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ABUNDANCE AND REPRODUCTION OF SONGBIRDS IN BURNED AND UNBURNED PINE FORESTS OF THE GEORGIA PIEDMONT

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Abstract.—We studied the abundance and productivity of songbirds in prescribed burned and unburned mature (>60 yr) pine forests at Piedmont National Wildlife Refuge, Georgia, during 1993–1995. We estimated species abundance, richness, and evenness using data from 312 point counts in 18 burned sites and six unburned sites. We measured gross habitat features in 0.04-ha circles centered on each point count station. We calculated productivity estimates at nests of seven of the most common nesting species. Habitat components we measured in 1-, 2-, and 3-yr post-burn sites were similar, but most components differed between burned and unburned sites. Although 98 species were detected during point counts, we report only on the 46 species that nested in the area and were detected ≥10% of the counts in either habitat class. Twenty-one species preferred burned sites and six preferred unburned sites. Avian species richness and evenness were similar for burned and unburned sites. Burned sites were preferred for nesting over unburned sites. Only nine nests of six species were found in unburned sites. Productivity estimates were low in burned sites. One or more eggs hatched in only 59 of 187 nests monitored, and an average of only 0.82 chicks per nest were estimated to have fledged. Predation was the most common probable cause for nest failure, ranging from 45% in the Northern Cardinal (*Cardinalis cardinalis*) to 64% in the Summer Tanager (*Piranga rubra*). Because the sources of predation at the refuge are unknown, future research should address this issue.

ABUNDANCIA Y ASPECTOS DE LA REPRODUCCIÓN DE AVES CANORAS EN ÁREAS QUEMADAS Y NO-QUEMADAS DE BOSQUES DE PINO EN GEORGIA

Sinopsis.—De 1993–1995 estudiamos la abundancia y productividad de aves canoras en áreas de pinos maduros (arboles > a 60 años) que fueron quemadas (manejadas) y no-quemadas en el Refugio Nacional para la Vida Silvestre de Piedmont, Georgia. Estimamos la abundancia de especies, riqueza del áreas y uniformidad de la misma, utilizando datos de 312 conteos de punto en 18 áreas quemadas y seis áreas no-quemadas. Medimos la fisionomía del habitat en círculos de 0.04 ha centralizados en cada estación del punto. Calculamos los estimados de productividad de los nidos en siete de las especies más comunes de la localidad. El componente del habitat en lugares con tratamiento de fuego de 1-, 2-, y 3- años post-fuego, fue similar. No obstante, la mayoría de dichos componentes varió con respecto a las áreas no-quemadas. Aunque se detectaron 98 especies durante los conteos de punto, tan solo informamos sobre las 46 especies que anidaron en el refugio y que fueron detectadas en >10% de los conteos de cada tipo diferente de localidad. De éstas, 21 especies prefirieron áreas quemadas y seis no-quemadas. La riqueza de aves y uniformidad resultaron similares para ambos tipos de localidades. Los lugares quemados fueron preferidos para anidar sobre las áreas controles. Tan solo nueve nidos de seis especies fueron encontrados en las localidades no-quemadas. Los estimados de productividad fueron bajos en las áreas quemadas. Uno o más huevos eclosionaron en 59 de los 187 nidos monitoreados, y el bajo promedio de 0.82 pichones/nido abandonaron los mismos. La causa más probable de fracaso de nidos fue la depredación, fluctuando de 45% en *Cardinalis cardinalis* a 64% en *Piranga rubra.* Como se desconocen los organismos que actuaron como depredadores, los trabajos futuros deben tratar de identificarlos.

Much of the southeastern coastal plain was once covered by a vast longleaf pine (*Pinus palustris*) forest (Frost 1993). Lumbering and agricultural practices have reduced this important forest type to a small fraction of its original size. Historically, the longleaf pine community was maintained in that condition by frequent naturally occuring fires (Gano 1917, Lemon 1949, Vogl 1973, Frost 1993). Logging and agricultural interests have so fragmented the original forest until the incidence of natural fire is drastically reduced. To maintain open mature pine forests on some federal lands as required habitat for endangered Red-cockaded Woodpeckers (see Table 2 for scientific names), prescribed fire is used as a management tool (Brennan et al. 1995, Plentovich et al. 1998). Some Neotropical migrants that historically nested in the vast longleaf pine ecosystem are now rapidly declining. These include the Prairie Warbler, Yellow-breasted Chat, Common Yellowthroat, and Indigo Bunting (Peterjohn and Sauer 1993). The effects of prescribed burning on breeding songbirds other than Red-cockaded Woodpeckers is poorly understood and has been identified as a high priority research need by the U.S. Fish and Wildlife Service (Frank Bowers, pers. comm.). We conducted this study to compare songbird productivity and species abundance, richness, and evenness in burned and unburned mature pine forests, and to compare the vegetational characteristics of the two forest types. The information gathered may be useful in developing long-term management plans that benefit nesting songbirds utilizing areas maintained for Red-cockaded Woodpeckers.

STUDY AREA AND METHODS

The study location was the 15,000-ha Piedmont National Wildlife Refuge in central Georgia that was established in 1940 as part of a federal program to reclaim areas decimated by inadequate farming practices. This area of the Piedmont physiographic region is characterized by gentle rolling hills (250 m average elevation) with hardwood, pine, or mixed pine-hardwood forests, but extensive acreage has been cleared for agricultural and silvicultural purposes. The refuge's primary mission is to provide suitable habitat for the endangered Red-cockaded Woodpecker. The refuge is divided into compartments of approximately 405 ha and most are periodically burned during the non-growing season (December–March) on a 3–4 yr rotation to minimize the encroachment of hardwoods. To assess the effects of prescribed burning on birds at the refuge, we selected mature (>60 yr) pine sites >100 ha in size with similar canopy composition. As the study progressed, burned sites were added in accordance with the refuge's prescribed fire itinerary. A total of eighteen post-burn sites (eight 1-yr, six 2-yr, and four 3-yr sites) and six sites not burned >20 years (controls) were chosen. In all sites, loblolly pine (*Pinus taeda*) was the dominant canopy species and various oaks (*Quercus* spp.) and hickories (*Carya* spp.) dominated the mid-story. Manual hardwood removal had not been used in any burned study sites before prescribed fire was applied. Red-cockaded Woodpecker clusters occupied 14 of the burned sites, but none were observed in the unburned sites.

As a gauge of avifaunal habitat use on the refuge, we conducted fixed-radius point counts (Hutto et al. 1986) beginning the first week in April and continuing weekly for 13 wk during 1993–1995. Nine count stations were established in the interior of each site in a 3 × 3 grid where possible, with 122 m between stations. Stations were placed approximately 100 m from forest edges where feasible. In irregularly shaped tracts, the stations were placed along a zig-zag transect, which minimized departure from the 3 × 3 grid (White et al. 1996). We surveyed sites for 5 min at each station between sunrise and 1100 h. All individuals seen or heard were recorded, excluding birds flying overhead. Surveys from each of the nine points at a site were not independent (White et al. 1996). So, weekly survey data from each site were pooled and treated as one count. We randomly rotated assignments among study sites and switched starting points between subsequent counts to reduce observer and station bias. Counts were not conducted on rainy and windy days.

For general habitat descriptions, we measured vegetational characteristics in 0.04-ha circles centered on each count station using a variation of the James and Shugart (1970) method. Measurements were taken in July 1993–1995. In each 0.04-ha circle (162 in burned sites and 54 in unburned sites), we determined tree species composition and density by size class, tree basal area, shrub stem density, dead tree density, log density, percent canopy closure, percent herb cover, percent leaf litter, and slope.

For locating nests, we followed the recommendations of Martin and Geupel (1993) and Patnode and White (1992). All sites (burned and unburned) were searched weekly (≥35 h search time per season) by several observers from late April to mid-July during 1994 and 1995. We attached flagging to vegetation ≥5 m from nests to facilitate relocation of nests. Thereafter, we visited nests every 3–4 d (Gottfried and Thompson 1978, Nichols et al. 1984, Patnode and White 1992) to record the status and fate of nest contents. Nests ≤7 m above ground were viewed with an extendable 7-m mirrored pole (Patnode and White 1992).

We used the Mayfield (1961, 1975) method for calculating nest success and daily survival rates. We used point count data to calculate species abundance, richness (S), and evenness (J′) (Smith 1990). Point count data and habitat measurements were normally distributed (Shapiro and Wilk 1965), so we tested for year and site differences using two-way analysis of variance (ANOVA). We compared species abundance, richness, and

TABLE 1. Mean (±SE) habitat measurements in burned and unburned mature pine tracts at Piedmont National Wildlife Refuge, Georgia, 1994–1995.

Parameter	Unburned	Burned
Conifers ≥7.5 cm dbh (no./ha)	275 ± 22	206 ± 23
Hardwoods ≥7.5 cm dbh (no./ha)	457[a] ± 44	242[a] ± 43
Total trees ≥7.5 cm dbh (no./ha)	732[a] ± 22	448[a] ± 64
Canopy closure (%)	88[a] ± 3	73[a] ± 2
Basal area trees ≥7.5 cm dbh (m^2/ha)	27 ± 4	24 ± 1
Total snags ≥7.5 cm dbh (no./ha)	94[a] ± 7	37[a] ± 7
Logs ≥7.5 cm dbh (no./ha)	276[a] ± 50	186[a] ± 18
Shrub density (non-herbacious plants <7.5 cm dbh) (no./ha)	2225 ± 595	1229 ± 197
% herb cover	17[a] ± 8	39[a] ± 3
% leaf litter	23[a] ± 5	10[a] ± 2
Slope (°)	5 ± 1	3 ± 1

[a] Means within a row differ ($P < 0.05$, *t*-test).

evenness between burned and unburned sites using *t*-tests. Null hypotheses were rejected at $P < 0.05$.

RESULTS

Habitat descriptions.—Mean habitat measurements at 162 0.04-ha circles in 1-, 2-, and 3-yr post-burn sites were similar ($P > 0.05$, ANOVA) among and between burn classes, as were those at 54 0.04-ha circles in unburned sites. So, we pooled habitat measurements for each class for comparisons between classes (Table 1). Most habitat components that we measured differed ($P < 0.05$) between burned and unburned sites, except number of conifers, basal area of total trees, and shrub density. Although mean shrub density in unburned sites was nearly twice that in burned sites, high variability in unburned sites precluded significance ($P > 0.062$). Loblolly pine was the dominant canopy species in both classes and canopy closure in the unburned sites was near complete. Hardwoods in the burned sites were mostly restricted to streams and drains, but they were widely scattered throughout the unburned sites.

Avian abundance.—We conducted 312 point counts during 1993–1995, 234 in burned sites and 78 in unburned sites. We pooled abundance data for *t*-test comparisons because there were no differences ($P > 0.05$, ANOVA) among sites or years for any burn class. A total of 98 species was detected, but more than half were migrant species that nested farther north or were species seen infrequently and in small numbers. We report only on the 46 species that may have nested in the study area and were detected during ≥10% of the counts in either habitat type (Table 2). Forty-five of the species were observed in both habitat types; only the Red-cockaded Woodpecker was not found in unburned tracts. The 10 species detected most often across habitats in order of decreasing abundance were Pine Warbler, Eastern Towhee, Tufted Titmouse, Northern Cardinal, Red-eyed Vireo, Carolina Wren, Blue Jay, Summer Tanager, Red-bellied

TABLE 2. Mean (±SE) abundance (detections/count/site) and mean frequency of occurrence (%) of 46 avian species detected in unburned and burned mature pine habitats at Piedmont National Wildlife Refuge, Georgia, 1993–1995.

Species	Abundance		Frequency	
	Unburned	Burned	Unburned	Burned
Wild Turkey (*Meleagris gallopavo*)	0.20 ± 0.20	0.02 ± 0.01	15	22
Northern Bobwhite (*Colinus virginianus*)	0.11 ± 0.09	0.09 ± 0.04	22	24
Mourning Dove (*Zenaida macroura*)	0.54[a] ± 0.21	0.28[a] ± 0.10	46	38
Yellow-billed Cuckoo (*Coccyzus americanus*)	0.66[a] ± 0.09	0.47[a] ± 0.04	51	49
Red-headed Woodpecker (*Melanerpes erythrocephalus*)	0.17 ± 0.02	0.15 ± 0.07	20	31
Red-bellied Woodpecker (*Melanerpes carolinus*)	1.37[a] ± 0.30	0.98[a] ± 0.18	79	88
Downy Woodpecker (*Picoides pubescens*)	0.40 ± 0.15	0.35 ± 0.05	34	30
Hairy Woodpecker (*Picoides villosus*)	0.11 ± 0.09	0.14 ± 0.03	15	17
Red-cockaded Woodpecker (*Picoides borealis*)	0	1.38 ± 0.44	0	47
Northern Flicker (*Colaptes auratus*)	0.27[a] ± 0.10	0.47[a] ± 0.07	27	54
Pileated Woodpecker (*Dryocopus pileatus*)	0.23 ± 0.03	0.22 ± 0.08	58	70
Eastern Wood-Pewee (*Cantopus virens*)	0.04[a] ± 0.02	0.88[a] ± 0.20	9	66
Acadian Flycatcher (*Empidonax virescens*)	0.17[a] ± 0.04	0.47[a] ± 0.15	22	34
Great Crested Flycatcher (*Myiarchus crinitus*)	2.83[a] ± 0.66	1.69[a] ± 0.12	79	70
Blue Jay (*Cyanocitta cristata*)	2.12[a] ± 0.51	0.86[a] ± 0.13	93	70
American Crow (*Corvus brachyrhynchos*)	0.10 ± 0.10	0.22 ± 0.04	75	84
Carolina Chickadee (*Parus carolinensis*)	2.24 ± 0.10	2.30 ± 0.14	78	76
Tufted Titmouse (*Parus bicolor*)	3.25 ± 0.52	3.43 ± 0.34	99	97
Brown-headed Nuthatch (*Sitta pusilla*)	1.23[a] ± 0.49	2.99[a] ± 0.81	38	68
Carolina Wren (*Thryothorus ludovicianus*)	1.94[a] ± 0.25	2.31[a] ± 0.28	97	97
Blue-gray Gnatcatcher (*Polioptila caerulea*)	0.64[a] ± 0.28	1.57[a] ± 0.20	40	55
Wood Thrush (*Hylocichla mustelina*)	1.01 ± 0.52	0.56 ± 0.14	76	57
American Robin (*Turdus migratorius*)	0.10 ± 0.08	0.10 ± 0.05	7	10
Brown Thrasher (*Toxostoma rufum*)	0.34 ± 0.26	0.07 ± 0.03	32	4
White-eyed Vireo (*Vireo grisens*)	0.06 ± 0.03	0.38 ± 0.26	3	23
Blue-headed Vireo (*Vireo solitarius*)	0.61[a] ± 0.08	1.09[a] ± 0.21	37	58
Yellow-throated Vireo (*Vireo flavifrons*)	0.38[a] ± 0.09	0.62[a] ± 0.10	31	42
Red-eyed Vireo (*Vireo olivaceus*)	1.77[a] ± 0.42	2.37[a] ± 0.38	79	82
Northern Parula (*Parula americana*)	0.37[a] ± 0.25	1.02[a] ± 0.27	43	51
Yellow-throated Warbler (*Dendroica dominica*)	0.04[a] ± 0.01	0.31[a] ± 0.06	8	26

TABLE 2. Continued.

Species	Abundance		Frequency	
	Unburned	Burned	Unburned	Burned
Pine Warbler (*Dendroica pinus*)	6.94[a] ± 0.63	7.78[a] ± 0.92	95	97
Prairie Warbler (*Dendroica discolor*)	0.90[a] ± 0.56	5.10[a] ± 1.13	46	86
Black-and-white Warbler (*Mniotilta varia*)	0.58[a] ± 0.20	0.05[a] ± 0.02	19	5
Kentucky Warbler (*Oporornis formosus*)	0.13 ± 0.05	0.18 ± 0.15	12	14
Common Yellowthroat (*Geothlypis trichas*)	0.04[a] ± 0.02	0.21[a] ± 0.08	7	15
Hooded Warbler (*Wilsonia citrina*)	0.17 ± 0.02	0.26 ± 0.15	12	16
Yellow-breasted Chat (*Icteria virens*)	0.07[a] ± 0.01	1.09[a] ± 0.34	18	48
Summer Tanager (*Piranga rubra*)	1.82 ± 0.08	1.94 ± 0.17	75	81
Northern Cardinal (*Cardinalis cardinalis*)	3.32[a] ± 0.51	3.04[a] ± 0.39	95	97
Indigo Bunting (*Passerina cyanea*)	0.30[a] ± 0.07	1.58[a] ± 0.39	29	58
Eastern Towhee (*Pipilo erythrophthalmus*)	1.44[a] ± 0.72	3.79[a] ± 1.10	74	89
Bachman's Sparrow (*Aimophila aestivalis*)	0.04[a] ± 0.04	0.88[a] ± 0.31	1	45
Chipping Sparrow (*Spizella passerina*)	0.74[a] ± 0.13	1.22[a] ± 0.26	36	43
Field Sparrow (*Spizella pusilla*)	0.04[a] ± 0.02	1.83[a] ± 0.47	9	78
Brown-headed Cowbird (*Molothrus ater*)	0.11[a] ± 0.03	0.84[a] ± 0.29	21	43
American Goldfinch (*Carduelis tristis*)	0.09[a] ± 0.02	0.34[a] ± 0.08	4	15

[a] Means within a row differ ($P < 0.05$, *t*-test).

Woodpecker, and American Crow. Overall, mean abundance estimates (detections/count/site) were low for most species (Table 2). Also, there was much variation among counts for many species, as denoted by the relatively large standard errors. Significant ($P < 0.05$) habitat preferences, based on mean abundance, were observed in 29 species (Table 2). Of the 29 species, only seven species, the Mourning Dove, Yellow-billed Cuckoo, Red-bellied Woodpecker, Great Crested Flycatcher, Blue Jay, Black-and-white Warbler, and Northern Cardinal were found in greater numbers in unburned sites than in burned sites. We found no differences ($P > 0.05$) in bird species richness (41.8 ± 1.2, 40.7 ± 1.5) or evenness (0.8 ± 0.01, 0.8 ± 0.01) between burned and unburned mature pine tracts, respectively.

Reproductive success.—We monitored 233 nests of 23 species in burned and unburned sites during 1994 ($n = 113$) and 1995 ($n = 120$). Although nest search methods were similar in all sites, only nine nests (3.8%) of six species were found in unburned sites; this precluded us from testing for differences in avian productivity between habitats. Also, because of small sample sizes, we only present productivity estimates for the seven most-encountered species that nested in burned sites (187 nests). Overall, productivity estimates were low (Table 3). One or more eggs hatched in only 59 of 187 nests (32%) and an average of only 0.82 chicks per nest were estimated to have fledged. Of the 187 nest outcomes that we present, predation was the most common probable cause for nest failure, ranging from 45% in the Northern Cardinal to 64% in the Summer Tanager (Table 4). The second most common probable cause for nest failure was abandonment, ranging from 9% in the Prairie Warbler and Yellow-breasted Chat to 21% in the Northern Cardinal. Brood parasitism was low in our study area, although Brown-headed Cowbirds were present; six nests of the Prairie Warbler were found with cowbird eggs, but all nests were depredated eventually.

DISCUSSION

Johnston and Odum (1954) found significant increases in avian species abundance and richness with increasing plant succession in the Georgia Piedmont. Mature pine stands in their study had lower avian abundance and richness than did mixed pine-hardwood or pure hardwood stands. Dickson and Segelquist (1979) found that in Texas the highest breeding bird densities and diversity were achieved in stands with a maximum number of vertical layers of diverse vegetation in mature pine and mixed pine-hardwood stands. After 15 yr of fire suppression in a longleaf pine (*Pinus palustris*) forest in Florida, dramatic changes in vegetative structure resulted in a decrease in brush-nesting species and an increase in those preferring mesic conditions (Engstrom et al. 1984). On sites being returned to Red-cockaded Woodpecker habitat after fire suppression, avian densities increased or decreased depending on the bird species, but there were no differences in overall abundance or species richness in sites that were recently burned and thinned (Wilson et al. 1995).

TABLE 3. Productivity estimates for seven avian species nesting in burned mature pine forests at the Piedmont National Wildlife Refuge, Georgia, 1994–1995. Data for both seasons were pooled.

Parameter	Prairie Warbler	Eastern Towhee	Northern Cardinal	Yellow-breasted Chat	Indigo Bunting	Summer Tanager	Yellow-billed Cuckoo
No. active nests[a]	66	33	29	22	16	11	10
No. nests hatching ≥1 egg	21	7	10	7	8	2	4
Mean clutch size	3.4	2.8	2.6	2.8	2.6	2.4	2.1
Mayfield success rate (%)	32	5	42	12	21	12	31
Daily survival rate	0.95	0.89	0.96	0.91	0.94	0.92	0.95
Fledglings/active nest	0.90	0.68	0.86	0.95	1.30	0.45	0.60
Fledglings/nest hatching ≥1 egg	2.8	3.2	2.5	3.0	2.6	2.5	1.5

[a] ≥1 egg laid in nest.

TABLE 4. Probable fates of nest attempts for seven species nesting in burned mature pine forests at the Piedmont National Wildlife Refuge, Georgia, 1994–1995.

Nest fate (%)	PRAW[a]	EATO	NOCA	YBCH	INBU	SUTA	YBCU
≥1 chick fledged in nest	23	18	34	32	50	18	40
Predation (no disturbance)	50	55	35	45	24	64	40
Predation (disturbance)[b]	9	9	10	5	0	0	0
Cowbird eggs in nest	6	0	0	0	0	0	0
Weather-related failure	3	0	0	9	13	0	10
Abandoned	9	18	21	9	13	18	10

[a] Species codes for those species listed in Table 3.
[b] Nest disheveled or damaged.

Most of the gross habitat features that we measured in burned and unburned pine forests of the Georgia Piedmont differed significantly between habitats. However, interval since last burn (1-, 2-, or 3-yr post-burn) had no effect ($P > 0.05$) on measured components in burned tracts, probably because of high variability among surveys and uneven sample sizes. Also, observer bias may have contributed since some measurements were visual estimations (Ralph et al. 1993). Twenty-one avian species were more abundant in burned than in unburned tracts, but we found no differences ($P > 0.05$) in avian species richness or evenness between the two habitats during summer.

Productivity estimates of the seven species we studied in burned mature pine tracts at Piedmont National Wildlife Refuge were low, ranging from 0.6 to 1.3 fledglings per active nest. There is a dearth of information on songbird productivity in pine forests of the southeastern U.S., but similar success rates were reported for some species nesting in southern Georgia in burned areas adjacent to agricultural crops (Patnode and White 1992). Five of the seven species that we studied were Neotropical migrants that are declining across their range (Peterjohn and Sauer 1993, Sauer et al. 1997). Predation of nest contents appeared to be the major cause of nest failure in our study, ranging up to 64% in the Summer Tanager. Our results support those of other studies indicating predation as a significant factor in songbird nest failure (Angelstam 1986, Best and Stauffer 1980, Haskell 1995, Patnode and White 1992, Wilcove 1985, Yahner and Scott 1988), especially in fragmented habitats. We are uncertain why so few (nine) nests were found in unburned tracts. We used the same search methods for all areas. Fire-suppressed pine forests were less open than those burned regularly, resulting in fewer individuals and species of brush nesting birds (Engstrom et al. 1984). Our results corroborate those findings. Unburned tracts in our study had 732 trees ≥7.5 cm dbh/ha compared to 448 in burned tracts. Shrub density in our unburned sites was almost twice that in burned sites, although not significant. Four of the seven nesting species that we report on were significantly less abundant in fire-suppressed sites; therefore, reduced numbers of individuals may have curbed nesting efforts in some species.

Our objectives were to compare abundance and reproductive success of songbirds in burned and unburned mature pine forests at Piedmont National Wildlife Refuge, Georgia. Results were to be used in developing management plans that would enhance songbird productivity on the refuge. Although avian species richness and evenness were not different between classes, burned sites were much preferred for nesting over unburned sites. However, the rate of recruitment we estimated for Prairie Warblers, Eastern Towhees, Northern Cardinals, Yellow-breasted Chats, Indigo Buntings, Summer Tanagers, and Yellow-billed Cuckoos in burned sites is probably inadequate to maintain a stable population. Predation is the likely cause for most nest failures, but the sources are unknown. We suspect that snakes and other birds, such as Blue Jays (Patnode and White 1992), are mainly responsible because of a lack of disturbance at many of the nests. Future research should concentrate on identifying the major nest predators using 24-h surveillance equipment or other techniques.

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