INDUCTION OF RED-COCKADED WOODPECKER GROUP FORMATION BY ARTIFICIAL CAVITY CONSTRUCTION

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Abstract: Previous research suggested that red-cockaded woodpeckers (*Picoides borealis*) were reluctant to occupy sites lacking sufficient existing cavities, despite their being exclusively primary cavity users. We provisioned 10 vacant sites (sites lacking cavity tree clusters and red-cockadeds) and 10 abandoned sites (sites with existing clusters no longer occupied by red-cockadeds) in the Sandhills region of North Carolina with cavities and cavity starts we constructed in 1988 and 1989. By July 1989, 18 of 20 experimental sites had been occupied, resulting in the net addition of 12 social groups to the population. No control sites were occupied. Occupation of previously vacant areas and rapid increases in the number of social units in a population are rare events in this and other populations in the absence of cavity provisioning. Cavity provisioning can be used to stabilize or increase red-cockaded woodpecker populations.

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The red-cockaded woodpecker is an endangered species endemic to the pine forests of the southeastern United States (Jackson 1971). Red-cockaded woodpeckers are cooperative breeders and typically occur in groups (clans) consisting of a breeding pair and 0–3 male helpers (Ligon 1970, Lennartz et al. 1987, Walters et al. 1988). Each group inhabits and defends a territory consisting of foraging habitat and a cluster of cavity trees containing completed cavities and cavity starts (partially excavated cavities). They construct cavities for nesting and roosting within live pines, a process that takes from 10 months (Baker 1971) to several years (Jackson et al. 1979). Once completed, a cavity may be used for many years.

A major obstacle to conservation of the red-cockaded woodpecker has been the rarity with which new groups form (Ligon et al. 1986). New groups can form by creating new territories or by reoccupying abandoned ones. Birds can create new territories by pioneering, in which birds disperse into an area not previously occupied, or by budding, in which an existing territory (and often the existing group) is split into two (Hooper 1983, Walters 1990). In a population of over 200 groups in the Sandhills of North Carolina, territorial budding resulted in the formation of only 6 new groups in 8 years, whereas pioneering was never observed (Walters 1990). Reoccupation of abandoned territories is more common, resulting in the formation of 22 new groups in 8 years in the Sandhills, for example (Walters 1990). Still, in the Sandhills the rate of reoccupation of abandoned territories was only 8.7% per year, and only about half the reoccupations ultimately resulted in formation of new groups (Doerr et al. 1989).

Because a set of cavities requires so much time to construct, a red-cockaded woodpecker might be better off attempting to acquire an existing set of cavities, even if reproduction is thereby delayed, rather than constructing a set in a vacant area. Thus, birds might compete for territories with suitable existing cavities, rather than create new cavity clusters, or inhabit territories with too few or poor cavities. The population dynamics of the species seems to support this contention (Walters et al. 1988, Doerr et al. 1989). The hypothesis that red-cockaded woodpeckers compete for existing cavity tree clusters rather than construct new ones might explain why formation of new territories is so rare, and why some abandoned territories are not reoccupied, if the latter lack sufficient suitable cavities.

We tested this hypothesis by provisioning vacant areas and abandoned territories with cavities we constructed. If our hypothesis that red-cockadeds compete for existing clusters in preference to creating new ones is correct, we expect them to occupy vacant sites provisioned with artificially constructed clusters, but not those lacking clusters. However, if cluster presence or absence has no bearing on site preference, they should occupy both types of sites at an equal rate. In abandoned territories, we also removed hardwood understory and midstory from the vicinity of cavity trees. Hardwood encroachment on cavities is thought to lead to territory abandonment (Jackson 1978*a*, U.S. Fish Wildl. Serv. 1985, Conner and Rudolph 1989). If hardwood encroachment alone prevents reoccupation, we expect territories from which hardwoods are removed, regardless of whether or not they are provisioned with cavities, to be reoccupied at a higher rate than those in which hardwoods remain. If instead, or in addition, territories remain abandoned because cavities within them are unsuitable, we expect rates of reoccupation of territories without provisioned cavities, regardless of whether hardwoods are removed, to be lower than the rate of reoccupation of territories to which cavities have been added and from which hardwoods have been removed. Finally, we added cavities to some occupied territories. If artificially constructed cavities within occupied territories are used by birds, but those cavities placed in abandoned or vacant sites are not used, then our hypothesis is incorrect. If birds in occupied territories do not use artificially constructed cavities, we can conclude that these cavities are unsuitable and that our hypothesis is not adequately tested.

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STUDY AREA

Our study area encompassed over 110,000 ha in the Sandhills region of southcentral North Carolina within Moore, Hoke, Richmond, and Scotland counties. The area is forested predominantly with second-growth longleaf pine (*Pinus palustris*), with an understory of 1 to several species of oak (*Quercus* spp.). Dense understories and midstories are common where hardwood management (i.e., prescribed burning) and wildfires have been infrequent. A detailed description of the study area can be found in Walters et al. (1988).

Our research was part of a 10-year population study of the red-cockaded woodpecker in the Sandhills. The study population is 1 of the 3 largest remaining populations of the species. The locations of the 414 cavity tree clusters (colony sites) within the study area are known, and each is checked annually in the spring to determine if it is active or abandoned. Approximately 30% of the cavity tree clusters are abandoned at any given time (Doerr et al. 1989). All active clusters are monitored during the breeding season. All members of each of the approximately 225 groups in the study area are identified by their unique combinations of colored leg bands. All nestlings are colorbanded, and the identity of all fledglings is determined ($\bar{x} = 1.23$ fledglings/group). About 59% of the groups consist of male–female pairs, and 30% include ≥ 1 helpers. The remaining 11% of the social units consist of solitary (unpaired) males (Walters et al. 1988). Breeding vacancies are filled primarily by male helpers and dispersing fledglings. See Walters et al. (1988) for details of monitoring and censusing techniques.

METHODS

Experimental Design

Vacant Sites.—We located 20 vacant sites, each consisting of unoccupied forested areas that appeared suitable for red-cockaded woodpeckers within our study area. These vacant sites showed no evidence of past or present occupation by red-cockadeds; that is, they contained no starts, active cavities, inactive cavities, or resident red-cockaded woodpeckers. Each site was located at least 0.5 km from existing cavity tree clusters to avoid potential territory overlap. Previous research indicated that clusters 0.5 km apart were occupied by distinct groups in our study area (Walters et al. 1988). We paired the 20 vacant sites according to habitat characteristics: overstory type (longleaf pine, longleaf-loblolly pine [*P. taeda*], loblolly pine); overstory age (< or > 100 yr); and understory-midstory type (scrub oak, savannah, mesic hardwood, xeric hardwood, or golf course). We chose the experimental site within each pair by a coin toss. We provisioned each of the 10 vacant experimental sites with 2 complete cavities and 3 cavity starts, drilled in old, live pines, using the technique described in Copeyon (1990). We constructed cavities from February 1988 to February 1989, but ceased construction from April to October 1988 while we monitored breeding activities.

Where hardwood encroachment occurred, we used a chainsaw and hatchet to manually clear understory and midstory vegetation ≥0.75 m in height from a 5–10-m radius area surrounding each experimental tree so that woodpeckers would have unimpeded access to constructed cavities and starts. To control for the effect of this clearing, we selected 5 "control trees" in each of the 10 vacant control sites. We used the same criteria employed in selecting trees for cavity and start construction in vacant experimental sites to choose control trees, but we did not construct cavities or starts in them. We cleared hardwood understory and midstory from the vicinity of control trees in the same manner as for experimental sites.

Abandoned Sites.—From among 124 abandoned clusters in the study area (Doerr et al. 1989), we selected 20 composed mostly of what we perceived to be "unsuitable" cavities. These clusters had been abandoned for at least 3 years (range = 3–>10 yr) and were at least 0.5 km from all other clusters. Cavities can become unsuitable due to enlargement by other woodpecker species (Jackson 1978*b*), by cavity deterioration, or by hardwood encroachment. Deterioration, especially of the cavity floor, occurs as the heartwood decays over time (Conner and Locke 1982), which can cause cavity abandonment (Beckett 1971).

We paired these 20 abandoned clusters in the same manner as vacant sites, and again chose the experimental site within each pair by a coin toss. We provisioned the 10 abandoned experimental sites with 1–2 complete cavities and 3 starts per site, but we added no new cavities or starts to the 10 abandoned control sites. Whenever possible, cavities were constructed in the immediate vicinity of existing cavity trees within abandoned experimental sites. In all cases, new cavities were constructed within 100 m of existing cavities. As in vacant sites, we removed hardwood understory and midstory from around all experimental and control trees. When possible, we used 5 existing cavity and start trees as control trees within abandoned control sites. When fewer than 5 such trees existed, we selected additional control trees in the same manner as we selected control trees in vacant control sites.

We tested for effects of hardwood removal by pairing the abandoned control sites, which were cleared, with a set of abandoned understory control sites, from which we did not clear hardwood midstory and understory. We did not construct cavities in understory control sites.

Cavity-Limited Sites.—To test whether constructed cavities were acceptable to the birds, we chose occupied sites (termed cavity-limited sites) that had few roosting cavities relative to the number of red-cockaded woodpeckers present. We constructed 1 cavity and 1–2 starts in each of 7 cavity-limited sites.

Site Monitoring

We checked abandoned experimental and vacant experimental sites monthly throughout the breeding season (Apr–Jul 1988 and 1989) for evidence of use by red-cockaded woodpeckers. Because the birds chip into the sapwood to maintain a protective resin barrier around the cavities they use (Jackson 1977), active use can be reliably assessed by the presence of fresh resin wells. We considered a site active if at least 1 cavity or start tree had fresh resin wells, or if there were fresh wood chips in the cavity chamber or entrance tunnel. Activity was always confirmed by visiting the site at dusk to observe birds coming to roost. We also monitored abandoned control and understory control sites for signs of red-cockaded woodpecker occupation. We checked all cavity trees within abandoned control and understory control sites in the spring 1988 and 1989 for evidence of red-cockaded woodpecker activity. Cavity trees within abandoned control sites were again checked in the late summer 1989. Because sap flow from resin wells is detectable for many months, this frequency of inspection permitted detection of even brief occupation of cavities between visits. Between breeding seasons (Aug–Mar), we checked previously inactive experimental sites for activity every 1–2 months.

Once a site became active, we visited it every 9–11 days throughout the breeding season to determine the identity of the red-cockaded woodpeckers using the site. If we observed no birds during these visits, we visited the site at dusk to observe the birds coming to roost. Birds lacking bands were captured and banded. We thus knew the previous histories of most of the birds occupying sites so that we could, for example, determine whether occupation was by a new group or a previously existing group.

When nesting occurred within a site, we

checked the status of the nest (e.g., No. eggs, No. nestlings) every 9–11 days until nestlings reached the appropriate age (4–10 days) for banding. After banding nestlings, we next visited the site a few days after the young were scheduled to fledge to count and identify fledglings. See Walters et al. (1988) for details of monitoring procedures.

We monitored vacant control sites differently because they lacked cavities. We demarcated a 0.5-km radius area for each vacant control site and surveyed these areas for the presence of cavity and start trees in July–August 1989. We walked 11–12 straight-line transects about 80 m apart through the entire area.

Data Analysis

We used matched pairs tests to assess differences in success (occupation) and failure (no occupation) within matched pairs of experimental and control sites. The test statistic only involves pairs in which either the experimental or the control site is occupied; pairs in which both or neither of the experimental and control sites were occupied do not distinguish differences between sites. The null hypothesis is there is no difference in the proportion of successes between experimental and control sites; that is, there should be as many pairs in which only the control site is occupied as pairs in which only the experimental site is occupied. Our alternative hypothesis is that red-cockaded woodpeckers are more likely to occupy experimental sites than control sites; that is, there should be more pairs in which only the experimental site is occupied than pairs in which only the control site is occupied. We determined significance levels using binomial probability testing (Snedecor and Cochran 1980:112, 121–123). When a binomial probability distribution,

$$P(X = r) = \binom{n}{r} p^r (1 - p)^{n-r}$$

is applied to a matched pairs test, r = the number of pairs in which only the experimental site is occupied, p = the probability of obtaining such a pair, and n = the total number of pairs in which only 1 of the 2 sites is occupied. Under our null hypotheses, $p = ½$.

RESULTS

Vacant and Abandoned Sites

Red-cockaded woodpeckers were more likely ($P = 0.002$) to occupy vacant experimental sites than vacant control sites. Nine vacant experimental sites were occupied, whereas no vacant control sites were.

Red-cockaded woodpeckers were also more likely ($P = 0.002$) to occupy abandoned experimental sites than abandoned control sites. Nine abandoned experimental sites were occupied by red-cockaded woodpeckers, whereas no abandoned control sites were. Red-cockaded woodpeckers also failed to occupy understory control sites. Abandoned sites lacking constructed cavities were not occupied, regardless of whether we removed hardwood understory and midstory.

Despite the fact that experimental cavities were located within the immediate vicinity of existing cavities within abandoned experimental sites, red-cockaded woodpeckers almost exclusively used constructed cavities for roosting and nesting. In only 1 instance did a bird (F) use a pre-existing cavity within an abandoned experimental site. She used the cavity for approximately 3 months and then began roosting in one of the constructed cavities.

The 18 vacant experimental and abandoned experimental sites occupied represent a net addition of 12 social units to the population: 7 male–female pairs and 5 unpaired males. Ten sites were occupied by new social units: 6 pairs and 4 unpaired males. Four sites were captured, that is used by adjacent groups that continued to use their original cluster as well. Three sites were occupied by pairs that shifted from adjacent clusters, leaving the latter unoccupied. In 2 of these 3 cases, the pair's original cluster was occupied by new birds, a pair in 1 case and an unpaired male in the other. These 2 social units are included in the total of 12 new social units. Finally, 1 site was occupied by a solitary male, but an adjacent site formerly occupied by other birds was abandoned at the same time. Therefore, this social unit was not counted as an addition to the population.

New groups occupying experimental sites appeared to conduct all their activities, including foraging, in the vicinity of the site. When followed, they foraged within 0.25 km of the cavities, and they reacted aggressively to any neighboring or intruding birds encountered. Experimental sites captured by previously existing groups were used primarily for roosting by 1 group member. When followed from the cavity, such birds flew toward their group's cluster and rejoined the group. Once young fledged, often some or all of them accompanied the adult to the captured cluster.

Excluding the 3 pairs that shifted to experimental sites, the majority of the birds occupying experimental sites during the 1989 breeding season previously were floaters (birds that do not defend a particular territory or affiliate with a particular group), helpers, or fledglings—the classes of individuals that typically compete for breeding vacancies (Walters et al. 1988). Two of 6 females were fledglings, one was a floater, and three were breeders. Two of the breeders moved from an adjacent territory, and one moved from 3 territories away. In this population, 17% of surviving breeding females switch groups between years, and 61% of these move to an adjacent territory (Walters 1990). Three of 11 males were fledglings, one was a floater, three were helpers, two were breeders, and two were unbanded. (Unbanded birds dispersing into the study area are most likely fledglings; see Walters et al. [1988].) Two of the helpers moved from 2 territories away and one from an adjacent territory. One of the breeders moved from 3 territories away, and one from 2 territories away. In this population, 16% of surviving helpers disperse to become breeders each year, and 61% of these move to an adjacent territory, whereas only 2% of surviving breeding males moved, and 88% of these moved to an adjacent territory (Walters 1990). Thus, the movements of breeding males to experimental sites represent unusual events.

Nesting Success.—Six sites (3 vacant experimental and 3 abandoned experimental) were occupied by male–female pairs by April 1989, and all 6 pairs made nesting attempts during the 1989 breeding season. Three groups nested successfully on their first attempt, 2 groups failed in their only nesting attempt, and 1 group failed once but renested successfully. Nest failure averages 27% in this population (LaBranche 1988). Seven young (5 M and 2 F) were fledged from the 4 successful nests. This is 1.2 fledglings per breeding group, equal to the population average. None of the 3 pairs that first occupied experimental sites later than April attempted nesting.

Cavity-Limited Sites

As of November 1989, 6 of 7 constructed cavities had been used by red-cockaded woodpeckers, five for roosting, and one for roosting and nesting. Five of 12 constructed starts were partially or completely excavated. Three of the cavity-limited sites contained unpaired males prior to cavity construction, two contained pairs, one was captured, and one was recently abandoned. Two of the sites previously occupied by unpaired males still held an unpaired male in 1989, and the third was occupied by a pair. Both sites that previously held pairs still had pairs in 1989, the recently abandoned site was captured, and the captured site was occupied by a pair. In this population, 91% of sites that house groups in 1 year still house them the next, and 8.7% of abandoned sites are reoccupied annually (5.1% captured, 3.6% occupied by solitary M or pair). Of those sites occupied by solitary males, 26% still house solitary males the next year, whereas 39% are occupied by pairs (Doerr et al. 1989).

Other Occupants

Fourteen of 44 constructed cavities (32%) were used by species other than red-cockaded woodpeckers. Southern flying squirrels (*Glaucomys volans*) usurped 6 active and 4 inactive cavities. Female red-bellied woodpeckers (*Melanerpes carolinus*) roosted in 2 active cavities, and eastern bluebirds (*Sialia sialis*) and white-breasted nuthatches (*Sitta carolinensis*) each used 1 inactive cavity for nesting. All of these species used the constructed cavities without enlarging the drilled entrance tunnel (diam = 5 cm). Pileated woodpeckers (*Drycopus pileatus*) enlarged the entrances of 5 constructed cavities, three of which were being used for roosting by red-cockaded woodpeckers. Cavity restrictors (Carter et al. 1989) were added to these cavities to prevent further damage. Red-cockaded woodpeckers continued to use the cavities for roosting after restrictors were in place.

DISCUSSION

Red-cockaded woodpeckers will accept cavities constructed using our technique, both for roosting and nesting, even when other cavities are already present. Reproductive success in experimental sites compares favorably with that of the rest of the population, although data are limited. Although the technique requires considerable effort and imposes some risk to red-cockaded woodpeckers (Copeyon 1990), its use is justified in a variety of contexts, as outlined below.

Vacant Sites

Our manipulation resulted in more new territories in vacant areas than had occurred naturally in the population in the previous 8 years.

The addition of cavities induced birds to occupy clusters in areas in which they had failed to construct clusters for at least 15 years. The results of the experiment support our hypothesis that red-cockaded woodpeckers compete for existing cavity tree clusters in preference to creating new ones. We suggest that this is a likely explanation of the rarity of formation of new groups in the species. The birds readily located our cavities, suggesting that some potential habitat is unoccupied because of the lack of cavities.

Abandoned Sites

Cavity construction increased reoccupancy of abandoned clusters from the usual rate of 9% per year in our population (Doerr et al. 1989) to 90% in abandoned experimental sites. The response of red-cockaded woodpeckers to abandoned sites suggests that occupancy of cavity tree clusters is related to the quality of cavities. The almost exclusive use of constructed cavities for roosting and nesting supports our contention that the pre-existing cavities within abandoned experimental and abandoned control sites were unsuitable. Our results imply that otherwise suitable territories might remain abandoned simply because the cavity tree clusters within them contain inferior cavities.

Our results indicate that removing understory and midstory will at least sometimes be insufficient to induce reoccupation of abandoned territories. The results of the experiment indicate hardwood clearing in conjunction with cavity construction to be much more effective than hardwood clearing alone. Clearing might be most successful in sites that have been recently (1–2 yr) abandoned. But in long-abandoned clusters, cavities may deteriorate, so that the cluster becomes unacceptable because of unsuitable cavities as well as the presence of hardwoods. That red-cockaded woodpeckers reoccupy recently abandoned clusters at a much higher rate than long abandoned clusters (Doerr et al. 1989) is consistent with this scenario. It is also possible that some clusters are abandoned originally because of lack of suitable cavities, for example, when cavities are destroyed by pileated woodpeckers (J. H. Carter III, unpubl. data).

Although many occupants of experimental sites were floaters, helpers, and dispersing fledglings, a large percentage were breeding pairs who shifted from their clusters to adjacent experimental clusters. The movement of these birds into experimental sites could be due to the high quality of experimental clusters relative to the adjacent clusters. The clusters that breeders left were characterized by moderate to severe understory and midstory encroachment, and a small number of suitable cavities.

Cavity-Limited Sites

In many red-cockaded woodpecker populations, a substantial number of active clusters (11–36%) are occupied by unpaired territorial males, sometimes for long periods (Walters et al. 1988, Conner and Rudolph 1989). Possibly some of these clusters are unacceptable to females due to lack of sufficient cavities, and adding cavities to these clusters might facilitate their occupants' acquiring mates. We could not test this or other possible effects of adding cavities to occupied clusters with few existing cavities. Because a shortage of cavities in existing clusters is likely to become an increasingly important problem over the next 20 years (Costa and Escano 1989), it is important to examine these effects. Other possibilities are that adding cavities might reduce abandonment and increase retention of young as helpers.

MANAGEMENT IMPLICATIONS

Vacant Sites

Cavity construction represents the first management tool that has proven effective in inducing formation of new groups. Its potential for promoting population recovery is enormous. In many areas, formation of new groups is rare despite management designed to promote it (e.g., U.S. Fish Wildl. Serv. 1985, Ligon et al. 1986). On National Forests, unoccupied areas called recruitment stands are managed to provide habitat for colonization by red-cockaded woodpeckers (U.S. For. Serv. 1985), but red-cockaded woodpeckers generally have not occupied these stands. Our results suggest that recruitment stands might be more effective if provisioned with constructed cavities. Indeed, if our hypothesis that red-cockaded woodpeckers compete for existing clusters rather than construct new ones is correct, cavity construction will be necessary to induce occupation of any vacant areas, regardless of their quality.

To decrease the odds that constructed clusters will be used by existing groups rather than occupied by new ones, they should not be placed too near existing clusters. Our minimum distance of 0.5 km generally was effective in this respect, but did allow 4 constructed clusters to be captured by existing groups. Managers can probably depend on natural dispersal for occupancy of constructed cavities, although this has only been demonstrated in our relatively large study population.

Abandoned Sites

Cavity construction should be an integral part of rehabilitation of abandoned clusters. Where abandoned sites are numerous, cavity construction in abandoned sites could be even more effective in increasing populations than construction in vacant sites. Control of hardwood understory and midstory is also necessary, and where existing cavities are still suitable for roosting, it might be sufficient. If cavities have been enlarged or usurped by other species, application of restrictors to cavity entrances could render cavities suitable (Carter et al. 1989). But in most sites, especially those abandoned for several years, cavity construction should be employed.

Of course, cavity provisioning should be applied in conjunction with, not in place of, a comprehensive management strategy incorporating techniques such as prescribed burning during the growing season, long timber rotations, and uneven-aged timber management. These techniques promote the maintenance of high quality habitat (U.S. Fish Wildl. Serv. 1985, Ligon et al. 1986, Conner and Rudolph 1989), so that potential cavity trees are readily available, and cluster abandonment is rare. Although these techniques are necessary to maintain populations, we conclude that they are insufficient to promote population growth, and we recommend cavity provisioning, which increases the number of high quality clusters available for occupation by breeding groups, as a tool to promote recovery.

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