Wilson Bull., 109(4), 1997, pp. 614–629

WOODPECKER ABUNDANCE AND HABITAT USE IN THREE FOREST TYPES IN EASTERN TEXAS

CLIFFORD E. SHACKELFORD[1,2] AND RICHARD N. CONNER[1]

ABSTRACT.—Woodpeckers were censused in 60 fixed-radius (300 m) circular plots (divided into eight 45°-arc pie-shaped sectors) in mature forests (60–80 years-old) of three forest types (20 plots per type) in eastern Texas: bottomland hardwood forest, longleaf pine (*Pinus palustris*) savannah, and mixed pine-hardwood forest. A total of 2242 individual woodpeckers of eight species was detected in 144 h of censusing. Vegetation characteristics in plot sectors with and without woodpeckers were compared. Woodpecker presence and abundance were primarily associated with the occurrence of large snags and logs. Red-bellied Woodpeckers (*Melanerpes carolinus*) were the most abundant and widespread species, especially in areas containing more hardwoods than pines. Red-cockaded Woodpeckers (*Picoides borealis*) were the least abundant and most habitat-restricted woodpecker, occurring only in the longleaf pine savannah. Pileated Woodpeckers (*Dryocopus pileatus*) were the most evenly distributed species among the forest types, but occurred primarily in mature forests with large snags and logs. Bottomland hardwood forests were important for Northern Flickers (*Colaptes auratus*), Red-headed Woodpeckers (*Melanerpes erythrocephalus*), and Yellow-bellied Sapsuckers (*Sphyrapicus varius*) during the fall and winter, and for Downy Woodpeckers (*Picoides pubescens*) during the summer and winter. The Hairy Woodpecker (*P. villosus*) was most frequently encountered in areas of recent disturbance in the mixed pine-hardwood forests, especially in fall. Vocal imitation of a Barred Owl (*Strix varia*) increased the number of woodpecker detections by 71%. *Received 14 Jan. 1997, accepted 10 May 1997.*

Woodpeckers are generally considered to be valuable species because they eat a variety of insects considered to be harmful to forests (Steirly 1965, Dickson et al. 1979). As primary cavity excavators, they play an important role in forest ecosystems because their abandoned cavities provide shelter and nest sites for many other vertebrates (Scott et al. 1977, Conner 1978). Numerous studies have evaluated the habitat requirements of woodpeckers in a variety of forest cover types (Williams 1975; Bull and Meslow 1977; Conner 1980, 1983; Mellen 1987; Shackelford 1994; Loose and Anderson 1995). Snags (dead standing trees) are important to woodpeckers for foraging, roosting, nesting, and drumming (Conner 1978; Conner et al. 1975, 1994a). Increasing availability of snags has been shown to increase the abundance of cavity-nesting birds, especially woodpeckers (Balda 1975, Dickson et al. 1983). Therefore, an adequate supply of snags appears to be important to support large populations of woodpeckers.

[1] Wildlife Habitat and Silviculture Laboratory (Maintained in cooperation with the College of Forestry, Stephen F. Austin State University), Southern Research Station, USDA Forest Service, Nacogdoches, Texas 75962.

[2] Present address: Texas Partners In Flight, Texas Parks and Wildlife Department, 4200 Smith School Road, Austin, Texas 78744.

Forest management practices in most eastern Texas forests emphasize the production of wood products for human needs, sometimes at the expense of wildlife (USDA 1973, McWilliams and Lord 1988). If current and future forest management is to accommodate the needs of cavity-using wildlife, an understanding of the distribution, abundance, and habitat use of woodpeckers is essential for management decisions. We examined the habitat conditions associated with the presence and abundance of woodpeckers in a bottomland hardwood forest, a longleaf pine forest, and a mixed-pine hardwood forest in eastern Texas.

STUDY AREAS AND METHODS

Forests in eastern Texas are dominated by three native pine species and numerous species of hardwoods (McWilliams and Lord 1988). We censused woodpeckers twice a month for a twelve-month period from March 1991 to March 1992 in a mixed pine-hardwood forest and from September 1992 to September 1993 in both longleaf pine savannah and bottomland hardwood forest. The longleaf pine savannah study area consisted almost entirely of pure, longleaf pine forest and was located on the south side of the Angelina National Forest where it is managed as an open, park-like, fire-climax ecosystem for Red-cockaded Woodpeckers (*Picoides borealis*) (Conner and Rudolph 1989). The mixed pine-hardwood study area was located on the north side of the Angelina National Forest and was dominated by an overstory mix of loblolly (*Pinus taeda*) and shortleaf (*P. echinata*) pines and various species of hardwood (mostly *Quercus*, *Liquidambar*, and *Nyssa*). The bottomland hardwood forest study area was located along the upper Angelina River between Nacogdoches and Angelina counties southwest of Nacogdoches, Texas. Depending on water levels, this route was surveyed either by motor boat or all-terrain vehicle. The forest along this river consisted almost entirely of a hardwood overstory and midstory (mostly *Quercus*, *Liquidambar* and *Nyssa*) with virtually no understory. A sparse ground cover comprised of leaf litter and logs was typically washed away by periodic flooding.

Fixed-radius plots (Amman and Baldwin 1960, Edwards et al. 1981, Bibby et al. 1992) were used to determine the distribution, abundance, and habitat use of the following eight species of woodpeckers within the Pineywoods vegetational zone (Gould 1969) in eastern Texas: Northern Flickers (*Colaptes auratus*), Yellow-bellied Sapsuckers (*Sphyrapicus varius*) and Red-headed (*Melanerpes erythrocephalus*), Red-bellied (*M. carolinus*), Downy (*Picoides pubescens*), Hairy (*P. villosus*), Pileated (*Dryocopus pileatus*), and Red-cockaded woodpeckers. Woodpecker populations were censused in 20 circular plots (300-m radius, 28.3 ha, Fig. 1) in each of the three forest types (a total of 60 plots) along less-traveled roads and along the Angelina River. Routes within forest types were primarily placed in areas containing extensive tracts of forests and ranged in length from 35 to 45 km. As the location of plots was dependent on the presence of large tracts of unbroken mature forest, the distribution of plots along routes was occasionally interrupted by zones of fragmentation. The physical location of permanent plot centers within mature forest habitat was randomly determined. Adjacent plot boundaries were separated by at least 100 m (700 m from plot center to plot center), with adjacent plot boundary separation averaging about 1 km (1600 m from plot center to plot center).

All woodpeckers seen or heard were recorded from the center of each plot, during a 6-min period. For the first half of the censusing period, we used the 3-min unsolicited censusing method that was adopted by the Breeding Bird Survey in the 1960s and many other subsequent studies. The first 3-min period was spent tallying woodpecker detections, while

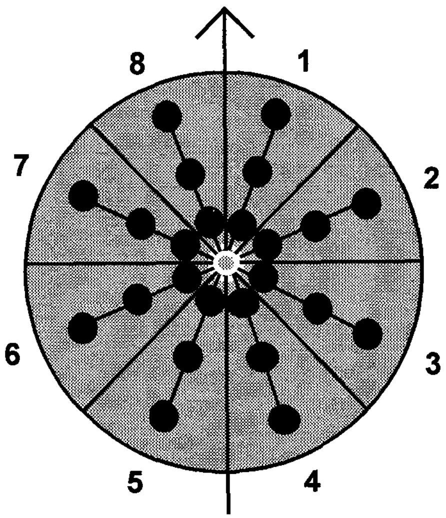

FIG. 1. Design of plots (300-m radius) used for censusing woodpeckers showing the eight 45°-arc sectors, each with a bisecting transect with three black dots indicating vegetation subplots.

the second 3-min period was spent recording woodpecker observations after the call of a Barred Owl (*Strix varia*) was vocally given by the observer for approximately 10 seconds at each minute of the 3-min period. This call technique was used to increase the probability of woodpecker detections, since we knew that woodpeckers often respond to the call of a Barred Owl, either by vocalizing or moving closer to the source of the call (pers. observ.). This method of censusing woodpeckers has not previously been tested, although there are a few published descriptions of soliciting woodpeckers for the purpose of detection (Rushmore 1973, Wright 1991). Previous studies using fixed-radius point counts have shown that avian detections usually decrease as a function of increasing time (Scott and Ramsey 1981, Hutto et al. 1986). Thus, increases in woodpecker detections following Barred Owl hooting should represent additional detections caused by the solicitation technique.

During the 6-min period at each plot we recorded (1) time, (2) species and numbers of woodpeckers, (3) the location and movement of each woodpecker from the observer to determine the effectiveness of the owl imitation and to keep from double-counting, (4) sector (45° arcs: 0–45°, 46–90°, etc., 8 total) where each woodpecker was first detected, and (5) whether the individual woodpecker was detected in the first 3-min period, the second 3-min period, or both periods.

One entire route (20 survey plots) was censused in a single morning. Woodpeckers were censused within three hours of sunrise, which is the peak, daytime activity period for most bird species (Howell 1951, International Bird Census Committee 1970). The direction in which a route was surveyed was alternated each survey. Each site was censused twice a month throughout the year and data were pooled by year and by season: spring (March, April and May), summer (June, July and August), fall (September, October and November) and winter (December, January and February).

Vegetation data within each plot were collected during the censusing year. A total of 24 circular subplots per plot was established, three in each of the eight sectors (Fig. 1). Each

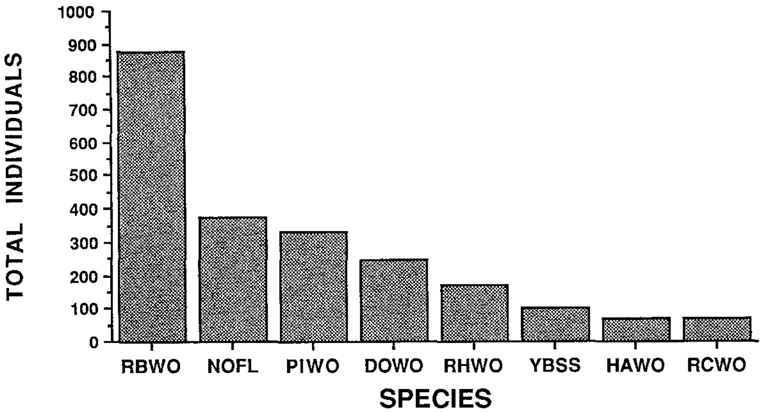

FIG. 2. The relative abundance of eight woodpecker species censused in mature forests in eastern Texas. RBWO = Red-bellied Woodpecker, NOFL = Northern Flicker, PIWO = Pileated Woodpecker, DOWO = Downy Woodpecker, RHWO = Red-headed Woodpecker, YBSS = Yellow-bellied Sapsucker, HAWO = Hairy Woodpecker, and RCWO = Red-cockaded Woodpecker. Individual woodpeckers were counted only once during each 6-min census period.

subplot had a radius of 11.2 m and an area of 0.04 ha (as described by James and Shugart [1970]; and Conner [1980, 1983]). The subplots were located along transects which bisected each sector, at a distance of 50 m, 150 m and 250 m from the center of each plot.

Forest habitat data were recorded at each of the subplots: (1) basal area of all pines and hardwoods (separately) with a one-factor metric prism and (2) number of snags and logs measured by diameter size class: sapling- (5–16 cm), pole- (17–32 cm) and sawtimber- (>32 cm) sized trees. The total number of all snags and logs of all three size classes was also recorded.

Within each forest type, we used two-tailed *t*-tests to compare vegetational characteristics between sectors where a woodpecker species was present and where the species was absent. A chi-square test for goodness of fit was used to evaluate the effectiveness of silent census-taking versus woodpecker detections following the imitation of a Barred Owl. One-way analysis of variance and Duncan's multiple range test were used to compare woodpecker abundances among habitat types.

To provide a visual comparison of the habitat used by all eight woodpecker species, we conducted a principal component analysis using all habitat variables and a varimax rotation of axes. Previous studies have successfully used principal component analysis to explore avian-habitat relationships (James 1971, Conner and Adkisson 1977, Conner et al. 1983). For comparison of woodpecker species, centroids were plotted within axes created by the first three components, and factor loadings were used to evaluate relationships of the canonical axes to original habitat variables. All analyses were calculated using PC-SAS (SAS Institute, Inc. 1988).

RESULTS

A total of 2242 woodpeckers representing eight species was detected during 144 h of observation (Fig. 2). When comparing the number of woodpeckers detected during the first 3-min (unsolicited) with the number

TABLE 1

CHI-SQUARE ANALYSES COMPARING NUMBERS OF WOODPECKERS DETECTED DURING 3-MIN OF UNSOLICITED CENSUSING AND 3-MIN OF SOLICITED CENSUSING USING THE IMITATION OF A BARRED OWL

Species[a]	Unsolicited	Solicited	% Increase	χ^2	*P*
YBSS	26	93	257.7	37.7	<0.01
RHWO	84	161	91.7	24.2	<0.01
NOFL	164	310	89.0	45.0	<0.01
RBWO	402	747	85.8	103.6	<0.01
DOWO	118	188	59.3	16.0	<0.01
RCWO	46	60	30.4	1.8	>0.10
HAWO	46	58	26.1	1.4	>0.10
PIWO	191	221	15.7	2.2	>0.10
Total	1077	1838	70.7	198.7	<0.01

[a] YBSS = Yellow-bellied Sapsucker, RHWO = Red-headed Woodpecker, NOFL = Northern Flicker, RBWO = Red-bellied Woodpecker, DOWO = Downy Woodpecker, RCWO = Red-cockaded Woodpecker, HAWO = Hairy Woodpecker, PIWO = Pileated Woodpecker.

detected during the second 3-min (solicited) of a census period, the imitation of a Barred Owl resulted in a 71% increase in woodpecker detections (Table 1). Some of the woodpeckers detected during the first 3-min period were also detected during the second 3-min sampling period. Chi-square analysis revealed that detections of five of the eight species increased significantly ($P < 0.01$) during the second 3-min period (Table 1). Most individuals of most species vocalized almost immediately after the first hoot was imitated by the observer. Many individuals would fly closer and perch directly over the observer's head, attempting to locate the supposed Barred Owl.

Seasonal abundance and woodpecker use of forest cover types.—Red-bellied Woodpeckers (N = 878) were the most numerous and widespread species, occurring in all three forest types each season (Fig. 3). Northern Flickers (N = 375) were second in abundance but occurred primarily during the fall and winter months, especially in bottomland hardwood forests (Fig. 3). Flickers were not permanent residents on any of the study sites. Pileated Woodpeckers (N = 334) were common throughout the year in all three forest types, while Downy Woodpeckers (N = 247) were most common in bottomland hardwood forests during summer and winter (Fig. 3). Red-headed Woodpeckers (N = 173) were present in bottomland hardwood forests only in the fall and winter, and in the longleaf pine savannah only in spring and summer (Fig. 3). Yellow-bellied Sapsuckers (N = 100) were most commonly found in bottomland hardwood forests in fall and winter, but were absent from eastern Texas in the late spring and summer

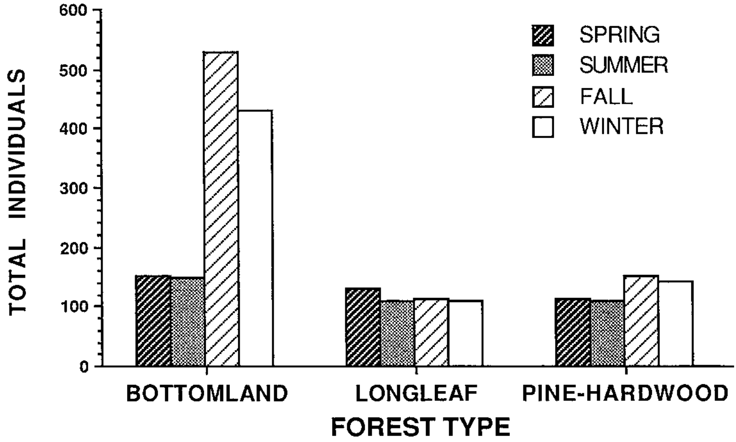

FIG. 3. Abundance of woodpecker species by season and forest type in eastern Texas. RBWO = Red-bellied Woodpecker, NOFL = Northern Flicker, PIWO = Pileated Woodpecker, DOWO = Downy Woodpecker, RHWO = Red-headed Woodpecker, YBSS = Yellow-bellied Sapsucker, HAWO = Hairy Woodpecker, and RCWO = Red-cockaded Woodpecker.

(Fig. 3). Hairy Woodpeckers (N = 68) occurred mostly in mixed pine-hardwood forests and were detected most frequently in the fall, while Red-cockaded Woodpeckers (N = 67) were found year around, but restricted to the longleaf pine savannah (Fig. 3). Hairy and Downy woodpeckers were virtually absent from the longleaf pine savannah suggesting that Red-cockaded Woodpeckers are the only regular *Picoides* occurring in these open longleaf pine sites (Fig. 3).

Numerous woodpeckers of all species, except Red-cockaded Woodpeckers, used bottomland hardwood forests during the fall and winter months suggesting the importance of this habitat type for woodpeckers during the non-breeding season (Fig. 4). Elevated woodpecker abundance during fall and winter in bottomland hardwood forests was primarily the result of migrating and wintering Northern Flickers, Red-headed Woodpeckers, and Yellow-bellied Sapsuckers in eastern Texas, as well as an increase in the number of resident Red-bellied Woodpeckers.

Significantly more Yellow-bellied Sapsuckers, Northern Flickers, Red-bellied, Downy, and Red-headed woodpeckers were detected in bottomland hardwood forests than in either of the other two forest types (Table 2). Hairy and Pileated woodpeckers were more abundant in the mixed pine-hardwood forest than the other two forest types (Table 2).

Woodpecker use of habitat in bottomland hardwood forests.—Woodpeckers, as a whole, were more abundant in bottomland hardwood forests

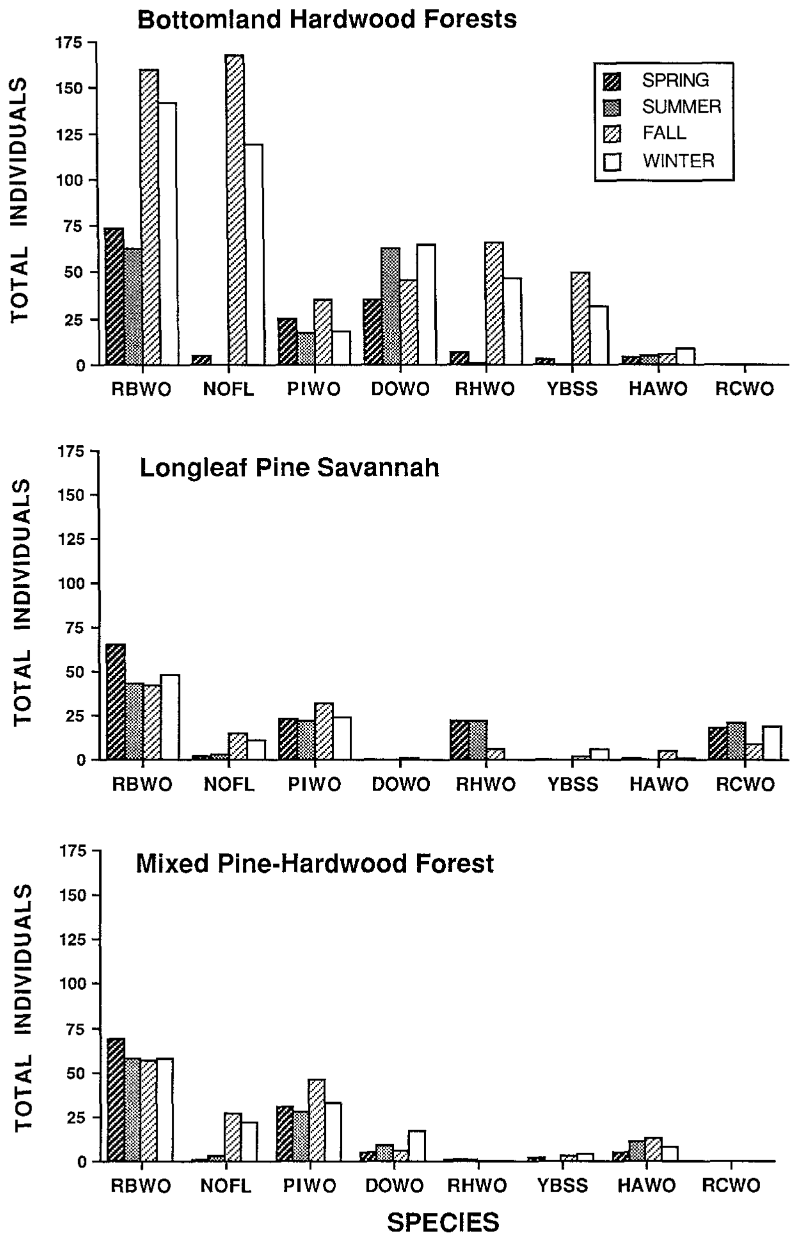

FIG. 4. Seasonal abundance of woodpeckers by forest type in eastern Texas.

TABLE 2

MEAN NUMBER OF WOODPECKERS (STANDARD DEVIATION) PER PLOT SECTOR (3.5 HA) IN THREE FOREST TYPES IN EASTERN TEXAS

Species[a]	Mixed Pine-Hardwood (N = 160)	Longleaf Pine (N = 159)	Bottomland Hardwood (N = 160)
RBWO	1.56 (2.03)a	1.26 (1.46)a	2.91 (2.05)b
NOFL	0.35 (0.71)a	0.20 (0.47)a	1.88 (1.45)b
PIWO	0.85 (1.22)a	0.64 (0.84)a,b	0.58 (0.76)b
DOWO	0.24 (0.65)a	0.01 (0.08)b	1.36 (1.27)c
RHWO	0.01 (0.11)a	0.33 (0.96)b	0.80 (1.78)c
YBSS	0.05 (0.22)a	0.06 (0.23)a	0.54 (0.98)b
HAWO	0.27 (0.70)a	0.06 (0.23)b	0.14 (0.42)b
RCWO	0.00 (0.00)a	0.46 (1.38)b	0.00 (0.00)a

[a] RBWO = Red-bellied Wodopecker, NOFL = Northern Flicker, PIWO = Pileated Woodpecker, DOWO = Downy Woodpecker, RHWO = Red-headed Woodpecker, YBSS = Yellow-bellied Sapsucker, HAWO = Hairy Woodpecker, RCWO = Red-cockaded Woodpecker. Means with common letters across a row were not significantly different from each other (One-way ANOVA and Duncan's MRT, $P < 0.05$).

than the other two forest types examined. Red-bellied Woodpeckers used areas with significantly greater numbers of sapling snags (present 0.19 ± 0.34/ha vs absent 0.08 ± 0.17/ha, $t = 2.24$, $P < 0.03$) and sawtimber logs (present 0.15 ± 0.31/ha vs absent 0.04 ± 0.10, $t = 3.02$, $P < 0.01$). During fall and winter, Northern Flickers were significantly more common in areas with sapling snags (present 0.20 ± 0.34/ha vs absent 0.07 ± 0.20/ha, $t = 2.77$, $P < 0.01$). The presence of Pileated Woodpeckers was associated with increasing numbers of pole-sized snags (present 0.14 ± 0.25/ha vs absent 0.06 ± 0.14/ha, $t = 2.53$, $P < 0.01$), sawtimber-sized logs (present 0.22 ± 0.38/ha vs absent 0.07 ± 0.19/ha, $t = 3.06$, $P < 0.01$), and total logs (present 0.35 ± 4.89/ha vs absent 0.46 ± 0.24/ha, $t = 3.53$, $P < 0.01$).

During fall and winter, Red-headed Woodpeckers were most common in areas containing high numbers of sawtimber-sized logs (present 0.35 ± 0.44/ha vs absent 0.06 ± 0.19/ha, $t = 4.10$, $P < 0.01$) and total numbers of logs (present 0.42 ± 0.45/ha vs absent 0.16 ± 0.34/ha, $t = 3.31$, $P < 0.01$). Yellow-bellied Sapsuckers were absent from areas containing a greater quantity of sawtimber-sized snags (present 0.04 ± 0.10/ha vs absent 0.08 ± 0.18/ha, $t = 2.02$, $P < 0.05$).

The presence of Hairy Woodpeckers was associated with lower hardwood basal area (present 14.50 ± 5.30 m^2/ha vs absent 17.04 ± 4.03 m^2/ha, $t = 2.48$, $P < 0.01$) and lower quantities of pole-sized snags (present 0.05 ± 0.10/ha vs absent 0.10 ± 0.21/ha, $t = 1.99$, $P < 0.05$) and sawtimber-sized snags (present 0.01 ± 0.06/ha vs absent 0.07 ± 0.17/ha, $t = 2.89$, $P < 0.01$).

Woodpecker use of habitat in longleaf pine forests.—Red-bellied Woodpeckers were absent from areas with a significantly higher basal area of pines (present 17.51 ± 2.89 m^2/ha vs absent 18.69 ± 3.86 m^2/ha, $t = 2.02$, $P < 0.05$). Northern Flickers were significantly more common in areas with sapling snags (present 0.02 ± 0.08/ha vs absent 0.00 ± 0.00/ha, $t = 2.78$, $P < 0.01$), yet were absent from areas with a significantly higher basal area of hardwoods (present 0.30 ± 0.44 m^2/ha vs absent 0.56 ± 0.91 m^2/ha, $t = 2.29$, $P < 0.02$). Pileated Woodpeckers were present in stands that had a high basal area of pines (present 18.69 ± 3.47 m^2/ha vs absent 17.32 ± 3.06 m^2/ha, $t = 2.65$, $P < 0.01$), but were absent from areas with increasing numbers of small diameter (sapling) snags (present 0.01 ± 0.03/ha vs absent 0.03 ± 0.09/ha, $t = 2.06$, $P < 0.04$).

In longleaf pine forests, Yellow-bellied Sapsuckers were absent from areas with increasing numbers of pole-sized logs (present 0.00 ± 0.00/ha vs absent 0.03 ± 0.13/ha, $t = 2.66$, $P < 0.01$), sawtimber-sized logs (present 0.00 ± 0.00/ha vs absent 0.03 ± 0.11/ha, $t = 3.38$, $P < 0.01$), and total logs (present 0.00 ± 0.00/ha vs absent 0.06 ± 0.18/ha, $t = 4.63$, $P < 0.01$), possibly suggesting the need for a sustained supply of living trees that provide an adequate supply of flowing sap. Hairy Woodpeckers were present in areas with a high pine basal area (present 20.91 ± 4.28 m^2/ha vs absent 17.76 ± 3.18 m^2/ha, $t = 2.82$, $P < 0.01$) and absent in sites without sapling snags (present 0.00 ± 0.00/ha vs absent 0.02 ± 0.07/ha, $t = 2.77$, $P < 0.01$).

Red-cockaded Woodpeckers were detected only in this forest type where their presence was significantly associated with lower basal area of hardwoods (present 0.55 ± 0.91 m^2/ha vs absent 0.09 ± 0.11 m^2/ha, $t = 2.04$, $P < 0.04$) and higher densities of pole-sized snags (present 0.09 ± 0.16/ha vs absent 0.02 ± 0.07/ha, $t = 2.26$, $P < 0.03$), total snags (present 0.15 ± 0.23/ha vs absent 0.05 ± 0.13/ha, $t = 2.14$, $P < 0.04$), and total logs (present 0.15 ± 0.25/ha vs absent 0.05 ± 0.14/ha, $t = 2.08$, $P < 0.05$).

Woodpecker use of habitat in mixed pine-hardwood forests.—Red-bellied Woodpeckers used areas in this forest type that had a significantly higher basal area of hardwoods (present 6.89 ± 3.68 m^2/ha vs absent 4.85 ± 2.56 m^2/ha, $t = 4.01$, $P < 0.01$) and were absent from areas with a significantly higher basal area of pines (present 8.49 ± 5.03 m^2/ha vs absent 10.47 ± 5.06 m^2/ha, $t = 2.30$, $P < 0.02$). Northern Flicker presence was significantly associated with higher basal area of hardwoods (present 7.22 ± 3.71 m^2/ha vs absent 5.94 ± 3.39 m^2/ha, $t = 1.99$, $P < 0.05$), numerous pole-sized logs (present 0.18 ± 0.34/ha vs absent 0.04 ± 0.14/ha, $t = 2.43$, $P < 0.02$), sawtimber-sized logs (present 0.28 ± 0.55/ha vs

TABLE 3

FACTOR LOADINGS FOR THE FIRST THREE PRINCIPAL COMPONENTS OF WOODPECKER HABITAT IN LONGLEAF PINE, MIXED PINE-HARDWOOD, AND BOTTOMLAND HARDWOOD FORESTS OF EASTERN TEXAS

Habitat variable	Factor 1	Factor 2	Factor 3
Midstory density	0.767	−0.132	−0.131
Canopy closure	0.290	−0.053	−0.112
Canopy height	0.115	0.300	−0.725
Basal area of hardwoods	0.940	−0.152	0.021
Basal area of pines	−0.939	0.108	−0.034
Basal area of sapling hardwoods	0.670	0.074	0.372
Basal area of pole hardwoods	0.630	−0.091	0.076
Basal area of sawtimber hardwoods	0.731	0.147	−0.055
Basal area of sapling pines	−0.417	0.009	0.654
Basal area of pole pines	−0.491	0.213	0.535
Basal area of sawtimber pines	−0.580	0.272	0.078
Total number of snags	0.133	0.444	0.197
Number of sapling-sized snags	0.253	0.278	0.244
Number of pole-sized snags	0.241	0.435	0.064
Number of sawtimber-sized snags	0.157	0.542	0.072
Total number of logs	0.314	0.837	−0.119
Number of sapling-sized logs	0.158	0.678	0.131
Number of pole-sized logs	0.212	0.640	−0.089
Number of sawtimber-sized logs	0.296	0.699	−0.164

absent 0.10 ± 0.26/ha, t = 1.97, $P < 0.05$) and total logs (present 0.57 ± 0.97/ha vs absent 0.22 ± 0.55/ha, t = 2.13, $P < 0.04$).

Pileated Woodpecker presence was associated with a higher basal area of hardwoods (present 7.22 ± 3.71 m^2/ha vs absent 5.94 ± 3.39 m^2/ha, t = 1.99, $P < 0.05$) and increasing numbers of pole-sized logs (present 0.18 ± 0.34/ha vs absent 0.04 ± 0.14/ha, t = 2.43, $P < 0.02$), sawtimber-sized logs (present 0.28 ± 0.55/ha vs absent 0.10 ± 0.26/ha, t = 1.97, $P < 0.05$), and total logs (present 0.57 ± 0.97/ha vs absent 0.22 ± 0.55/ha, t = 2.13, $P < 0.04$). Hairy Woodpeckers were most common in sites that had numerous sawtimber-sized snags (present 0.27 ± 0.43/ha vs absent 0.11 ± 0.26/ha, t = 2.02, $P < 0.05$) and sawtimber-sized logs (present 0.38 ± 0.64/ha vs absent 0.08 ± 0.21/ha, t = 2.56, $P < 0.02$).

Principal component analysis of woodpecker habitat.—The first six factors of the principal component analysis had significant eigenvalues (values >1.0). Although the first three components explained only 57.3% of the total variation, ordination of centroids for habitat used by the eight woodpecker species provided a meaningful graphic demonstration of differences in their habitat use (Fig. 5, Table 3). The position of the Red-

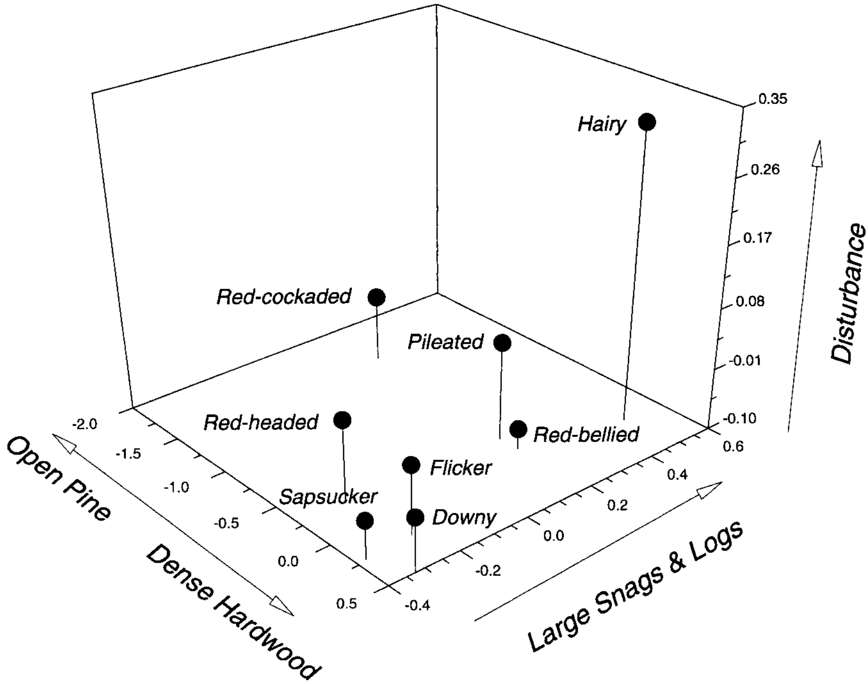

FIG. 5. Principal component analysis of habitat used by eight species of woodpeckers in eastern Texas with centroids for species plotted against the first three factors. Increasing values going left-back toward center-front (Factor 1 = "Open Pine to Dense Hardwood") represent increasing numbers, basal area, midstory density of hardwood trees, and increasing numbers of smaller-sized snags. Increasing values going center-front toward back-right (Factor 2 = "Large Snags and Logs") represent increasing numbers of large diameter logs and snags, increasing canopy height, and increasing forest maturity. Increasing values going low toward high (Factor 3 = "Disturbance") represent decreasing canopy height and increasing numbers of smaller-sized pines, characteristics associated with disturbance patches in a mature forest.

cockaded Woodpeckers' centroid is associated with pure pine stands in mature forest habitat with large diameter logs and snags present. The centroid for Hairy Woodpeckers suggests use of disturbed pine-hardwood stands where younger pines are present and large diameter snags and logs are fairly abundant. Centroids for Pileated and Red-bellied woodpeckers are associated with tall hardwood stands that have fairly high abundances of large diameter snags and logs. Centroids for Yellow-bellied Sapsuckers, Downy Woodpeckers, and Northern Flickers are associated primarily with tall hardwood stands that tend to have fewer numbers of large diameter snags and logs, but higher numbers of smaller diameter snags and logs than habitat used by the other woodpecker species.

DISCUSSION

Raphael and White (1984) observed that the diversity of cavity-nesting birds was related to snag-size diversity. Snag retention in southern forests is known to increase woodpecker diversity (Evans and Conner 1979, Dickson et al. 1983). In our study, the presence of snags and logs was associated with the habitat used by all eight species of woodpeckers. Pileated, Hairy, and Red-bellied woodpeckers were closely associated with the presence of large diameter snags and logs. Pileated Woodpeckers in Oregon (Bull and Meslow 1977) and Missouri (Renken and Wiggers 1989, 1993) used forests with numerous snags and logs. Throughout their range, Pileated Woodpeckers use snags for nesting and roosting, and snags and logs as foraging sites (Bull 1975, Conner et al. 1975, McClelland 1979, Mannan et al. 1980). In our study Red-headed Woodpeckers and Northern Flickers were associated with increasing numbers of small diameter snags. It is unclear why they were not more closely associated with large diameter snags because both species are known to use large diameter snags regularly for nesting (Conner et al. 1975, Conner 1976, Jackson 1976, Ingold 1989).

Forest age also influences habitat use by woodpeckers. Hairy, Red-bellied, Pileated, and Red-cockaded woodpeckers were associated with older-growth forest habitat. The Red-cockaded Woodpecker's requirement for old-growth forests is well known (Jackson and Jackson 1986, Rudolph and Conner 1991, Conner et al. 1994b). In Oregon, Pileated Woodpeckers selected mature forest habitat age-classes greater than 70 years of age, and selected against forest habitat age-classes less than 40 years of age (Mannan 1984, Mellen 1987, Mellen et al. 1992). Other studies suggest that mature and old-growth forests are as important to Pileated Woodpeckers as the availability of dead wood (Kilham 1976, Conner 1980, Mannan 1984, Bull and Holthausen 1993). These features, mature forest and dead wood, are usually found together in forests that have been affected minimally by humans (Thomas et al. 1988).

The presence of hardwood trees was associated with the occurrence of all woodpecker species except the Red-cockaded Woodpecker. Bottomland hardwood forests were heavily used by Northern Flickers, Yellow-bellied Sapsuckers, and Red-bellied and Red-headed woodpeckers during fall and winter. Abundant acorn crops have been associated with woodpecker use of bottomland hardwood forests (Kilham 1958). Red-headed Woodpeckers favor open park-like woodlands for nesting (Bock et al. 1971, Conner 1976). This species tends to be a short-range migrant and when breeding habitat does not contain abundant mast for winter forage, Red-headed Woodpeckers often concentrate in bottomland hardwood forests (Kilham 1958, Bock et al. 1971, Moskovits 1978, Conner et al. 1994a). Downy Woodpeckers were also most abundant in bottomland hardwood forests, and were virtually absent from longleaf pine savannah. Consistent with previous studies (Bent 1939, Reller 1972, Conner 1980, Short 1982), Red-bellied Woodpeckers were more commonly detected in hardwood stands than in pine stands. Consistent with the observations of our study, Red-cockaded Woodpeckers are typically found in the open, fire-disclimax, mature-pine ecosystems of the southeastern United States where hardwood occurrence is reduced by fire (Hooper et al. 1980, Conner and O'Halloran 1987).

Disturbances in mature forest habitat benefited only one of the woodpecker species we studied. Hairy Woodpeckers occurred most frequently in mature, mixed pine-hardwood forests, especially in the residual trees of small disturbances associated with pine bark beetle infestations and timber thinning activities. Hairy Woodpeckers are seldom abundant, but occur in a wide range of habitats (Bent 1939, Short 1982). In New York (Kisiel 1972) and Virginia (Conner 1980), Hairy Woodpeckers used forests with more hardwoods than conifers, but in Colorado they used forests with more conifers than hardwoods (Stallcup 1968).

CONCLUSIONS AND MANAGEMENT IMPLICATIONS

Woodpecker abundance was primarily influenced by the presence and numbers of live hardwood trees, snags, and logs. Management for woodpeckers in mixed pine-hardwood forests should encourage provision and maintenance of large diameter snags and logs as well as a balance of hardwoods and pines. Management for woodpeckers in the longleaf pine savannah should encourage the maintenance of a greater basal area of mature pines and numerous large diameter snags and logs. The continuous use of prescribed fires should be employed to keep pioneering hardwoods to a minimum, thus maintaining the savannah condition. Management for woodpeckers in bottomland hardwood forests should include provision of a mature overstory where trees are left to die of natural causes supplying woodpeckers with a sufficient number of both small and large snags and logs.

Imitating the call of a Barred Owl increased detections of woodpeckers relative to the numbers detected when the observer was silent, but did not work equally well on all species. Because of the large home range of many woodpecker species and their often difficult detection, owl "hooting" by census takers should be considered during future studies on woodpeckers as a possible means to provide a more complete sample of woodpecker populations. It is likely that different species of owls should be used in different geographic locations to get the same mobbing effect.

ACKNOWLEDGMENTS

Part of this study (mixed pine-hardwood) was carried out as M. S. thesis research (Dept. of Biology, Stephen F. Austin State Univ.) by the first author under the direction of the second author, with much assistance from the Southern Research Station in Nacogdoches, Texas. We thank C. D. Fisher for technical advice as thesis chairman, G. L. Rogers, R. E. Brown, and D. Saenz for field assistance, and N. E. Koerth for computer and statistical assistance. We thank E. Bull, D. Ingold, R. Hutto, and R. Thill for constructive comments on the manuscript.

LITERATURE CITED

AMMAN, G. D. AND P. H. BALDWIN. 1960. A comparison of methods for censusing woodpeckers in spruce-fir forests of Colorado. Ethology 41:699–706.

BALDA, R. P. 1975. Vegetation structure and breeding bird diversity. Pp. 59–80 *in* Proc. symposium management of forest and range habitat for nongame birds. U. S. For. Serv. Gen. Tech. Rep. WO-1.

BENT, A. C. 1939. Life histories of North American woodpeckers. U.S. Natl. Mus., Washington, D.C. Bull. 174.

BIBBY, C. J., N. D. BURGESS, AND D. A. HILL. 1992. Bird census techniques. Academic Press, San Diego, California.

BOCK, C. E., H. H. HADOW, AND P. SOMERS. 1971. Relations between Lewis' and Red-headed woodpeckers in southeastern Colorado. Wilson Bull. 83:237–248.

BULL, E. L. 1975. Habitat utilization of the Pileated Woodpecker, Blue Mountains, Oregon. M. S. thesis. Oregon State Univ. Corvallis, Oregon.

——— AND R. S. HOLTHAUSEN. 1993. Habitat use and management of Pileated Woodpeckers in northeastern Oregon. J. Wildl. Manage. 57:335–345.

——— AND E. C. MESLOW. 1977. Habitat requirements of the Pileated Woodpecker in northeastern Oregon. J. For. 75:335–337.

CONNER, R. N. 1976. Nesting habitat for Red-headed Woodpeckers in southwestern Virginia. Bird-Banding 47:40–43.

———. 1978. Snag management for cavity nesting birds. Pp. 120–128 *in* Proc. workshop management of southern forests for nongame birds. (R. M. DeGraaf, tech. coord.). U. S. For. Serv. Gen. Tech. Rep. SE-14.

———. 1980. Foraging habitats of woodpeckers in southwestern Virginia. J. Field Ornithol. 51:119–127.

———. 1983. Comparisons of woodpecker nesting and foraging habitats in Virginia. Raven 54:64–70.

———. AND C. S. ADKISSON. 1977. Principal component analysis of woodpecker nesting habitat. Wilson Bull. 89:122–129.

———, J. G. DICKSON, B. A. LOCKE, AND C. A. SEGELQUIST. 1983. Vegetation characteristics important to common songbirds in east Texas. Wilson Bull. 95:349–361.

———, R. G. HOOPER, H. S. CRAWFORD, AND H. S. MOSBY. 1975. Woodpecker nesting habitat in cut and uncut woodlands in Virginia. J. Wildl. Manage. 39:144–150.

———, S. D. JONES, AND G. D. JONES. 1994a. Snag condition and woodpecker foraging ecology in a bottomland hardwood forest. Wilson Bull. 106:242–257.

——— AND K. A. O'HALLORAN. 1987. Cavity-tree selection by Red-cockaded Woodpeckers as related to growth dynamics of southern pines. Wilson Bull. 99:398–412.

——— AND D. C. RUDOLPH. 1989. Red-cockaded Woodpecker colony status and trends on the Angelina, Davy Crockett, and Sabine National Forests. U.S.D.A. For. Serv., Res. Pap. SO-250.

———,———, D. SAENZ, AND R. R. SCHAEFER. 1994b. Heartwood, sapwood, and fungal decay associated with Red-cockaded Woodpecker cavity trees. J. Wildl. Manage. 58: 728–734.

DICKSON, J. G., R. N. CONNER, R. R. FLEET, J. A. JACKSON, AND J. C. KROLL (EDS.). 1979. The role of insectivorous birds in forest ecosystems. Academic Press, New York, New York.

———, R. N. CONNER, AND J. H. WILLIAMSON. 1983. Snag retention increases bird use of a clear-cut. J. Wildl. Manage. 47:799–804.

EDWARDS, D. K., G. L. DORSEY, AND J. A. CRAWFORD. 1981. A comparison of three avian census methods. Pp. 170–176 *in* Estimating numbers of terrestrial birds. (C. J. Ralph and J. M. Scott, eds.). Stud. Avian Biol. 6.

EVANS, K. E. AND R. N. CONNER. 1979. Snag management. Pp. 214–225 *in* Proc. Workshop Management of North–central and Northeastern forests for Nongame Birds. (R. M. DeGraaf and K. E. Evans, compilers). U. S. For. Serv. Gen. Tech. Rep. NC-51.

GOULD, F. W. 1969. Texas plants—a checklist and ecological summary. Tex. Agr. Exp. Sta. Bull. MP-585.

HOOPER, R. G., A. F. ROBINSON, JR., AND J. A. JACKSON. 1980. The Red-cockaded Woodpecker: notes on life history and management. U. S. For. Serv. Gen. Rep. SA-GR9.

HOWELL, L. C. 1951. Roadside census as a method of measuring bird populations. Auk 68: 334–357.

HUTTO, R. L., S. M. PLETSCHET, AND P. HENDRICKS. 1986. A fixed-radius point count method for nonbreeding and breeding season use. Auk 103:593–602.

INGOLD, D. J. 1989. Nesting phenology and competition for nest sites among Red-headed and Red-bellied woodpeckers and European Starlings. Auk 106:209–217.

INTERNATIONAL BIRD CENSUS COMMITTEE. 1970. An international standard for mapping method in bird census work recommended by the International Bird Census Committee. Audubon Field Notes 24:722–726.

JACKSON, J. A. 1976. A comparison of some aspects of the breeding ecology of Red-headed and Red-bellied woodpeckers in Kansas. Condor 78:67–76.

——— AND B. J. S. JACKSON. 1986. Why do Red-cockaded Woodpeckers need old trees? Wildl. Soc. Bull. 14:318–322.

JAMES, F. C. 1971. Ordinations of habitat relationships among breeding birds. Wilson Bull. 83:215–236.

——— AND H. H. SHUGART, JR. 1970. A quantitative method of habitat description. Aud. Field Notes 24:727–736.

KILHAM, L. 1958. Territorial behavior of wintering Red-headed Woodpeckers. Wilson Bull. 70:347–358.

———. 1976. Winter foraging and associated behavior of Pileated Woodpeckers in Georgia and Florida. Auk 93:15–24.

KISIEL, D. S. 1972. Foraging behavior of *Dendrocopus villosus* and *D. pubescens* in eastern New York state. Condor 74:393–398.

LOOSE, S. S. AND S. H. ANDERSON. 1995. Woodpecker habitat use in the forests of southeast Wyoming. J. Field Ornithol. 66:503–514.

MANNAN, R. W. 1984. Summer area requirements of Pileated Woodpeckers in western Oregon. Wildl. Soc. Bull. 12:265–268.

———, E. C. MESLOW AND H. M. WIGHT. 1980. Use of snags by birds in Douglas-fir forests, western Oregon. J. Wildl. Manage. 44:787–797.

MCCLELLAND, B. R. 1979. The Pileated Woodpecker in forests of the northern Rocky Mountains. Pp. 283–299 *in* The role of insectivorous birds in forest ecosystems. (Dickson, J. G., R. N. Conner, R. R. Fleet, J. A. Jackson, and J. C. Kroll, eds.). Academic Press, New York, New York.

McWilliams, W. H. and R. G. Lord. 1988. Forest resources of east Texas. U. S. For. Serv. Res. Bull. SO-136.

Mellen, T. K. 1987. Home range and habitat use of Pileated Woodpeckers, western Oregon. M. S. thesis. Oregon State Univ. Corvallis, Oregon.

———, E. C. Meslow, and R. W. Mannan. 1992. Summertime home range and habitat use of Pileated Woodpeckers in western Oregon. J. Wildl. Manage. 56:96–103.

Moskovits, D. 1978. Winter territorial and foraging behavior of Red-headed Woodpeckers in Florida. Wilson Bull. 90:521–535.

Raphael, M. G. and M. White. 1984. Use of snags by cavity-nesting birds in the Sierra Nevada. Wildl. Monogr. 84:1–66.

Reller, A. W. 1972. Aspects of behavioral ecology of Red-headed and Red-bellied woodpeckers. Am. Midl. Nat. 88:270–290.

Renken, R. B. and E. P. Wiggers. 1989. Forest characteristics related to Pileated Woodpecker territory size in Missouri. Condor 91:642–652.

——— and ———. 1993. Habitat characteristics related to Pileated Woodpecker densities in Missouri. Wilson Bull. 105:77–83.

Rudolph, D. C. and R. N. Conner. 1991. Cavity tree selection by Red-cockaded Woodpeckers in relation to tree age. Wilson Bull. 103:458–467.

Rushmore, F. M. 1973. Techniques for calling sapsuckers and finding their nesting territories. U. S. For. Serv. Res. Pap. NE-281.

SAS Institute, Inc. 1988. SAS/STAT user's guide. Release 6.03 edition. SAS Institute Inc., Cary, North Carolina.

Scott, J. M. and F. L. Ramey. 1981. Length of count period as a possible source of bias in estimating bird densities. Pp. 409–413 *in* Estimating numbers of terrestrial birds (C. J. Ralph and J. M. Scott, eds.). Stud. Avian Biol. No. 6.

Scott, V. E., K. E. Evans, D. R. Patton, and C. P. Stone. 1977. Cavity-nesting birds of North American forests. U. S. For. Serv. Ag. Handbook No. 511, U. S. Dept. Ag., U. S. For. Serv., Washington, D.C.

Shackelford, C. E. 1994. Habitat characteristics of woodpeckers in pine and mixed pine-hardwood forests in eastern Texas. M. S. thesis. Stephen F. Austin State Univ., Nacogdoches, Texas.

Short, L. L. 1982. Woodpeckers of the world. Mono. Ser. 4, Delaware Museum of Natural History, Greenville, Delaware.

Stallcup, P. L. 1968. Spatio-temporal relationships of nuthatches and woodpeckers in ponderosa pine forests of Colorado. Ecology 49:831–843.

Steirly, C. C. 1965. Role of woodpeckers in the control of southern pine beetles in Virginia. Raven 36:55–59.

Thomas, J. W., L. F. Ruggiero, R. W. Mannan, J. W. Schoen, and R. A. Lancia. 1988. Management and conservation of old-growth forests in the United States. Wildl. Soc. Bull. 16:252–262.

U. S. Department of Agriculture. 1973. The outlook for timber in the United States. U. S. For. Serv. For. Res. Rep. 20.

Williams, J. B. 1975. Habitat utilization by four species of Woodpeckers in a central Illinois woodland. Amer. Midl. Nat. 93:354–367.

Wright, R. 1991. Pileated Woodpecker responds to owl tape. Nebraska Bird Rev. 59:98–99.