

**A 10-Year Population Survey of
Red-cockaded Woodpeckers on a
5,181-Hectare Study Site, Apalachicola
National Forest, Florida**

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A 10-Year Population Survey of Red-cockaded Woodpeckers on a 5,181-Hectare Study Site, Apalachicola National Forest, Florida

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Abstract: The status and population ecology of the endangered red-cockaded woodpecker (*Picoides borealis*) was investigated on a 5,181-ha tract of longleaf pine (*Pinus palustris*) and slash pine (*P. elliottii*) forest in the Apalachicola National Forest, Florida, during the 10 years 1980–1989. The number of clusters, active and abandoned, increased from 42 in 1981 to 47 in 1989; the increase of 5 clusters, all active, included 2 previously unlocated clusters (1987) and 3 new clusters (1987 and 1988). Two of these new clusters were established through “budding,” and the third apparently was a product of pioneering. There was a net gain of only 1 active cluster between 1981 (N = 40) and 1989 (N = 41); the number of active clusters was lowest in 1985 (N = 34) and greatest in 1988 (N = 42). The number of living cavity trees averaged 5.5 per cluster annually. The annual mortality rate of cavity trees averaged $\leq 4\%$ annually, except for the $\geq 19\%$ loss of cavity trees attributable to Hurricane Kate in 1985. The rate of nestling production within active clusters averaged 73% for the 10 years 1980–1989, ranging from a low of 62% in 1985 to a high of 93% in 1989. Sixty-eight (62%) of 109 individual nest cavities produced nestlings in ≥ 2 years; these cavities yielded 85% of the total production of nestlings. Nestlings were produced in 1 individual nest cavity for 10 consecutive years. The amount of suitable foraging habitat within a 1.2-km radius of active clusters averaged 193.7 ha (SD = 1.5, N = 10) annually, and was substantially greater than areal foraging habitat requirements previously reported for this population. Thus, changes in cluster status and nestling production observed during the 10-year period more likely were related to demographic and behavioral factors rather than to habitat loss by clearcutting. Management practices in effect between 1980 and 1989 were sufficient to sustain the resident red-cockaded woodpecker population on the study site. However, these findings may not be applicable to those areas of the Apalachicola National Forest characterized by lesser stocking rates or different timber harvest regimes.

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the ANF. Specifically, we wanted to ascertain if the loss of suitable foraging habitat by clearcutting affected cluster status and nestling production. Other documentation included (1) the gain and loss of cavity trees within clusters, (2) the identification of multiyear use of nest cavities, and (3) the formation of new clusters.

Table 1. Status of red-cockaded woodpecker clusters, Apalachicola National Forest, Florida, May–June, 1980–1989.

Cluster status	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	Total/ mean
Active											
N	24	40	38	36	35	34	36	41	42	41	367
%	92	95	90	86	83	81	86	89	89	87	88
Active with nestlings ^{a,b}											
N	19	28	28	25	22	21	24	33	32	38	270
%	79	70	74	69	63	62	67	80	76	93	73
Inactive											
N	2	2	4	6	7	8	6	5	5	6	51
%	8	5	10	14	17	19	14	11	11	13	12
Total clusters											
N	26 ^c	42	42	42	42	42	42	46 ^d	47 ^e	47	418
%	100	100	100	100	100	100	100	100	100	100	100

^aBased on evidence of nestling production (i.e., detection of audible vocalizations by nestlings, observed feeding of nestlings by adults, or occurrence of juveniles in cluster following fledging).

^bNestling production was not significantly related to year ($X^2 = 15.21$, $P > 0.05$, $df = 9$).

^cThe initial survey for clusters on the study site had not been completed before the end of the 1980 breeding season.

^dFour additional clusters were discovered during the 1987 breeding season.

^eOne additional cluster was discovered during the 1988 breeding season.

STUDY AREA

The study was conducted on the western district (Townships 3 and 4 South, Ranges 7 and 8 West) of the ANF, which is located in Liberty County in the Florida Panhandle (Fig. 1). Bounded on the east by Florida Highway 12 and on the west by Florida Highway 379, the 5,181-ha study site consisted of 7 contiguous USFS management compartments: 26, 27, 28, 29, 67, 69, and 72. Dominant vegetative types included longleaf pine (*Pinus palustris*) flatwoods (31%), slash pine (*P. elliottii*) plantations (24%), titi (*Cliftonia monophylla* and *Cyrilla* spp.) thickets (23%), slash pine flatwoods (11%), pondcypress (*Taxodium ascendens*) and tupelo (*Nyssa* spp.) swamps (7%), and savannahs (4%) (Tanner and Terry 1982).

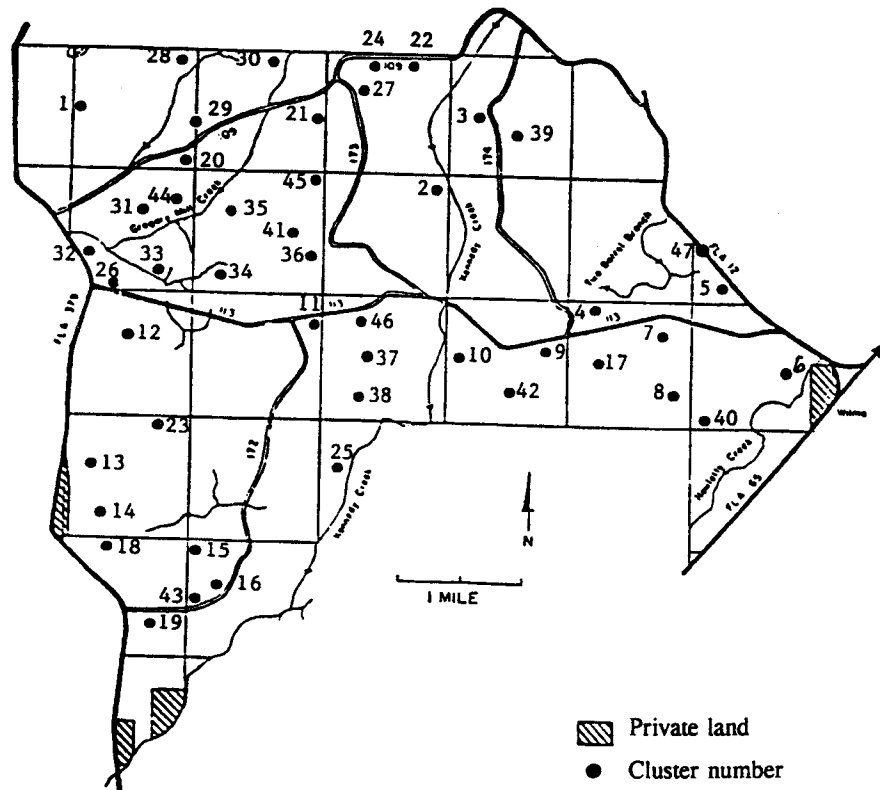


Fig. 1. Location of red-cockaded woodpecker clusters, Apalachicola National Forest, Florida, 1980–1989.

The study site is approximately 18 m above sea level, and has a generally flat terrain. Soils range from very poorly drained to extremely dry, with Surrency, Bladen, Dothan, and Leefield series being the most common (Tanner and Terry 1982). The mean annual temperature for the area is 20°C and the mean annual precipitation is 149 cm (National Oceanic and Atmospheric Administration 1978). The site is located only 40 km north of the Gulf of Mexico and is vulnerable to tropical storms and hurricanes, as evidenced by the substantial impact of Hurricane Kate in November 1985.

METHODS

All clusters known to occur on the study site were surveyed during the 1987–1989 breeding seasons (May–June). The cavity trees previously located within each cluster were classified as either living or dead, and each cluster was surveyed for new and/or previously unknown cavity trees. Living cavity trees with recent resin wells and fresh pine gum were deemed active; those with aged resin wells and little or no fresh pine gum were deemed inactive (Jackson 1977). If a previously located cavity tree could not be found, it was classified as unknown and considered to be living until proven otherwise; such cavity trees often were located at a later date.

The status of each cluster also was determined annually during the breeding season. Clusters occupied by ≥ 1 red-cockaded woodpecker and/or containing ≥ 1 active cavity tree were classified as active; all other clusters were classified as inactive. Active clusters were monitored annually for nestling production. The flushing of an adult red-cockaded woodpecker from a cavity during daylight hours (0800–1800 h EST) was considered indicative of a nesting attempt. Determination of actual nestling production, however, was based on (1) the detection of audible vocalizations by young in the nest cavity, (2) observed feeding of nestlings by adult red-cockaded woodpeckers, or (3) the occurrence of juveniles in the cluster following fledging.

These monitoring procedures were identical to those employed during the 1980–1986 breeding seasons. The status of individual cavity trees within clusters, however, was not determined between 1982 and 1985 due to limited funding and manpower.

The entire 5,181-ha study site was resurveyed for new or previously unlocated clusters during the 1987 and 1989 breeding seasons. Surveys were conducted by systematically walking all natural pine stands ≥ 50 years of age. Aerial photographs (1 inch:12,000 scale) were used to select the stands to be surveyed. When a new or previously unlocated cluster was discovered, its location was plotted on an aerial photograph, and the associated cavity trees were inventoried and classified as previously described. Additionally, an attempt was made to determine how and when the cluster had been established.

The amount of suitable foraging habitat within a 1.2-km (0.75-mi) radius of each cluster on the study site was documented for the 10 years 1980–1989 from records obtained from the Supervisor's Office, National Forests of Florida, Tallahassee, and the Apalachicola District Office, Apalachicola National Forest, Bristol. Red-cockaded woodpeckers prefer to forage in pine

stands with trees >20 cm diameter at breast height (dbh) (Hooper and Lennartz 1981, DeLotelle et al. 1983, Porter and Labisky 1986). Smaller pines may be used, but trees <10–13 cm dbh rarely are selected for foraging (Hooper and Lennartz 1981, DeLotelle et al. 1983). Accordingly, we defined suitable foraging habitat as pine stands, both natural and planted, with an average dbh >13 cm. In general, this corresponds to the poletimber and sawtimber condition classes as defined by the U.S. Forest Service (1992). The 1.2-km radius designation was derived from the habitat management guidelines established for the red-cockaded woodpecker on the ANF (U.S. Forest Service 1991).

A stand map (1.64 inch = 1 km) of the study site was prepared from USFS compartment maps, and a grid overlay (1 square = 1 ha) was used to estimate the amount of suitable foraging habitat annually available within 1.2 km of each cluster. Foraging habitat was lost or gained between years by clearcutting or stand maturation, respectively. Pine plantations were regarded as suitable foraging habitat at age 25 (M. L. Porter, unpubl. data) or when they were classified as sawtimber by the USFS, whichever occurred first. Seed tree and shelterwood cuts were not considered to represent a loss of habitat. Private land occurring within 1.2 km of clusters was excluded from all foraging habitat calculations because of the lack of reliable data on the chronology of timber harvest.

The average amount of primary foraging habitat (i.e., pine stands that were preferred or avoided with selection) for 4 red-cockaded woodpecker clans on our study site was 82 ha (Porter and Labisky 1986). Thus, we hypothesized that clusters with ≥ 82 ha of suitable foraging habitat within a 1.2-km radius were more likely to be active and produce nestlings than those with less habitat.

RESULTS

Cluster Status

The number of clusters, active and inactive, known to occur on the study site increased from 42 in 1981 to 47 in 1989 (Table 1). However, there was a net increase of only 1 active cluster between 1981 ($N = 40$) and 1989 ($N = 41$). Notably, the number of active clusters declined progressively from 40 to 34 during the 5 years 1981–1985. This downward trend was reversed in 1986, with the number of active clusters being 41 in 1987, 42 in 1988, and 41 in 1989. The proportion of clusters that were active averaged 88%, and ranged from 81% to 95%, during the 10-year period 1980–1989 (Table 1).

Of the initial 42 clusters located on the study site, 33 (79%) remained active throughout the 9 years 1981–1989, 2 (5%) remained inactive, 4 (10%) active clusters were abandoned, and 3 (7%) reflected an active/inactive/active status among years (Appendix A). The probability of an active cluster becoming inactive annually was 2%, whereas the probability of an inactive cluster becoming active annually was 7%.

Surveys for New Clusters

The initial survey of the ANF study site, conducted in 1980 and 1981, yielded 42 clusters, of which 40 were active. The entire site was resurveyed for clusters in 1984, 1987, and 1989. The 1984 resurvey revealed no additional clusters. The 1987 resurvey produced 4 additional clusters, all of which were active; the addition of these clusters increased the number of clusters on the study site to 46, 41 of which were active. Although the study site was not systematically resurveyed in 1988, 1 additional active cluster was located that year, bringing the total number of clusters to 47, 42 of which were active. The 1989 resurvey produced no additional clusters; and the total remained at 47, 41 of which were active. The individual histories of the 5 new clusters are presented by cluster.

Cluster No. 43 (1987).—The formation of Cluster No. 43 was traceable from past history. Three of the cavity trees in this cluster originally were part of Cluster No. 16, which was located approximately 0.4 km to the northeast. These 3 cavity trees had been inactive since their discovery in 1980 and there was no evidence of red-cockaded woodpecker activity within the immediate vicinity of these cavity trees in May 1986. In the spring of 1987, however, 2 new, active cavity trees were discovered near the 3 inactive trees and, notably, there was a red-cockaded woodpecker nest in 1 of the new cavity trees. The presence of a separate red-cockaded woodpecker nest in Cluster No. 16 confirmed that a new group had been formed and a new cluster established.

Cluster No. 44 (1987).—Cluster No. 44 was located in a longleaf pine savannah that had been surveyed in both 1980 and 1984. Although this cluster could have been in the early stages of initiation during either of these surveys (i.e., partially completed start cavities that often are difficult to observe), the light amount of resin present on each of the 4 cavity trees suggested that the site did not become fully established until after the 1984 survey. Cluster No. 44 was considered a newly established cluster.

Cluster No. 45 (1987).—Cluster No. 45 was located in an isolated stand of longleaf pine that had not been surveyed in previous years because the stand was not visible on the aerial photographs. This cluster appeared to be several years old, although the amount of resin accumulation on the 3 cavity trees was not as extensive as that on the cavity trees in Cluster No. 46.

Cluster No. 46 (1987).—Cluster No. 46 appeared to have been established for some time, as evidenced by the heavy accumulation of resin on each of the 3 cavity trees. This cluster was on the edge of a slash pine plantation in a small stand of longleaf pine (<30 trees). Because this stand was not readily discernible on the aerial photographs, it had not been surveyed in previous years; in fact, it was only by chance that the cavity trees were observed during the 1987 survey.

Cluster No. 47 (1988).—Cluster No. 47 consisted of 2 cavity trees originally thought to be associated with Cluster No. 5, which was located 0.5 km to the southeast. One of these trees contained an active start cavity when it was first observed in 1986. However, this tree had died by 1987, at which time it exhibited no signs of recent use by red-cockaded woodpeckers. The other cavity tree also had contained an active start cavity when it was first discovered in 1984 and exhibited a second start cavity in 1986. In May 1988, this latter cavity had been completed and contained a red-cockaded woodpecker nest. A search within the immediate vicinity of the nest revealed no additional cavity trees. This fact, coupled with the presence of a separate red-cockaded woodpecker nest in Cluster No. 5, suggested that a new group had been formed and a new cluster established. Thus, the formation of Cluster No. 47 essentially mirrors the formation of Cluster No. 43.

Cavity Trees

The number of living cavity trees per cluster averaged 5.5 annually, with nearly equal proportions being in active and inactive categories (Table 2, Appendix B). The annual mortality rate of red-cockaded woodpecker cavity trees, with the exception of damage wrought by Hurricane Kate in 1985, was $\leq 4\%$ (Table 3). Importantly, however, Hurricane Kate caused the death of a

Table 2. Status of living cavity trees in red-cockaded woodpecker clusters, Apalachicola National Forest, Florida, 1980–1989.^a

Number of living cavity trees per cluster	Year ^b						Annual mean (N=6)
	1980 (N=42)	1981 (N=42)	1986 (N=42)	1987 (N=46)	1988 (N=47)	1989 (N=47)	
Active							
Mean	3.6	3.0	1.9	2.1	2.0	2.4	2.5
SD	2.1	1.7	1.3	1.5	1.3	1.4	0.7
Range	0–8	0–7	0–6	0–8	0–7	0–6	
Inactive							
Mean	1.8	2.7	2.8	2.7	2.7	3.0	2.6
SD	1.8	2.4	2.3	2.1	2.0	2.0	0.4
Range	0–8	0–10	0–10	0–8	0–7	0–8	
Total ^c							
Mean	5.4	5.6	5.3	5.4	5.3	5.9	5.5
SD	3.0	3.0	3.4	3.3	3.4	3.3	0.2
Range	1–13	1–13	0–13	1–16	1–16	1–14	

^aThe status of individual cavity trees was not determined during the 4 years 1982–1985.

^bData for 1980 were collected during July through August; data for all other years were collected during April through June.

^cIncludes active, inactive, and unknown cavity trees (i.e., previously located cavity trees that could not be found). Because unknown cavity trees were often located at a later date, they were classified as living until proven otherwise.

Table 3. Mortality of red-cockaded woodpecker cavity trees, Apalachicola National Forest, Florida, 1980–1989.^a

Cavity trees	Year ^b				
	1980	1981	1986	1987	1988
Number living ^c	227	237	221	247	249
Number dying ^d	2	64 ^e	8	4	11
Percent mortality	1	27	4	2	4

^aThe status of individual cavity trees was not determined during the 4 years 1982–1985.

^bData for 1980 were collected during July through August; data for all other years were collected during April through June.

^cRefers to the number of living cavity trees during the designated year. Includes active, inactive, and unknown cavity trees (i.e., previously located cavity trees that could not be found). Because unknown cavity trees were often located at a later date, they were classified as living until proven otherwise.

^dRefers to the number of cavity trees dying between the designated year and subsequent year.

^eA minimum of 44 (69%) of the 64 cavity trees dying between 1981 and 1986 were killed by Hurricane Kate in November 1985.

minimum of 44 (19%) of the 237 living cavity trees recorded in 1981; this equated to a loss of approximately 1 cavity tree per cluster.

The average addition of new cavity trees (0.4) per cluster annually, either by the discovery of previously unlocated cavity trees or by the excavation of cavities in new trees by red-cockaded woodpeckers, exceeded the average loss of cavity trees (0.1) per cluster site annually (Table 4, Appendix C). This differential resulted in a net gain of 0.3 cavity trees per cluster site annually.

Table 4. Gain and loss of cavity trees in red-cockaded woodpecker clusters, Apalachicola National Forest, Florida, 1980–1989.^a

Number of cavity trees per cluster	Year ^b						Annual mean
	1980	1981	1986	1987	1988	1989	
Living ^c							
Mean	5.4	5.6	5.3	5.4	5.3	5.9	5.5
SD	3.0	3.0	3.4	3.3	3.4	3.3	0.2
Range	1–13	1–13	0–13	1–16	1–16	1–14	
N	42	42	42	46	47	47	6
Dying ^d							
Mean		<0.1	1.5 ^e	0.2	0.1	0.2	0.1 ^f
SD		0.2	1.4	0.5	0.3	0.5	0.1
Range		0–1	0–5	0–2	0–1	0–2	
N		42	42	42	46	47	4
Newly located/excavated ^g							
Mean		0.3	1.1	0.5	0.1	0.9	0.4 ^f
SD		0.6	1.4	0.8	0.3	1.2	0.3
Range		0–3	0–5	0–3	0–1	0–4	
N		42	42	42	46	47	4
Gained or lost ^h							
Mean		0.2	-0.4	0.3	<0.1	0.6	0.3 ^f
SD		0.7	1.8	1.0	0.5	1.4	0.2
Range		-1→+3	-5→+3	-3→+3	-1→+1	-2→+4	
N		42	42	42	46	47	4

^aThe status of individual cavity trees was not determined during the 4 years 1982–1985.

^bData for 1980 were collected during July through August; data for all other years were collected during April through June.

^cRefers to the number of living cavity trees during the designated year. Includes active, inactive, and unknown cavity trees (i.e., previously located cavity trees that could not be found.) Because unknown cavity trees were often located at a later date, they were classified as living until proven otherwise.

^dRefers to the number of cavity trees dying between the designated year and the preceding year.

^eA minimum of 44 (69%) of the 64 cavity trees dying between 1981 and 1986 were killed by Hurricane Kate in November 1985.

^fData for 1981–1986 were not comparable with other data (i.e., multiple vs. single years) and therefore were not included in the annual mean.

^gRefers to the number of living cavity trees newly located or newly excavated during the designated year.

^hRefers to the net change in the number of living cavity trees between the designated year and the preceding year.

Nestling Production and Nest-cavity Fidelity

The rate of nestling production within active clusters averaged 73% (SD = 9.3) for the 10 years 1980–1981, ranging from a low of 62% in 1985 to a high of 93% in 1989 (Table 1). Rates of nestling production for the 4 years 1982–1985, which were characterized by a decline in active clusters, averaged 67%, whereas those for the 4 years 1986–1989, which were characterized by an increase in active clusters, averaged 79%; this difference, however, was not significant ($t = 1.97$, $P > 0.05$, $df = 6$).

Sixty-eight (62%) of 109 individual nest cavities produced nestlings during 2 or more breeding seasons; these cavities yielded 85% of the nestling production (Table 5). On a per-cavity basis, each of the 109 nest cavities yielded 2.46 successful nestlings during the 10-year period. Nest-cavity fidelity waned progressively with the passage of years. It is noteworthy, however, that the group in Cluster No. 6 nested successfully in the same nest cavity for 10 consecutive years.

Year-to-year site fidelity also is reflected in the use of cavity trees and nest cavities on a consecutive-year basis. Of groups that produced nestlings in 2 consecutive years, 58% used the same tree and same nest cavity, 3% used the same tree but a different nest cavity, and 17% used a different tree and cavity (Table 6).

Table 5. Use of individual nest cavities by red-cockaded woodpecker groups that produced nestlings during the 10 breeding seasons 1980–1989, Apalachicola National Forest, Florida.

Number of breeding seasons an individual cavity was used	Number of nest cavities		Cumulative number of breeding seasons the same cavity produced nestlings	
	N	%	N	%
1	41	38	41	15
2	28	26	56	21
3	14	13	42	16
4	12	11	48	18
5	9	8	45	17
6	2	2	12	4
7	2	2	14	5
8	0	0	0	0
9	0	0	0	0
10	1	1	10	4
Total	109 ^a	101	268 ^b	100

^aTotal number of different nest cavities.

^bTotal number of nests.

Table 6. Year-to-year use of individual cavity trees and nest cavities by red-cockaded woodpecker groups that produced nestlings, Apalachicola National Forest, Florida, 1980–1989.

	1980	1981	1982	1983	1984	1985	1986	1987	1988	Total
Number of active clusters where the nest tree and cavity were located	19	28	27 ^a	25	21 ^b	21	24	33	32	230
Cluster/nesting status in the subsequent year										
Inactive										
N	0	0	2	0	0	0	0	0	0	2
%	0	0	7	0	0	0	0	0	0	1
Active: no nest										
N	3	4	5	9	5	6	4	7	2	45
%	16	14	19	36	24	29	17	21	6	20
Successful ^c : same nest tree and cavity										
N	14	16	14	9	13	11	16	20	21	134
%	74	57	52	36	62	52	67	61	66	58
Successful: same nest tree, different cavity										
N	0	0	0	0	2	0	0	1	5	8
%	0	0	0	0	9	0	0	3	16	3
Successful: different nest tree and cavity										
N	2	7	6	6	1	4	4	5	4	39
%	10	25	22	24	5	19	17	15	12	17
Successful: nest tree and cavity not located										
N	0	1	0	1	0	0	0	0	0	2
%	0	4	0	4	0	0	0	0	0	1

^aThe nest for Cluster No. 36 was not located; success based on occurrence of juveniles in cluster following fledging.

^bThe nest for Cluster No. 22 was not located; success based on occurrence of juveniles in cluster following fledging.

^cSuccessful = active clusters where there was evidence of nestling production (i.e., detection of audible vocalizations by nestlings, observed feeding of nestlings by adults, or occurrence of juveniles in cluster following fledging).

Foraging Habitat

Annually, the amount of suitable foraging habitat within a 1.2-km radius of all clusters (active and inactive) on the ANF study site averaged 197.3 ha (SD = 2.9, N = 10). Considering active clusters only, the annual amount of suitable foraging habitat averaged 193.7 ha (SD = 1.5, N = 10). During the 10 years 1980–1989 only 1 cluster (No. 18) had <82 ha of suitable foraging habitat, and this occurred only in 1983, when the cluster was restricted to 76 ha within a 1.2-km radius (Appendix D). Notably, Cluster No. 18 was active

and produced nestlings during each year of the study following its discovery in 1981 (Appendix A).

All clearcutting on the study site occurred between 1982 and 1986 (Table 7, Appendix D). The most clusters were affected by clearcutting in 1982 and 1984, whereas the average amount of foraging habitat lost per cluster was greatest in 1982 and 1986. In some cases the foraging habitat gained through stand maturation was enough to compensate for that lost by clearcutting (Appendix D). More often, however, the area clearcut did not represent a reduction in the amount of suitable foraging habitat within a 1.2-km radius to <82 ha. Consequently, we were unable to test our original hypothesis that clusters with ≥ 82 ha of foraging habitat would be active and produce young more often than those with less habitat.

An examination of the 4 clusters abandoned during the study revealed no obvious relationship between the amount of available foraging habitat and cluster status. Prior to abandonment, 2 clusters (Nos. 1 and 11) gained foraging habitat, 1 cluster (No. 26) lost foraging habitat, and 1 cluster (No. 33) experienced no change (Appendix D). Similarly, of the 3 clusters abandoned and subsequently reoccupied during the study, 2 clusters (Nos. 30 and 32) lost foraging habitat prior to abandonment and 1 (No. 42) experienced no change (Appendix D). Prior to reoccupancy, 2 of these clusters (Nos. 32 and 42) lost foraging habitat and 1 (No. 30) remained unchanged (Appendix D). During the 10-year study, the least amount of foraging habitat within a 1.2-km radius of any abandoned or abandoned/reoccupied cluster was 157 ha.

Table 7. Clearcutting of suitable foraging habitat within a 1.2-km radius of red-cockaded woodpecker clusters, Apalachicola National Forest, Florida, 1980–1989.

Year	Number of clusters	Suitable foraging habitat clearcut (ha)		
		Mean	SD	Range
1980	0			
1981	0			
1982	15	37.3	15.5	8–68
1983	10	11.0	5.8	7–24
1984	15	14.1	8.2	7–30
1985	10	17.6	7.7	6–27
1986	3	19.0	9.6	8–26
1987	0			
1988	0			
1989	0			

DISCUSSION

Cluster Status

The occupancy status of red-cockaded woodpecker clusters is a dynamic process characterized by a pattern of occupancy, abandonment, and reoccupancy (Doerr et al. 1989). Rates of change, however, are notably slow. During a 9-year study period in North Carolina, Doerr et al. (1989) reported that 70% of clusters were active annually, and that the probability of a cluster status change from active to inactive, or vice versa, was only 9% annually.

Cluster abandonment usually begins with the loss of the resident group's breeding female (Doerr et al. 1989). The breeding male may continue to occupy the cluster, but if he fails to attract a mate, the cluster is either abandoned after his death or "captured" by a neighboring group. (Note: A captured cluster is active, but does not represent a new breeding group because the attendant birds continue to occupy their original cluster.) Over time, a captured cluster may be incorporated into the neighboring group's home range, abandoned, or usurped by a solitary male. If the solitary male successfully attracts a mate, a new breeding group is formed; if the solitary male fails to attract a mate, the cluster is either abandoned or captured and the cycle continues. It is important to note that habitat quality influences reoccupancy rates of abandoned clusters. Clusters suffering from hardwood encroachment and a lack of suitable cavities are less likely to be reoccupied than those with open understories and an abundance of suitable cavities (Doerr et al. 1989). The amount of available foraging habitat, as well as the occurrence of cavity competitors, also may influence reoccupancy rates (Doerr et al. 1989).

The pattern of cluster status observed on the ANF study site during the 9 years 1981–1989 resembled the processes described above. Of the 42 clusters documented in 1981, 79% remained active, 5% remained inactive, 10% were abandoned, and 7% were abandoned and subsequently reoccupied (Table 1, Appendix A). Because the study population was not marked, it was impossible to document the social structure of the birds occupying the active clusters. However, active clusters with no nesting activity and active clusters with nestling production suggest occupancy by solitary males and breeding groups, respectively. Therefore, 3 of the 4 clusters abandoned during the study (Nos. 11, 26, and 33) probably were occupied by breeding groups prior to abandonment; the fourth abandoned cluster (No. 1) probably was occupied by a solitary male. Similarly, 2 of the 3 reoccupied clusters (Nos. 32 and 42) probably were occupied by solitary males prior to abandonment and by

breeding groups upon reoccupancy. The third reoccupied cluster (No. 30) apparently was occupied by a breeding group both before abandonment and after reoccupancy (Appendix A).

Surveys for New Clusters

Territorial budding is one process whereby new breeding groups of red-cockaded woodpeckers are established (Hooper 1983). Budding occurs when 2 breeding groups become occupants of a home range formerly occupied by a single breeding group. Thus, in order for budding to occur, the home range of the original breeding group must possess resources capable of supporting 2 breeding groups (Hooper 1983). Budding may occur when a group's home range includes a captured cluster that is usurped by a solitary male who subsequently attracts a mate (Doerr et al. 1989). Budding also may occur in home ranges that do not include captured clusters. Regardless of the method, budding occurs only rarely. In North Carolina, establishment of new breeding groups through budding occurred at a rate of only 0.4% annually (Doerr et al. 1989).

New breeding groups also may be formed through a process called pioneering (Hooper 1983). Pioneering involves the establishment of a cluster, by a solitary male or breeding group, in previously unclaimed habitat (i.e., habitat previously devoid of cavities). Prior to our study, only 13 instances of pioneering had been reported in the literature—1 at Noxubee National Wildlife Refuge, Mississippi (Jackson 1987); 2 at Piedmont National Wildlife Refuge, South Carolina (Lennartz and Heckel 1987); and 10 at Francis Marion National Forest, South Carolina (Hooper et al. 1991).

After the initial survey was completed in 1980, 5 new breeding groups were documented on the ANF study site. Two of these groups (Nos. 43 and 47) clearly were established through budding, as evidenced by the occurrence of 2 separate nests in clusters formerly occupied by a single breeding group. This equates to an annual budding rate of 0.5% per cluster, which is comparable to that documented in North Carolina (Doerr et al. 1989). Two other breeding groups (Nos. 45 and 46) probably were present for several years prior to their discovery. The clusters occupied by these groups were characterized by cavity trees with moderate to heavy resin accumulation, suggesting long-term usage; however, the history of their establishment is unknown. The fifth new breeding group (No. 44) may have been formed by pioneering. The cluster occupied by this group was discovered in 1987 in an area where previous surveys (1980 and 1984) had yielded no cavity trees. The light accumulation of resin on the cavity trees suggested recent cavity

excavation. Furthermore, none of the nearby clusters was abandoned during the year preceding the discovery of Cluster No. 44. This circumstantial evidence strongly suggested that Cluster No. 44 was a product of pioneering.

Cavity Trees

The mean of 5.5 cavity trees/cluster for the ANF study site (Table 2) was comparable to cluster data reported for other localities. Thompson and Baker (1971) reported a mean of 4.2 cavity trees/cluster for 229 clusters located in 10 southeastern states. Nine clusters in central Florida (DeLotelle et al. 1983) averaged 7.9 cavity trees/cluster and 19 clusters in the Big Cypress National Preserve, Florida (Patterson and Robertson 1981), averaged 7.7 cavity trees/cluster. The lowest reported mean, 3.4 cavity trees/cluster, was for 21 clusters in coastal South Carolina (Grimes 1977), whereas the highest mean, 11.1 cavity trees/cluster, was for 102 clusters in the Sandhills region of North Carolina (Carter et al. 1983).

The mean of 2.5 active cavity trees/cluster (Table 2) for the ANF study site also was comparable to clusters in other locations—2.3 active cavity trees/cluster for 49 clusters in southern Florida (Shapiro 1983), 2.9 active cavity trees/cluster for 9 clusters in central Florida (DeLotelle et al. 1983), 3.1 active cavity trees/cluster for 21 clusters in coastal South Carolina (Grimes 1977), and 4.3 active cavity trees/cluster for 32 clusters in southeastern Oklahoma (Wood 1983a).

Cavity-tree mortality is a natural phenomenon within red-cockaded woodpecker clusters; typical causes of mortality include bark beetles, wind, fire, and lightning (Conner et al. 1991). Reported estimates of annual cavity-tree mortality for other red-cockaded woodpecker populations ranged between 2 and 7% (Beckett 1971, Lay and Swepston 1973, Wood 1983a). Comparatively, annual cavity-tree mortality on the ANF study site ranged between 1 and 4%, except for 1985 when $\geq 19\%$ of the cavity trees were destroyed by Hurricane Kate (Table 3). Thus, in non-hurricane years, cavity trees constitute a reasonably stable resource. Hurricanes, however, can cause substantial cavity-tree mortality and, subsequently, lead to a decline in red-cockaded woodpecker abundance (Engstrom and Evans 1990, Hooper et al. 1990). Interestingly, the damage caused by Hurricane Kate on the ANF study site did not appear to have had a deleterious effect on the resident red-cockaded woodpecker population. In fact, both the number of active clusters and the rate of nestling production increased in 1986, the year following the hurricane (Table 1).

Nestling Production and Nest-cavity Fidelity

The annual rate of nestling production observed on the ANF study site (73%) (Table 1) was within the range reported for other populations—62% in Oklahoma (Wood 1983*b*), 78% in central Florida (DeLotelle and Newman 1981), and 81% in the Big Cypress National Preserve, Florida (Patterson and Robertson 1981). The depressed rate of nestling production observed between 1982 and 1985 (Table 1) is difficult to explain but may have been related to the status and social structure of the resident red-cockaded woodpecker population. For example, low rates of nestling production on the Angelina (64%), Davy Crockett (33%), and Sabine (43%) national forests in east Texas were attributed to habitat loss and/or degradation, which precipitated a decline in the number of active clusters and a preponderance of solitary males occupying active clusters (Conner and Rudolph 1989). Although the social structure of the red-cockaded woodpecker population on the ANF study site was unknown, the number of active clusters declined between 1982 and 1985, suggesting a trend parallel to that observed in Texas. Conversely, the increased rate of nestling production observed on the ANF study site between 1986 and 1989 may have been related to the increased number of active clusters (Table 1) and a higher proportion of active clusters occupied by breeding groups. However, changes in cluster status and social composition on the ANF study site probably were precipitated by some factor other than habitat, as evidenced by the abundance of suitable foraging habitat. Other possible explanations for depressed rates of nestling production include predation, intraspecific cavity usurpation, and fire damage to cavity trees (LaBranche and Walters 1994).

The red-cockaded woodpeckers on the ANF study site exhibited a strong fidelity to their nest cavities; 62% of all nestling production occurred in cavities used during 2 or more breeding seasons (Table 5). These observations were consistent with those of other researchers. Of 3 nest cavities monitored by Baker (1971) in northern Florida, 1 was used for 4 consecutive years and another for 3 consecutive years. Harlow (1983) monitored 28 clusters on the Francis Marion National Forest in South Carolina and found that 66% of the nest cavities were used during 2 or more breeding seasons. These findings suggest that the loss of a nest cavity within a cluster could jeopardize the nesting success of the resident breeding group. Although all cavity trees within a cluster should be protected, special efforts, if necessary, should be made to ensure that nest-cavity trees are neither harmed during prescribed burns (Stamps et al. 1983, LaBranche and Walters 1994) nor obstructed by midstory vegetation.

Foraging Habitat

The amount of foraging habitat required by a group of red-cockaded woodpeckers is related to habitat quality. On the Francis Marion National Forest in South Carolina, prior to Hurricane Hugo, 51 ha of foraging habitat were considered sufficient to support a red-cockaded woodpecker group (Lennartz and Henry 1985). This high-quality habitat consisted of well-stocked (13.8–20.7 m² basal area/ha) pine and pine-hardwood stands (>50% basal area in pine) >30 years old (40% >60 years old) with 59.3 pines >25.4 cm dbh/ha. Porter and Labisky (1986) reported an average primary foraging area (pine stands with stems >20 cm dbh and >20 m height) of 82 ha for 4 groups on our ANF study site. The larger foraging area on the ANF was attributed to a difference in habitat quality—foraging habitat on the ANF was younger, less contiguous, and less well-stocked than that on the Francis Marion National Forest (Porter and Labisky 1986).

Findings from the ANF study site suggested that the red-cockaded woodpecker population was not limited by foraging habitat during the 10 years 1980–1989. The 193 ha of suitable foraging habitat available within a 1.2-km radius of clusters greatly exceeded the foraging area requirements previously reported by Lennartz and Henry (1985) and Porter and Labisky (1986). Thus, changes in cluster status or nestling production on the ANF study site were more likely related to demographic and behavioral factors than to loss of foraging habitat by clearcutting.

Although the amount of clearcutting on the ANF study site had no discernable effect on the resident red-cockaded woodpecker population, this result must be viewed with caution. The large size and contiguous distribution of the ANF red-cockaded woodpecker population may render it more resilient to landscape changes than smaller, more isolated populations. In eastern Texas, where populations are smaller and more fragmented, forest removal had a negative impact on cluster status, group size, and population size (Conner and Rudolph 1991, Rudolph and Conner 1994). Further, because our study population was not marked, we do not know how many active clusters were inhabited by solitary males; a preponderance of solitary males may be indicative of a declining population (James 1991). Finally, the abundance of suitable foraging habitat on the ANF study site provided a reservoir of alternative foraging areas that could be used when existing habitat was lost. Such opportunities typically do not exist for smaller populations in more fragmented habitat.

MANAGEMENT RECOMMENDATIONS

Between 1980 and 1985, management of the red-cockaded woodpecker on the ANF was predicated on the 1979 edition of the Regional Wildlife Habitat Management Handbook (U.S. Forest Service 1979). Per that document, (1) logging was prohibited within a 60-m zone around each cavity tree, except to preserve or enhance the habitat; (2) clusters were not included in timber-harvest rotations; (3) prescribed burning was emphasized to control hardwood growth in clusters; (4) stand rotations of ≥ 80 years for longleaf pine and ≥ 70 years for other pines were recommended; (5) 40–101 ha of pine and pine-hardwood forest > 20 years old were provided as foraging habitat for each cluster; and (6) recruitment stands of potential nesting habitat were established to promote population expansion. In 1985, the Handbook was revised (U.S. Forest Service 1985) to increase protection of the red-cockaded woodpecker. This revision, which remained in effect through 1989, required that replacement stands of potential nesting habitat be established for all active clusters. Population objectives were established for each national forest within the species' range, with additional recruitment stands being required on forests where the existing population was below the defined goal. The revised Handbook also strengthened the foraging habitat guidelines. Foraging habitat was defined as well-stocked ($13.8\text{--}20.7\text{ m}^2/\text{ha}$) pine and pine-hardwood forest ($> 50\%$ basal area in pine) > 30 years old ($40\% > 60$ years) and with 59.3 pines > 25.4 cm dbh/ha. Each active cluster, replacement stand, and recruitment stand was required to have 50.6 ha of foraging habitat contiguous to and within an 800-m radius of its center.

We conclude that the management practices in effect between 1980 and 1989 were sufficient to sustain the resident red-cockaded woodpecker population on the ANF study site. Since our study was completed, red-cockaded woodpecker management on the ANF has been governed by a set of interim standards and guidelines (U.S. Forest Service 1990, 1991) which are part of an environmental impact assessment initiated in response to observed population declines on most national forests in the southeastern United States (Costa and Escano 1989). These standards and guidelines provide additional protection by prohibiting clearcutting within 400 m of clusters, except to convert off-site pines back to longleaf, and by limiting stand regeneration methods within 400–1,200 m of clusters to shelterwood and seed-tree cuts. In June 1995, the U.S. Forest Service issued the Final Environmental Impact Statement (FEIS) for the management of red-cockaded woodpeckers on the southern national forests (U.S. Forest Service 1995). Management under the FEIS will continue to focus on protecting cavity trees and clusters, but also will emphasize recovery at the regional level by establishing Habitat

Management Areas, Management Intensity Levels, and population objectives for each national forest where the species occurs. This approach will allow individual forests the flexibility to integrate the new red-cockaded woodpecker management direction with other biological, social, and economic factors specific to a geographic area.

The red-cockaded woodpecker population on the ANF study site should remain stable, and perhaps increase, under the FEIS management direction. However, it is important to note that our results may not be applicable to those areas of the ANF characterized by lesser stocking rates or different timber harvest regimes. James (1991) found evidence of a population decline on the eastern district of the ANF, whereas our study was conducted on the western district where the red-cockaded woodpecker population is believed to be increasing. Consequently, we recommend a site-specific approach to red-cockaded woodpecker management on the ANF, which is in concert with the flexibility provided under the FEIS (U.S. Forest Service 1995). We also advocate long-term population monitoring to distinguish between actual changes in abundance and normal fluctuations related to demographic and/or behavioral factors.

CONCLUSIONS

Forest management practices on the ANF study site during the 10 years 1980–1989 did not have a discernable negative impact on the resident population of red-cockaded woodpeckers. Despite clearcutting activity, the remaining habitat was sufficient to support a stable, albeit dynamic, population. Although the number of active clusters fluctuated from year to year, losses due to abandonment typically were offset by the reoccupancy of inactive clusters or the establishment of new clusters. We speculate that the study population, if managed in accordance with the new FEIS directive, will maintain its current level of abundance, or perhaps increase; however, we caution that populations in other management units of the ANF may not respond similarly.

The study also revealed that (1) the red-cockaded woodpecker population was able to compensate for a 20% loss of cavity trees without experiencing a decline in the number of active clusters or the rate of nestling production; (2) nest-cavity fidelity was high, which emphasized the importance of protecting nest-cavity trees from fire and hardwood encroachment; and (3) the amount and quality of available habitat was sufficient to allow the establishment of new clusters by both territorial budding and pioneering.

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Appendix A. Nesting history of red-cockaded woodpecker clusters, Apalachicola National Forest, Florida, 1980–1989.

Cluster	Year and code ^a																													
	1980			1981			1982			1983			1984			1985			1986			1987			1988			1989		
	S ^b	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C
1	AF			AS 154	1		AS 2	1		AS 2	1		AS 152	3		AS 152	2		AN			AN			AN			I		
2	U			AF			AS 250	1		AF			AS 5	2		AS 5	2		AS 252	1		AS 252	1		AS 252	1		AS 315	1	
3	AS 7	1		AS 7	1		AN			AF			AS 279	1		AN			AN			AS 279	1		AN			AS 279	1	
4	AS 15	1		AS 15	1		AF			AS 143	1		AN			AF			AS 15	2		AS 15	2		AN			AS 374	1	
5	AS 19	1		AS 19	1		AS 17	1		AF			AS 17	1		AS 17	1		AS 17	1		AS 17	1		AS 17	1		AS 17	1	
6	AS 24	1		AS 24	1		AS 24	1		AS 24	1		AS 24	1		AS 24	1		AS 24	1		AS 24	1		AS 24	1		AS 24	1	
7	AF			AF			AS 29	1		AS 28	1		AS 28	1		AF			AS 28	1		AS 28	1		AS 28	1		AS 28	1	
8	AS 123	2		AS 123	2		AS 263	1		AF			AS 123	2		AF			AF			AS 256	1		AS 256	1		AS 256	1	
9	AS 31	1		AF			AS 31	1		AS 31	1		AS 31	1		AS 31	1		AS 31	1		AS 31	1		AS 31	1		AS 210	1	
10	AS 38	1		AN			AF			AS 265	1		AS 265	1		AS 108	1		AS 108	1		AS 314	4		AS 314	4		AN		
11	AS 42	1		AS 42	1		AS 42	1		I			I			I			I			I			I			I		
12	AS 49	1		AS 49	1		AS 49	1		AS 155	2		AN			AS 297	1		AS 155	2		AS 155	2		AS 155	2		AS 155	2	
13	AS 53	1		AS 53	1		AS 54	1		AN			AN			AF			AS 54	1		AN			AN			AS 361	1	
14	AS 140	1		AS 57	1		AS 57	1		AS 57	1		AS 58	1		AS 58	1		AF			AS 58	1		AS 58	1		AS 58	1	
15	AN			AN			AN			AN			AS 63	1		AN			AS 63	1		AS 63	1		AS 63	2		AS 63	1	
16	AS 66	1		AS 66	1		AS 66	1		AS 66	1		AS 64	1		AS 64	1		AS 64	1		AS 64	1		AN			AS 368	1	
17	U			AS 68	3		AS 68	3		AF			AF			AS 68	3		AS 68	3		AN			AS 69	5		AS 69	5	
18	U			AS 72	1		AS 72	1		AS 72	1		AS 73	1		AS 73	1		AS 72	1		AS 72	1		AS 72	1		AS 72	1	
19	AS 78	3		AS 78	3		AS 78	3		AS 78	3		AS 78	3		AS 78	2		AS 78	2		AS 78	2		AS 78	2		AS 78	2	
20	AS 88	1		AS 88	1		AS 264	3		AS 273	1		AS 273	1		AS 273	1		AF			AS 88	1		AS 88	1		AS 88	1	
21	AS 96	2		AS 93	2		AS 93	2		AS 93	2		AF			AS 249	1		AN			AS 249	1		AS 93	2		AS 93	2	
22	AS 101	1		AS 101	1		AS 101	1		AS 101	1		AS ^c			AF			AS 149	1		AS 149	1		AS 149	1		AS 149	1	
23	AS 105	1		AN			AS 109	1		AS 109	1		AS 109	1		AS 109	1		AS 109	1		AN			AS 349	1		AS 349	1	
24	AS 111	1		AS 111	1		AS 111	1		AS 111	1		AN			AF			AS 275	1		AS 275	1		AS 275	1		AN		
25	U			AS 229	1		AN			AS 229	1		AS 292	1		AS 292	1		AS 229	1		AS 229	1		AS 229	1		AS 229	1	
26	AS 107	1		AS 107	1		AS 107	1		I			I			I			I			I			I			I		
27	U			AF			AN			AS 114	2		AS 114	2		AS 114	2		AS 114	2		AS 328	1		AS 328	1		AS 328	2	
28	U			AS 161	1		AS 161	1		AS 161	1		AF			AN			AN			AS 308	1		AS 308	1		AS 308	1	
29	U			AS 165	3		AF			AF			AS 274	1		AS 274	1		AS 274	1		AS 274	1		AS 347	1		AS 347	1	
30	U			AS 168	1		AS 168	1		AS 170	1		AF			I			AF			AS 170	1		AN			AS 351	2	

Appendix A. Continued.

Cluster	Year and code ^a																													
	1980			1981			1982			1983			1984			1985			1986			1987			1988			1989		
	S ^b	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C	S	T	C
31	U			AS	179	1	AS	180	1	AS	281	1	AN			AN			AS	300	1	AS	300	1	AS	300	1	AS	300	1
32	U			AN			AN			AN			I			I			AS	309	1	AN			AS	348	1	AS	348	1
33	U			AF			I			I			I			I			I			I			I			I		
34	U			AS	189	1	AS	189	1	AS	197	1	AS	185	1	AF			AF			AS	196	2	AS	189	2	AS	189	2
35	I			I			I			I			I			I			I			I			I			I		
36	U			AS	200	1	AS ^c			AS	200	1	AS	200	1	AS	200	1	AF			AN			AN			AN		
37	U			AS	217	1	AS	215	1	AS	215	1	AN			AS	215	1	AS	215	1	AS	217	1	AS	217	1	AS	215	1
38	I			I			I			I			I			I			I			I			I			I		
39	AF			AF			AF			AN			AN			AN			AN			AN			AS	299	2	AS	299	1
40	U			AS	243	1	AS	243	1	AS	243	1	AF			AS	242	4	AF			AS	243	1	AN			AS	373	2
41	U			AF			AF			AF			AF			AN			AS	262	1	AS	260	1	AF			AS	262	1
42	AN			AN			I			I			I			I			I			AS	344	1	AS	313	1	AS	313	1
43 ^d																						AS	317	1	AS	317	1	AS	317	1
44	U			U			U			U			U			U			U			AS	321	1	AN			AS	322	1
45	U			U			U			U			U			U			U			AF			AS	330	1	AS	330	1
46	U			U			U			U			U			U			U			AS	337	1	AS	337	1	AS	339	1
47 ^e																									AS	290	2	AS	290	2

^aCode designations: S = cluster status; T = nest tree number; C = cavity number.

^bCluster status designations: AF = active cluster where an adult red-cockaded woodpecker was flushed from a cavity on ≥ 1 separate occasions but no nestlings were heard or seen; AS = active cluster where there was evidence of nestling production (i.e., detection of audible vocalizations by nestlings, observed feeding of nestlings by adults, or occurrence of juveniles in cluster following fledging); AN = active cluster where there was no evidence of nestling production; I = inactive cluster; U = unknown (cluster not yet discovered).

^cBased on occurrence of juveniles in cluster following fledging; nest tree and nest cavity unknown.

^dCluster No. 43 "budded" from Cluster No. 16 in 1987 (see text for explanation).

^eCluster No. 47 "budded" from Cluster No. 5 in 1988 (see text for explanation).

Appendix B. Number of living cavity trees in red-cockaded woodpecker clusters, Apalachicola National Forest, Florida, 1980–1989.^a

Cluster ^d	Year ^b and status ^c																							
	1980				1981				1986				1987				1988				1989			
	A	I	U	T	A	I	U	T	A	I	U	T	A	I	U	T	A	I	U	T	A	I	U	T
1	3	0	0	3	2	2	0	4	0	0	0	0	0	1	0	1	0	1	0	1	0	2	0	2
2	4	1	0	5	5	2	0	7	2	4	0	6	3	4	0	7	3	3	0	6	3	3	0	6
3	7	1	0	8	7	1	0	8	3	4	1	8	3	4	1	8	2	6	1	9	2	6	1	9
4	4	2	0	6	4	2	0	6	3	3	0	6	2	4	0	6	1	4	1	6	3	4	0	7
5	6	2	0	8	5	3	0	8	6	4	0	10	5	4	0	9	4	4	0	8 ^e	6	5	0	11
6	3	1	0	4	3	2	0	5	2	2	1	5	2	2	1	5	2	3	1	6	2	2	1	5
7	3	2	0	5	3	2	0	5	3	2	0	5	4	1	0	5	3	2	0	5	3	1	0	4
8	6	3	0	9	5	5	0	10	2	7	0	9	2	7	0	9	2	7	0	9	3	5	0	8
9	6	1	0	7	4	3	0	7	2	1	4	7	3	2	3	8	3	1	4	8	4	1	3	8
10	8	4	0	12	4	8	0	12	2	5	3	10	3	5	3	11	3	4	4	11	2	6	3	11
11	2	0	0	2	1	1	0	2	0	2	0	2	0	3	0	3	0	3	0	3	0	2	1	3
12	6	2	0	8	5	3	0	8	2	2	0	4	4	2	0	6	3	3	0	6	4	4	0	8
13	3	1	0	4	3	1	0	4	2	2	0	4	2	2	0	4	1	3	0	4	3	2	0	5
14	7	1	0	8	5	3	0	8	2	1	3	6	1	3	3	7	2	2	3	7	5	3	2	10
15	4	1	0	5	3	2	0	5	1	1	0	2	2	1	0	3	3	0	0	3	3	0	0	3
16	5	2	0	7	3	4	0	7	2	5	0	7	2	2	0	4 ^f	1	3	0	4	2	5	0	7
17	2	2	0	4	1	3	0	4	1	2	1	4	1	3	0	4	2	1	1	4	1	3	0	4
18	4	2	0	6	4	2	0	6	3	1	2	6	2	2	2	6	2	2	2	6	4	4	2	10
19	5	2	0	7	4	3	0	7	3	3	0	6	3	3	0	6	2	4	0	6	4	2	0	6
20	7	6	0	13	3	10	0	13	2	10	1	13	3	8	1	12	3	6	2	11	4	5	1	10
21	3	6	0	9	2	10	0	12	5	7	1	13	8	7	1	16	7	7	2	16	3	8	3	14
22	5	4	0	9	4	5	0	9	3	8	1	12	2	8	2	12	4	7	1	12	3	7	1	11
23	3	1	0	4	4	1	0	5	2	4	0	6	2	6	0	8	2	7	0	9	3	7	0	10
24	3	8	0	11	3	7	0	10	2	8	3	13	3	7	3	13	3	7	3	13	2	8	3	13
25	2	1	0	3	2	1	0	3	2	2	0	4	3	1	0	4	2	2	0	4	2	3	0	5
26	2	0	0	2	2	0	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2	0	2
27	5	0	0	5	2	3	0	5	2	2	0	4	3	1	0	4	2	2	0	4	1	4	0	5
28	1	4	0	5	1	4	0	5	1	1	1	3	1	2	0	3	2	1	0	3	2	1	0	3
29	3	2	0	5	4	1	0	5	2	1	0	3	1	2	0	3	2	2	0	4	2	2	0	4
30	2	2	0	4	2	2	0	4	1	3	0	4	1	3	0	4	3	2	0	5	2	2	0	4

Appendix B. Continued.

Cluster ^d	Year ^b and status ^c																			
	1980				1981				1986				1987				1988			
	A	I	U	T	A	I	U	T	A	I	U	T	A	I	U	T	A	I	U	T
31	3	2	0	5	2	3	0	5	2	3	1	6	1	4	1	6	1	4	1	6
32	2	2	0	4	2	2	0	4	1	1	2	4	2	1	2	5	3	1	2	6
33	1	1	0	2	1	1	0	2	0	1	0	1	0	1	0	1	0	1	0	1
34	8	1	0	9	7	2	0	9	1	3	0	4	2	1	0	3	2	1	0	3
35	0	2	0	2	0	3	0	3	0	3	0	3	0	3	0	3	0	3	0	3
36	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2	2	0	0	2
37	4	1	0	5	4	1	0	5	3	1	0	4	3	2	0	5	2	3	0	5
38	1	3	0	4	0	4	0	4	1	1	0	2	1	1	0	2	0	2	0	2
39	2	0	0	2	1	0	0	1	1	2	0	3	1	2	0	3	1	2	0	3
40	2	0	0	2	1	1	0	2	1	0	0	1	1	0	0	1	1	0	0	1
41	1	0	0	1	2	0	0	2	4	1	0	5	2	3	0	5	2	3	0	5
42	1	0	0	1	2	0	0	2	0	2	0	2	2	2	0	4	2	1	0	3
43													2	2	0	4	1	3	0	4
44													4	0	0	4	2	1	0	3
45													2	1	0	3	2	1	0	3
46													2	1	0	3	2	1	0	3
47																	1	0	0	1
Total	151	76	0	227	124	113	0	237	79	117	25	221	98	126	23	247	93	128	28	249
%	67	33	0	100	52	48	0	100	36	53	11	100	40	51	9	100	37	51	11	99

^aThe status of individual cavity trees was not determined during the 4 years 1982–1985.

^bData for 1980 were collected during July through August; data for all other years were collected during April through June.

^cStatus designations: A = active; I = inactive; U = unknown (i.e., previously located cavity trees that could not be found); T = total. Because unknown cavity trees often were relocated at a later date, they were classified as living until proven otherwise.

^dCluster Nos. 43–46 were discovered in 1987. Cluster No. 47 was discovered in 1988.

^eOne cavity tree in Cluster No. 5 became part of Cluster No. 47 in 1988.

^fThree cavity trees in Cluster No. 16 became part of Cluster No. 43 in 1987.

Appendix C. Number of living cavity trees gained and lost in red-cockaded woodpecker clusters, Apalachicola National Forest, Florida, 1980–1989.^a

Cluster ^d	Year ^b and status ^c																							
	1980				1981				1986				1987				1988				1989			
	D	N	L	C	D	N	L	C	D	N	L	C	D	N	L	C	D	N	L	C	D	N	L	C
1			3		0	1	4	+1	4	0	0	-4	0	1	1	+1	0	0	1	0	0	1	2	+1
2			5		0	2	7	+2	2	1	6	-1	0	1	7	+1	1	0	6	-1	0	0	6	0
3			8		0	0	8	0	2	2	8	0	0	0	8	0	0	1	9	+1	0	0	9	0
4			6		0	0	6	0	1	1	6	0	1	1	6	0	0	0	6	0	1	2	7	+1
5			8		0	0	8	0	3	5	10	+2	1	0	9	-1	0	0	8	-1 ^e	0	3	11	+3
6			4		0	1	5	+1	0	0	5	0	0	0	5	0	0	1	6	+1	1	0	5	-1
7			5		0	0	5	0	0	0	5	0	0	0	5	0	0	0	5	0	1	0	4	-1
8			9		0	1	10	+1	2	1	9	-1	0	0	9	0	0	0	9	0	1	0	8	-1
9			7		0	0	7	0	0	0	7	0	0	1	8	+1	0	0	8	0	0	0	8	0
10			12		0	0	12	0	4	2	10	-2	0	1	11	+1	0	0	11	0	0	0	11	0
11			2		0	0	2	0	0	0	2	0	0	1	3	+1	0	0	3	0	0	0	3	0
12			8		0	0	8	0	5	1	4	-4	0	2	6	+2	0	0	6	0	0	2	8	+2
13			4		0	0	4	0	1	1	4	0	0	0	4	0	0	0	4	0	0	1	5	+1
14			8		0	0	8	0	2	0	6	-2	0	1	7	+1	0	0	7	0	0	3	10	+3
15			5		0	0	5	0	3	0	2	-3	0	1	3	+1	0	0	3	0	0	0	3	0
16			7		0	0	7	0	2	2	7	0	0	0	4	-3 ^f	0	0	4	0	0	3	7	+3
17			4		0	0	4	0	0	0	4	0	0	0	4	0	0	0	4	0	0	0	4	0
18			6		0	0	6	0	2	2	6	0	0	0	6	0	0	0	6	0	0	4	10	+4
19			7		0	0	7	0	2	1	6	-1	1	1	6	0	0	0	6	0	0	0	6	0
20			13		0	0	13	0	1	1	13	0	1	0	12	-1	1	0	11	-1	1	0	10	-1
21			9		0	3	12	+3	0	1	13	+1	0	3	16	+3	0	0	16	0	2	0	14	-2
22			9		0	0	9	0	2	5	12	+3	0	0	12	0	0	0	12	0	1	0	11	-1
23			4		0	1	5	+1	0	1	6	+1	0	2	8	+2	0	1	9	+1	0	1	10	+1
24			11		1	0	10	-1	2	5	13	+3	0	0	13	0	0	0	13	0	0	0	13	0
25			3		0	0	3	0	1	2	4	+1	0	0	4	0	0	0	4	0	0	1	5	+1
26			2		0	0	2	0	1	1	2	0	0	0	2	0	0	0	2	0	0	0	2	0
27			5		0	0	5	0	2	1	4	-1	2	2	4	0	0	0	4	0	0	1	5	+1
28			5		0	0	5	0	4	2	3	-2	1	1	3	0	0	0	3	0	0	0	3	0
29			5		0	0	5	0	3	1	3	-2	0	0	3	0	0	1	4	+1	0	0	4	0
30			4		0	0	4	0	1	1	4	0	0	0	4	0	0	1	5	+1	1	0	4	-1

Appendix C. Continued

Cluster ^d	Year ^b and status ^c																			
	1980				1981				1986				1987				1988			
	D	N	L	C	D	N	L	C	D	N	L	C	D	N	L	C	D	N	L	C
31			5		0	0	5	0	1	2	6	+1	0	0	6	0	0	0	6	0
32			4		0	0	4	0	1	1	4	0	0	1	5	+1	0	1	6	+1
33			2		0	0	2	0	1	0	1	-1	0	0	1	0	0	0	1	0
34			9		0	0	9	0	5	0	4	-5	1	0	3	-1	0	0	3	0
35			2		0	1	3	+1	0	0	3	0	0	0	3	0	0	0	3	0
36			2		0	0	2	0	0	0	2	0	0	0	2	0	0	0	2	0
37			5		0	0	5	0	1	0	4	-1	0	1	5	+1	0	0	5	0
38			4		0	0	4	0	2	0	2	-2	0	0	2	0	0	0	2	0
39			2		1	0	1	-1	0	2	3	+2	0	0	3	0	0	0	3	0
40			2		0	0	2	0	1	0	1	-1	0	0	1	0	0	0	1	0
41			1		0	1	2	+1	0	3	5	+3	0	0	5	0	0	0	5	0
42			1		0	1	2	+1	0	0	2	0	0	2	4	+2	1	0	3	-1
43														4			0	0	4	0
44														4			1	0	3	-1
45														3			0	0	3	0
46														3			0	0	3	0
47																1				
Total			227		2	12	237	+10	64 ^g	48	221	-16	8	23	247	+12	4	6	249	+1

^aThe gain and loss of cavity trees was not determined during the 4 years 1982-1985.

^bData for 1980 were collected during July through August; data for all other years were collected during April through June.

^cStatus designations: D = number of cavity trees dying between the designated year and the preceding year; N = number of living cavity trees newly located or newly excavated during the designated year; L = total number of living cavity trees during the designated year; C = net change (i.e., gain or loss) in the number of living cavity trees between the designated year and the preceding year.

^dCluster Nos. 43-46 were discovered in 1987. Cluster No. 47 was discovered in 1988.

^eOne cavity tree in Cluster No. 5 became part of Cluster No. 47 in 1988.

^fThree cavity trees in Cluster No. 16 became part of Cluster No. 43 in 1987.

^gA minimum of 44 (69%) of the 64 cavity trees dying between 1981 and 1986 were killed by Hurricane Kate in November 1986.

Appendix D. Hectares of suitable foraging habitat^a available, clearcut, and gained within 1.2 km of red-cockaded woodpecker clusters, Apalachicola National Forest, Florida, 1980–1989.

CL ^c	PL ^d	Year and code ^b																											
		1980			1981			1982			1983			1984			1985			1986			1987			1988			1989
		AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV
1	17	233	0	0	233	0	+32	265	0	0	265	0	0	265	0	0	265	0	0	265	0	0	265	0	0	265	0	0	265
2	0				105	0	0	105	0	0	105	0	0	105	-10	0	95	0	0	95	0	+16	111	0	0	111	0	0	111
3	4	139	0	0	139	0	0	139	0	0	139	0	0	139	0	+11	150	0	0	150	0	0	150	0	+13	163	0	0	163
4	0	307	0	0	307	0	0	307	-36	0	271	0	0	271	0	0	271	0	0	271	0	0	271	0	0	271	0	0	271
5	0	295	0	0	295	0	0	295	-31	0	264	-7	0	257	0	0	257	0	0	257	0	0	257	0	0	257	0	0	257
6	39	206	0	0	206	0	0	206	-32	0	174	-9	0	165	0	0	165	0	0	165	0	0	165	0	0	165	0	0	165
7	0	202	0	0	202	0	0	202	-68	0	134	0	0	134	0	0	134	0	0	134	0	0	134	0	0	134	0	0	134
8	97	215	0	0	215	0	0	215	-62	0	153	0	0	153	-14	0	139	0	0	139	0	0	139	0	0	139	0	0	139
9	7	340	0	0	340	0	0	340	-48	0	292	0	0	292	0	0	292	0	0	292	0	0	292	0	0	292	0	0	292
10	7	246	0	0	246	0	0	246	-14	0	232	0	0	232	-15	0	217	0	0	217	0	+16	233	0	0	233	0	0	233
11	0	189	0	0	189	0	0	189	0	+59	248	0	0	248	0	0	248	-20	0	228	0	0	228	0	0	228	0	0	228
12	0	180	0	0	180	0	0	180	-35	+37	182	-7	0	175	0	0	175	0	0	175	0	+21	196	0	0	196	0	0	196
13	61	106	0	0	106	0	0	106	0	+65	171	-18	0	153	0	+17	170	0	0	170	0	+23	193	0	0	193	0	0	193
14	66	98	0	0	98	0	0	98	0	+54	152	-24	0	128	0	+14	142	0	0	142	0	0	142	0	0	142	0	0	142
15	0	162	0	0	162	0	0	162	0	+68	230	0	0	230	0	+16	246	0	0	246	-8	0	238	0	0	238	0	0	238
16 ^e	0	169	0	0	169	0	0		0	+23		0	0		0	0		0	0		-23	0	155	0	0	155	0	0	155
17	69				311	0	0	311	-51	0	260	0	0	260	0	0	260	0	0	260	0	0	260	0	0	260	0	0	260
18	22				90	0	0	90	0	0	90	-14	0	76	0	+17	93	0	0	93	0	0	93	0	0	93	0	0	93
19	11	137	0	0	137	0	0	137	0	0	137	0	0	137	-24	0	113	0	0	113	-26	0	87	0	0	87	0	0	87
20	0	242	0	0	242	0	0	242	0	0	242	0	+62	304	0	0	304	0	0	304	0	0	304	0	0	304	0	0	304
21	58	170	0	0	170	0	+27	197	0	0	197	0	0	197	-8	0	189	0	0	189	0	0	189	0	0	189	0	0	189
22	97	128	0	0	128	0	0	128	0	0	128	0	0	128	0	0	128	0	0	128	0	0	128	0	+14	142	0	0	142
23	0	124	0	0	124	0	0	124	0	+127	251	0	0	251	0	0	251	0	0	251	0	+10	261	0	0	261	0	0	261
24	125	114	0	0	114	0	0	114	0	0	114	0	0	114	0	0	114	0	0	114	0	0	114	0	+12	126	0	0	126
25	0				161	0	0	161	0	+8	169	0	0	169	-9	0	160	0	0	160	0	0	160	0	0	160	0	0	160
26	0	275	0	0	275	0	0	275	-37	0	238	-8	0	230	-8	0	222	-23	0	199	0	0	199	0	0	199	0	0	199
27	32				183	0	+24	207	0	0	207	0	0	207	-11	0	196	0	0	196	0	0	196	0	+14	210	0	0	210
28	204				94	0	0	94	0	0	94	0	0	94	0	0	94	0	0	94	0	0	94	0	0	94	0	0	94
29	32				228	0	+10	238	0	0	238	0	+27	265	0	0	265	0	0	265	0	0	265	0	0	265	0	0	265

Appendix D. Continued.

		Year and code ^b																											
CL ^c	PL ^d	1980			1981			1982			1983			1984			1985			1986			1987			1988			1989
		AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV	CC	GA	AV			
30	179				157	0	+28	185	0	0	185	0	+7	192	0	0	192	0	0	192	0	0	192	0	0	192	0	0	192
31	0				320	0	+11	331	0	0	331	0	+14	345	-9	0	336	-26	0	310	0	0	310	0	0	310	0	0	310
32	0				313	0	0	313	-32	0	281	0	0	281	-7	0	274	-27	0	247	0	0	247	0	0	247	0	0	247
33	0				312	0	0	312	-35	0	277	-7	0	270	-8	0	262	-24	0	238	0	0	238	0	0	238	0	0	238
34	0				212	0	0	212	-8	+25	229	-8	+75	296	0	0	296	-6	0	290	0	0	290	0	0	290	0	0	290
35	0	216	0	0	216	0	0	216	0	0	216	-8	+87	295	0	0	295	-6	0	289	0	0	289	0	0	289	0	0	289
36	0				172	0	0	172	0	0	172	0	+52	224	-7	0	217	-16	0	201	0	+8	209	0	0	209	0	0	209
37	0				144	0	0	144	0	+7	151	0	0	151	-30	0	121	-16	0	105	0	0	105	0	0	105	0	0	105
38	0	152	0	0	152	0	0	152	0	+27	179	0	0	179	-28	0	151	0	0	151	0	0	151	0	0	151	0	0	151
39	0	137	0	0	137	0	0	137	0	0	137	0	0	137	0	+16	153	0	0	153	0	0	153	0	0	153	0	0	153
40	90				168	0	0	168	-35	0	133	0	0	133	-24	0	109	0	0	109	0	0	109	0	0	109	0	0	109
41	0				167	0	0	167	0	0	167	0	+72	239	0	0	239	-12	0	227	0	+7	234	0	0	234	0	0	234
42	129	230	0	0	230	0	0	230	-35	0	195	0	0	195	0	0	195	0	0	195	0	0	195	0	0	195	0	0	195
43	0																					117	0	0	117	0	0	117	
44	0																					323	0	0	323	0	0	323	
45	0																					218	0	0	218	0	0	218	
46	0																					154	0	0	154	0	0	154	
47	0																								231	0	0	231	

^aSuitable foraging habitat was defined as pine stands, both natural and planted, with an average dbh >13 cm (see text for further explanation).

^bCode designations: AV = suitable foraging habitat available during the breeding season of the designated year; CC = suitable foraging habitat clearcut between July of the designated year and June of the subsequent year; GA = suitable foraging habitat gained through stand maturation (see text for explanation) between July of the designated year and June of the subsequent year.

^cCL = cluster number.

^dPL = Hectares of private land within 1.2 km of the designated cluster. Private lands were excluded from the foraging habitat analysis.

^eFourteen hectares of foraging habitat were clearcut within 1.2 km of Cluster No. 16 between 1982 and 1986. Because the clearcut year was unknown, years 1982-1986 for Cluster No. 16 were excluded from the foraging habitat analysis.