EFFECTS OF PRESCRIBED BURNING FREQUENCY ON AVIAN COMMUNITIES IN LONGLEAF PINE FORESTS IN WESTERN LOUISIANA

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ABSTRACT

We examined the effects of four prescribed burning regimes (annual, 2- to 3-y, 4- to 7-y, and unburned) on avian communities in western Louisiana longleaf pine (*Pinus palustris*) stands for two spring (May and June) and two winter (January and February) seasons. Avian species richness and abundance were evaluated by season. During spring, red-cockaded woodpeckers (*Picoides borealis*), Bachman's sparrows (*Aimophila aestivalis*), and pine warblers (*Dendroica pinus*) showed increasing abundance with increasing frequency of fire. Four resident and six Neotropical migrant species increased with decreased frequency of fire ($P \leq 0.05$). During winter, numbers of red-cockaded woodpeckers, pine warblers, and brown-headed nuthatches (*Sitta pusilla*) increased with increased regularity of fires; no temperate-zone migrant species displayed such an increase. Six resident and six temperate-zone migrant species increased with decreasing frequency of fire ($P \leq 0.05$). Although avian species richness and abundance increased with decreasing frequency of fire, species that increased in abundance or were not present in frequently burned stands are not currently in jeopardy. The longleaf pine–grassland forest type occupies <5% of its original area; therefore, this type must be maintained and its extent expanded because it is critical to some avian species that are declining in numbers.

Keywords: avian communities, birds, longleaf pine, *Pinus palustris*, prescribed burning frequency, western Louisiana.

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INTRODUCTION

Longleaf pine (*Pinus palustris*) ecosystems are fire-maintained, subclimax forests (Wahlenburg 1946) that have occurred along the Atlantic and Gulf coastal plains in the southeastern United States for the past 8 million y (Webb 1986). These ecosystems are dependent on fire to limit encroachment of hardwoods that compose most climax communities on the coastal plains (Engstrom et al. 1984).

Prior to European colonization, longleaf pine was the dominant vegetation on as much as 37.2 million ha of uplands in the Southeast (Frost 1993). However, only a small percentage of that area is currently occupied by longleaf pine forests (Platt et al. 1988, Frost 1993, Landers et al. 1995). Exploitation of virgin forests, fire suppression, reforestation to other pine species, and conversion of longleaf pinelands to other land uses have resulted in the loss of as much as 35.6 million ha of longleaf pine–dominated forests (Frost 1993, Landers et al. 1995, Outcalt and Sheffield 1996).

Frequent burning in a longleaf pine forest results in a pine–grassland savannah with little or no hardwood midstory or understory. In pine-dominated stands, however, the impact of burning on avian abundance and composition is species specific; thus, generalizations about correlations between birds and fire are difficult (Bendell 1974, Sousa 1984, Rotenberry et al. 1993). Burning benefits pine–grassland obligate species; however, species dependent on deciduous canopy vegetation, midstory and understory trees and shrubs, or accumulated litter are disadvantaged (Dickson 1981, Dickson et al. 1993). In recent years, Neotropical migratory birds (NTMBs) have become the focus of concern due to decreasing abundance throughout the breeding ranges of some species (Robbins et al. 1992). Sauer and Droege (1992) analyzed continent-wide Breeding Bird Survey data and found significant declines in some species, particularly among eastern species breeding in forest ecosystems, including those that are dependent on pine–grassland and other early succession habitats (Jackson 1988). Several studies have investigated the impacts of longleaf pine restoration and management on avian communities (Rutledge and Conner 2002, Tucker et al. 2004, Wood et al. 2004). However, no studies have investigated the effects of prescribed burning frequency on abundance and composition of resident and migratory bird communities in longleaf pine forests in western Louisiana. This study investigated the impacts of burning frequency on avian communities in longleaf pine forests dominated by sawtimber size-class trees (>24.5 cm diameter at breast height [DBH], i.e., diameter at 1.37 m above groundline on uphill side of the tree; Stoddard and Stoddard 1987).

STUDY AREA

This study took place on and adjacent to the Fort Polk Military Reservation, approximately 20 km southeast of Leesville, Louisiana (lat 93°15′N, long

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31°00′W). This area was part of the Louisiana Longleaf Pinelands Region of the Gulf Coastal Plain (Nelson and Zillgitt 1969). It was characterized by gently rolling topography with upland areas dominated by longleaf pine in the overstory. The forests were interspersed with perennial and intermittent streams bordered by riparian zones that were dominated by hardwoods (Hamilton and Yurkunas 1987). Overstory trees were 40–50 y old and were of the sawtimber size class.

Six study sites were selected according to previous burning frequency. Two study sites, Bunkhouse East and Forest Service Road West, were in stands on annual burning cycles. Likewise, there were two study sites, Bunkhouse West and Forest Service Road East, in stands on 2- to 3-y burning cycles. These four sites were on U.S. Forest Service land immediately adjacent to the military reservation. Each site was part of a large (>50 ha) stand that had been prescribed burned for numerous years; normally the burns took place in late February or March. The study site on the 4- to 7-y burning cycle, Castor, was on the military reservation. It also was part of a large stand (>50 ha) that had been burned in late fall by an unplanned fire 4 y prior to the initiation of the study. Fire had been excluded from the unburned study site, Airport, for at least 20 y, and probably for the life of the stand. The entire stand was small (<10 ha) and adjacent to urban areas on the reservation.

Both annually burned sites (Bunkhouse East and Forest Service Road West) were open, park-like, pure longleaf pine stands interspersed with small areas of natural longleaf regeneration; there were few snags (<5/ha) on either site. Bunkhouse East had almost no hardwood midstory (i.e., woody plants >2.54 cm DBH with canopies below the general level of the forest canopy) or understory (i.e., woody plants >1.0 m tall but <2.54 cm DBH). Forest Service Road West had a few midstory hardwoods and scattered understory woody vegetation, mostly concentrated in and around a minor drainage that had no distinguishable channel. Both study sites had dense forest floor vegetation (i.e., plants <1.0 m tall) dominated by grasses with scattered herbaceous and woody plants (Laterza 1999). Laterza (1999:31–45) provides detailed descriptions of study site vegetation.

Overstory vegetation and forest floor characteristics of the 2- to 3-y burning cycle stands (Bunkhouse West and Forest Service Road East) were marginally similar to those of the annually burned stands. However, each had more midstory and understory hardwood species and stems per hectare than did the annually burned sites. Bunkhouse West contained a small perennial stream bordered by a 20-m-wide riparian zone with dense hardwood midstory and understory vegetation; two avian transects ran perpendicularly through the riparian zone. Forest Service Road East contained a shallow drainage similar to that on Forest Service Road West. Numerous scattered understory hardwoods and vines were associated with the drainage. One avian transect crossed perpendicularly through the drainage; another ran diagonally along it such that a portion of the drainage area was included in the avian sampling area. Snags were rare (<2.5/ha) on each study site (Laterza 1999).

Characteristics of the vegetation on the Castor study site, burned on a 4- to 7-y cycle, were very different from those of the more frequently burned study sites. Castor had a greater overstory hardwood component, and the combined numbers of loblolly (*P. taeda*) and shortleaf pines (*P. echinata*) in the overstory were approximately equal to that of longleaf pine. Also, Castor had dense midstory and understory vegetation dominated by hardwood species. Although the forest floor vegetation was dominated by grasses, an increase in woody plants was evident as compared to the more frequently burned sites. The study site contained approximately 16 snags/ha (Laterza 1999).

The unburned Airport study site had the fewest overstory pines; however, diameter of overstory pines was significantly larger than on the more frequently burned sites. Numbers of overstory hardwood species and stems per hectare were similar to those on Castor and higher than on the other sites. Both the midstory and understory were well developed and very dense; each was dominated by hardwood species. Forest floor vegetation was dominated by woody plant species, and vines were prevalent. The site contained approximately 13 snags/ha (Laterza 1999).

METHODS

Sampling Birds

Birds were sampled using the fixed-width strip transect method (Conner and Dickson 1980). Four transects (i.e., replications), each 100 m wide and 200 m long and spaced at least 100 m apart, were established within each study site. The centerline of each transect was marked with plastic flagging along its entire length, and exterior boundaries were marked as needed. The starting and ending points of each transect were recorded using the Global Positioning System.

Bird counts were performed each spring and winter for 2 y. Spring counts were conducted between mid-May and mid-June, 1995 and 1996; winter counts were performed between mid-January and mid-February, 1996 and 1997 (Conner and Dickson 1980). Prior to the beginning of each season, several training sessions were held for participating observers. These sessions allowed the observers to become familiar with the study sites and the local avifauna.

Each study site was sampled nine mornings each season. Each of three observers sampled a pair of sites each morning. For each pair, the study site sampled first was rotated every other morning; beginning points on each site also were alternated. Sampling of the six study sites was performed on a rotational basis such that each observer sampled each site three times per season. To reduce weather and observer bias, birds were sampled only on days when all three observers could participate. Birds were recorded if they were within the transect, flew into or out of the transect (Conner and Dickson 1980), or flew over the transect and appeared to be associated with overstory vegeta-

Table 1. Average numbers of species and individuals per survey (18 surveys) and results of Kruskal–Wallis tests and associated Nemenyi multiple comparisons by season for study sites used for avian sampling on or adjacent to the Fort Polk Military Reservation in western Louisiana, 1995–1997.

Season	Study site burning regime and name[a]					
	Annual		2–3 y		4–7 y	Unburned
	BNKH East	FSRD West	BNKH West	FSRD East	Castor	Airport
Spring						
Avg. no. species/survey	5.44a[b] (21)	6.28ab (22)	6.83ab (26)	7.67b (23)	11.06c (34)	11.06c (29)
Avg. no. individuals/survey	12.67a	13.00a	13.33a	12.83a	20.33b	28.72b
Winter						
Avg. no. species/survey	5.78a (27)	6.67ab (26)	7.28ab (28)	7.39ab (31)	8.28b (26)	11.78c (29)
Avg. no. individuals/survey	18.61a	43.06a	27.39a	25.89a	24.67a	48.56b

[a] Abbreviations: BNKH, Bunkhouse; FSRD, Forest Service Road.
[b] Within rows, values followed by same letter did not differ ($\alpha = 0.05$). Total numbers of species recorded are in parentheses.

tion. Data recorded for each observation included species name and number of individuals.

Data Analysis

Because of differences in riparian zones in the annual and 2- to 3-y burning regime study sites, each site was considered separately rather than as a replicate. Each day was considered as a single sampling unit; thus, sample size was nine per study site per season. For each study site, Mann–Whitney *U*-tests ($\alpha = 0.10$) were used to test for differences in numbers of bird species and individuals between years by season. If no differences were detected, the two years of data for each study site were pooled; thus, sample size became 18 for each season. Numbers of bird species, individuals, and individuals of selected species were compared among study sites by season using Kruskal–Wallis tests; differences were examined with nonparametric Tukey-type multiple comparisons using the Nemenyi test ($\alpha = 0.05$) (Zar 1996). These tests used ranked observation data pooled by study site and season. Therefore, more weight was given to frequency of occurrence than to actual numbers observed; it was thus possible that average numbers of species, individuals, or individuals of a selected species recorded per survey were similar between two or more study sites, yet were statistically different.

The null hypotheses tested were that 1) for each study site, seasonal avian species richness and abundance did not differ between years; and 2) within a season, avian species richness, abundance, and numbers of individuals of selected species did not differ among study sites.

RESULTS

Avian Communities

During 216 avian surveys, 5,362 individuals of 72 species were observed among all study sites. Eighteen species recorded during spring were also recorded during winter. Mann–Whitney *U*-tests comparing seasonal numbers of species and individuals between years by study sites revealed only 2 of 24 comparisons differed; more individuals were recorded in winter 1997 than in winter 1996 on two sites (annually burned Forest Service Road West and 2- to 3-y burned Bunkhouse West). Therefore, for each study site, data gathered during the two years were pooled by season for further analyses.

Spring Birds

During the spring surveys, 1,822 individuals representing 46 species of birds were recorded (Laterza 1999:47–48). Average numbers of species and individuals recorded per survey increased with decreasing burning frequency. Multiple range tests formed three groups for species richness and two for avian abundance. For both parameters, values for the 4- to 7-y burned Castor and unburned Airport study sites were similar and were higher than values for the more frequently burned study sites (Table 1). The lowest avian richness and abundance values were recorded on the annually burned Bunkhouse East study site; values recorded there were less than half as large as those recorded on the Castor and Airport study sites. Richness and abundance values for the other three frequently burned study sites were only slightly higher than those recorded on Bunkhouse East (Table 1).

Bachman's sparrows (*Aimophila aestivalis*), northern cardinals (*Cardinalis cardinalis*), pine warblers (*Dendroica pinus*), and Carolina wrens (*Thryothorus ludovicianus*) were the most abundant species recorded during spring surveys. Abundances of these species and 16 others were compared among study sites (Table 2). Ten species were classified as residents (Robbins et al. 1983) and nine as Neotropical migrants (Peterjohn et al. 1995). Among resident species, red-cockaded woodpeckers (*Picoides borealis*), Bachman's sparrows, and pine warblers were more abundant on study sites subjected to annual or 2- to 3-y burning regimes than on the less frequently burned sites. Northern cardinals, Carolina wrens, tufted titmice (*Baeolophus bicolor*), and Carolina chickadees (*Poecile carolinensis*) were most abundant on the less frequently burned sites. Red-bellied woodpeckers (*Melanerpes carolinus*), blue jays (*Cyanocitta cristata*), and brown-headed nuthatches (*Sitta pusilla*) showed no differences in abundances among burning regimes.

Six species of NTMBs (great crested flycatcher

Table 2. Average numbers of individuals of selected species per survey and results of Kruskal–Wallis tests and associated Nemenyi multiple comparisons among avian study sites on or adjacent to the Fort Polk Military Reservation in western Louisiana during spring (May–June), 1995 and 1996.

Species	Study site burning regime and name[a]					
	Annual		2–3 y		4–7 y	Unburned
	BNKH East	FSRD West	BNKH West	FSRD East	Castor	Airport
Residents						
Red-cockaded woodpecker	0.06 (1)a[b]	1.44 (15)b	0.94 (11)b	0.67 (7)a	0.00	0.00
Red-bellied woodpecker	0.00	0.16 (3)	0.06 (1)	0.11 (2)	0.06 (1)	0.44 (5)
Blue jay	0.50 (6)	0.06 (1)	0.61 (5)	0.50 (6)	0.89 (5)	0.61 (6)
Bachman's sparrow	4.50 (18)a	3.61 (18)ab	3.89 (18)a	1.78 (15)b	0.56 (8)c	0.17 (3)c
Northern cardinal	0.11 (2)a	0.17 (3)a	0.89 (11)a	0.78 (8)a	2.70 (17)b	5.11 (17)b
Pine warbler	2.61 (17)ab	3.11 (16)a	2.06 (16)ab	2.61 (17)ab	1.67 (13)ab	1.61 (9)b
Carolina wren	0.22 (3)a	0.33 (5)a	0.44 (7)a	0.72 (11)ab	1.72 (16)bc	4.44 (16)c
Brown-headed nuthatch	1.28 (12)	0.44 (4)	1.06 (7)	1.17 (8)	0.61 (8)	0.56 (5)
Tufted titmouse	0.00	0.06 (1)a	0.00	0.06 (1)a	0.72 (8)ab	1.67 (13)b
Carolina chickadee	0.00	0.11 (1)a	0.00	0.50 (4)ab	0.72 (9)b	0.83 (8)b
Neotropical migrants						
Great crested flycatcher	0.00	0.11 (2)a	0.06 (1)a	0.28 (5)ab	0.61 (5)b	0.83 (11)b
Chipping sparrow	0.39 (1)	0.39 (4)	0.39 (4)	0.28 (5)	0.00	0.00
Indigo bunting	1.17 (13)a	0.67 (9)ab	0.11 (2)b	0.72 (9)ab	0.83 (9)a	0.61 (6)ab
Summer tanager	0.33 (5)a	0.22 (4)a	0.17 (3)a	0.33 (4)a	2.06 (16)b	1.17 (14)b
Red-eyed vireo	0.00	0.00	0.06 (1)a	0.00	0.67 (9)b	1.50 (12)b
White-eyed vireo	0.17 (1)a	0.00	0.11 (2)a	0.33 (6)ab	0.89 (11)bc	2.61 (17)c
Yellow-breasted chat	0.11 (2)a	0.39 (4)a	0.28 (4)a	1.28 (16)b	1.72 (15)b	0.11 (3)a
Hooded warbler	0.00	0.00	0.33 (5)ab	0.00	0.50 (9)bc	1.39 (12)c
Blue-gray gnatcatcher	0.00	0.00	0.00	0.06 (1)a	1.56 (10)b	1.22 (11)b

[a] Abbreviations: BNKH, Bunkhouse; FSRD, Forest Service Road.
[b] Within rows, values followed by same letter did not differ ($\alpha = 0.05$). Numbers in parentheses are frequencies of occurrence among 18 surveys.

[*Myiarchus crinitus*], summer tanager [*Piranga rubra*], red-eyed vireo [*Vireo olivaceus*], white-eyed vireo [*Vireo griseus*], hooded warbler [*Wilsonia citrina*], and blue-gray gnatcatcher [*Polioptila caerulea*]) were more abundant on the less frequently burned Castor and unburned Airport study sites than on the more frequently burned sites (Table 2). Yellow-breasted chat (*Icteria virens*) numbers were higher on Forest Service Road East (2- to 3-y burn) and Castor (4- to 7-y burn) sites than on other sites. Indigo bunting (*Passerina cyanea*) and chipping sparrow (*Spizella passerina*) numbers were not different among study sites.

Winter Birds

During the 1996 and 1997 winter sampling periods, 3,540 individuals of 44 species were observed among all study sites (Laterza 1999:54–55). As with spring birds, average numbers of species and individuals recorded per survey increased with decreasing burning frequency. Multiple range tests distinguished three groups for species richness and two for bird abundance (Table 1). Although average number of individuals per survey on the annually burned Forest Service Road West study site was similar to that on the unburned Airport study site (Table 1), differences between the two sites were significant because of infrequent observations of large flocks of birds on the Forest Service Road West study site. Species of birds that were relatively abundant during winter included the American goldfinch (*Carduelis tristis*), white-throated sparrow (*Zonotrichia albicollis*), dark-eyed junco (*Junco hyemalis*), and pine warbler (Table 3). There were sufficient data to compare abundances among study sites for 12 resident and 10 temperate-zone migrant species (Table 3).

During winter, red-cockaded woodpeckers, pine warblers, and brown-headed nuthatches were more abundant on the frequently burned stands than on the Castor or Airport study sites (Table 3). Bachman's sparrows showed a similar though nonsignificant trend (Table 3). Red-cockaded woodpecker and pine warbler abundances were similar during spring (Table 2). However, the brown-headed nuthatch responded differently. During spring, there were no differences in numbers recorded among study sites (Table 2) whereas during winter, this species was more abundant in the annually burned stands than in the other stands (Table 3).

Red-bellied woodpeckers, northern cardinals, Carolina wrens, and Carolina chickadees were more abundant on the unburned Airport study site than on the other study sites. Likewise, the tufted titmouse increased in abundance with decreasing burning frequency. There were no differences in numbers of pileated woodpeckers (*Dryocopus pileatus*) and blue jays among study sites; although numbers of American crows (*Corvus brachyrhynchos*) differed among study sites, they did not exhibit a trend across burning regimes (Table 3).

Species commonly found in western Louisiana only during winter (Robbins et al. 1983) were classified as temperate-zone migrants. Five of 10 temperate-zone migrants displayed increasing abundance with decreasing burning frequency (Table 3). The white-

throated sparrow, yellow-rumped warbler (*Dendroica coronata*), and American robin (*Turdus migratorius*) were most abundant on the unburned Airport study site. Similarly, the yellow-bellied sapsucker (*Sphyrapicus varius*), ruby-crowned kinglet (*Regulus calendula*), and hermit thrush (*Catharus guttatus*) were recorded in greatest numbers on the unburned Airport study site; however, abundances of these species on that site were not different from abundances on the Castor site (4- to 7-y burn) (Table 3).

Dark-eyed juncos and cedar waxwings (*Bombycilla cedrorum*) did not exhibit significant trends among the study sites. These species were usually recorded in flocks; thus, there were large but nonsignificant differences in numbers of each among the study sites. Although there were significant differences among study sites in numbers of American goldfinches, there were no differences across burning regimes. The chipping sparrow, a NTMB (Peterjohn et al. 1995) typically found year-round in the western Louisiana region (Robbins et al. 1983), tended to be higher in abundance on more frequently burned sites, but differences were not significant (Table 3). For the purpose of this study, that species was grouped with temperate-zone migrants.

DISCUSSION

Spring Birds

Resident Species

Frequent prescribed burning benefits resident species such as the red-cockaded woodpecker and Bachman's sparrow, both closely associated with southeastern pine–grassland ecosystems (Dunning 1993, Kaufman 1996). The red-cockaded woodpecker inhabits mature, open pine forests, and control of midstory hardwoods is necessary to prevent colony abandonment (Locke et al. 1983, Conner and Rudolph 1989). In this study, no red-cockaded woodpeckers were observed on study sites where hardwoods were well established in the midstory (i.e., Castor [4- to 7-y burn] and Airport [unburned]). Bachman's sparrows also exhibited strong preferences for stands with annual or 2- to 3-y burning regimes and were a common species in these stands during spring. These results corroborate the importance of the pine–grassland savannah habitat type to this species (Plentovich et al. 1998, Tucker et al. 2004), which is undergoing a population decline in the southern United States (Dunning and Watts 1990, Brennan 1991). Frequent prescribed burning in pine forests is critical for this species and thus is an important management tool for increasing population numbers (Dunning 1993).

Frequent use of prescribed fire, however, may eliminate dead trees and thus discriminate against cavity-nesting species (Wood and Niles 1978). Although we did not test between seasons, brown-headed nuthatches, tufted titmice, and Carolina chickadees appeared to be less abundant on the frequently burned sites during spring than during winter. All three species are cavity nesters, and relatively low spring numbers were probably due to lack of snags and thus cavities for nest sites.

High spring numbers of tufted titmice and Carolina chickadees in the less frequently burned stands were probably due to greater numbers of snags and better developed understories and midstories than in the more frequently burned stands (Conner et al. 1983). In eastern Texas, Carolina chickadees were abundant in areas with open understories (Whiting 1978, Conner et al. 1983) and were positively associated with density of midstory hardwoods (Conner et al. 1983). These differing understory findings suggest that density of midstory hardwoods is more important to Carolina chickadees than is condition of the understory.

Carolina chickadees were most abundant on the unburned Airport study site, which had a well-developed midstory and understory (Jones 1997). In eastern Texas, this species was abundant in areas with open understories and was positively associated with density of midstory hardwoods (Conner et al. 1983). Results of the two studies suggest that density of midstory hardwoods is more important to the Carolina chickadee than condition of the understory.

Also in eastern Texas, abundances of northern cardinals, Carolina wrens, and tufted titmice were positively correlated with increasing shrub-level and hardwood midstory vegetation density (Conner et al. 1983). Results of this study agree with those findings in that all three species declined as frequency of prescribed burning increased. Northern cardinals and Carolina wrens typically nest in understory or midstory vegetation (Kaufman 1996, Halkin and Linville 1999); thus, it is not surprising that reduction or elimination of these vegetation strata with frequent prescribed fire adversely affected abundances of the two species.

Neotropical Migrants

Six NTMB species, the great crested flycatcher, summer tanager, red-eyed vireo, white-eyed vireo, hooded warbler, and blue-gray gnatcatcher, exhibited increased abundance with decreasing burning frequency. Of these, the great crested flycatcher, summer tanager, red-eyed vireo, and blue-gray gnatcatcher are commonly associated with mixed pine–hardwood forests (Hespenheide 1971, Whiting 1978, Kaufman 1996). Increased midstory and overstory hardwood vegetation in the Castor (4- to 7-y burn) and Airport (unburned) stands apparently benefited these species.

Red-eyed vireos were abundant only on the unburned and least frequently burned study sites where midstory and overstory hardwoods were prevalent (Jones 1997). Results of this study support findings that such vegetation is important for this species. In eastern Texas, red-eyed vireos were positively associated with increasing numbers of tree species, vegetation height, percent hardwood saplings, density of large trees, and numbers of shrub species (Conner et al. 1983). Similarly, in Arkansas and Mississippi (James 1971, Wood et al. 2004), red-eyed vireos in pine forests were typically associated with well-devel-

Table 3. Average numbers of individuals of selected species per survey and results of Kruskal–Wallis tests and associated Nemenyi multiple comparisons among avian study sites on or adjacent to the Fort Polk Military Reservation in western Louisiana during winter (January–February), 1996 and 1997.

Species	Study site burning regime and name[a]					
	Annual		2–3 y		4–7 y	Unburned
	BNKH East	FSRD West	BNKH West	FSRD East	Castor	Airport
Residents						
Red-cockaded woodpecker	0.94 (8)a[b]	1.94 (16)b	2.39 (17)b	2.06 (16)b	0.00	0.00
Pileated woodpecker	0.39 (7)	0.11 (1)	0.06 (1)	0.33 (6)	0.22 (4)	0.28 (4)
Red-bellied woodpecker	0.00	0.00	0.06 (1)a	0.06 (1)a	0.22 (4)a	1.39 (12)b
Blue jay	0.11 (2)	0.17 (3)	0.06 (1)	0.06 (1)	0.00	0.94 (7)
American crow	0.66 (3)ab	0.17 (2)a	0.17 (3)ab	0.39 (5)ab	1.06 (5)ab	1.06 (9)b
Bachman's sparrow	0.94 (8)	0.00	0.06 (1)	0.89 (8)	0.06 (1)	0.00
Northern cardinal	0.00	0.00	0.44 (5)a	0.89 (8)ab	1.67 (14)b	5.11 (17)c
Pine warbler	5.06 (17)a	4.28 (15)ab	3.27 (16)bc	2.83 (14)bc	3.06 (17)b	1.22 (8)c
Carolina wren	0.28 (4)a	1.22 (9)ab	1.00 (12)ab	1.06 (9)ab	1.33 (13)b	3.39 (16)c
Brown-headed nuthatch	2.67 (13)ab	2.11 (16)a	1.61 (9)abc	0.89 (7)c	0.94 (10)bc	0.39 (4)c
Tufted titmouse	0.11 (2)a	0.17 (2)ab	0.33 (1)ab	0.17 (3)abc	1.00 (9)bc	0.83 (9)c
Carolina chickadee	0.11 (2)a	0.22 (4)a	0.28 (3)a	0.83 (5)a	0.83 (4)a	1.56 (13)b
Temperate-zone migrants						
Yellow-bellied sapsucker	0.11 (2)a	0.00	0.11 (2)a	0.11 (2)a	0.56 (2)9ab	1.06 (13)b
American goldfinch	0.83 (2)a	20.22 (9)b	4.67 (6)ab	6.89 (5)ab	2.39 (5)ab	1.72 (5)ab
White-throated sparrow	0.72 (3)a	7.67 (10)b	3.89 (12)b	4.61 (12)b	4.67 (13)b	17.22 (18)c
Chipping sparrow	0.67 (6)	1.39 (8)	0.28 (3)	0.83 (4)	0.39 (4)	0.17 (3)
Dark-eyed junco	2.67 (2)	0.28 (1)	5.44 (4)	1.28 (4)	0.83 (2)	0.00
Cedar waxwing	0.28 (1)	0.00	0.56 (1)	0.00	1.22 (2)	1.11 (3)
Yellow-rumped warbler	0.06 (1)a	0.33 (2)a	0.39 (4)a	0.17 (1)a	0.44 (3)a	2.28 (13)b
Ruby-crowned kinglet	0.06 (1)a	0.00	0.11 (2)a	0.00	0.28 (4)ab	1.11 (10)b
Hermit thrush	0.00	0.06 (1)a	0.28 (5)ab	0.22 (4)a	0.50 (6)b	0.94 (11)b
American robin	0.56 (2)a	0.00	0.22 (2)a	0.28 (3)a	1.94 (5)a	4.72 (14)b

[a] Abbreviations: BNKH, Bunkhouse; FSRD, Forest Service Road.
[b] Within rows, values followed by same letter did not differ ($\alpha = 0.05$). Numbers in parentheses are frequencies of occurrence among 18 surveys.

oped deciduous midstory and overstory trees. White-eyed vireos and hooded warblers are typically associated with dense, shrubby undergrowth (Whiting 1978, Engstrom et al. 1984). Both species were most abundant on Castor and Airport sites, where less frequent application of prescribed fire encouraged dense understory vegetation. Similarly, Conner et al. (1983) found that white-eyed vireos were positively associated with increasing density of shrub stems, foliage density from 0 to 1 m in height, and numbers of shrub species.

Winter Birds

Resident Species

Generally, habitat associations of the red-cockaded woodpecker, blue jay, northern cardinal, pine warbler, Carolina wren, tufted titmouse, and Carolina chickadee during winter were similar to those during spring. Although pileated woodpeckers were more abundant during winter than during spring, relatively low numbers were recorded during both seasons and no trends were evident. The red-bellied woodpecker, which did not display a significant trend among study sites during spring, was more abundant on the unburned Airport study site than on the remaining study sites during winter; the difference between seasons was due to an increase in numbers on the Airport study site during winter. That increase may have been due to expanded visibility resulting from the lack of leaves on deciduous vegetation. Red-bellied woodpeckers are commonly associated with woodlands dominated by deciduous tree species (Shackelford et al. 2000) and, as such, the Airport study site had the most suitable habitat.

Only 19 Bachman's sparrows were recorded during winter; thus, statistical tests showed no differences among study sites. The reason for the lower numbers of Bachman's sparrows during winter surveys is unknown but is likely a result of reduced visibility and therefore detectability of the species; Bachman's sparrows are secretive and difficult to locate during winter (Wilson et al. 1995, Kaufman 1996). Approximately 95% of the individuals recorded during each season were on the annual and 2- to 3-y burning regime study sites. These results support the conclusions of Tucker et al. (2004) that in the longleaf pine–grassland savannah habitat type, a 2- or 3-y burning rotation is critical for Bachman's sparrows during both seasons.

Unlike during spring, when low numbers of brown-headed nuthatches in the more frequently burned stands was possibly due to lack of snags and thus cavities, this species was among the most common in those study sites during winter. Although no significant difference for brown-headed nuthatch abundance was evident during spring, winter data indicated increasing abundance with increased frequency of fire (Tables 2, 3). As brown-headed nuthatches are associated with open, mature pine forests (O'Halloran and Conner 1987, Kaufman 1996), the annual and 2- to

3-y burning regime study sites had the most suitable habitat during both seasons.

Temperate-Zone Migrants

During winter, the yellow-bellied sapsucker, white-throated sparrow, yellow-rumped warbler, ruby-crowned kinglet, hermit thrush, and American robin increased in abundance with decreasing burning frequency. These species commonly winter in forests with hardwood trees and dense undergrowth (Whiting 1978, Kaufman 1996), and frequent prescribed burning may reduce habitat suitability. Yellow-bellied sapsuckers forage by pecking holes into the cambium of trees and feeding on oozing sap and insects attracted to the sap (Bent 1964). During winter, white-throated sparrows commonly forage in dense thickets that provide cover and where seeds are abundant beneath leaf litter (Falls and Kopachena 1994). Yellow-rumped warblers and ruby-crowned kinglets forage in understory vegetation in deciduous forests, feeding on insects and insect larvae (Kaufman 1996). Typically, robins congregate in large flocks in habitats containing berry-producing trees and shrubs during winter (Whiting 1978, Kaufman 1996). American robins were most abundant during winter on the Castor and Airport study sites, which had high densities of a variety of berry-producing plants such as yaupon (*Ilex vomitoria*), privet (*Ligustrum* spp.), American beautyberry (*Callicarpa americana*), and American holly (*Ilex opaca*).

As during spring, winter abundances of chipping sparrows were not different among study sites. During spring, chipping sparrows were not recorded on the Castor and Airport study sites and lack of a trend was probably due to low numbers recorded. Conversely, wintering chipping sparrows were recorded in adequate numbers to statistically analyze. However, they were recorded on all study sites but with variable abundances that lacked a discernable trend.

MANAGEMENT IMPLICATIONS

Prescribed burning is an important tool with which resource managers can accomplish many objectives. Obviously, the frequency at which prescribed fire is applied in a longleaf pine forest will influence the vegetational structure and composition of individual stands. Although frequent fires in longleaf pine stands that lead to pine–grassland savannah may discriminate against bird species that typically inhabit pine and mixed pine–hardwood stands with well-developed understory and/or midstory vegetation, this habitat type is critical to many avian species, particularly pine–grassland obligates.

Longleaf pine was once the dominant vegetation cover type in the southeastern United States. At present, <5% of this forest type remains. Areas currently containing this vegetation type must be maintained in order to provide suitable habitat for the red-cockaded woodpecker, Bachman's sparrow, and many other pine–grassland species. Furthermore, increasing the area of longleaf pine–grassland savannah through creation and/or restoration efforts is vital to maintaining or increasing populations of these species. In addition to birds, there is evidence that restoration of the pine–grassland savannah habitat type may be beneficial to many small mammals (Masters et al. 1998) which, in turn, could benefit many bird, mammal, and reptile species that depend on such animals as prey.

Finally, riparian zones and mesic sites influence avian species composition in longleaf pine–grassland savannah habitats. In this study, 16 bird species common to the less frequently burned Castor and unburned Airport study sites were recorded on the four frequently burned study sites in vegetation associated with small drainages. Such areas provided habitat for avian species that are not normally associated with the longleaf pine–grassland savannah habitat type. These results suggest that riparian zones and mesic sites containing hardwoods may be extremely beneficial for maintaining a wide array of bird species in frequently burned longleaf pine stands.

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