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Is a "hands-off" approach appropriate for red-cockaded woodpecker conservation in twenty-first-century landscapes?

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Abstract The endangered red-cockaded woodpecker (*Picoides borealis*) is well adapted to fire-maintained pine ecosystems of the southeastern United States. Management practices vary greatly among land ownerships. In some wilderness areas and state parks, a "no management" policy has eliminated use of prescribed fire, artificial cavities, and woodpecker translocation, tools that have proved effective elsewhere in recovering woodpecker populations. We compared forests with essentially "no management" to actively managed forests of similar tree ages and similar red-cockaded woodpecker population demographics. We also compared sites that had received no management in the past to the same sites after management. In every case, populations in forests that did not use state-of-the-art management for woodpeckers declined severely compared to those in managed forests. Because managed forests typically used all available management techniques concurrently, it was not possible to separate and rank effectiveness of specific management activities. One exception was the Wade Tract in Georgia, where prescribed fire was the primary activity for herbaceous layer and hardwood management in a high-density, stable woodpecker population. Wilderness areas, which are intended to be pristine places that preserve biodiversity, are losing red-cockaded woodpeckers, a keystone species in the ecosystem, at an alarming rate. Collectively, 9 groups of red-cockaded woodpeckers were present in 4 wilderness areas in Texas national forests in 1983. At the close of the millennium, only one woodpecker group remained and its continued existence is unlikely without management. The very fragmented features of present-day landscapes and intervention by humans impair the effectiveness of natural disturbance processes, primarily growing-season fire, that historically produced and maintained open pine savannas with grass-forb herbaceous layers in the pre-Columbian forests of the southeastern U.S.; therefore, active management must be used if the red-cockaded woodpecker is to persist.

Key words fire-maintained ecosystems, *Picoides borealis*, red-cockaded woodpecker, wilderness

The red-cockaded woodpecker (*Picoides borealis*) is unique among North American woodpeckers in that it evolved in and is well adapted to southern, fire-maintained pine ecosystems (Jackson 1971). Unlike many other woodpeckers that are closely associated with hardwood trees (Shackelford and Conner 1997), this endangered woodpecker is generally intolerant of hardwood midstory

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Red-cockaded woodpecker at a natural cavity.

(United States Fish and Wildlife Service 1985) and tends to prefer a regularly burned, open pine savanna with a diverse grass–forb herbaceous layer (James et al. 1997). Prescribed fire under the control of forest managers is currently the primary method by which fire occurs within the present-day pine ecosystems (Boyer 1990). Unlike pre-Columbian times, natural wildfires are currently suppressed because of their potential threat to life and property.

Today's fragmented landscapes and fire suppression to prevent property damage impair the ability of natural disturbance processes, particularly fire, to maintain the open character (low basal area) and grass-forb herbaceous layer of pine ecosystems in the southeastern U.S. (Conner et al. 1997, James et al. 1997). In addition, management policies on sonic public lands, such as wilderness areas, national parks, and state parks, typically minimize or eliminate prescribed fire and mechanical techniques as management options to serve as an alternative to natural processes.

Of great concern are current attempts through litigation to eliminate or reduce the ability of federal agencies to use prescribed fire and manage habitat for red-cockaded woodpeckers on public lands in general. The Texas Committee on Natural Resources, an environmental group, has alleged that prescribed fire and hardwood midstory reduction in upland pine ecosystems harms the pine ecosystem and negatively affects the red-cockaded woodpecker (Civil Action L-85-69-CA in Beaumont, Texas). This environmental group is actively pursuing a federal court injunction to prevent or limit the use of prescribed fire in pine ecosystems managed for red-cockaded woodpeckers. If successful, its efforts could lead to the elimination of fire-maintained pine ecosystems on some public lands.

If natural processes (e.g., lightning-started fires) are no longer able to maintain southern pine ecosystems, do limitations on forest management impact red-cockaded woodpecker populations? In this paper we explore the effects of a "hands-off approach" versus "state-of-the-art woodpecker management" by presenting case histories that compare unmanaged and managed woodpecker population trends within Texas national forests and in old-growth pine areas in Oklahoma, Louisiana, and Georgia.

Case histories from Texas national forests

Wilderness areas in national forests in eastern Texas

Red-cockaded woodpeckers occurred in 4 of 5 national forest wilderness areas in eastern Texas during the late 1970s and early 1980s prior to their official designation as wilderness. These areas, designated as RARE II lands, were set aside for protection in 1979 and 1980 and subsequently designated as wilderness areas by Congress in 1984 (Hendee 1986). Texas wilderness areas are mainly second-growth forest (Continuous Inventory of Stand Condition information 1996, unpublished database, National Forests and Grasslands in Texas). Since their designation under RARE II, none of the areas has received any timber harvesting, artificial cavities, mechanical midstory reduction, or prescribed fire. However, a first-year red-cockaded woodpecker was translocated to Upland Island Wilderness Area on 2 separate occasions.

Loblolly pines (*Pinus taeda*) dominate the canopy of Little Lake Creek Wilderness Area in the Sam Houston National Forest and Big Slough Wilderness Area in the Davy Crockett National For-

Active artificial cavity (insert type) in a pine

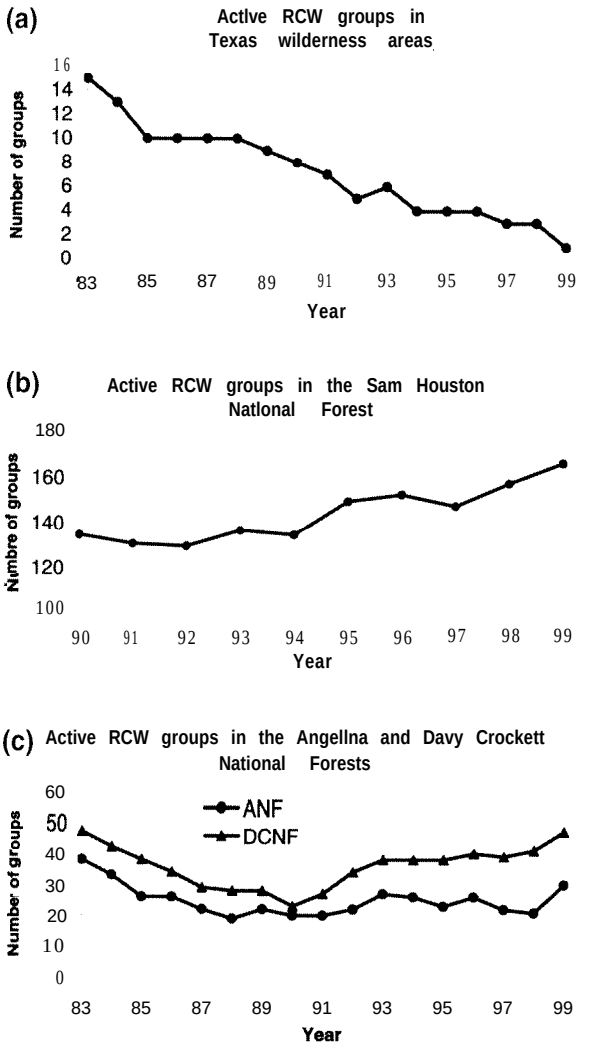

Figure 1. Red-cockaded woodpecker population trends in Texas national forests: (*a*) number of woodpecker groups in Texas wilderness areas 1983 to 1999, (*b*) number of woodpecker groups in the Sam Houston National Forest in Texas from 1990 to 1999, and (*c*) number of woodpecker groups in the Angelina and Davy Crockett national forests from 1983 to 1999. Note that Judge Parker ordered active red-cockaded woodpecker management in 1988 on the national forests in Texas.

est (Continuous Inventory of Stand Condition information 1996, unpublished database, National Forests and Grasslands in Texas). A mix of loblolly and shortleaf pines (*P. echinata*) dominate the overstory of Turkey Hill Wilderness Area in the northern portion of the Angelina National Forest, and the overstory of Upland Island Wilderness Area in the southern portion of the forest is dominated by longleaf pines (*P. palustris*).

Red-cockaded woodpeckers have declined steadily on wilderness areas within Texas national forests (Figure 1*a*). A single woodpecker group that was present in Big Slough Wilderness Area disappeared by 1989. Turkey Hill Wilderness Area had 3 groups of woodpeckers in 1983, but they were extirpated by 1991. Upland Island Wilderness Area supported 5 groups of woodpeckers in 1983, but the last group disappeared between late 1998 and early 1999. In 1999, only one group of red-cockaded woodpeckers remained in Little Lake Creek Wilderness Area, where 6 groups had occurred in 1990; extirpation of this lone group seems imminent.

General-use areas on the national forests in Texas

In contrast to wilderness areas, red-cockaded woodpecker habitat within general-use areas in Texas national forests is actively managed for the woodpecker. As with wilderness areas, all general-use areas on the national forests in Texas are predominantly second-growth forest (Continuous Inventory of Stand Condition information 1996, unpublished database, National Forests and Grasslands in Texas). Basic stand characteristics (soils, tree age, and dominant and co-dominant tree species) of the general-use areas are very similar to those found within wilderness areas. The overstory of the Sam Houston National Forest is composed

primarily of loblolly pine. Shortleaf pine is present in many older stands and dominates on some older sites (Rudolph and Conner 1994). The overstory 011 the Davy Crockett National Forest also is composed primarily of loblolly and shortleaf pines in the uplands (Conner and Rudolph 1989). Where red-cockaded woodpeckers occur on the northern portion of Angelina National Forest, the canopy is dominated by loblolly and shortleaf pines: longleaf pines dominate the uplands on the southern portion (Conner and Rudolph 1989).

Past woodpecker management (1983 to 19X7) in the general-use areas was **judged** to be inadequate in June 1988 by Judge Robert Parker. Judge Parker, in civil action L-85-69-CA in 1988, determined that the United States Forest Service's failure to reduce encroachment of hardwoods in red-cockaded woodpecker cluster areas and failure to implement prescribed fire were major causes associated with red-cockaded woodpecker population declines on Texas national forests. Judge Parker also ruled that failure of the agency lo conduct such management constituted "Take" under Section 9 **of** the Endangered Species Act (Pub. L. 93-205, HI Stat. 884, Dec. 197.1). In essence, Judge Parker's 1988 decision concluded that a lack of management is detrimental to this species. He ordered the United States Forest Service to establish :I pine basal area of 13.6 m^2 /ha within 1,200 m of' any woodpecker cavity-tree cluster and establish a program of hardwood midstory removal in and adjacent to cluster sites. In addition, Judge Parker halted even-aged harvesting techniques and ordered a program of uneven-aged management that preserves "old growth" pines within 1,200 m of any cluster site. He also restricted vehicular travel to the essential minimum on misting nonpaved roads within 1 ,200 m of any cluster site. In a second court order, Judge Parker encouraged use of artificial cavities (Copeyon 1990, Allen 199 I), and one to several artificial cavities were subsequently installed within most active and inactive clusters in national forests in Texas. Currently, losses of cavities (caused by cavity-tree mortality or cavity enlargement) in active clusters are usually mitigated quickly by installing an artificial cavity.

In 1990, I 35 groups of woodpeckers were present on the Sam I Iouston National Forest. Complete population data prior to 1990 for this forest does not exist. By 1999, the population had grown Lo 1 67 groups (Figure 1 *b*). During this same time period. the Sam Houston National Forest donated over 100 first-year woodpeckers to other forests in attempts to increase their populations.

Red-cockaded woodpecker population databases for the Angelina and Davy Crockett national forests first became available in 1983, well before Judge Parker's 1988 court decision (Conner and Rudolph 1989). The Angelina National Forest population had 30 groups of woodpeckers iii 1983 but declined to 16 in 1988. The population began to increase soon after the implementation of the court order and by 1999 it again reached 30 groups (Figure 1*c*). The Davy Crockett National Forest population had 46 groups in 1983 and that number declined to 22 groups in 1990. This population increased to 47 groups by 1999 following implementation of court-ordered management and woodpecker translocation (Figure I *c*).

Case histories for old-growth pine forests

McCurtain County Wilderness Area

I Iistorically, the McCurtain County Wilderness Area was a fire-maintained shortleaf pine–bluestem (*Andropogon* spp.) ecosystem iii the Interior Highlands of southeastern Oklahoma (Carter 1965, 1967). In 1926, fire suppression **was** instituted within this area (Carter 1967), and the property was designated ;I wilderness area by the Oklahoma State Legislature in 195 1. With designation as a wilderness area, all timber harvesting was eliminatccl and fire continued to be excluded, causing a hardwood invasion into the midstory and lower canopy (Masters et al. 1995).

The number of' red-cockaded woodpecker groups present on McCurtain County Wilderness Area when fire was first excluded in 1926 is unknown. In 1077, 35 woodpecker groups were present (Wood and Lewis 1977), but this number declined by more than 50% to 17 groups by 1985 (Masters et al. 1989). Aware of the woodpecker population decline, Kelly et al. (1994) suggested that reestablishment of fire could be used to restore the original character of the area and might be beneficial to red-cockaded woodpeckers. Historical evidence suggested that frequent firm, with mean fire-return intervals of 3.5 and 5.6 years within 300- and 800-ha plots, respectively, would be adequate to restore the open shortleaf pine ecosystem within the wilderness area (Masters et al. 1995).

In 1992, hardwood midstory removal in cluster areas and prescribed fire were implemented to

improve red-cockaded woodpecker habitat (J. Skeen, personal communication). Although shortleaf pines in excess of 200-300 years old are still abundant in McCurtain County Wilderness Area for cavity excavation, artificial cavities (Copeyon 1990, Allen 1991) and woodpecker translocations also were used to attempt to increase the existing woodpecker population. In 1999, only I 1 groups remained on the wilderness area (J. Skeen, personal communication). Although the population continues to decline, it appears that the rate of decline has slowed since management practices were implemented to improve woodpecker habitat (Figure 2*a*).

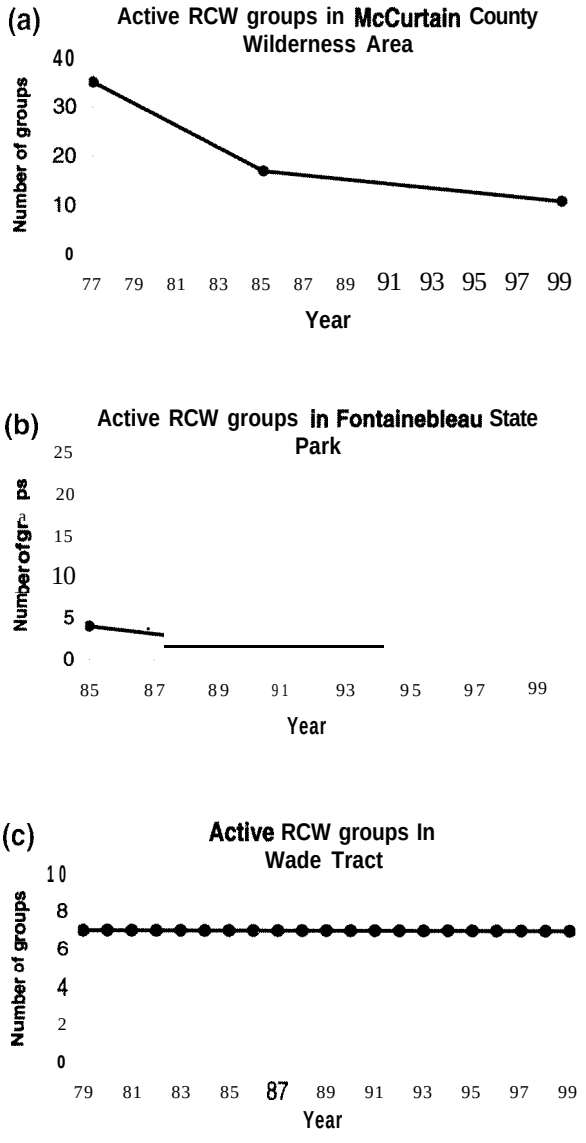

Figure 2. Red-cockaded woodpecker population trends in old-growth pine forests: (*a*) number of woodpecker groups in McCurtain County Wilderness Area in Oklahoma from 1977 to 1999, (*b*) number of woodpecker groups in Fontainebleau State Park in Louisiana from 1985 to 1999, and (*c*) number of woodpecker groups in the Wade Tract in Georgia from 1979 to 1999.

Fontainebleau State Park

In Fontainebleau State Park in southeastern Louisiana, old pines were abundant i n the mid-1980s and red-cockaded woodpeckers used I 56- 17 1 year-old loblolly pines and 208-374 year-old longleaf pines for roost and nest trees (Teitelbaum and Smith 1985). No artificial cavities were installed in the state park, and because prescribed fire was rarely used, an extremely dense hardwood midstory was present throughout much of the park.

In 1983, Teitelbaum and Smith (1985) reported 16 active cavities in a 32-ha study area on the northern portion of Fontainebleau State Park. Data from the Louisiana Department of Wildlife and Fisheries Natural Heritage Program suggest that there were at least 2 groups in 1983 (S. Shively, personal communication). By 1994, all red-cockaded woodpeckers had been extirpated from the state park (S. Shively, personal communication; Figure 2*b*). In 1995, bark beetles (*Ips* spp. and *Dendroctonus* spp.) infested the pines in Fontainebleau State Park and all pines were removed where red-cockaded woodpeckers had occurred (S. Shively, personal communication).

Red-cockaded woodpeckers also inhabited the property immediately north and across the street from Fontainebleau State Park, the grounds of the Southeast Louisiana State Hospital. Unlike the park, the hospital grounds are mowed regularly, giving them an open, parklike appearance. Natural Heritage Program data indicate that there were j-4 groups of' woodpeckers on the hospital grounds in 1988, and three groups still persisted in 1996 (S. Shively, personal communication).

Other unmanaged old-growth sites

Two additional old-growth pine areas in the South deserve anecdotal mention. The Chinsegut 1 Iill Preserve in Hernando County, Florida, is a "virgin" old-growth longleaf pine forest (160 ha) that is somewhat comparable to the Wade Tract (Hirth et al. 199 I). However, controlled burning was conducted on the site until 1960, then excluded until 1 977, when winter burning was reintroduced. During the 17-year period of fire exclusion a dense hardwood midstory and understory developed, and the "cooler" winter burning could not eliminate the

hardwood encroachment. Avian community sampling between 1976 and 1979 did not detect red-cockaded woodpeckers on the site, although the presence of inactive red-cockaded woodpecker cavity trees indicated they had previously inhabited the forest (T. Engstrom, personal observation). Encroaching hardwood vegetation combined with isolation from other woodpecker groups likely caused the extirpation of red-cockaded woodpeckers from this old-growth longleaf pine forest (Hirth et al. 1991).

A nearly identical scenario occurred on the Flomaton Tract in Alabama, where fire was excluded from another virgin, old-growth longleaf pine forest (25 ha) for over 40 years (Kush and Meldahl 1995). As with the Chinsegut Hill Preserve, the Flomaton Tract now has a well-developed colloquial hardwood midstory and only inactive red-cockaded woodpecker cavity trees remain to indicate that the endangered bird once occupied the forest (Ii. N. Conner and R.T. Engstrom, personal observations).

The Wade Tract

In contrast to McCurtain County Wilderness Area, Fontainebleau State Park, and other unmanaged old-growth sites, the Wade Tract is an 80-ha portion of managed old-growth longleaf pine forest near Thomasville in southwestern Georgia (Engstrom and James 1981, Platt et al. 1988). This stand has been used for research since 1979, when a conservation easement held by Tall Timbers Research Station was established. This stand is embedded in a predominantly forested landscape of private ownership that is used primarily for northern bobwhite (*Colinus virginianus*) hunting. The forest habitat surrounding the Wade Tract has been managed under a single-tree harvesting system (Ned 1967) for at least 50 years. Prior to the conservation casement, the only trees removed from the Wade Tract were dead or dying trees salvaged after lightning strikes or bark-beetle attacks.

The Wade Tract is dominated by longleaf pine (>90% of the number of trees and basal area of trees >8 cm DBH) and is relatively open (mean density: 127 trees/ha), with a lush, herbaceous ground cover (Engstrom and James 1981). Many of the overstory trees are 200 to 250 years old (Platt et al. 1988). Prescribed tire has been the primary management activity on the Wade Tract since the easement was granted in 1979. Typically, annual fires were set after the quail-hunting season from March to early April. The fire regime of the Wade Tract was changed to May-June fires in 1982 to mimic more closely the timing of natural fires started by lightning. Currently, one-half of the Wade Tract is burned annually during the growing season. A large red-cockaded woodpecker population surrounds the Wade Tract; thus, demographic isolation is not a problem (Engstrom and Baker 1995).

Seven red-cockaded woodpecker groups have existed on the Wade Tract for 20 years (Engstrom and James 198 I, Engstrom and Sanders 1997, Figure 2*c*). L. Neel (personal communication) first observed red-cockaded woodpeckers there in 195 I, which indicates that the woodpecker has inhabited the tract for at least 50 years. Given the old-growth condition of this forest, it is likely that a red-cockaded woodpecker population has been present for hundreds of years.

Discussion

Jackson et al. (1986) suggested that there was good potential to increase red-cockaded woodpecker numbers on wilderness areas in fire-disclimax ecosystems if such areas were maintained with fire to prevent hardwood encroachment. Over a decade later, red-cockaded woodpeckers are nearly completely extirpated from Texas and McCurtain County wilderness areas (Figures 1*a* and 2*a*). In contrast, actively managed populations in general-use areas on Texas national forests and the Wade Tract appear to be doing significantly better (Figures I *b*, *c*, and 2*c*). So what happened?

Factors affecting population trends

Pine tree age. It is well documented that red-cockaded woodpeckers require old pines (Jackson 1979, Conner and O'Halloran 1987, DeLotelle and Epting 1988), and harvesting these pines has been the primary reason for the bird's initial decline and endangered status. McCurtain County Wilderness Area, Fontainebleau State Park, and the Wade Tract all had abundant old-growth pines, yet woodpecker populations in McCurtain County and Fontainebleau both declined severely, whereas the Wade Tract population remained stable. The pines in the wilderness areas on the national forests in Texas are approximately the same age as the pines on the general-use areas of these forests. Again, the woodpecker populations in the unmanaged areas declined, yet no decline occurred in the managed areas with similarly aged pines. Because pines of similar ages existed in managed and unmanaged

sites, it is improbable that the observed declines in unmanaged areas arc the result of differences in the numbers of old pine trees.

Cavity availability. Cavity losses through tree mortality or cavity enlargement by other species can exceed new-cavity excavation (Conner and Rudolph 1995*a*). Replacement cavities often require several years to excavate (Conner and Rudolph 1995*a*); thus, cavity losses can threaten the persistence of a woodpecker group at a cavity-tree cluster. The woodpecker groups in wilderness areas on the national forests in Texas never received any artificial cavities, but groups in the general-use areas began to receive them after 1990 (Conner et al. 1995).

Woodpecker populations in McCurtain County Wilderness Area showed a rapid decline prior to the use of artificial cavities. After artificial cavities were installed, the rate of decline in this population slowed considerably (Figure 2*a*). As with other woodpecker management techniques, the apparent success of the insert cavities is confounded by concurrent reduction of hardwood midstory and woodpecker reintroductions.

it is unclear whether cavity availability played a role in the extirpation of red-cockaded woodpeckers in Fontainebleau State Park. The Wade Tract never received artificial cavities, yet the population has remained stable, demonstrating that under excellent habitat and demographic conditions, use of artificial cavities is not necessary.

Habitat fragmentation and demographic isolation. Habitat fragmentation caused by deforestation has been shown to negatively affect woodpecker group size and magnify the effects of demographic isolation (Conner and Rudolph 1989, 199 1 ; Rudolph and Conner 1994). Because of this process, the rate of successful dispersal of juvenile birds to other woodpecker groups to fill breeding vacancies likely has decreased in most populations (Conner and Rudolph 199 1) and has contributed to population declines.

All of the woodpecker populations in the wilderness areas in the national forests in Texas were small and somewhat isolated from larger populations, which likely contributed to their declines. However, James (1995) suggested that red-cockaded woodpeckers appear to be quite persistent even in small populations as long as the habitat remains in good condition. Many woodpecker groups on the general-use areas of the Texas national forests were as isolated as wilderness woodpecker groups during the same time period, but translocations of birds to these sites helped alleviate the problem of inadequate natural dispersal, and the numbers of these groups remained stable or increased. The population on the McCurtain County Wilderness Area was quite large (35 groups) when it was first reported in 1977 (Wood and Lewis 1977), but it still declined rapidly. The population decline slowed after a woodpecker reintroduction program was begun, midstory around cavity trees was reduced, and artificial cavities were installed. Because none of the translocated woodpeckers could be relocated following reintroduction attempts, wc do not believe that this technique provided any benefit. Therefore, we suggest that demographic isolation may not have been a major factor in the initial decline in this population. Although demographic problems probably contributed to the extirpation of the Fontainebleau State Park population, woodpeckers still occur on the mowed grounds of the state hospital across the street, suggesting that demographic isolation also may not have played an important role iii the extirpation of this population.

Augmentation and reintroduction. Singles and pairs of first-year birds have been translocated to the general-use areas of the national forests in Texas, whereas only one site in the Upland Island Wilderness Area received a single bird on 2 separate occasions (Rudolph et al. 1992, Carrie et al. 1999). A large portion of the observed population increases in the general-use areas appears to be the direct result of these translocations (Saenz, unpublished data). McCurtain County Wilderness Area and the general-use areas on Texas national forests provide good examples of population trends pre- and post-translocation. The rate of population decline slowed in McCurtain County, and populations in the national forests in Texas increased soon after translocation programs began.

Midstory and herbaceous layer condition. Cluster abandonment by red-cockaded woodpeckers is correlated with increasing encroachment of hardwood vegetation, which results from infrequent or total absence of fire in pine ecosystems (Beckett 1971, Van Balen and Doerr 1978, Conner and Rudolph 1989, Loeb et al. 1992). This species appears to prefer open pine stands with a grass-forb herbaceous layer (James et al. 1997).

Wilderness areas on Texas national forests and in McCurtain County Wilderness Area, forests without or with recently initiated midstory and herbaceous-layer management programs, showed severe woodpecker population declines compared to areas with

Table 1. Principal causes of decline of red-cockaded woodpeckers and practices that can potentially reverse declines.

Cause	Effect	Solution
Loss of old living pine trees	Insufficient numbers and quality of trees in which cavities that are used for nesting and roosting can be constructed (Conner and O'Halloran 1987). Lower quality foraging (Collins1998). Old living pine trees are preferred foraging locations (Engstrom and Sanders 1997).	Alternative silviculture in forests managed for timber production (Rudolph and Conner 1996). Installation of artificial cavities (Copeyon 1990, Allen 1991).
Hardwood intrusion	Alteration of arthropod food base (James et al. 1997, Collins 1998). Cluster abandonment (Loeb et al. 1992)	Use prescribed growing-season fire to inhibit hardwood growth (Boyer 1990). Mechanical removal of hardwoods. (Conner et al. 1995). Chemical treatment of hardwoods (Conner 1989).
Small population size	Demographic stochasticity (Conner and Rudolph 1991). Possible inbreeding depression (Meffe and Carroll 1997)	Translocation of first-year woodpeckers for augmentation and reintroduction (Carrie et al. 1999.)
Forest fragmentation	Less foraging habitat (Conner and Rudolph 1991). Increased risk of predation (Meffe and Carroll 1997). Increased loss of cavity trees caused by wind damage (Conner and Rudolph 1995*b*).	Silvicultural techniques (Rudolph and Conner 1996), conservation goals, and agreements among public and private organizations and individuals.

aggressive prescribed fire programs and midstory management. Unfortunately, other management practices, such as artificial cavity installation and woodpecker translocation, confound the importance of the midstory reduction with fire and mechanical means. A notable exception that focuses on the importance of hardwood midstory reduction is available from Texas prior to the advent of translocation and artificial cavity installation programs. Between 1983 and 1988, cavity-tree clusters that were relatively devoid of hardwood midstory on the Angelina and Davy Crockett national forests had a statistically significant greater probability of remaining active than clusters containing a well-developed hardwood midstory (Conner and Rudolph 1989).

Fontainebleau State Park was not managed actively for red-cockaded woodpeckers, whereas the grounds of' Southeast Louisiana State Hospital (the property immediately adjacent to this state park) were mowed regularly. Neither artificial cavities nor woodpecker translocations were used on the hospital grounds. Because the woodpeckers wet-c extirpated from the state park but still reside on the hospital grounds, a compelling argument can be made that deteriorating midstory conditions in the state park were the direct cause of the extirpation. The Wade Tract, where habitat is prescribed-burned every 2 years and the woodpecker population has remained stable for at least LO years, is an excellent example of the benefit to red-cockaded woodpeckers of a prescribed fire program that manages niiclstory and maintains a diverse herbaceous layer.

Conclusions

Red-cockaded woodpecker management for most populations today is emergency management. Typically, all possible woodpecker recovery techniques are concurrently implemented; therefore, no single management technique can be identified as being the most important to influence red-cockaded woodpecker population recovery. Collectively, a lack of available cavities, excessive hardwood midstory, forest fragmentation, and demographic isolation all contribute to woodpecker population decline and eventual extirpation. Each of these problems by itself could cause extirpation. The relative speed at which each of these factors causes extirpation and the synergistic effects of multiple problems are unknown.

Several methods can be used to restore pine ecosystems to a condition suitable for red-cockaded woodpeckers (Table1). In most situations, fire should be reintroduced as a management tool, as it is an essential ecosystem process (Brender and Cooper 1968). In addition to reducing hardwoods within woodpecker cluster sites, fire provides sufficient disturbance for the persistence of open pine stands and a diverse herbaceous layer that provides habitat for many other sensitive plants and animals. Without fire, pine regeneration will become limited (Langdon 1981) and the ecosystem will succeed into a hard-

wood-dominated forest. Where timber harvesting is permitted (nonwilderness areas), only silvicultural options that assure a sustainable supply of mature (100- to 150+-year-old) pines should be used. Artificial cavities and woodpecker translocations should be implemented until the populations reach levels at which natural cavity excavation rates and woodpecker dispersal are adequate to maintain the populations independent of human intervention.

Artificial cavities, mechanical midstory removal, and woodpecker translocation are short-term fixes to a larger problem, a loss of ecosystem integrity. In addition to the red-cockaded woodpecker, a variety of other plant and animal species associated with the fire-maintained pine savanna ecosystem are being eliminated from a large portion of their range (Platt 1999). Unfragmented habitat and all appropriate ecosystem processes, particularly fire, are essential to maintain upland pine habitat for woodpecker conservation and maintenance of the high biodiversity characteristic of these ecosystems. A goal of the Wilderness Act of 1964 (PL 88-577) was to maintain wilderness in its aboriginal condition. For some, this concept apparently has been replaced with the idea that wilderness is a "no management" area. The "no management" philosophy has been catastrophic for red-cockaded woodpeckers in particular and fire-maintained ecosystems in general. Wilderness areas still have the potential to be places where red-cockaded woodpeckers can regain a stronghold. However, this will not likely occur without fire (though smoke-management issues in the 21st century may play a major role in limiting use of fire in some locations, thus necessitating use of mechanical midstory control). Use of fire also fits the "minimal-tool rule" for wilderness management (Hendee 1986). Fire has been and continues to be the primary driving force in creating and maintaining southern pine ecosystems, the system in which red-cockaded woodpeckers evolved.

Prescribed fire being used to reduce hardwood midstory vegetation to maintain optimal red-cockaded woodpecker habitat.

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