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THE RED-COCKADED WOODPECKER'S ROLE IN THE SOUTHERN PINE ECOSYSTEM, POPULATION TRENDS AND RELATIONSHIPS WITH SOUTHERN PINE BEETLES

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Abstract.-This study reviews the overall ecological role of the Red-cockaded Woodpecker *(Picoides borealis)* in the southern pine ecosystem. It is the only North American woodpecker species to become well adapted to a landscape that was relatively devoid of the substrate typically used by woodpeckers for cavity excavation (i.e. snags and decayed, living hardwoods). Its adaptation to use living pines for cavity excavation has expanded the use of this fire-disclimax ecosystem for numerous other cavity-using species. As such, the Red-cockaded Woodpecker represents an important keystone species of fire-disclimax pine ecosystems of the South. Historically, populations of this woodpecker and other cavity dependent species decreased dramatically with the logging of the southern pine forests between 1870 and 1930. Woodpecker populations continued to decline into the 1980s as a result of inadequate old-growth pine habitat, and suppression of fire which permitted encroachment of hardwoods into the previously pine-dominated ecosystem. Management practices initiated after 1988 have resulted in woodpecker population increases on Texas national forests. Cavity-tree mortality and southern pine beetle *(Dendrocconus frontalis)* infestation of cavity trees on the Angelina National Forest in eastern Texas were studied from 1983 through 1996. The intensive management activities initiated to stabilize severely declining woodpecker populations in 1989 may have increased beetle infestation rates of cavity trees in loblolly (*Pinus taedu)* and shortleaf (*Pinus echinata)* pine habitat resulting in a net loss of cavity trees over the past seven years. Initial results suggest that beetle-caused mortality of cavity trees may be related in part to ambient southern pine beetle population levels in surrounding forest stands.

As a cooperative breeder (Ligon 1970), the Red-cockaded Woodpecker (*Picoides* borealis) lives in family groups composed of a breeding pair and one to several helpers (Walters et al. 1988; Walters 1990). The woodpecker excavates cavities into the heartwood of old pines that typically are infected with red heart fungus *(Phellinus pini*), have relatively thin sapwood, and a large diameter of heartwood (Conner & Locke 1982; Conner et al. 1994; Hooper 1988; Hooper et al. 199 1 b; Rudolph et al. 1995). Red-cockaded Woodpeckers peck shallow excavations, termed resin wells, around their cavity entrances (Jackson 1978b).

Daily pecking at these sites causes a copious flow of pine resin from resin wells down the bole of the pine (Ligon 1970). Bark scaling and resin flow serve as a deterrent by creating a barrier against climbing rat snakes (*Elaphe obsoleta*) (Jackson 1974; Rudolph et al. 1990b), but have little deterrent effect against southern flying squirrels (*Glaucomys volans*), which frequently use unenlarged cavities (Rudolph et al. 1990a; Loeb 1993).

Pileated Woodpeckers (*Dryocopus pileatus*) enlarge many cavities (expand the cavity entrance tube and cavity chamber by excavation) and occasionally nest in Red-cockaded Woodpecker cavities (Conner et al. 1991). Over a nine year period Pileated Woodpeckers enlarged 55 Red-cockaded Woodpecker cavities on the Angelina National Forest in eastern Texas (Conner & Rudolph 1995a). An average of 6.1 cavities was enlarged per year, representing 2.4 percent of the cavity trees present each year on the forest. The enlarged cavities created by Pileated Woodpeckers provide cavity sites for many other relatively large secondary cavity users, such as fox squirrels (*Sciurus niger*), American Kestrels (*Falco sparverius*), Wood Ducks (*Aix sponsa*), and Eastern Screech-Owls (*Otis asio*).

THE ROLE OF RED-COCKADED WOODPECKERS AS A KEYSTONE SPECIES

Although the Red-cockaded Woodpecker is often singled out as an example of single species management, it is in fact a keystone species of fire-disclimax, pine ecosystems of the South, and is the primary species to excavate cavities in what can be an otherwise cavity-barren environment (Conner 1995). Cavity excavation by Red-cockaded Woodpeckers in live pines requires a relatively long period of time, averaging 1.8 yr in loblolly pines (*Pinus taeda*), 2.4 yr in shortleaf pines (P. *echinata*), and 6.3 yr in longleaf pines (P. *palustris*) (Conner & Rudolph 1995a). Thus, the cavities they create tend to be in high demand by other species (Dennis 197 1; Rudolph et al. 1990a; Loeb 1993; Conner et al. 1996).

Approximately 24 species of vertebrates are known to use Red-cockaded Woodpecker cavities (Dennis 1971; Baker 197 1; Beckett 197 1; Hopkins & Lynn 1971; Jackson 1978a; Harlow & Lennartz 1983; Rudolph et al. 1990a; Loeb 1993; Kappes & Harris 1995). Although the majority of these vertebrates use either enlarged or abandoned cavities, several species, such as Red-bellied (*Melanerpes carolinus*) and

Red-headed (M. *erythrocephalus*) woodpeckers and southern flying squirrels, appear to actively compete with Red-cockaded Woodpeckers for normal, unenlarged cavities. Because of the dependence of many other cavity nesters on Red-cockaded Woodpecker cavities, forest biodiversity would suffer substantially in the absence of this endangered woodpecker in southern pine ecosystems.

RED-COCKADED WOODPECKER POPULATION STATUS, TRENDS AND ESSENTIAL MANAGEMENT

Two major factors are associated with the historic declines of Red-cockaded Woodpeckers throughout the southeastern United States (Fig. 1). Loss of old-growth pine forest initially caused severe population losses (USFWS 1985). In the coastal plain of Texas, "bonanza era" harvesting occurred between 1890 and 1930 (Maxwell & Baker 1983; McWilliams & Lord 1988). Subsequent to the loss of old-growth pines and fragmentation of southern pine forests through harvesting, the suppression of natural tires and development of artificial fire breaks, such as roads, reservoirs and agricultural lands across the landscape, permitted a gradual encroachment of hardwoods into what had been the open-pine savannahs of the South.

Because of continuing loss and fragmentation of pine forest habitat and exclusion of fire, the Red-cockaded Woodpecker continued to decline throughout its range during the 1970s, 1980s and early 1990s (Jackson 1980; Baker 1982; 1983; Carter et al. 1983; Eddleman & Clawson 1987; Ortego & Lay 1988; Conner & Rudolph 1989; Costa & Escano 1989; Masters et al. 1989) despite more than two decades of protection under the Endangered Species Act and two recovery plans. Of the 26 Red-cockaded Woodpecker populations on national forests in the South, 11 were still declining between 1990 and 1992 and 15 appeared to be stable (USDA 1995). South-wide, only the Francis Marion National Forest population in South Carolina (prior to Hurricane Hugo) increased without the aid of artificial cavities and woodpecker translocations (Hooper et al. 199 la). The largest remaining woodpecker population (nearly 700 woodpecker groups on the Apalachicola National Forest in Florida) has recently exhibited signs of population declines within the smaller subpopulations on the eastern portion of the forest (James 199 1).

Small Red-cockaded Woodpecker populations (< 50 woodpecker groups) are highly vulnerable to demographic problems resulting from

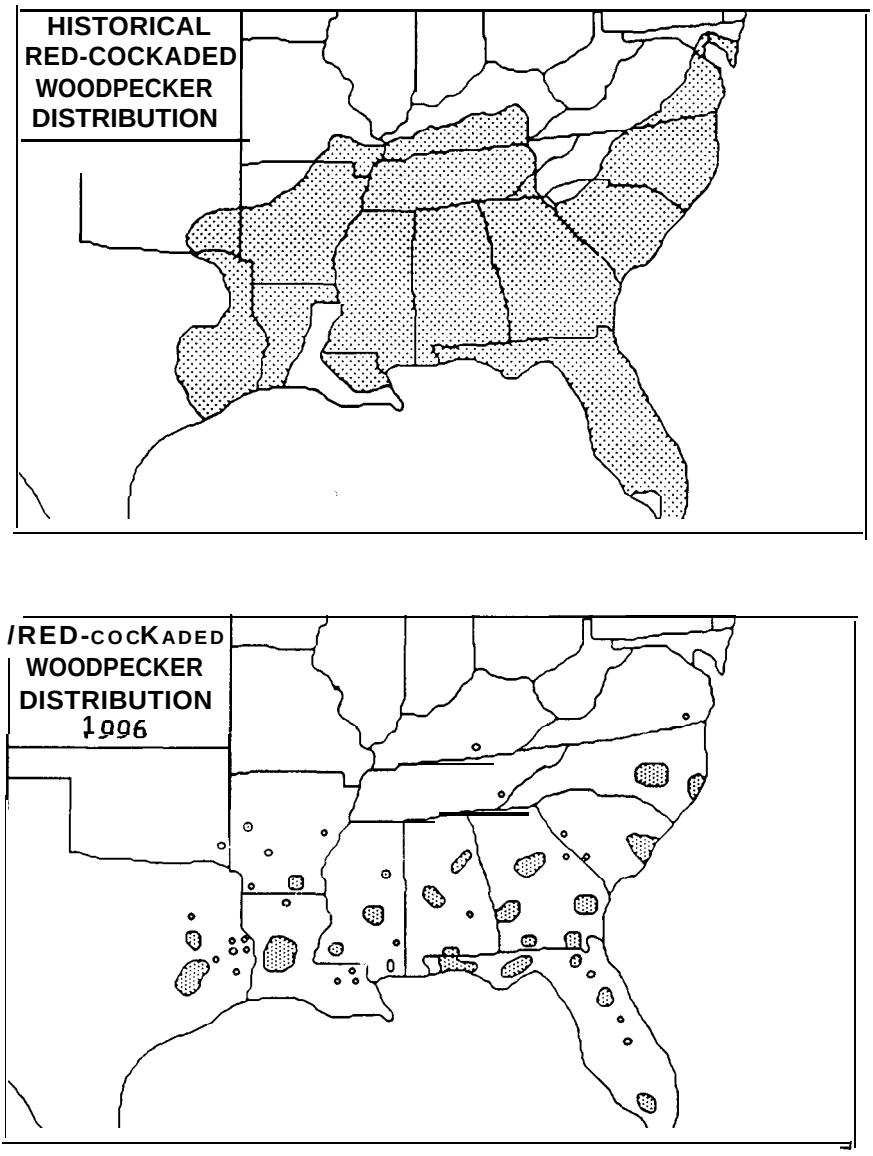

Figure 1. Historical and present distribution of Red-cockaded Woodpeckers in the southeastern United States.

cluster isolation and habitat fragmentation, and thus, are more likely to suffer population declines than larger populations (Walters et al. 1988; Conner & Rudolph 1989; 199 1 a; Costa & Escano 1989; Hooper & Lennartz 1995; Rudolph & Conner 1994). Populations or subpopulations composed of < 10 groups with large distances between clusters are

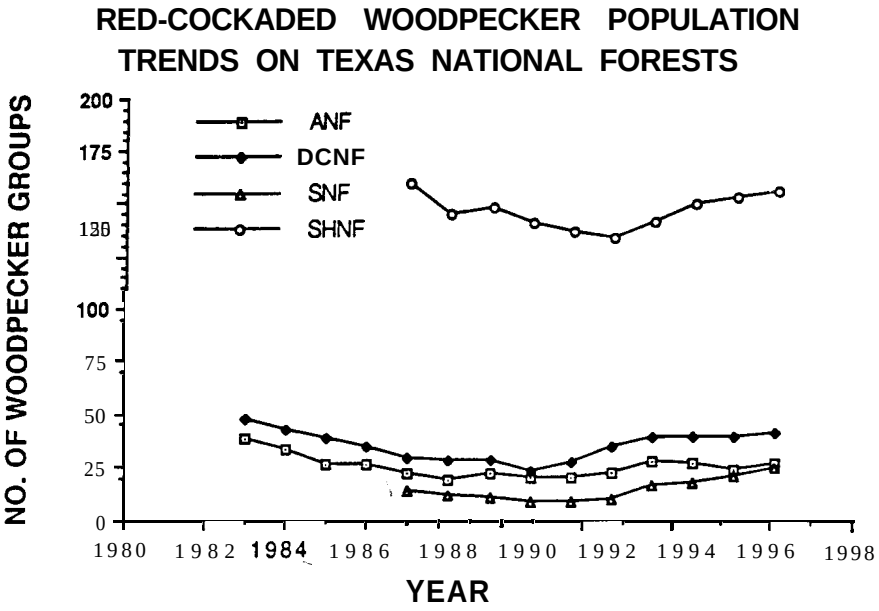

Figure 2. Population trends of Red-cockaded Woodpeckers on the Angelina, Davy Crockett, Sabine and Sam Houston National Forests between 1983 and 1996.

in critical danger of extirpation (Conner & Rudolph 1989; 1991a).

In Texas, Red-cockaded Woodpecker populations declined during the 1960s (Lay 1969; Lay & Russell 1970), 1970s (Jackson et al. 1978), and 1980s (Ortego & Lay 1988; Conner & Rudolph 1989; Rudolph & Conner 1994). Populations continued to decline on the Angelina and Davy Crockett National Forests between 1983 and 1988, appeared to stabilize between 1988 and 1991, and increased in 1992 and 1993 (Fig. 2, also see Conner et al. 1995). Populations on the Sabine National Forest decreased between 1987 and 1990, but increased in 1992 and 1993. Woodpecker populations on the Sam Houston National Forest decreased between 1989 and 1992, but increased in 1993 (Conner et al. 1995). Populations on the Davy Crockett, Sabine and Sam Houston National Forests have continued to increase through 1996 and the Angelina National Forest appears to be stable (Fig. 2).

As of spring 1996, approximately 316 groups of Red-cockaded Woodpeckers were present in Texas. The Sam Houston National Forest had 156 groups present, with 40 on the Davy Crockett National Forest, 26 on the Angelina National Forest, and 24 on the Sabine National Forest. The W. Goodrich Jones and I. D. Fairchild State Forests had

14 and six groups, respectively, with two groups present on the Huntsville State Fish Hatchery. The Alabama-Coushatta Indian Reservation had two groups and the Big Thicket National Preserve one group. Approximately 45 groups occurred on private lands, primarily lands belonging to private industrial timber companies.

Several significant problems have affected small, isolated Red-cockaded Woodpecker populations in Texas and elsewhere in the South. Encroachment of hardwood vegetation is a primary cause of cluster abandonment (Conner & Rudolph 1989; Locke et al. 1983 ; Van Balen & Doerr 1978). On the Angelina and Davy Crockett National Forests between 1981 and 1987 the woodpeckers abandoned cavity-tree clusters with abundant hardwood vegetation at a significantly higher rate than clusters with little or no hardwood vegetation (Conner & Rudolph 1989). Although Conner & Rudolph (1989) identified hardwood midstory encroachment in clusters as the major probable cause of population declines in Texas, they later identified a lack of suitable cavity trees, cluster isolation, and forest fragmentation as contributing factors (Conner & Rudolph 1991b). Midstory reduction within cluster areas on national forests was aggressively pursued by mechanical means during the late 1980s and early 1990s (Conner & Rudolph 1991a; Conner et al. 1995). Efforts to thin pine stands within and around cavity-tree cluster areas were also intensified. Beginning in late 1989, use of artificial cavities (Allen 1991; Copeyon 1990) and cavity restrictors to prevent cavity enlargement (Carter et al. 1989) became widespread on all Texas national forests. In the early 1990s Red-cockaded Woodpeckers were translocated to augment single woodpecker clusters (DeFazio et al. 1987), temporarily solving problems created by cluster isolation and demographic dysfunction (Conner et al. 1995). In several instances pairs of Red-cockaded Woodpeckers were reintroduced to sites of previous extirpation (Rudolph et al. 1992).

The 1988 court-ordered management plan in Texas enjoined clear-cutting within 1200 m of Red-cockaded Woodpecker cavity-tree clusters in an effort to prevent habitat fragmentation and provide sufficient older growth pines for nesting, roosting and foraging. Any possible beneficial effects of this component of the court order have not had sufficient time to come to fruition. Thus, the court-ordered change in timber harvesting techniques (single tree selection rather than clear-cutting) can not account for the observed favorable Red-cockaded Woodpecker population response (Conner et al. 1995).

Collectively, an aggressive management program that included

hardwood midstory control through mechanical means and fire, cavity restrictors and thinning within cluster areas stabilized some Red-cockaded Woodpecker populations (1989-1991, Fig. 2). Red-cockaded Woodpecker population increases on the Texas national forests occurred only after the beginning of aggressive installation of artificial cavities and translocation of woodpeckers which began in 1991 (Conner et al. 1995).

SOUTHERN PINE BEETLES AND RED-COCKADED WOODPECKER CAVITY TREE MORTALITY

Southern pine beetles (*Dendroctonus frontalis*) are the major cause of cavity tree death on Texas national forests (Conner et al. 1991). Growth of multiple-tree infestations (beetle spots) normally occurs from early spring to late summer (Coulson et al. 1972; Belanger et al. 1993), is facilitated by attractant pheromones (Thatcher et al. 1980), and can rapidly eliminate entire cavity tree clusters (Billings & Varner 1986). Southern pine beetles killed more than 350 cavity trees, including more than 50 entire clusters, during a major infestation on the Sam Houston National Forest between 1983 and 1985 (Billings & Varner 1986; Conner et al. 1991). During major epidemics, southern pine beetles account for more than 75% of cavity tree mortality, whereas losses to these bark beetles during endemic population levels are about 53 % (Fig. 3).

Although less catastrophic, losses of single cavity trees to southern pine beetle infestations are persistent and cumulative. Bark beetle infestation of single cavity trees affects primarily active woodpecker cavity trees. Such trees are typically infested during the fall, serve as over-wintering sites for beetle brood development, and southern pine beetles emerge prior to summer of the following year (Conner et al. 1991; Conner & Rudolph 1995b; Rudolph & Conner 1995). Regular annual losses of cavity trees by single tree infestations have the potential to significantly impact woodpecker groups over the long term by reducing the number of suitable cavities for roosting and nesting (Conner & Rudolph 1995b).

From fall 1983 through summer 1996, southern pine beetles infested and killed 62 single Red-cockaded Woodpecker cavity trees (active and inactive combined) on the northern portion of the Angelina National Forest, where loblolly and shortleaf pine predominate (Fig. 4). The number of woodpecker groups on this portion of the Angelina National Forest ranged between seven and 11 over this 13-year period. Southern pine beetles typically infested cavity trees during the fall (October and

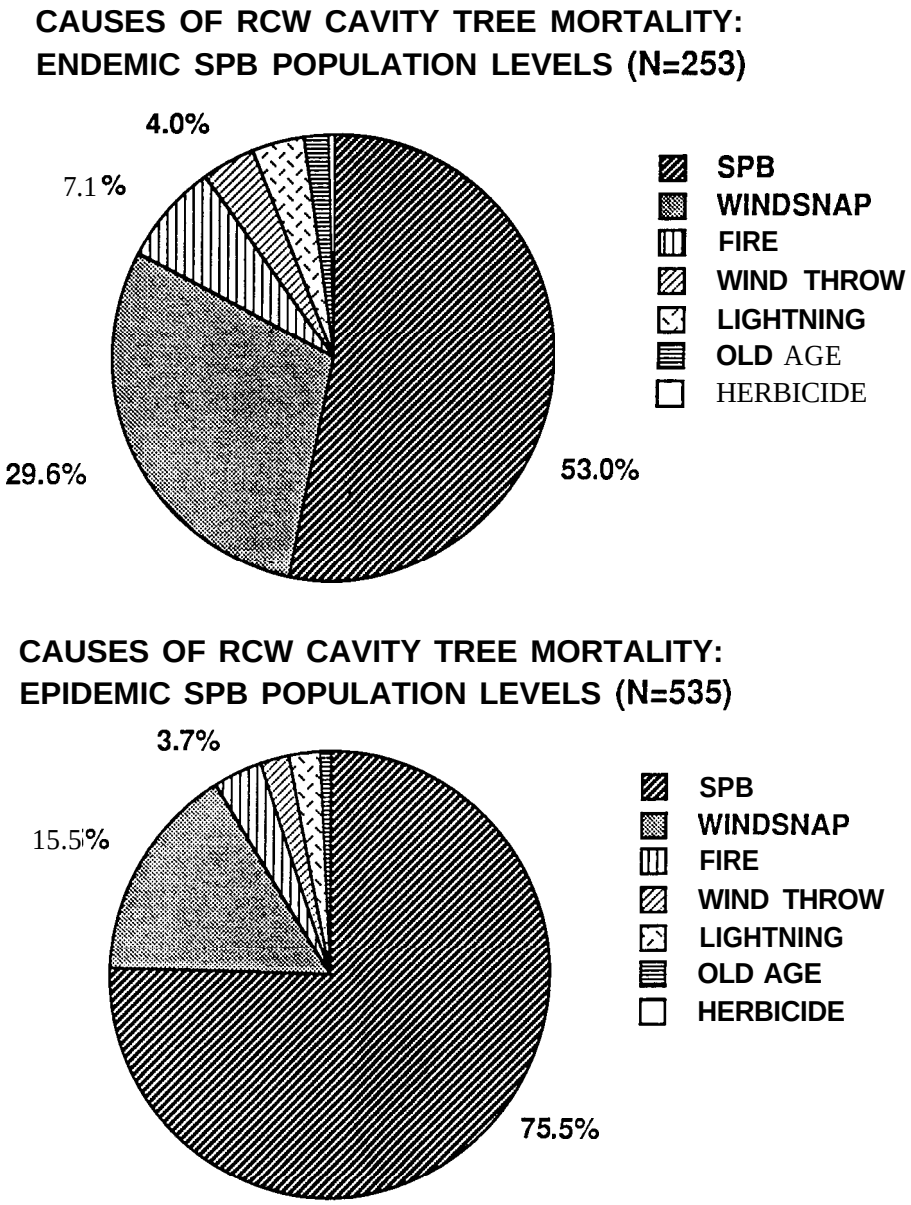

Figure 3. Causes of Red-cockaded Woodpecker cavity tree mortality during periods of endemic and epidemic southern pine beetle population levels in eastern Texas between 1983 and 1988.

November) and trees appeared dead (dropped all needles and some bark pecked off by woodpecker6 at mid bole height) by the following spring

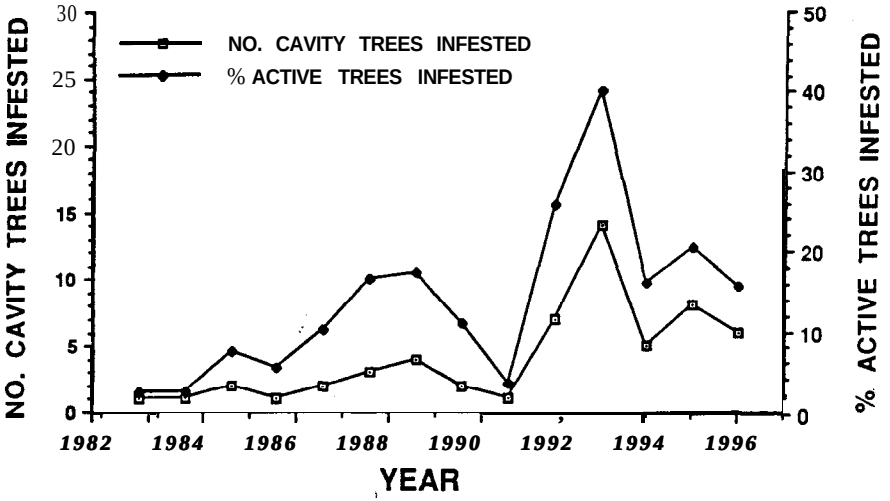

Figure 4. The number of Red-cockaded Woodpecker cavity trees (loblolly and shortleaf pines only) and percentage of active cavity trees infested and killed by southern pine beetles on the northern portion of the Angelina National Forest from 1983 to 1996.

(March through June) (Conner & Rudolph 1995b). In about 40% of the cases (25 of 62), the cavity tree killed had been the nest tree of the preceding breeding season. Typically, bark beetles infest active cavity trees at a much higher average annual rate than inactive trees (Conner & Rudolph 1995b; Rudolph & Conner 1995).

The intensified forest management that occurred following the development of the 1988 court-ordered management plan included complete removal of hardwood tree species and substantial reduction of pine basal area to bring clusters into a 14 to 16 m^2/ha basal area range. Typically, the entire hardwood and pine midstory was removed by mechanical equipment, as mentioned above, and caused substantial site disturbance to woodpecker cluster areas (Conner & Rudolph 199 la). Seven cavity trees (out of 346 cavity tree years) were killed by single-tree beetle infestation during the five-year period (1983-1987) immediately prior to initiation of intensive management for Red-cockaded Woodpeckers on the northern portion of the Angelina National Forest. Over the next nine years during intensified management (1988-1996), 49 cavity trees (out of 729 cavity tree years) were killed. This was a much higher mortality rate (6.7% vs 2.0%) than the previous five-year period ($\chi^2 = 9.6$, $P < 0.002$).

From 1984 through 1996, the number of detected southern pine beetle infestations (spots) and the number of pines infested within these spots

varied considerably on the northern portion of the Angelina National Forest (Fig. 5). The annual number of single cavity trees infested by southern pine beetles (1984-1995) was correlated with the number of southern pine beetle infestations ($r = 0.71$, N = 11, $P = 0.02$), but not correlated with the total number of pines infested within the general area ($r = 0.49$, $P = 0.13$) of the cavity tree clusters. However, because of the small sample sizes for these correlations, the biological significance of the results remains inconclusive.

Southern pine beetle infestation is not typically a problem in longleaf pine because of this species' copious production of pine resin, which serves as the pine's first line of defense against beetle infestation (Wahlenberg 1946; Hodges et al. 1977). Loblolly and shortleaf pines produce less pine resin and they are generally more susceptible to southern pine beetle infestation (Hodges et al. 1977). The coincidental timing of increased cavity tree losses with initiation of intensive management in loblolly and shortleaf pine habitat on the Angelina National Forest is of considerable concern and suggests that efforts to correct habitat problems may be associated with increases in southern pine beetle infestation of active cavity trees. Physical disturbance of soils and root systems of trees during thinning and midstory removal operations increases the risk of beetle infestation and the susceptibility of pines to attack (Nebeker & Hodges 1985; Hicks et al. 1987; Mitchell et al. 1991). Infestation of cavity trees occurred primarily within active woodpecker clusters. Intensive management activities focused primarily on active cavity tree clusters when they were first initiated, again suggesting the possibility of a relationship between cluster management activities and beetle infestation of cavity trees. Midstory removal and thinning of pines was restricted to woodpecker cluster areas and did not include the surrounding general forest. Thus, present management produces a pocket of relatively open pine forest surrounded by a sea of pines and dense hardwood midstory. Southern pine beetles have a search image for vertically oriented dark objects (e.g., pine boles) and hardwood foliage can interfere with beetle movements (Schowalter & Turchin 1993). Green leaf volatiles from deciduous foliage also interrupt bark beetle aggregation response to attractant pheromones (Dickens et al. 1992). Management's creation of islands of open pine forest within a sea of forest with midstory may accumulate southern pine beetles within Red-cockaded Woodpecker cluster areas. Additional research is needed to determine if management essential for woodpecker recovery is increasing the frequency of southern pine beetle infestation of cavity trees. Fortunately, the severe losses of cavity trees to southern

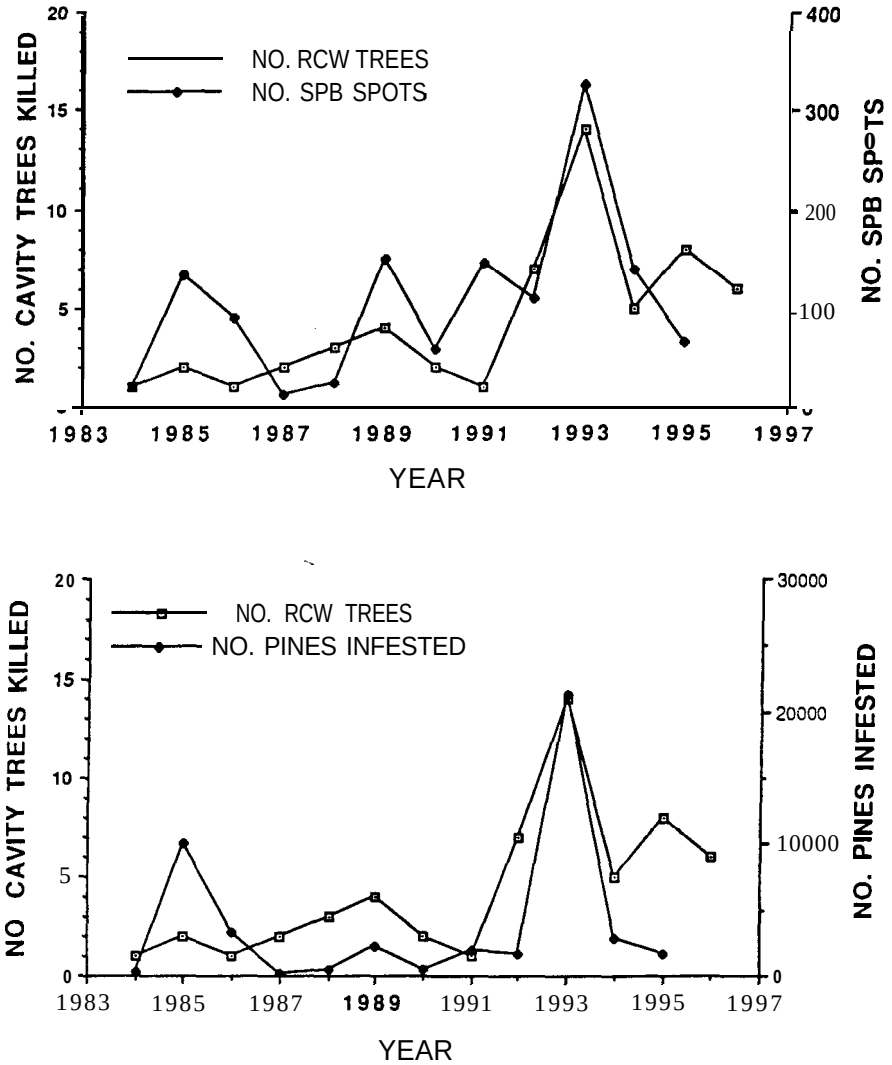

Figure 5. Southern pine beetle induced mortality of Red-cockaded Woodpecker cavity trees on the northern portion of the Angelina National Forest versus the number of southern pine beetle spots and the number of pines infested in loblolly-shortleaf pine forest habitat surrounding Red-cockaded Woodpecker cavity-tree clusters between 1984 and 1995.

pine beetle infestation can be offset by the new technology of artificial cavity installation (Copeyon 1990; Allen 1991).

Southern pine beetles are a problem pest in southern pines throughout the southeastern United States (Thatcher et al. 1980). Verbal reports from Arkansas, Louisiana, and Mississippi suggest that beetles are

infesting active cavity trees at higher than expected rates (Oliveria, pers. comm.). Thus, observations made here in Texas likely represent a southwide problem in areas where Red-cockaded Woodpeckers use loblolly and shortleaf pines for cavity trees.

THE FUTURE OUTLOOK FOR RED-COCKADED WOODPECKERS IN TEXAS

The biological diversity of southern pine ecosystems in Texas is closely tied to management of the Red-cockaded Woodpecker because of the dependence of many birds, mammals, amphibians, reptiles and arthropods on woodpecker cavities. Some problems such as the high loss rates of cavity trees to southern pine beetle infestation in loblolly and shortleaf pine habitat still need solutions. However, intensive management and subsequent favorable population responses observed on Texas national forests indicate that recovery of the Red-cockaded Woodpecker is possible. The outlook for Red-cockaded Woodpeckers in Texas and the rest of the, South is good; the ecological need exists and scientific technology is available to recover this endangered woodpecker and the ecosystem in which it thrives. The final outcome rests on the management priorities of federal and state agencies, and private land managers.

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