permanent resident of open pine forests, rarer in winter
Field Sparrow	common permanent resident of old fields, breeding on lower terraces
Song Sparrow	very common winter visitor of open, scrubby areas

Rare birds and species' extinction and immigration

Rare bird populations are difficult to monitor. We propose that rare to uncommon species previously known on the SRS, or suspected to be there in the near future because of changes in land use, be monitored using presence/absence

surveys for the species by habitats from stratified random transects (or areas, e.g., timber compartments) on the SRS. Species richness estimates for rare to uncommon species (or the "species at risk" bird community) as well as rate of change in species richness over time can be determined and tested with probability (Boulinier et al. 1998, Nichols et al. 1998a,b). These new methods will allow us to better understand changes associated with the environment. Changes in species richness would be quantitative and testable (significantly increasing or decreasing) rather than a number index (Burnham 1981).

For which species should we expect changes (local extinctions and invasions)? Species that are likely indicators of change (e.g., regional population declines/increases for reasons other than habitat loss) should be compared with information from the 1950s and with future surveys (Table 7; Norris 1963). Obviously one type of survey will not be sufficient to locate all the species. Waterbirds have increased because of large increases in open water habitat and habitat changes caused by operations on the SRS during the last 40 years. Roosting, nesting, and aerial counts may be required to adequately survey waterbirds. Many common landbirds that are likely indicators of landscape change, such as the Red-eyed Vireo, should be monitored (Table 7). These species can be surveyed most effectively by line transects; however, point counts and spot-mapping of territorial males should be done for comparisons. Others, e.g., the Loggerhead Shrike and Common Ground Dove, may be monitored efficiently by roadside surveys, such as the call counts developed for game birds (with and without call playbacks). For the more secretive birds, tape playbacks of calls or songs may be required for adequate surveys. Both winter and spring-summer surveys must also be considered to determine avifaunal changes on the SRS. With standardization of methods and continual surveys, e.g., every 3–4 yr or more often, much could be learned about birds of the SRS. This knowledge may elucidate causes for declines and increases, as well as potential methods through management and preservation to maintain the bird community on the SRS and in the eastern United States. With such a large area available for research it would be prudent to use the landscape of the SRS to test hypotheses involving the bird community. Much could be learned about bird communities and populations in relation to habitat change by studying an adjacent similar area of the same size as SRS, but with completely different land use trends in the last 45 yr. With increases in human populations, especially in the southeastern United States, more research of large species groups or bird communities on the SRS may be important to the survival of many bird populations as well as to our knowledge on how to manage our resources for the future.

ACKNOWLEDGEMENTS

We thank J. B. Dunning, Jr., J. C. Kilgo, and an anonymous reviewer for their helpful comments and suggestions for improvement of earlier drafts of the manuscript.

APPENDIX 1 SCIENTIFIC NAMES OF BIRDS MENTIONED IN TEXT OR TABLES

Pied-billed Grebe	*Podilymbus podiceps*
Least Bittern	*Ixobrychus exilis*
Yellow-crowned Night Heron	*Nyctanassa violacea*
Wood Stork	*Mycteria americana*
Turkey Vulture	*Cathartes aura*
Canada Goose	*Branta canadensis*
Wood Duck	*Aix sponsa*
Hooded Merganser	*Lophodytes cucullatus*
Broad-winged Hawk	*Buteo platypterus*
American Kestrel	*Falco sparverius*
Northern Bobwhite	*Colinus virginianus*
King Rail	*Rallus elegans*
Virginia Rail	*Rallus limicola*
Purple Gallinule	*Porphyrula martinica*
Killdeer	*Charadrius vociferus*
American Woodcock	*Scolopax minor*
Mourning Dove	*Zenaida macroura*
Common Ground Dove	*Columbina passerina*
Yellow-billed Cuckoo	*Coccyzus americanus*
Great Horned Owl	*Bubo virginianus*
Barred Owl	*Strix varia*
Short-eared Owl	*Asio flammeus*
Common Nighthawk	*Chordeiles minor*
Chimney Swift	*Chaetura pelagica*
Ruby-throated Hummingbird	*Archilochus colubris*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Red-bellied Woodpecker	*Melanerpes carolinus*
Downy Woodpecker	*Picoides pubescens*
Hairy Woodpecker	*Picoides villosus*
Red-cockaded Woodpecker	*Picoides borealis*
Northern Flicker	*Colaptes auratus*
Pileated Woodpecker	*Dryocopus pileatus*
Eastern Wood-Pewee	*Contopus virens*
Acadian Flycatcher	*Empidonax virescens*
Great Crested Flycatcher	*Myiarchus crinitus*
Eastern Kingbird	*Tyrannus tyrannus*
Loggerhead Shrike	*Lanius ludovicianus*
White-eyed Vireo	*Vireo griseus*
Yellow-throated Vireo	*Vireo flavifrons*
Red-eyed Vireo	*Vireo olivaceus*
Blue Jay	*Cyanocitta cristata*
American Crow	*Corvus brachyrhynchos*
Fish Crow	*Corvus ossifragus*
Purple Martin	*Progne subis*

APPENDIX 1 CONTINUED

Barn Swallow	*Hirundo rustica*
Carolina Chickadee	*Poecile carolinensis*
Tufted Titmouse	*Baeolophus bicolor*
Brown-headed Nuthatch	*Sitta pusilla*
Carolina Wren	*Thryothorus ludovicianus*
Bewick's Wren	*Thryomanes bewickii*
House Wren	*Troglodytes aedon*
Marsh Wren	*Cistothorus palustris*
Blue-gray Gnatcatcher	*Polioptila caerulea*
Eastern Bluebird	*Sialia sialis*
Wood Thrush	*Hylocichla mustelina*
Northern Mockingbird	*Mimus polyglottos*
Brown Thrasher	*Toxostoma rufum*
European Starling	*Sturnus vulgaris*
Northern Parula	*Parula americana*
Yellow-throated Warbler	*Dendroica dominica*
Pine Warbler	*Dendroica pinus*
Prairie Warbler	*Dendroica discolor*
Black-and-White Warbler	*Mniotilta varia*
American Redstart	*Setophaga ruticilla*
Prothonotary Warbler	*Protonotaria citrea*
Swainson's Warbler	*Limnothlypis swainsonii*
Ovenbird	*Seiurus aurocapillus*
Louisiana Waterthrush	*Seiurus motacilla*
Kentucky Warbler	*Oporornis formosus*
Common Yellowthroat	*Geothlypis trichas*
Hooded Warbler	*Wilsonia citrina*
Yellow-breasted Chat	*Icteria virens*
Summer Tanager	*Piranga rubra*
Eastern Towhee	*Pipilo erythrophthalmus*
Bachman's Sparrow	*Aimophila aestivalis*
Chipping Sparrow	*Spizella passerina*
Field Sparrow	*Spizella pusilla*
Savannah Sparrow	*Passerculus sandwichensis*
Grasshopper Sparrow	*Ammodramus savannarum*
Song Sparrow	*Melospiza melodia*
Northern Cardinal	*Cardinalis cardinalis*
Blue Grosbeak	*Guiraca caerulea*
Indigo Bunting	*Passerina cyanea*
Painted Bunting	*Passerina ciris*
Red-winged Blackbird	*Agelaius phoeniceus*
Eastern Meadowlark	*Sturnella magna*
Brown-headed Cowbird	*Molothrus ater*
Orchard Oriole	*Icterus spurius*
House Sparrow	*Passer domesticus*