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AVIAN COMMUNITY RESPONSE TO SOUTHERN PINE ECOSYSTEM RESTORATION FOR RED-COCKADED WOODPECKERS

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ABSTRACT.—The effects of Red-cockaded Woodpecker (*Picoides borealis*) management on nontarget birds is not widely known. Intensive management for pine specialists such as the Red-cockaded Woodpecker may negatively impact both Nearctic-Neotropical and Temperate Zone migrants associated with hardwood vegetation. To evaluate possible positive and negative associations, we surveyed avian communities from 1995–1997 using point counts within managed Red-cockaded Woodpecker cavity tree clusters and mature forest control sites in longleaf pine (*Pinus palustris*) and loblolly (*P. taeda*)-shortleaf (*P. echinata*) pine habitats. In general, sites managed for Red-cockaded Woodpeckers supported more diverse and numerous bird populations than mature forest control sites. During the breeding season in loblolly-shortleaf and longleaf pine habitats, respectively, species richness was 47% and 23% greater, avian abundance was 57% and 65% greater, and bird species diversity was 25% and 21% greater within managed Red-cockaded Woodpecker cluster sites than within control sites. During winter, species richness and avian abundance each were 52% higher within managed Red-cockaded Woodpecker cluster sites than control sites in loblolly-shortleaf pine habitat. *Received 30 January 2002, accepted 12 August 2002.*

Studies in Texas and across the southeastern United States have indicated that many Red-cockaded Woodpecker (*Picoides borealis*) populations on national forest lands declined during the 1980s (Conner and Rudolph 1989, Costa and Escano 1989) and 1990s (U.S. Dept. of Agriculture 1995), although a few have increased (Hooper et al. 1991, Richardson and Stockie 1995). In an effort to stabilize and recover populations of this endangered woodpecker, the U.S. Forest Service initiated habitat management to restore southern pine ecosystems and provide vegetative and landscape conditions more suitable for the woodpecker on national forests throughout the southeastern United States (U.S. Dept. of Agriculture 1995). An integral part of this new management direction is the restoration of pine ecosystems with a grass-forb herbaceous layer and reduction of hardwood mid- and understory vegetation within Red-cockaded Woodpecker habitat management areas through mechanical removal of encroaching hardwood midstory and an aggressive prescribed fire program.

The Red-cockaded Woodpecker is a cooperatively breeding species indigenous to the southeastern United States (Conner et al. 2001). Young woodpeckers, typically males from previous broods, often remain with the breeding pair and assist in subsequent nesting efforts by feeding and incubating young, excavating cavities, and helping to defend the group's territory (Ligon 1970, Lennartz et al. 1987, Walters et al. 1988, Conner et al. 2001). An aggregation of cavity trees, termed the cavity tree cluster, is defended by a group of woodpeckers.

Throughout the eastern and western United States, populations of many species of Nearctic-Neotropical migrant birds appear to be suffering long term declines (Whitcomb et al. 1981, Ambuel and Temple 1983, Robbins et al. 1989). Declines of some Nearctic-Neotropical migratory birds may be related to increased nest predation and Brown-headed Cowbird (*Molothrus ater*) nest parasitism (Gates and Gysel 1978, Whitcomb et al. 1981, Wilcove 1985, Small and Hunter 1988, Terborgh 1989). Extensive opening and thinning of the forest associated with Red-cockaded Woodpecker management could increase the apparent edge as perceived by Brown-headed Cowbirds. Nest parasitism and predation rates

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appear to be greater in edge habitats than in forest interiors (Gates and Gysel 1978, Temple and Cary 1988).

Concern over declining populations of many Nearctic-Neotropical migrant birds recently has intensified and programs to determine causes and reverse declines have been sought (Keast and Morton 1980, Hagan and Johnston 1992, Finch and Stangel 1993). Effects of Red-cockaded Woodpecker management on sensitive species such as Bachman's (*Aimophila aestivalis*) and Henslow's (*Ammodramus henslowii*) sparrows and Southeastern American Kestrels (*Falco sparverius paulus*) are of concern to managers. Hunter et al. (1994) predicted that management for Red-cockaded Woodpeckers and other southern pine specialists would benefit these generally rare species. They also concluded that management that promotes hardwoods within longleaf (*Pinus palustris*) and loblolly (*P. taeda*)-shortleaf (*P. echinata*) pine stands is largely detrimental to pine specialists and provides little benefit to Nearctic-Neotropical migrants associated with hardwood forests. Many Nearctic-Neotropical migrants are known to be positively associated with hardwood mid- and understory foliage (Conner and Adkisson 1975; Conner et al. 1979, 1983; Dickson et al. 1993a). Removal or reduction of these components of forest structure has the potential to greatly reduce species that depend upon hardwood foliage for nesting and foraging in both the mid- and understory layers.

Alternatively, restoration of an open grass-forb herbaceous layer may provide suitable habitat for increases of avian species that have been reduced in numbers by past exclusion of fire, such as the Northern Bobwhite (*Colinus virginianus*; Brennan 1991). Bowman et al. (1999) noted numerous benefits of Red-cockaded Woodpecker management for some game species; white-tailed deer (*Odocoileus virginianus*) benefited from increased forage production, Wild Turkey (*Meleagris gallopavo*) hens benefited from improved nesting habitat and increased soft mast production, and Northern Bobwhites benefited from increases in herbaceous ground cover, arthropods, and native legumes, which improved nesting and foraging habitat quality.

The relationships between management of woodpecker clusters and both Nearctic-Neotropical migrants and resident bird populations are not precisely known. Preliminary results from a one-season study in loblolly pine habitat in Mississippi during winter suggest that avian species richness and abundance were greater in managed woodpecker clusters than in control areas (Brennan et al. 1995). Wilson et al. (1995) indicated that some ground-nesting birds in shortleaf pine forests in Arkansas were more abundant in untreated forest than in sites thinned and burned for Red-cockaded Woodpeckers. However, restoration of shortleaf pine-grassland communities appeared to favor some Nearctic-Neotropical migrants such as Eastern Wood-Pewees (*Contopus virens*) and Prairie Warblers (*Dendroica discolor*). Plentovich et al. (1998) suggested that management for Red-cockaded Woodpeckers enhances Bachman's Sparrow habitat. Based on an analysis of information synthesized from the literature, Hunter et al. (1994) speculated that Red-cockaded Woodpecker management might have a negative stand level impact on some Nearctic-Neotropical migrants, but such problems would likely not operate at a larger landscape scale. Breeding Bird Surveys indicated that 86 species of birds (excluding Nearctic-Neotropical migrants) are known to use longleaf pine forests where management regimes of selective harvesting and growing season fire closely resemble Red-cockaded Woodpecker management (Engstrom 1993).

Because limited information was available on the relationships between Red-cockaded Woodpecker management and avian communities in both loblolly-shortleaf pine and longleaf pine habitats, we examined species presence and relative abundance in both pine habitat types during spring and winter over a 3-year period. We also examined vegetation characteristics potentially associated with differences among bird communities. In addition to avian community level relationships, we explored both the positive and negative associations of management with Nearctic-Neotropical migrants, year round residents, and winter residents.

METHODS

We surveyed avian communities using point, time-area counts (Reynolds et al. 1980) during the spring (1 May through 15 June) and winter (1 January through 15 February) seasons of 1995, 1996, and 1997. We surveyed birds in 20 Red-cockaded Woodpecker cavity tree clusters where management had been implemented recently and in 20 control areas within 800 m of woodpecker clusters where no additional management was implemented and hardwood midstory was present. We randomly selected control areas by using a hand held spinner to determine a direction to walk from the center of the woodpecker cluster area. If an appropriate mature forest stand of similar tree height to the cluster was not found within 800 m, a new random direction was selected. Within all 20 cavity tree clusters, all hardwoods <20 m from cavity trees had been removed, all midstory and understory hardwoods within the entire cluster area had been mulched, and the clusters had been thinned (overstory pines were removed) and prescribed burned within the past five years. Further management in cluster areas and control sites was not conducted during the study. We evaluated woodpecker cavity tree clusters in both longleaf pine and loblolly-shortleaf pine habitats. Longleaf pine study areas for woodpecker clusters and surrounding habitat were located in eastern Texas on the southern portion of the Angelina National Forest (31° 15′ N, 94° 15′ W) and loblolly-shortleaf pine study areas were located on the northern portion of that forest.

We established avian census points for time-area counts in woodpecker clusters in the geometric center of cluster areas and at randomly determined points in control areas. We selected census points in control areas by walking 100 m into the stand during our walk from cluster areas. We counted birds weekly at each census point, six times per season (Reynolds et al. 1980), and we calculated a mean abundance value for each species at each point per season per year for subsequent analyses. Two observers surveyed all points on each census day with each observer surveying 10 treatment and 10 control points per day. Bird detections were recorded upon entrance into the 50-m radius around the census point to account for birds that may flush and leave the area and all birds observed or heard within the circular plot were recorded for a total of 5 min (Hutto et al. 1986). Birds flying above the forest canopy were not counted. Surveys began at sunrise and ended <3 h later. We did not survey birds during heavy or moderate rain or high wind (>19 kph), but did survey during mist and light drizzle (Conner and Dickson 1980).

We measured forest structure and tree species composition within cavity tree clusters and control areas. We established an 11.2-m radius plot at each census point and measured vegetation height, tree density and basal area of over- and midstory trees, canopy closure, and horizontal foliage density (MacArthur and MacArthur 1961) at 1, 2, and 3 m. We estimated grasses and dicotyledonous/fern ground cover using a 4-cm diameter tube held vertically (James and Shugart 1970).

We used a Kolmogorov-Smirnov test to evaluate the distribution of data by season and treatment (SAS Institute, Inc. 1988). Data deviated slightly from normality ($0.049 > P > 0.046$) in a few instances. Because skewness and kurtosis were not a problem, we used parametric analyses to evaluate data as suggested by Sokal and Rohlf (1969:377). We used two-way analysis of variance (year × treatment) to compare avian species richness, equitability, and abundance among treatments during spring and winter ($\alpha = 0.05$). We also compared avian abundance for species detected during spring and winter among habitat treatments using two-way analysis of variance (year × treatment). We examined variation in forest structure and vegetation characteristics among treatments with a one-way analysis of variance. We used Duncan's Multiple Range Test to evaluate specific differences among treatments because sample size among treatments was equal. We included 22 species of rarely detected birds (<10 individuals detected at all points) in calculations of species richness and equitability, but excluded them from analyses beyond the community level because of their low detection rate.

RESULTS

Red-cockaded Woodpecker management restored vegetation structure to a more open park-like condition (Table 1). Hardwood basal area was 97% less in woodpecker cluster areas than in mature forest control sites. Hardwood midstory, as measured by hardwood stem density, also tended to be less (88–100%) in woodpecker cluster areas than in control sites. In response to a more open canopy, the absence of a hardwood midstory layer, and soil disturbance in cluster areas, woody shrub layer vegetation was 20–140% more abundant in cluster areas than in control sites. The openness created by the removal of hardwood midstory also was associated with a 200–300% increase in the grass component and concurrent 57–63% decrease in the fern and dicotyledonous component of the ground cover, suggesting the initial success of management in restoring woodpecker clusters to an open pine ecosystem.

Sites managed for Red-cockaded Woodpeckers generally supported more abundant and species rich bird populations than mature forest control sites (Table 2). During spring, species richness and avian abundance were greater within managed Red-cockaded Woodpecker cavity tree cluster sites in loblolly-shortleaf (23, 57, and 25% greater, respectively) and longleaf pine habitats (47, 65, and 21% greater, respectively) than in their respective mature forest control sites. Species richness and avian abundance each were 52%

TABLE 1. Forest vegetation characteristics measured at bird census point-count sites in Red-cockaded Woodpecker (*Picoides borealis*, RCW) cavity tree clusters and noncluster control sites in loblolly-shortleaf pine and longleaf pine forest types during 1995 on the Angelina National Forest in eastern Texas (n = 10 for each treatment). Values are means (SD). Within each row, values with the same letter are not significantly different ($P > 0.05$, one-way ANOVA with Duncan's Multiple Range Test).

	Habitat treatment			
Vegetation characteristic	Loblolly-shortleaf pine RCW cluster	Loblolly-shortleaf pine control	Longleaf pine RCW cluster	Longleaf pine control
Forest stand height (m)	27.4 (1.9)A	30.2 (2.0)B	24.5 (2.6)C	26.2 (2.9)AC
Forest stand age (year)	75.4 (11.9)A	63.8 (7.9)B	64.6 (12.2)B	57.1 (5.8)B
Canopy closure (%)	73.0 (12.7)A	82.8 (7.9)A	58.6 (17.0)B	75.8 (11.4)A
Pine basal area (m^2/ha)	19.7 (3.9)A	20.6 (5.6)A	18.5 (5.3)A	13.5 (3.5)B
Hardwood basal area (m^2/ha)	0.1 (0.3)A	4.9 (2.4)B	0.1 (0.3)A	3.6 (3.7)B
Hardwood stems 5–14 cm	0.1 (0.3)A	5.1 (3.2)B	0.0 (0.0)A	2.4 (1.4)C
Hardwood stems 15–32 cm	0.1 (0.3)A	0.8 (1.3)A,B	0.1 (0.3)A	2.9 (4.8)B
Foliage density 0–1 m (×100)	14.2 (5.6)A	6.1 (5.2)B	7.8 (2.4)B	6.5 (3.4)B
Foliage density 1–2 m (×100)	5.3 (4.5)A	2.2 (1.9)A,B	1.7 (1.9)B	4.1 (4.5)A,B
Foliage density 2–3 m (×100)	2.6 (2.2)A	1.0 (0.8)A,B	0.8 (0.2)B	2.5 (2.4)A
Grass ground cover (%)	19.8 (22.6)A,B	7.0 (12.7)B	27.5 (22.2)A	8.5 (18.0)B
Dicot fern ground cover (%)	18.0 (10.1)A	48.0 (24.2)B	30.8 (18.8)A,B	72.5 (23.3)C

greater within managed Red-cockaded Woodpecker cluster sites than within control sites in loblolly-shortleaf pine habitat during winter. We did not detect a significant difference in species richness, abundance, or equitability between managed and control sites in longleaf pine during winter (Table 2). We also did not detect a relationship between habitat treatment and avian equitability during either spring or winter.

Management for Red-cockaded Woodpeckers appeared to benefit many bird species during the breeding season. We detected greater abundances of American Kestrels, Northern Bobwhites, Red-cockaded Woodpeckers, Brown-headed Nuthatches (*Sitta pusilla*), Yellow-breasted Chats (*Icteria virens*), Bachman's Sparrows, and Indigo Buntings (*Passerina cyanea*) in sites managed for Red-cockaded Woodpeckers than in control sites in both pine cover types (Table 3). Eastern Wood-Pewees and White-eyed Vireos (*Vireo griseus*) were more abundant in managed woodpecker clusters than in control sites in

TABLE 2. Spring and winter avian community characteristics summarized from bird census point-count sites in Red-cockaded Woodpecker (*Picoides borealis*; RCW) cavity tree clusters and noncluster control sites in loblolly-shortleaf pine and longleaf pine forest types from 1995–1997 on the Angelina National Forest in eastern Texas (n = 30 for each treatment; 10 sites × 3 years). Values are means (SD). Within each row, values with the same letter are not significantly different ($P > 0.05$, two-way ANOVA, year × treatment, with Duncan's Multiple Range Test).

	Habitat treatment			
Avian community characteristic	Loblolly-shortleaf pine RCW cluster	Loblolly-shortleaf pine control	Longleaf pine RCW cluster	Longleaf pine control
Spring				
Species richness	10.3 (3.5)A	7.0 (2.8)B,C	7.2 (2.6)B	5.7 (2.7)C
Avian abundance (no.)	31.5 (14.2)A	20.1 (8.8)B	22.0 (11.5)B	13.3 (10.2)C
Equitability (J')	0.9 (0.1)A	0.8 (0.1)A	0.9 (0.1)A	0.9 (0.2)A
Winter				
Species richness	8.2 (3.6)A	5.4 (2.5)B	6.7 (3.0)A,B	6.8 (3.0)A,B
Avian abundance (no.)	42.3 (27.4)A	27.9 (23.4)B	30.3 (23.6)B	25.8 (25.9)B
Equitability (J')	0.8 (0.2)A	0.7 (0.2)A	0.8 (0.1)A	0.8 (0.1)A

TABLE 3. Mean number of birds detected per trip during spring summarized from bird census point-count sites in Red-cockaded Woodpecker (*Picoides borealis*; RCW) cavity tree clusters and noncluster control sites in loblolly-shortleaf pine and longleaf pine forest types from 1955–1997 on the Angelina National Forest in eastern Texas (n = 30 for each treatment; 10 sites × 3 years). Values are means (SD). Within each row, values with the same letter are not significantly different ($P > 0.05$; two-way ANOVA, year × treatment, with Duncan's Multiple Range Test).

	Habitat treatment			
Species	Loblolly-shortleaf pine RCW cluster	Loblolly-shortleaf pine control	Longleaf pine RCW cluster	Longleaf pine control
Year round residents				
Wood Duck (*Aix sponsa*)	0.33 (1.0)^{A}	0.07 (0.4)^{A,B}	0.03 (0.2)^{B}	0.0 (0.0)
American Kestrel (*Falco sparverius*)	0.03 (0.2)^{A}	0.0 (0.0)	0.23 (0.8)^{A}	0.0 (0.0)
Northern Bobwhite (*Colinus virginianus*)	0.03 (0.2)^{A}	0.0 (0.0)	0.20 (0.6)^{B}	0.0 (0.0)
Mourning Dove (*Zenaida macroura*)	0.33 (0.9)^{A}	0.10 (0.4)^{A,B}	0.43 (0.8)^{A}	0.03 (0.2)^{B}
Red-bellied Woodpecker (*Melanerpes carolinus*)	0.33 (0.6)^{A}	0.27 (0.6)^{A}	0.33 (0.6)^{A}	0.13 (0.4)^{A}
Hairy Woodpecker (*Picoides villosus*)	0.17 (0.5)^{A}	0.03 (0.2)^{A}	0.03 (0.2)^{A}	0.03 (0.2)^{A}
Red-cockaded Woodpecker (*Picoides borealis*)	2.47 (3.0)^{A}	0.03 (0.2)^{B}	2.37 (2.7)^{A}	0.0 (0.0)
Pileated Woodpecker (*Dryocopus pileatus*)	0.13 (0.3)^{A}	0.10 (0.3)^{A}	0.10 (0.3)^{A}	0.03 (0.2)^{A}
Blue Jay (*Cyanocitta cristata*)	0.47 (0.9)^{A}	0.06 (0.9)^{A,B}	1.07 (1.0)^{B}	1.10 (1.4)^{B}
American Crow (*Corvus brachyrhynchos*)	0.23 (0.7)^{A}	0.53 (1.7)^{A}	0.77 (1.5)^{A}	0.30 (0.7)^{A}
Carolina Chickadee (*Poecile carolinensis*)	0.83 (1.3)^{A}	0.87 (1.2)^{A}	0.13 (0.3)^{B}	0.40 (0.7)^{A,B}
Tufted Titmouse (*Baeolophus bicolor*)	0.37 (0.8)^{A}	0.60 (0.9)^{A}	0.0 (0.0)	0.57 (1.2)^{A}
Brown-headed Nuthatch (*Sitta pusilla*)	2.57 (2.5)^{A}	0.23 (0.6)^{B}	3.0 (3.3)^{A}	0.23 (0.9)^{B}
Carolina Wren (*Thryothorus ludovicianus*)	1.53 (1.6)^{A}	1.60 (1.4)^{A}	0.97 (1.5)^{A}	1.33 (1.4)^{A}
Pine Warbler (*Dendroica pinus*)	8.53 (3.7)^{A}	8.10 (3.7)^{A}	5.20 (3.2)^{B}	3.90 (3.2)^{B}
Northern Cardinal (*Cardinalis cardinalis*)	2.40 (2.3)^{A}	2.17 (1.8)^{A,B}	0.87 (1.9)^{B}	2.37 (4.0)^{A}
Bachman's Sparrow (*Aimophila aestivalis*)	0.83 (1.3)^{A}	0.0 (0.0)	1.63 (1.8)^{B}	0.0 (0.0)
Nearctic-Neotropical migrants and summer residents				
Yellow-billed Cuckoo (*Coccyzus americanus*)	0.10 (0.3)^{A}	0.23 (0.5)^{A}	0.06 (0.3)^{A}	0.13 (0.3)^{A}
Eastern Wood-Pewee (*Contopus virens*)	0.63 (1.1)^{A}	0.10 (0.3)^{B}	0.0 (0.0)	0.07 (0.2)^{B}
Great Crested Flycatcher (*Myiarchus crinitus*)	0.00 (0.0)	0.07 (0.3)^{A}	0.0 (0.0)	0.07 (0.4)^{A}
White-eyed Vireo (*Vireo griseus*)	0.83 (1.3)^{A}	0.0 (0.0)	0.20 (0.7)^{B}	0.17 (0.5)^{B}
Red-eyed Vireo (*Vireo olivaceus*)	0.63 (1.2)^{A}	1.80 (1.7)^{B}	0.0 (0.0)	0.33 (0.5)^{A}
Wood Thrush (*Hylocichla mustelina*)	0.03 (0.2)^{A}	0.17 (0.5)^{A}	0.0 (0.0)	0.07 (0.4)^{A}
Hood Warbler (*Wilsonia citrina*)	0.40 (0.7)^{A}	0.50 (0.9)^{A}	0.13 (0.4)^{A}	0.57 (1.2)^{A}
Yellow-breasted Chat (*Icteria virens*)	2.00 (2.6)^{A}	0.03 (0.2)^{B}	0.87 (1.9)^{C}	0.0 (0.0)
Summer Tanager (*Piranga rubra*)	0.96 (1.2)^{A}	1.23 (1.6)^{A}	0.13 (0.4)^{B}	0.73 (0.9)^{A}
Blue Grosbeak (*Passerina caerulea*)	0.10 (0.4)	0.0 (0.0)	0.0 (0.0)	0.0 (0.0)
Indigo Bunting (*Passerina cyanea*)	3.50 (2.7)^{A}	0.13 (0.3)^{B}	2.87 (2.5)^{A}	0.40 (0.7)^{B}

loblolly-shortleaf pine habitat. Blue Grosbeaks (*Passerina caerulea*) were detected only in managed loblolly-shortleaf pine habitat. A few species had a negative relationship with Red-cockaded Woodpecker management: the Great Crested Flycatcher (*Myiarchus crinitus*), Red-eyed Vireo (*Vireo olivaceus*), Tufted Titmouse (*Baeolophus bicolor*), Wood Thrush (*Hylocichla mustelina*), Summer Tanager (*Piranga rubra*), and Northern Cardinal (*Cardinalis cardinalis*). Abundances of at least eight breeding bird species did not appear to be related to woodpecker management.

During winter in loblolly and shortleaf pine we detected greater abundances of Wood Ducks (*Aix sponsa*), American Kestrels, Red-bellied Woodpeckers (*Melanerpes carolinus*), Red-cockaded Woodpeckers, Pileated Woodpeckers (*Dryocopus pileatus*), Carolina Chickadees (*Poecile carolinensis*), Brown-headed Nuthatches, Golden-crowned Kinglets (*Regulus satrapa*), Pine Warblers (*Dendroica pinus*), and Chipping Sparrows (*Spizella passerina*) within managed sites than within control sites (Table 4). Only Blue Jays (*Cyanocitta cristata*), Yellow-bellied Sapsuckers (*Sphyrapicus varius*; longleaf pine only), and Hermit Thrushes (*Catharus guttatus*) were de-

TABLE 4. Mean number of birds detected per trip during winter summarized from bird census point-count sites in Red-cockaded Woodpecker (*Picoides borealis*; RCW) cavity tree clusters and noncluster control sites in loblolly-shortleaf pine and longleaf pine forest types from 1995–1997 on the Angelina National Forest in eastern Texas ($n = 30$ for each treatment; 10 sites × 3 years). Values are means (SD). Within each row, values with the same letter are not significantly different ($P > 0.05$; two-way ANOVA, year × treatment, with Duncan's Multiple Range Test).

	Habitat treatment			
Species	Loblolly-shortleaf pine RCW cluster	Loblolly-shortleaf pine control	Longleaf pine RCW cluster	Longleaf pine control
Year round residents				
Wood Duck (*Aix sponsa*)	0.07 (0.4)^{A}	0.0 (0.0)	0.07 (0.04)^{A}	0.0 (0.0)
American Kestrel (*Falco sparverius*)	0.20 (0.5)^{A}	0.0 (0.0)	0.10 (0.3)^{A}	0.0 (0.0)
Mourning Dove (*Zenaida macroura*)	0.0 (0.0)	0.0 (0.0)	0.13 (0.5)^{A}	0.17 (0.7)^{A}
Red-bellied Woodpecker (*Melanerpes carolinus*)	0.60 (1.0)^{A,B}	0.0 (0.0)	0.67 (0.9)^{A}	0.27 (0.5)^{B}
Hairy Woodpecker (*Picoides villosus*)	0.07 (0.3)^{A}	0.0 (0.0)	0.0 (0.0)	0.13 (0.4)^{A}
Red-cockaded Woodpecker (*Picoides borealis*)	2.13 (2.5)^{A}	0.0 (0.0)	1.93 (2.6)^{A}	0.03 (0.2)^{B}
Pileated Woodpecker (*Dryocopus pileatus*)	0.37 (0.7)^{A}	0.10 (0.3)^{B}	0.10 (0.3)^{B}	0.10 (0.3)^{B}
Blue Jay (*Cyanocitta cristata*)	0.06 (0.4)^{A}	0.07 (0.4)^{A}	0.0 (0.0)	0.43 (0.9)^{B}
American Crow (*Corvus brachyrhynchos*)	0.06 (0.3)^{A}	0.20 (0.5)^{A}	0.73 (1.5)^{B}	0.30 (0.9)^{A,B}
Carolina Chickadee (*Poecile carolinensis*)	1.53 (1.8)^{A}	0.73 (1.4)^{B}	0.60 (1.0)^{B}	0.57 (1.1)^{B}
Tufted Titmouse (*Baeolophus bicolor*)	0.73 (1.1)^{A}	0.37 (0.6)^{A,B}	0.23 (0.6)^{B}	0.40 (0.7)^{A,B}
Brown-headed Nuthatch (*Sitta pusilla*)	3.40 (2.6)^{A}	0.33 (0.7)^{B}	3.0 (2.7)^{A}	0.57 (1.1)^{B}
Carolina Wren (*Thryothorus ludovicianus*)	1.10 (1.4)^{A}	1.03 (1.4)^{A}	0.50 (0.8)^{A}	0.90 (1.1)^{A}
Pine Warbler (*Dendroica pinus*)	17.47 (11.3)^{A}	13.00 (8.5)^{B}	8.63 (4.9)^{C}	7.60 (4.9)^{C}
Northern Cardinal (*Cardinalis cardinalis*)	0.63 (0.9)^{A}	0.50 (0.9)^{A}	0.13 (0.4)^{A}	0.53 (1.4)^{A}
Bachman's Sparrow (*Aimophila aestivalis*)	0.0 (0.0)	0.0 (0.0)	0.03 (0.2)	0.0 (0.0)
Temperate zone migrants and winter residents				
Yellow-bellied Sapsucker (*Sphyrapicus varius*)	0.17 (0.4)^{A}	0.13 (0.3)^{A}	0.30 (0.5)^{A}	0.70 (1.0)^{B}
Eastern Phoebe (*Sayornis phoebe*)	0.17 (0.4)^{A}	0.20 (0.5)^{A}	0.07 (0.3)^{A}	0.07 (0.3)^{A}
Golden-crowned Kinglet (*Regulus satrapa*)	0.80 (1.7)^{A}	0.27 (0.7)^{B}	0.03 (0.2)^{B}	0.17 (0.5)^{B}
Ruby-crowned Kinglet (*Regulus calendula*)	1.20 (1.6)^{A,B}	0.70 (1.0)^{B}	0.90 (1.2)^{A,B}	1.47 (1.2)^{A}
Eastern Bluebird (*Sialia sialis*)	0.37 (1.7)^{A}	0.0 (0.0)	0.0 (0.0)	0.07 (0.4)^{A}
Hermit Thrush (*Catharus guttatus*)	0.0 (0.0)	0.10 (0.3)^{A}	0.07 (0.3)^{A}	0.33 (0.7)^{B}
American Robin (*Turdus migratorius*)	0.13 (0.3)^{A}	0.27 (0.7)^{A}	0.40 (1.5)^{A}	0.13 (0.3)^{A}
Yellow-rumped Warbler (*Dendroica coronata*)	1.37 (1.9)^{A}	1.33 (1.8)^{A}	1.13 (1.3)^{A}	2.10 (1.9)^{A}
Chipping Sparrow (*Spizella passerina*)	0.10 (0.3)^{A}	0.0 (0.0)	0.06 (0.3)^{A}	0.0 (0.0)
White-throated Sparrow (*Zonotrichia albicollis*)	0.80 (1.8)^{A}	0.13 (0.7)^{A}	1.43 (4.5)^{A}	0.93 (2.8)^{A}
Dark-eyed Junco (*Junco hyemalis*)	1.60 (3.6)^{A}	0.53 (2.2)^{A}	1.00 (2.6)^{A}	1.10 (2.6)^{A}
American Goldfinch (*Carduelis tristis*)	6.90 (14.2)^{A}	6.33 (17.1)^{A}	7.73 (19.2)^{A}	6.60 (20.0)^{A}

tected less often in managed sites than in control sites during winter. Twelve bird species appeared to have no relationship with woodpecker management during winter.

DISCUSSION

Management for Red-cockaded Woodpeckers, which included hardwood removal from around cavity trees, mulching of midstory and understory vegetation, overstory pine thinning, and prescribed fire, altered forest structure primarily in the midstory, understory, and herbaceous layers. Soil disturbance and reduction of hardwood midstory foliage and thinning of the canopy, which increased light penetration close to the ground, apparently permitted an increase in the density of woody shrubs and grasses. The abundance of species such as Indigo Buntings and Yellow-breasted Chats during the breeding season was associated with increases in shrub layer woody vegetation, as would be expected based on results of previous studies (Conner et al. 1983; Dickson et al. 1984, 1993b; Conner and Dickson 1997). Consistent with Powell et al. (2000), we found no statistical evidence that habitat management for Red-cockaded Woodpeckers was negatively associated with Wood Thrush abundance. The abundance of American Kestrels, Bachman's Sparrows, and Northern Bobwhites, as observed by Wilson et al. (1995), likely are associated with the increase in grasses in the herbaceous layer and the arthropod populations the grasses supported (Collins et al. 2002). The greater abundance of Brown-headed Nuthatches and Red-cockaded Woodpeckers within managed sites likely is associated with these species apparent avoidance of hardwood vegetation (Conner et al. 1983, Conner and Rudolph 1989, Loeb et al. 1992). Brown-headed Nuthatches also are known to respond favorably to thinning of loblolly pine plantations (Wilson and Watts 1999).

The observed increase in breeding bird species richness and abundance in both loblolly-shortleaf and longleaf pine habitats appears to be the community level result of the collective positive relationship of individual species with the increase in shrub layer vegetation and grasses associated with Red-cockaded Woodpecker management. Open forest habitat created by Red-cockaded Woodpecker management in both longleaf and loblolly-shortleaf pine types appears to provide habitat for many mature forest bird species but also permits the presence of some shrub-associated bird species during the breeding season.

Gates and Gysel (1978) suggested that increased openness of forest habitat might increase the rate of nest parasitism by Brown-headed Cowbirds, a distinct possibility in forest habitat in close proximity to agricultural lands. During 3 years of study, we detected Brown-headed Cowbirds only twice in one of the habitat treatments, a managed Red-cockaded Woodpecker cluster in loblolly-shortleaf pine habitat, most likely because agricultural areas were not a significant component of the overall forest landscape.

A positive community level response was detected only in loblolly-shortleaf pine habitat during winter; we did not detect any community level relationships of woodpecker management in longleaf pine habitat during winter. The observed increases in bird species richness and abundance in loblolly-shortleaf pine habitat during winter also may have been associated with favorable bird response to the greater presence of grasses and woody shrub level plants (Conner et al. 1979, Dickson et al. 1995). Although the Henslow's Sparrow is a species of concern known to winter in eastern Texas, we did not detect any individuals during winter surveys in any of the habitat treatments, which probably reflects the difficulty in detecting this species during point counts in winter.

Based on our observations, management for Red-cockaded Woodpeckers appears to have a negative relationship with only a few avian species, none of which are of immediate conservation concern. Some of the species that exhibited declines in abundance were common and ubiquitous species such as Blue Jays and Northern Cardinals. Reductions in the abundances of Great Crested Flycatchers, Red-eyed Vireos, Wood Thrushes, Summer Tanagers, and Northern Cardinals likely were associated with the decrease in hardwood foliage in the overstory and midstory. Red-cockaded Woodpecker management was positively associated with many bird species, including the American Kestrel, Red-cockaded Woodpecker, and Bachman's Sparrow, which are species of serious regional conservation concern. Overall, woodpecker management was associated with an increase in landscape level biodiversity by adding habitat features needed by shrub and grass-associated birds.

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