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HOME RANGE SIZE AND FORAGING HABITAT OF RED-COCKADED WOODPECKERS IN THE OUACHITA MOUNTAINS OF ARKANSAS

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ABSTRACT.—We obtained data for 23 habitat characteristics from plots at foraging sites of five groups of Red-cockaded Woodpeckers (*Picoides borealis*) and compared to randomly selected plots. Five groups occupied an average home range size of 24.82 ha. The birds foraged mainly in large pines having high crown volume and a long exposed bole. Foraging birds also favored stands with little understory and open spacing between foraging trees and neighboring ones. Shortleaf pine (*Pinus echinata*) was used in foraging 95% of the time over hardwoods. Woodpecker home range sizes in this shortleaf pine habitat were much smaller than in other types of forests. This may be due to the physical attributes of shortleaf pines combined with the ridged topography of the Ouachita Mountains. The vegetational requirements for foraging stressed the largest pines, open forest, and reduced hardwood understory, thus agreeing with other foraging studies of Red-cockaded Woodpeckers. *Received 31 Oct. 1996, accepted 10 Oct. 1997.*

The numerous studies of Red-cockaded Woodpeckers (*Picoides borealis*) have almost all been conducted in areas of level terrain and in forests dominated by either longleaf (*Pinus palustrus*) or loblolly pine (*Pinus taeda*), or both. Our study, conducted in the Ouachita National Forest in western Arkansas, is quite different in that the terrain was characterized by steep ridge and ravine topography and shortleaf pine (*Pinus echinata*) was the only pine. Our objective was to gain information on home range size and foraging habitat for the endangered woodpecker in this different environment.

STUDY AREA AND METHODS

Study area.—The study site was in Scott County, in the Ouachita National Forest of west-central Arkansas, a well forested area typified by shortleaf pine stands managed for timber production. It is in the Fourche Mountain subdivision of the Ouachita Mountains (Shepherd 1984) consisting of long, narrow, east-west running ridges with steep relief on sandstone and shale bedrock. Shortleaf pine dominates the forest overstory while post oak (*Quercus stellata*), blackjack oak (*Q. marilandica*) and hickories (*Carya* spp.) comprise the understory.

This area contains the only known Red-cockaded Woodpeckers in the Ouachita Mountains of western Arkansas. Burnside (1983) found two active clusters (colonies) in the area in the late 1970s. Now about 14 active clusters containing 30–35 birds are known, some outside of Scott County.

Home range.—In February, 1990, 26 Red-cockaded Woodpeckers were captured and banded using unique combinations of both numbered aluminum U.S. Fish and Wildlife Service bands and plastic color bands. This allowed field identification of each bird. Five of these woodpecker groups (clans) were selected for study, designated groups A–E, each having a pair of adult birds at the beginning of the study.

Observations of Red-cockaded Woodpecker foraging activity and group movements were conducted on a daily basis from from 22 May 1990 through 16 August 1990 and then limited to one or two days per week from 6 October 1990 to 16 February 1991. Observations of foraging activity lasted from 2–6 h at various times during the day. Length of observations varied because of the difficulty in maintaining constant contact with individual birds, particularly in the post-breeding period when the birds were away from cluster sites much of the day and frequently obstructed from view by deciduous vegetation. Marked birds were viewed at distances varying from 5–50 m, to avoid behavior modification from the observer's presence.

Trees at the periphery of the home ranges were marked with plastic flagging and when range limits were fully characterized, these trees were accurately recorded on topographic maps. Home range sizes were determined using a computer digitizing method to measure the area included within mapped convex polygons formed by connecting adjacent boundary trees with straight lines. This is the commonly used minimum area method (Mohr 1947), useful in comparing with results of other studies, including results obtained from using Global Positioning Systems (Franzreb and Barnhill 1995). Sherrill and Case (1980) noted the terms territory and home range are used interchangeably by most authors, but suggested that territory implies a defended area traversed in daily foraging. The

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term home range will be used exclusively in the present study to indicate area used for all the woodpecker activities.

Foraging habitat.—Following the method of James et al. (1981), modified from James and Shugart (1970), vegetational characteristics were measured in circular plots centered on trees within home ranges where Red-cockaded Woodpeckers were found foraging. There were a total of 110 such foraging trees from the five woodpecker home ranges. These sites were initially located for later analysis by observing individual foraging woodpeckers and marking trees used at approximately 15 min intervals.

The habitat samples were 0.04 ha (0.1 acre) circles centered at the foraging tree in which all trees and shrubs with a diameter at breast height (DBH) greater than 7.6 cm (3 in.) were counted, trunk DBH measured, and tree identified as to hardwood or pine. Using a reach stick (James and Shugart 1970) to measure DBH, these trees and shrubs were separated into the following DBH size classes: 7.6–15.2 cm (3–6 in.), 15.2–22.9 cm (6–9 in.), 22.9–30.5 cm (9–12 in.), 30.5–38.1 cm (12–15 in.), and >38.1 cm (>15 in.). Shrub density was measured by counting woody stems less than 7.6 cm (3 in.) in diameter intercepted at waist height in two, 30.5 cm (1 ft.) wide orthogonal transects across the diameter of each plot (22.6 m or 74 ft.) oriented in cardinal compass directions. Using a clinometer, average canopy height, average understory height (shrubs and trees <7.6 cm DBH), and height of the selected foraging tree were measured in each plot.

Data obtained from the foraging tree (center tree of each plot) included type of tree (pine or hardwood), height and DBH, lower crown height, crown diameter, crown volume, number of limbs below the crown, and lowest limb height. Crown volume was calculated using a modified formula for the volume of a cylinder (James et al. 1981): $V = \frac{1}{2} \pi (D^2) \times (H_t - H_l)$, where V = crown volume, D = average crown diameter, H_t = tree height, and H_l = lower crown limit. This formula was modified to calculate a laterally distended cylinder, which more closely represents the actual shape of the crown of the trees. Distance from a foraging tree to its nearest neighbor of equal or greater DBH was noted as was distance to nearest neighbor greater than 7.6 cm DBH. This gives information on spacing of trees of the same size (or greater) as the foraging tree and also spatial distribution of all trees in the foraging area.

Foraging habitat samples were compared with an equal number (110) of random (control) samples representing available habitat in the study area. A random sample was located 100 m (328 ft.) from each foraging tree in a direction indicated by a blind twist of a compass dial. The closest tree greater than 7.6 cm DBH at that site became the center tree for a random plot, using the same methods as for foraging trees.

Data analysis.—Data obtained from vegetational samples were analyzed using Wilcoxon Matched-pairs Signed-ranks Tests to compare habitat factors selected by Red-cockaded Woodpeckers with random samples. Also, Principal Component analysis, Logistic Regression analysis, and Discriminant Function analysis were performed on the same habitat data. A variance stabilization procedure (VARSTB) was applied prior to performing Discriminant Function analyses. Tests ($\alpha = 0.05$) were performed using Statistical Analysis System (SAS Institute 1985) software.

RESULTS

Home range.—Estimates of home range size for each of the groups of Red-cockaded Woodpeckers was as follows: Group A = 19.37 ha, Group B = 42.54 ha, Group C = 17.06 ha, Group D = 24.58 ha, and Group E = 20.54 ha.

Habitat.—Analysis of the 23 vegetational characteristics (Table 1) showed that differences related mainly to the foraging tree. Characteristics that were significantly greater in Red-cockaded Woodpecker foraging plots than in control plots were: center tree height and diameter (DBH), lower crown height, crown diameter, crown volume, number of limbs below the crown, and lowest limb height. The woodpeckers commonly foraged in pines while hardwoods were significantly more common at the center of random plots (Table 1). Distance to the nearest neighbor of equal or greater DBH from the center tree and average canopy height of the surrounding forest was significantly greater in woodpecker foraging plots than in random plots. The presence at foraging sites of fewer hardwoods in 7.6–15.2 cm (3–6 in.) DBH and 15.2–22.9 cm (6–9 in.) DBH size classes was significant. These last four characteristics relate to the greater forest maturity at woodpecker foraging sites than in the random plots.

Red-cockaded Woodpeckers were almost totally restricted to shortleaf pine when foraging, selecting pines 95% of the time, hardwoods 5% of the time, whereas pines constituted 60% of the forest structure, hardwoods 40%. Only the largest pines [defined as those trees >30.5 cm DBH since few truly large shortleaf pines (>50.8 cm DBH) exist in the study area as a result of extensive regional logging in the early 1900s] of those available were heavily used by the individual woodpecker groups (Fig. 1). A comparison of the usage of five size classes of shortleaf pines by the woodpeckers and the overall availability of these pines (Fig. 2) stresses the importance of larger pines in foraging. There was nearly

TABLE 1. Analysis of 23 vegetational characteristics in the foraging habitat of Red-cockaded Woodpeckers in the Ouachita National Forest, Arkansas.[a]

Vegetational characteristics	Foraging plot mean	Random plot mean	*P*-value[b] (α = 0.05)
Center tree type[c]	0.06	0.35	0.0001
Center tree height (m)	21.78	17.63	0.0001
Center tree DBH (cm)	35.08	27.81	0.0001
Lower crown height (m)	13.02	10.06	0.0001
Crown diameter (m)	7.02	6.08	0.0029
Crown volume (m^3)	825.65	611.38	0.0054
Distance to nearest neighbor of = or > DBH (m)	6.26	5.41	0.0388
Distance to nearest neighbor >7.6 cm DBH (m)	9.82	9.92	>0.05
Number of limbs below crown	1.42	0.80	0.0013
Lowest limb height (m)	11.35	9.28	0.0001
Pines 7.6–15.2 cm DBH (No. of trees)	1.96	1.30	>0.05
Pines 15.2–22.9 cm DBH	1.80	1.55	>0.05
Pines 22.9–30.5 cm DBH	2.17	1.93	>0.05
Pines 30.5–38.1 cm DBH	2.35	1.97	>0.05
Pines >38.1 cm DBH	1.41	1.00	>0.05
Hardwoods 7.6–15.2 cm DBH (No. of trees)	4.85	5.99	0.0279
Hardwoods 15.2–22.9 cm DBH	1.67	2.28	0.0309
Hardwoods 22.9–30.5 cm DBH	0.73	0.80	>0.05
Hardwoods 30.5–38.1 cm DBH	0.36	0.52	>0.05
Hardwoods >38.1 cm DBH	0.25	0.32	>0.05
Shrub density measure (No. of stems)	4.91	5.00	>0.05
Average canopy height (m)	19.42	18.63	0.0301
Average understory height (m)	2.19	2.45	>0.05

[a] First 10 characteristics pertain to the center tree.
[b] Wilcoxon Matched-pairs Signed-ranks Test.
[c] Value based on assigned values of pine = 0 and hardwood = 1.

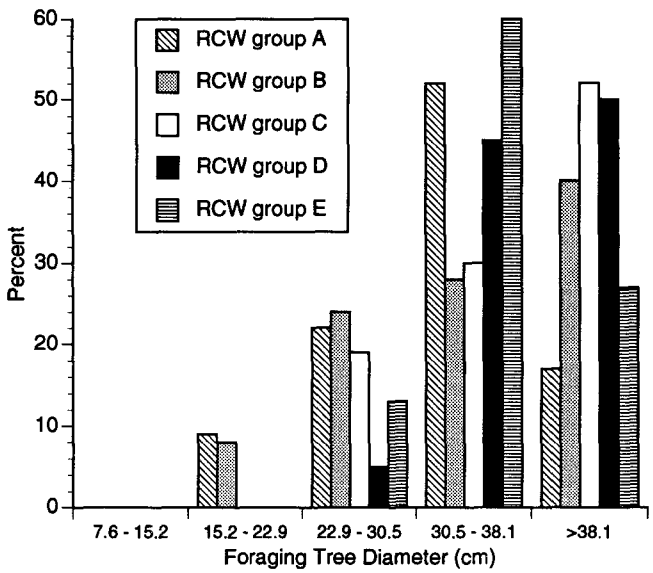

FIG. 1. Percent foraging use of five size classes of shortleaf pines by five groups of Red-cockaded Woodpeckers (RCW) in the Ouachita National Forest, Arkansas (110 samples).

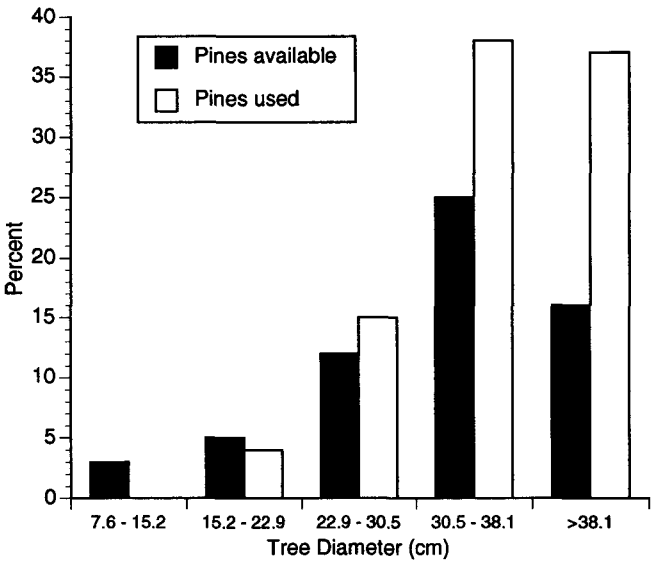

FIG. 2. Percent shortleaf pine usage (110 foraging trees) in five size classes selected by five groups of Red-cockaded Woodpeckers compared to percentage of overall shortleaf pine availability (110 random trees).

equal use of both the two largest sizes of pines (n = 104 combined) even though the larger of the two categories contained relatively the smallest number of pines (n = 38). Although hardwoods (n = 14) were much less common than pines and were mostly in the smallest size class, the few used in foraging were larger trees.

Densities of shortleaf pines more than 30.5 cm DBH/ha were determined for each home range along with the total number of stems greater than 30.5 cm DBH/home range (noted in parentheses) as follows: Group A = 67.0 (1297.8), Group B = 64.0 (2722.6), Group C = 97.25 (1659.1), Group D = 139.5 (3428.9), and Group E = 73.5 (1509.7). Mean number of stems greater than 30.5 cm DBH/ha for all groups = 88.25 and mean number of stems greater than 30.5 cm DBH/home range for all groups = 2123.6.

Principal Component analysis combining foraging and random habitat samples of all five groups of Red-cockaded Woodpeckers (Table 2) showed that six of the same important tree size characteristics that were statistically significant in Table 1 were highly correlated with the first Principal Component (PC-I). Because PC-I always represents the greatest variance in a system analyzed, this means that tree size attributes of the center trees in sample plots were the most variable components in the habitat of the study area. Because a zero (0) was assigned if the center tree was a pine, and a one (1) assigned to hardwood center trees, the high negative correlation with PC-I for center tree type (Table 2) indicates a preference for pines in foraging. The scatter of individual plots along this axis showed that the random plots were distributed along the whole axis from small to large sized center trees, the center trees being either hardwood or pine. However, the woodpecker foraging plots were highly concentrated at the end characterized by big pine trees. Therefore, PC-I (Table 2) supports the findings obtained from paired comparisons of vegetational characteristics (Table 1). PC-II emphasizes crown size, average canopy height, and distance between trees (Table 2), which pertains to degree of forest openness. This axis did not separate the foraging and random plots. Logistic Regression analysis also confirmed through a stepwise elimination procedure that center tree size, in this case tree height, was the statistically significant factor separating woodpecker foraging from non-foraging sites.

The situation shown by Principal Components was tested using stepwise Discriminant Function analysis, which showed center tree DBH and height as well as tree type and num-

TABLE 2. Results of Principal Component analysis of 23 vegetational characteristics, comparing foraging sites with random samples, for five combined groups of Red-cockaded Woodpeckers in the Ouachita National Forest, Arkansas.[a]

Vegetational characteristics	PC-I	PC-II
Center tree type (pine or hardwood)	−0.65[b]	0.34
Center tree height	0.92	−0.14
Center tree DBH	0.86	0.25
Lower crown height	0.83	−0.33
Crown diameter	0.58	0.53
Crown volume	0.53	0.59
Distance to nearest neighbor of = or > DBH	0.47	0.60
Distance to nearest neighbor >7.6 cm DBH	0.29	0.44
Number of limbs below crown	0.09	0.02
Lowest limb height	0.76	−0.32
Pines 7.6–15.2 cm DBH	−0.18	−0.09
Pines 15.2–22.9 cm DBH	−0.07	−0.22
Pines 22.9–30.5 cm DBH	0.17	−0.48
Pines 30.5–38.1 cm DBH	0.32	−0.47
Pines >38.1 cm DBH	0.03	−0.07
Hardwoods 7.6–5.2 cm DBH	−0.36	0.02
Hardwoods 15.2–22.9 cm DBH	−0.42	0.08
Hardwoods 22.9–30.5 cm DBH	−0.23	0.02
Hardwoods 30.5–38.1 cm DBH	−0.16	−0.04
Hardwoods >38.1 cm DBH	−0.17	−0.02
Shrub density measure	0.12	0.38
Average canopy height	0.23	−0.69
Average understory height	−0.32	0.07

[a] First 10 characteristics listed pertain to sample plot center tree.
[b] Underlined values indicate high correlation ($P < 0.05$) with the respective factors.

ber of limbs below the crown were significant in separating woodpecker usage and control sites, again confirming a dependance on tall, large diameter pines by Red-cockaded Woodpeckers for foraging. The discrimination was noteworthy in that the analysis correctly classified 82% of the foraging plots and 87% of the random plots out of the 110 samples of each type.

DISCUSSION

Home range.—The average home range size of 24.82 ha found in this study was much smaller than the overall mean size of 76.13 ha calculated from this plus 14 previous studies on Red-cockaded Woodpeckers (Table 3). The two prior findings that were closest to our results were 17.2 and 32.1 ha reported by Crosby (1971) and Sherrill and Case (1980), respectively.

In evaluating this large difference in home range size, the number of birds in each group studied must be considered because an increase in group size could cause an increase in home range size. However, Nesbit et al. (1978) found that a small group does not necessarily inhabit a small home range. In that case three groups containing two to four birds occupied an average home range size of 69.8 ha. This suggests that other factors affect home range size, such as habitat quality and forest type (e.g., dominant pine species).

Previous studies were conducted in forests of pine other than shortleaf, except for Wood (1983). Most show rather large home range sizes (Table 3) compared to our study. Perhaps the structural and growth characteristics of shortleaf pine make it possible for home ranges to be smaller than in longleaf or loblolly pine forests. According to Mattoon (1915), shortleaf pines typically have crowns composed of numerous small branches forming a narrow pyramidal shape permitting the high density of trees characterizing shortleaf pine forests. The crown of longleaf pine is similar to that of shortleaf at first but in mature trees the crowns broaden, lowering tree density in longleaf stands compared to shortleaf stands. Loblolly pine maintains a dispersed, large branched crown throughout its life resulting in less tree density than shortleaf pine.

The above suggests shortleaf pines may have more branch surface area in the crown than other pines, providing relatively greater area for woodpecker foraging, possibly reducing the number of trees needed in the home range. Add to this the observation that shortleaf pines grow more densely than other pines. This combination of increased foraging area and tree density in shortleaf stands could provide needed resources in smaller areas of shortleaf pine than in loblolly and longleaf stands.

Another reason for smaller home ranges in this study may be the topography of the Ouachita Mountains. When the home ranges were positioned on a topographic map, each home range nearly fit in ravines between ridge lines, rarely crossing over to the opposite side of a ridge. A possible reason for this home range configuration is that Red-cockaded Woodpecker groups are quite social and vocal when foraging (Ligon 1970). Foraging on op-

TABLE 3. Comparison of Red-cockaded Woodpecker home range sizes from 15 studies.

Study and location	Season[a]	No. groups	Birds per group	Ave. home range size (ha)	Range in size (ha)	Forest type[b]
Baker (1971)						
Florida	S	1	8	65.6	—	MX
Crosby (1971)						
Florida	S	2	2	17.2	14.4–20.0	LO
DeLotelle et al. (1987)						
Florida	Y	6	2–8	150.0	116.2–198.8	LO
DeLotelle et al. (1995)						
Florida	Y	13	1–3	129.0	86.0–161.0[c]	LO
Epting et al. (1995)						
Florida & Georgia	Y	18	?	79.8	21.0–107.0	MX
Franzreb & Barnhill (1995)						
South Carolina	S, W	7	?	49.7	14.5–93.6	MX
Hooper et al. (1982)						
South Carolina	Y	24	2–6	86.9	34.0–225.0	MX
Jackson & Parris (1995)						
Louisiana	Y	8	1–5	135.0	109.0–170.0[d]	MX
James et al. (1981)						
Arkansas	S	2	3–5	56.7	35.7–86.6	LB
Nesbit et al. (1978)						
Florida	W	3	2–4	69.8	58.4–91.4	MX
Repasky & Doerr (1991)						
North Carolina	Y	2	?	159.5	139.0–180.0	LO
Sherrill & Case (1980)						
South Carolina	W	4	2–8	32.1	20.6–43.7	LO
Skorupa & McFarlane (1976)						
South Carolina	S, W	2	2–4	41.9	17.6–65.8	MX
Wood (1983)						
Oklahoma	S	1	4	44.1	—	SL
Present study						
Arkansas	Y	5	2–3	24.8	17.1–42.5	SL
	Overall average size			76.1 ha		

[a] Seasons: S = summer, W = winter, Y = year-round.
[b] Forest types: LO = longleaf pine, LB = loblolly pine, SL = shortleaf pine, MX = mixed pine species.
[c] Territory sizes only.
[d] Pre-disturbance home range sizes.

posite sides of ridges may prevent communications between group members thus confining home ranges to individual ravine watersheds.

Habitat quality may affect the home range size in that small home ranges could occur in better habitat. DeLotelle et al. (1987) indicated average home range sizes in central Florida were larger than in South Carolina where habitat was considered better. Population densities of Red-cockaded Woodpeckers are low in the Ouachita Mountains so there would be low competition for optimal habitat. Thus, it is expected that these birds would occupy the best available microhabitats, which often happens in other avian species (Wiens 1973). Having optimum habitat available these Red-cockaded Woodpeckers may be showing an inverse relationship between quality of habitat and size of home range (i.e., the better the habitat the smaller the home range). Davis (1982) found this relationship existed between habitat quality and the breeding and nonbreeding territory size in Belted Kingfishers (*Megaceryle alcyon*).

Annual duration of home range observations can affect the outcome of range delineations. Year-round observations often result in a more accurate outline of the total home range occupied by Red-cockaded Woodpecker groups (Hooper et al. 1982) while studies that use partial year data may not provide as precise a depiction of the bird's home range. Our study, though not continuous year-round, does

combine data from spring and summer when home ranges tend to be smaller with data from fall and winter when home ranges are larger.

Habitat.—Foraging habitat data collected for the five groups of Red-cockaded Woodpeckers indicate a overwhelming preference for large (mean height = 21.78 m, mean DBH = 35.08 cm) shortleaf pines as a foraging substrate (Tables 1 and 2; Figs. 1 and 2). This supports previous findings showing a preference for large pine trees in foraging (Skorupa and McFarlane 1976, Hooper and Lennartz 1981, Epting et al. 1995). Other vegetational characteristics were preferentially selected too by Red-cockaded Woodpeckers (Table 1) including trees with a high exposed bole (mean height of lowest limb = 11.35 m), wide crown diameter (mean crown diameter = 7.02 m) and high crown volume (mean crown volume = 825.65 m^3). In total, all these characteristics emphasize the use of large pine trees by foraging Red-cockaded Woodpeckers.

Space between trees with a diameter equal to or greater than that of foraging trees also proved significant (Table 1), with a mean distance between trees of 6.26 m, indicating a greater "openness" between trees than what was found in the control samples (mean distance between trees in control = 5.41 m). Also, the paucity of small hardwoods (particularly in the range of 7.6–22.9 cm DBH) in foraging samples (Table 1) indicated that, as in other types of pine forests, Red-cockaded Woodpeckers prefer foraging areas that are open without small or midsized hardwood understory (Ligon 1970, Hooper et al. 1980, Hovis and Labisky 1985). The vegetational cline on PC-II also stressed this "openness" (Table 2) but actually foraging and random trees were not separated on this axis. Therefore, forest openness may not be as important as having large pine trees for foraging Red-cockaded Woodpeckers.

In nearby McCurtain County in southeast Oklahoma, Wood (1983) showed a significantly lower midstory vegetation height in the "use" (used for woodpecker foraging) compared to "non-use" areas or less intensively used areas. The present study supports Wood's data in midstory height (Table 1). However, Wood found Red-cockaded Woodpeckers foraged in dense overstory while our results show utilization of less dense overstory shown by the greater distance between large trees, higher lowest limb, and taller canopy height for foraging than random trees (Table 1). A probable cause for this difference is that the Wilderness Area in Wood's study is a virgin forest with a restrictive policy against fire and vegetational controls such as mechanical midstory removal and stand thinning, while the Ouachita National Forest is a managed forest that experiences vegetational control, both by fire and mechanical means. This thinning by the Forest Service, in effect, optimizes foraging habitat for the woodpeckers, allowing for selection of habitat preferences while the unmanaged Wilderness Area forces the birds to use dense pine stands with heavy mid and understory vegetation.

Red-cockaded Woodpeckers have small home ranges and rather specific foraging requirements in shortleaf pine forests. The small home range sizes shown here could be related to a combination of high habitat quality and the presence of close topographic boundaries. The foraging specificity shown by Red-cockaded Woodpeckers is a requirement of large pine trees with an open spatial arrangement between trees and small amounts of associated mid and understory vegetation. Such conditions are known to be critical for Red-cockaded Woodpecker populations in other forest types, but this is the first confirmation of its importance in a shortleaf pine forest. The almost exclusive use of pines for foraging is also supported by other studies.

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