LONGLEAF PINES USED FOR CAVITIES BY RED-COCKADED WOODPECKERS

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Abstract: I studied characteristics and availability of young (≤80 yr old) and old (≥100 yr old) longleaf pines (*Pinus palustris*) used and not used for cavities by red-cockaded woodpeckers (*Picoides borealis*), and the associated population densities of red-cockaded woodpeckers in Osceola and Ocala national forests (NF) in Florida, and in Francis Marion NF in South Carolina. In Francis Marion NF old noncavity trees were common (17/ha); 6% of the cavity trees were young; decayed heartwood was frequent in old (97%) and young (86%) cavity trees ($P = 0.299$), but rare in young noncavity trees (9%); and population density was high (8.3 colonies/1,000 ha). In Osceola and Ocala NF, respectively, old noncavity trees were rare (<1/ha); 65 and 76% of the cavity trees were young; decayed heartwood was frequent in old cavity trees (80 and 90%), but less so in young cavity trees (27 and 32%) ($P \leq 0.007$); young cavity trees had faster growth rates than young noncavity trees ($P \leq 0.001$); and population densities were low (1.7 and 1.4 colonies/1,000 ha). Red-cockaded woodpeckers may have been using the easiest trees to excavate. The order of preference appeared to be trees with decayed heartwood and then fast-growing trees with sound heartwood. Because decay increases with tree age and decayed trees are the most preferred, older trees apparently provide red-cockaded woodpeckers with more and better opportunities for cavity excavation than younger trees. Results support past recommendations of providing longleaf pines >95 years old to red-cockaded woodpeckers for cavity excavation.

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The red-cockaded woodpecker is reported to require old, living pine trees (>95 yr for longleaf pine and >75 yr for other species) for cavity excavation (U.S. Fish and Wildl. Serv. 1985). However, most studies have found some cavity trees 20–45 years younger than the recommended ages (Hopkins and Lynn 1971, Thompson and Baker 1971, Jones and Ott 1973, Shapiro 1983, Hovis and Labisky 1985). The mean age of 610 longleaf pines with red-cockaded woodpecker cavities was 86 years (Wood 1983). Field and Williams (1985:95) reviewed 43 studies that mentioned maturity as a characteristic of cavity trees and concluded "... selection of old cavity trees or old colony stands by red-cockaded woodpeckers cannot be supported at this time."

Later studies implied selection for older trees (Hovis and Labisky 1985, Conner and O'Halloran 1987, DeLotelle and Epting 1988), but cavity-tree age data are subject to bias. Cavities are usually used for several years (some >20) and each cavity lasts the life of the tree (Lay and Russell 1970, Beckett 1971, Jackson 1978). Thus, when aged during studies, cavity trees are older than when first selected by woodpeckers.

Jackson et al. (1979) partially eliminated age bias by looking only at incompleted cavities; however, cavity trees tend to be aggregated in clusters (colonies). Trees selected for new cavities tend to be within or close to the aging colony, increasing the likelihood that older trees are selected.

Red-cockaded woodpeckers use young (≤80 yr old) longleaf pines for cavities, but it is not clear why they use them or how important young trees are relative to old trees. To address these questions, I compared the use, characteristics, and availability of cavity trees and noncavity trees in Osceola and Ocala NF in Florida and Francis Marion NF in South Carolina.

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METHODS

Determining Population Densities

I collected data on active colonies in the Francis Marion NF (1980–81) and Osceola NF (1985) with a stratified random sample of management compartments. I used the method of Harlow et al. (1983) to estimate active colonies/sample compartment, and used a ratio estimator (Cochran 1977) with ha of pine as an auxiliary variate to estimate colonies in each forest.

Virtually all colonies were known in Ocala

NF (D. J. Bethancourt, U.S. For. Serv., pers. commun.). In 1984 I visited all known colonies in Ocala NF and determined the number active based on tree condition (Hooper et al. 1980) and the presence of red-cockaded woodpeckers.

To compare populations among study areas, I computed the number of active colonies/1,000 ha of habitat. Habitat was defined as pine stands ≥30 years old to include foraging habitat (Hooper and Harlow 1986). These data were obtained from NF records and included loblolly pine (*P. taeda*) in Francis Marion NF and slash pine (*P. elliottii*) in Osceola NF.

Determining Tree Characteristics

Tree characteristics were collected from 127 longleaf pines with cavities and 220 longleaf pines without cavities during 1981–86. Young cavity trees in Osceola and Ocala NF and old cavity trees in Francis Marion NF were randomly selected, but I used all old cavity trees I could find in Osceola and Ocala NF, and all young cavity trees I could find in Francis Marion NF. The age distribution of longleaf pine trees with cavities was estimated by randomly sampling the study areas. As an index to the availability of trees for cavities, the area of longleaf pine stands >50 years old was determined from NF records.

Longleaf pines ≤80 years old were classified as young and those ≥100 years old were classified as old. Tree ages were estimated by counting annual rings from an increment core (5 mm diam) taken at breast height. A factor of 7 was added to account for years of growth up to breast height. Heartwood diameter was estimated from the same core by doubling the distance from pith to the sapwood. Width of sapwood was the distance from cambium to heartwood. Heartwood diameter and width of sapwood were also determined for young cavity trees below the cavity.

Growth rate was determined by finding the minimum and maximum number of annual rings within 5-cm segments of the age core. Occurrence of decayed heartwood was visually determined from cores above and below the cavity. Tree basal area was determined with a prism having a basal area factor of 2.3 m. Each sample tree was a plot center.

Young trees without cavities were randomly selected from longleaf pine stands chosen at random from all longleaf stands within 5 years of the mean age of young cavity trees. Ten prism points (Dilworth and Bell 1982) were randomly located in each stand. A tree indicated by the prism, ≥minimum diameter at breast height (dbh), and within 5 years of the mean age of young cavity trees was randomly selected at each point. Abundance of relic pines (≥100 yr old) was determined at the same time.

In Francis Marion NF, I sampled adjacent noncavity trees for decay. The tree closest to each young cavity tree with a dbh ±2 cm of the cavity-tree dbh was used as an adjacent tree. Trees were drilled at 1.5-m intervals from 3 to 12 m above the base of the tree with an electric drill and 3.2-mm bit. Shavings were visually examined for decay. If diagnosis was uncertain after drilling, the tree was increment bored.

Statistical Analysis

Differences between young versus old cavity trees and between young cavity trees versus random trees without cavities were tested with t-tests. I tested for differences among study areas in old cavity trees, young cavity trees, and randomly selected trees without cavities with 1-way analysis of variance. Individual means among areas were compared with Duncan's multiple range test. I tested the null hypotheses of decayed heartwood occurring with equal frequency in different national forests and in cavity trees of different ages with the log-likelihood ratio for contingency tables and Fisher's exact test, respectively. The null hypothesis that cavity tree ages were the same among areas was tested with a G-test using age classes: ≤80, 80–99, and ≥100 years old. Differences in young cavity trees and adjacent trees in Francis Marion NF were tested with paired t-tests. The means for diameter of heartwood were tested with analysis of covariance using dbh as a covariate.

RESULTS

Population Densities

Francis Marion NF had 406 colonies (95% CI = 238–574) of red-cockaded woodpeckers, the largest estimated population of the 3 study areas. The population in Osceola NF was estimated to be 52 colonies (95% CI = 24–80). In 1984–85, 52 active colonies were counted in Osceola NF (A. W. Stockle, Fla. Game and Fresh Water Fish Comm., pers. commun.). I estimated Ocala NF had 18 active colonies in 1984. This estimate was substantiated by an independent evaluation in 1985 (M. J. Robertson, U.S. For. Serv., pers. commun.). The active colonies/1,000 ha of habitat in Francis Marion, Osceola, and Ocala NF were 8.3, 1.7, and 1.4 ha, respectively.

Use and Availability of Young and Old Pines for Cavities

Age distributions of cavity trees were different among study areas ($P = 0.001$). In Osceola and Ocala NF 76 and 65%, respectively, of the cavity trees were ≤80 years old compared to 6% in Francis Marion NF. Fifty-eight percent of the cavity trees in Francis Marion NF were ≥100 years old but only 12.5 and 15.6% of the cavity trees in Osceola and Ocala NF, respectively, were ≥100 years old.

Longleaf pines ≥100 years old were rare in Ocala and Osceola NF. In Osceola NF, none of the longleaf pine stands were ≥100 years old and in Ocala NF only 0.2% were ≥100 (Fig. 1). In addition, no relic longleaf pines ≥100 years old were found in the 5 longleaf pine stands randomly sampled in Ocala NF and only 1 was recorded from the 6 stands sampled in Osceola NF. Three relic trees were found in stands not sampled in Osceola NF, but none were encountered in Ocala NF.

In contrast, longleaf pines ≥100 years old were more common in Francis Marion NF. Although only 1.2% of the longleaf stands were ≥100 years old (Fig. 1), many of the old longleaf pines were scattered relics and patches of relics. A random sample of 8 longleaf pine stands had a mean of 17 relic longleaf pines/ha (SE = 3.8).

On both Florida sites the 60–69-year-old age class had the highest frequency of cavity trees and the greatest area in longleaf pine stands (Fig. 1). There were relatively few cavity trees in the next younger age class (50–59 yr old) and considerable recruitment of new cavity trees was occurring in the 60–69 age class. Few cavity trees of that age class were found in Francis Marion NF. In Florida, the proportions of cavity trees in the 70–79 and older age classes were greater than the proportions of pine stands in the respective age classes. In Francis Marion NF, the proportion of cavity trees was still low in the 70–79 age class, but increased dramatically in the older age classes. There were relatively few ha of longleaf pine stands in the ≥100 age class in Francis Marion NF, but relic pines of that age were common.

Comparison of Trees Among Areas

There were differences ($P \leq 0.01$) in major characteristics of young and old cavity trees among the study areas. Young cavity trees in Ocala NF had a greater dbh, height, diameter of heartwood, and a faster growth rate than young cavity trees in other sites (Table 1). No differences ($P > 0.05$) were found in these same means between Osceola NF and Francis Marion NF. Despite their larger size, young cavity trees in Ocala NF were younger than young cavity trees in Francis Marion NF. The frequency of decayed heartwood in young cavity trees was different ($P = 0.0001$) among the 3 study areas (Table 2).

Old cavity trees in Osceola NF were smaller and had a slower growth rate than old cavity trees in Francis Marion NF (Table 1). In Osceola NF, old cavity trees also had less heartwood than old cavity trees in the other study areas. Among the 3 areas, no difference ($P = 0.273$) was found in the frequency that decayed heartwood occurred in old cavity trees (Table 2). No difference ($P = 0.906$) among areas was found for the mean age of randomly selected young trees without cavities (Table 1). Differences ($P \leq 0.004$) among areas were found for means of all other measured characteristics of random trees.

Comparison of Young and Old Cavity Trees

Trees were selected for study on the basis of a minimum or maximum age. Given these differences in age, however, it is notable that differences were not found in all other variables thought to be important in selection of cavity trees. Importantly, the frequency of decayed heartwood in young and old cavity trees in Francis Marion NF was not different ($P = 0.299$) (Table 2). In addition, 9 of 10 longleaf pines 80–85 years old had decay at the cavity level. The dbh of young and old cavity trees in Osceola NF did not differ ($P = 0.284$) (Table 1) nor did the diameter of heartwood in young and old cavity trees in the Florida sites ($P \geq 0.071$) (Table 1).

In Ocala NF, young cavity trees had a larger dbh ($P = 0.040$) and width of sapwood ($P = 0.001$) than old cavity trees (Table 1). Young cavity trees in Francis Marion NF were smaller ($P \leq 0.022$) than old cavity trees in dbh, height, and diameter of heartwood (Table 1). The fre-

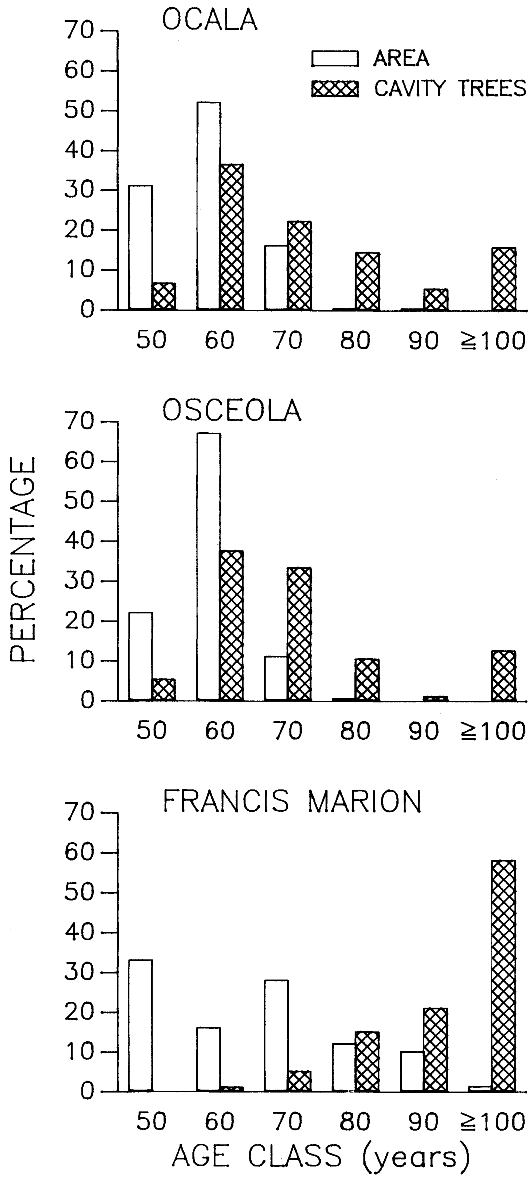

Fig. 1. Distribution of ages of longleaf pines with red-cockaded woodpecker cavities and area of longleaf pine stands >50 years old in the Ocala, Osceola, and Francis Marion national forests, 1981–86. Sample size for cavity trees was 77, 96, and 100 in Ocala, Osceola, and Francis Marion national forests, respectively. Area in longleaf pine >50 years old was 11,940 ha, 8,630 ha, and 8,180 ha in Ocala, Osceola, and Francis Marion national forests, respectively. The abundance of relic trees is not represented in the graphs.

quency of decayed heartwood in young cavity trees in the Florida sites was considerably less ($P = 0.007$) than for old cavity trees (Table 2). In all study areas, old cavity trees had slower growth rates than young cavity trees ($P \leq 0.001$)

Table 1. Comparison of characteristics of young (≤80 yr old) longleaf pine trees with red-cockaded woodpecker cavities to old (≥100 yr old) longleaf pine trees with cavities and to randomly selected young (≤80 yr old) longleaf pine trees without cavities in Ocala and Osceola national forests, Florida, and Francis Marion National Forest, South Carolina, 1981–86.

	Ocala National Forest						Osceola National Forest						Francis Marion National Forest					
	Young		Old		Random		Young		Old		Random		Young		Old		Random	
Variable	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD
Age (yr)	65.5	6.3	153.2[a]****	41.1	69.5**	6.1	70.1	6.1	163.0****	48.6	68.9	7.4	72.3	9.2	130.7****	18.8	69.1	7.9
Dbh (cm)	46.4	5.6	41.7*	6.7	39.4****	4.7	37.7	3.3	36.2	4.6	35.8*	3.6	37.5	6.0	45.2****	5.2	38.1	5.7
Ht (m)	25.6	2.3	not measured		23.4***	2.5	23.4	1.9	19.2****	2.1	24.6**	2.0	23.3	3.4	25.5*	3.3	23.6	2.1
Heartwood																		
diam (cm)	24.3	4.6	27.4	3.8	18.6****	4.1	17.5	4.4	17.8	4.6	17.2	5.1	18.6	4.3	25.1****	5.6	14.7**	5.3
Sapwood (cm)	9.4	2.2	6.5***	1.9	8.7	2.1	8.3	2.1	8.1	1.9	7.6	2.2	7.4	1.5	7.6	2.1	9.9****	2.5
Min. growth[b]	25.9	5.4	62.6***	23.0	31.6****	5.9	31.1	5.1	75.0***	24.7	35.2***	5.7	33.1	6.9	51.0****	11.2	28.3**	5.8
Max. growth[c]	6.6	2.1	20.2****	6.1	9.4****	2.4	11.1	3.1	27.1**	13.2	10.6	2.8	11.5	4.0	17.6****	5.1	12.2	3.2
Basal area																		
(m^2/ha)	10.6	5.5	6.2*	3.4	12.6	4.4	13.1	5.3	14.0	5.9	12.9	4.5	14.5	5.5	14.8	6.3	16.2	5.0
Cavity ht (m)	7.3	1.8	8.0	2.2			6.6	1.4	7.0	2.4			7.4	2.3	10.1***	3.1		
n	25		10		57		30		10		72		22		30		69	

[a] Means differed between young vs. old cavity trees or between young cavity trees vs. young random trees without cavities within a Natl. For. (* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$; **** $P \leq 0.0001$).
[b] Max. no. annual rings in 5 cm.
[c] Min. no. rings in 5 cm.

Table 2. Number of young (≤80 yr old) and old (≥100 yr old) longleaf pines with decayed versus sound heartwood used for cavities by red-cockaded woodpeckers in Ocala and Osceola national forests, Florida, and Francis Marion National Forest, South Carolina, 1981–86.

Cavity tree	Ocala Decayed	Ocala Sound	Osceola Decayed	Osceola Sound	Francis Marion Decayed	Francis Marion Sound	P^a
Young	8	17	8	22	19	3	0.001
Old	9	1	8	2	29	1	0.273
P^b	0.003		0.007		0.299		

[a] Probability of no difference in frequency of decay for either young or old cavity trees among the national forests, based on G-tests.
[b] Probability of no difference in frequency of decay between young and old cavity trees within a national forest, based on 2-tailed Fisher's exact test.

(Table 1). These differences were probably due to decreasing diameter growth with age (Wahlenberg 1946:219) and/or suppression from surrounding trees. However, even the most rapid sustained growth at any time in the tree's life was less in old cavity trees than in young cavity trees ($P \le 0.004$) (Table 1).

Comparison of Young Trees With and Without Cavities

Decay was found more frequently in young cavity trees in Francis Marion NF than in adjacent trees without cavities (86.4 vs. 9.1%, respectively [$P = 0.001$]). Adjacent trees without cavities did not differ ($P > 0.05$) from young trees with cavities in age, dbh, height, growth rate, or surrounding basal area, but cavity trees did have more heartwood than adjacent trees (18.6 vs. 16.1 cm, respectively [$P = 0.018$]). I was unable to test for decay in adjacent trees without cavities in the Florida sites.

Among areas, the only consistency in results between young cavity trees and young trees without cavities was the lack of difference ($P > 0.083$) in basal area of pines surrounding the trees (Table 1). Although no differences ($P = 0.556$) in the dbh and height of young cavity trees and random trees were found in Francis Marion NF, young cavity trees had more heartwood ($P = 0.003$) and less sapwood ($P = 0.0001$) than random trees without cavities. There was also a difference in the minimum growth rate ($P = 0.002$), indicating young trees with cavities grew slower than random trees during some time of their life. The opposite results were found in Osceola NF; young cavity trees and random trees differed in height ($P = 0.005$) and dbh ($P = 0.021$) but not in diameter of heartwood ($P = 0.811$) or sapwood ($P = 0.120$), and random trees had a slower minimum growth rate than cavity trees ($P = 0.001$) (Table 1).

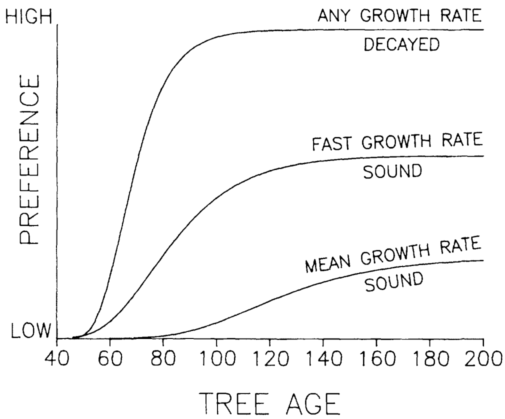

Fig. 2. Relative preference by red-cockaded woodpeckers for trees to excavate cavities from among longleaf pines of different ages, growth rates, and heartwood conditions in Florida and South Carolina.

In Ocala NF, young cavity trees were younger than the randomly selected young trees without cavities ($P = 0.008$) (Table 1). This result is surprising because young cavity trees also had a greater dbh ($P = 0.0001$), height ($P = 0.0004$), and heartwood diameter ($P = 0.0001$) than older randomly selected trees without cavities. Consistent with their larger size, young cavity trees had a faster growth rate than the random trees ($P = 0.0001$) (Table 1). The difference in mean heartwood diameter was still significant ($P = 0.008$) after taking into account the difference in dbh.

DISCUSSION

My study suggests that red-cockaded woodpeckers are using trees that are the easiest to excavate from among those available. A hierarchy of preference of trees for cavities based on condition of heartwood, growth rate, and age seems tenable (Fig. 2). In this simple model, the any growth : decayed curve reflects a high preference for any tree with decayed heartwood. In Francis Marion NF, the frequency of decayed heartwood was high in young and old cavity trees, and low in trees without cavities. Red-cockaded woodpeckers in Florida were probably selecting for decayed heartwood in young cavity trees also, though the frequency of decay was less than in Francis Marion NF. The lower frequency of decay in Florida probably resulted from the low incidence of decay in trees ≤80 years old and the lack of old trees. Based on the use of young trees with decay, the increase in preference was at least as rapid for ages ≤80 years as that shown. Beyond 80 years there may be little increase in preference and preference may decline in very old trees because some become hollow in advanced stages of decay.

Decayed heartwood is clearly not a requirement for cavity excavation, but studies have indicated high use of trees with decayed heartwood by red-cockaded woodpeckers (Jackson 1977, Conner and Locke 1982). This consistency among studies suggests some benefit to the bird from decayed heartwood. It normally takes red-cockaded woodpeckers >1 year to excavate a cavity and decayed heartwood could contribute substantially to efficiency of excavation (Jackson and Jackson 1986, Conner and O'Halloran 1987). The greater density of red-cockaded woodpeckers in Francis Marion NF, the area where decayed heartwood was most prevalent in cavity trees, supports this idea.

Preference for fast-growing trees with sound heartwood (fast growth : sound) was less than for trees with decay (any growth : decayed), but greater than for average-growing trees with sound heartwood (mean growth : sound) (Fig. 2). Lacking a sufficient number of young or old trees with decayed heartwood, red-cockaded woodpeckers in Ocala NF used large, fast-growing young trees. In addition to young cavity trees being larger and younger than randomly selected young trees without cavities, the mean dbh of young cavity trees without decay was 6.7 cm larger than those with decay ($P \leq 0.003$). Similarly, Jackson (1977) found loblolly pine cavity trees without decay to be younger and larger than those with decay. Rapid diameter growth may make cavity excavation easier. Fast-growing trees tend to have a wide core of juvenile wood adjacent to the pith (Thomas 1984) and are noticeably easier to increment bore. Overall tree size was smaller in Osceola NF but woodpeckers there also used the larger, faster growing trees from among those available.

The ranking of the 3 preference curves is clear (Fig. 2). Their relative spacing in the model is also supported because young, fast-growing trees without decay are sometimes used for cavities even when old trees are abundant (R. G. Hooper, unpubl. data), and not all old cavity trees have decay.

Heartwood has been though to be a critical factor in cavity excavation (Beckett 1971, Hooper et al. 1980, Jackson and Jackson 1986, Conner and O'Halloran 1987). Cavities are about 8–13 cm wide (Hooper et al. 1980). The minimum heartwood diameter at the cavity level of young cavity trees was 12.4 cm; therefore, all cavity trees had at least the minimum amount of heartwood to envelop most cavities. Given the inconsistent results among areas, greater amounts of heartwood may not be increasingly beneficial. Factors such as decay and juvenile wood appear to be more important. Other factors such as resin flow, differential growth (Conner and O'Halloran 1987), and juxtaposition of other trees may play a role in tree selection. However, the growth rate : decay model (Fig. 2) is consistent with use of old trees, use of trees with decayed heartwood, and use of young trees for cavities when old trees are and are not available.

The frequency with which trees with a particular characteristic are used is controlled by availability and preference; thus, a model for use would be more complex than a model for preference. However, preferential use of old trees seems clear. Young trees with decay are rare and decay increases steadily with age (Wahlenberg 1946:177). The high use of decayed trees and their increasing availability with age results in preferential use of old trees. Although red-cockaded woodpeckers use young trees for cavities, older trees provide more opportunities for cavity excavation and some additional benefit, possibly efficiency of excavation.

MANAGEMENT IMPLICATIONS

The recommendation that red-cockaded woodpeckers be provided with longleaf pines >95 years old for cavity trees (U.S. Fish and Wildl. Serv. 1985) is supported by my study. Because decayed heartwood, apparently the primary factor in tree use, is infrequent at this initial age, longleaf pine stands managed for new colony sites should continue to increase in value to the red-cockaded woodpecker as trees age.

Managers should designate and manage stands 60–80 years old as potential colony sites when older stands are absent. Two different stand conditions appear especially favorable for potential sites: fast-growing stands on good-quality sites that have been thinned to encourage diameter growth throughout the history of the stand, and overstocked stands on poor-quality sites, which should have a higher incidence of decay than stands of similar age growing under better conditions (Wahlenberg 1946:177).

Relic trees are an important source of cavity trees for red-cockaded woodpeckers. Special consideration should be given to retaining relic trees during thinnings of stands in areas managed for red-cockaded woodpeckers.

LITERATURE CITED

BECKETT, T. 1971. A summary of red-cockaded woodpecker observations in South Carolina. Pages 87–95 *in* R. L. Thompson, ed. The ecology and management of the red-cockaded woodpecker. U.S. Bur. Sport Fish. and Wildl., and Tall Timbers Res. Stn., Tallahassee, Fla.

COCKRAN, W. G. 1977. Sampling techniques. Third ed. John Wiley & Sons, New York, N.Y. 428pp.

CONNER, R. N., AND B. A. LOCKE. 1982. Fungi and red-cockaded woodpecker cavity trees. Wilson Bull. 94:64–70.

———, AND K. A. O'HALLORAN. 1987. Cavity tree selection by red-cockaded woodpeckers as related to growth dynamics of southern pines. Wilson Bull. 99:392–412.

DELOTELLE, R. S., AND R. J. EPTING. 1988. Selection of old trees for cavities by red-cockaded woodpeckers. Wildl. Soc. Bull. 16:48–52.

DILWORTH, J. R., AND J. F. BELL. 1982. Variable probability sampling: variable plot and three-P. Oregon State Univ. Bookstores, Corvallis. 130pp.

FIELD, R., AND B. K. WILLIAMS. 1985. Age of cavity trees and colony stands selected by red-cockaded woodpeckers. Wildl. Soc. Bull. 13:92–96.

HARLOW, R. F., R. G. HOOPER, AND M. R. LENNARTZ. 1983. Estimating numbers of red-cockaded woodpecker colonies. Wildl. Soc. Bull. 11:360–363.

HOOPER, R. G., AND R. F. HARLOW. 1986. Forest stands selected by foraging red-cockaded woodpeckers. U.S. For. Serv. Res. Pap. SE-259. 10pp.

———, A. F. ROBINSON, JR., AND J. A. JACKSON. 1980. The red-cockaded woodpecker: notes on life history and management. U.S. For. Serv., Southeast. Area, State and Private For., Atlanta, Ga. 8pp.

HOPKINS, M. L., AND T. E. LYNN, JR. 1971. Some characteristics of red-cockaded woodpecker cavity trees and management implications in South Carolina. Pages 140–169 *in* R. L. Thompson, ed. The ecology and management of the red-cockaded woodpecker. U.S. Bur. Sport Fish. and Wildl., and Tall Timbers Res. Stn., Tallahassee, Fla.

HOVIS, J. A., AND R. F. LABISKY. 1985. Vegetative associations of red-cockaded woodpecker colonies in Florida. Wildl. Soc. Bull. 13:307–314.

JACKSON, J. A. 1977. Red-cockaded woodpeckers and pine red heart disease. Auk 94:160–163.

———. 1978. Competition for cavities and red-cockaded woodpecker management. Pages 103–112 *in* S. A. Temple, ed. Endangered birds: management techniques for preserving threatened species. Univ. Wisconsin Press, Madison.

———, M. R. LENNARTZ, AND R. G. HOOPER. 1979. Tree age and cavity initiation by red-cockaded woodpeckers. J. For. 77:102–103.

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

JONES, M. K., JR., AND F. T. OTT. 1973. Some characteristics of red-cockaded woodpecker cavity trees in Georgia. Oriole 38:33–39.

LAY, D. W., AND D. N. RUSSELL. 1970. Notes on the red-cockaded woodpecker in Texas. Auk 87: 781–786.

SHAPIRO, A. E. 1983. Characteristics of red-cockaded woodpecker cavity trees and colony areas in southern Florida. Fla. Sci. 46:89–95.

THOMAS, R. J. 1984. Characteristics of juvenile wood. Pages 40–52 *in* R. C. Kellison, ed. Utilization of the changing wood resource in the southern United States. North Carolina State Univ., Raleigh.

THOMPSON, R. L., AND W. W. BAKER. 1971. A survey of red-cockaded woodpecker habitat requirements. Pages 170–186 *in* R. L. Thompson, ed. The ecology and management of the red-cockaded woodpecker. U.S. Bur. Sport Fish. and Wildl., and Tall Timbers Res. Stn., Tallahassee, Fla.

U.S. FISH AND WILDLIFE SERVICE. 1985. Red-cockaded woodpecker recovery plan. U.S. Fish and Wildl. Serv., Atlanta, Ga. 88pp.

WAHLENBERG, W. G. 1946. Longleaf pine. C. L. Pack For. Found., Washington, D.C. 429pp.

WOOD, D. A. 1983. Foraging and colony habitat characteristics of the red-cockaded woodpecker in Oklahoma. Pages 51–58 *in* D. A. Wood, ed. Red-cockaded woodpecker symposium II. Fla. Game and Fresh Water Fish. Comm., Tallahassee, Fla.

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