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Nest Boxes Reduce Flying Squirrel Use of Red-Cockaded Woodpecker Cavities

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Abstract

*Reproductive success of red-cockaded woodpeckers (*Picoides borealis*) appears to be reduced when even a single cavity in a cluster of woodpecker cavities is occupied by a southern flying squirrel (*Glaucomys volans*). One potential technique for reducing flying squirrel use of woodpecker cavities is the addition of nest boxes to clusters. In this study we evaluated the effects of nest boxes and red-cockaded woodpecker presence (activity) on flying squirrel use of cavities at the Joseph W. Jones Ecological Research Center in Newton, Georgia from 26 September 2002 until 26 June 2003. The interaction between presence of nest boxes and woodpecker activity significantly affected success (proportion of time no flying squirrels occupied any cavities in a cluster; $F_{1,16} = 5.10$, $P = 0.04$). Success was higher in active clusters with nest boxes (95%) than active clusters without nest boxes (83%) but was similar in inactive clusters (success with and without nest boxes = 78%). The proportion of cavities usurped by squirrels cluster^{-1} month^{-1} was higher for inactive clusters (0.07) than for active clusters (0.03; $F_{1,16} = 6.59$, $P = 0.02$). The number of usurped nest boxes per cluster was higher for active clusters (5.67) than inactive clusters (2.71; $F_{1,8} = 4.56$, $P = 0.07$). Our results indicate that nest box addition coupled with flying squirrel removal may reduce flying squirrel use of cavities, especially when cavities occur in clusters containing red-cockaded woodpeckers.* (WILDLIFE SOCIETY BULLETIN 34(1):171–176; 2006)

Key words

cavity nests, flying squirrels, Glaucomys volans, *nest boxes, nest usurpation,* Picoides borealis, *red-cockaded woodpeckers*.

The federally endangered red-cockaded woodpecker (*Picoides borealis*) occurs in old growth pine stands of the southeastern United States (United States Fish and Wildlife Service 2003). They are cooperatively breeding birds, which excavate roost and nest cavities in living pines (*Pinus* spp; Steirly 1957, Lennartz et al. 1983). Other species also use cavities made by red-cockaded woodpeckers, including other cavity nesting birds and southern flying squirrels (Harlow and Lennartz 1983). The southern flying squirrel (*Glaucomys volans*) is the most common cavity usurper of red-cockaded woodpeckers (Harlow and Lennartz 1983, Rudolph et al. 1990, Loeb 1993, Kappes and Harris 1995, Laves and Loeb 1999).

Cavity usurpation appears to reduce reproductive potential of red-cockaded woodpeckers. They are less likely to nest or successfully fledge if even 1 cavity in a cluster (aggregation of trees with cavities) is occupied by another species (Harlow and Lennartz 1983, Richardson and Stockie 1995, Franzreb 1997, Kappes 1997, Loeb and Hooper 1997). However, Rudolph et al. (1990) found that flying squirrels never kept red-cockaded woodpeckers from roosting in an optimal cavity. Conner et al. (1996) reported 6 cases where flying squirrels and red-cockaded woodpeckers nested in the same tree. In all cases the nests were successful, indicating that close proximity of squirrels did not reduce nest success (Conner et al. 1996).

It is equally unclear whether removal of flying squirrels actually impacts their use of cavities. The finding that flying squirrel removal from cavities benefited red-cockaded woodpecker reproductive success was supported by Laves and Loeb (1999). However, Mitchell et al. (1999) found that removing flying squirrels had no effect on red-cockaded woodpecker reproduction.

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While woodpeckers are less likely to nest or successfully fledge if 1 cavity in a cluster is occupied by another species, occupation of an external nest box in the same area has no effect (Loeb and Hooper 1997). While the woodpeckers typically do not use them, adding external nest boxes to a cluster may reduce cavity usurpation by other species (McComb and Noble 1981, Loeb and Hooper 1997). In 1 study cavity use by all species other than red-cockaded woodpeckers decreased 25% the first year boxes were added and 16% the second year (Loeb and Hooper 1997).

We attempted to reduce flying squirrel usurpation of red-cockaded woodpecker cavities through the addition of nest boxes to clusters and removal of any squirrels present. We added nest boxes to cluster areas and evaluated the effects of nest boxes and red-cockaded woodpecker presence on flying squirrel usurpation of cavities and the number of flying squirrels using a cluster.

Study Area

We conducted our study on the 11,736 ha Joseph W. Jones Ecological Research Center (Ichauway) in southwestern Georgia, USA. It was located in Baker County, about 61 km southwest of Albany, Georgia. Ichauway is a privately funded research institution that the Woodruff Foundation began in the 1920s as a quail plantation. Predominant vegetative communities included longleaf pine (*Pinus palustris*) savannah and hardwood forest. Gopher tortoises (*Gopherus polyphemus*), raccoon (*Procyon lotor*), opossum (*Didelphis virginiana*), bobcats (*Lynx rufus*), white-tailed deer (*Odocoileus virginianus*), southern flying squirrels, and red-cockaded woodpeckers, along with other species typical of the longleaf pine community, can be found on Ichauway. At the beginning of the 2003 breeding season, there were 27 red-cockaded woodpeckers on Ichauway. Areas on the property

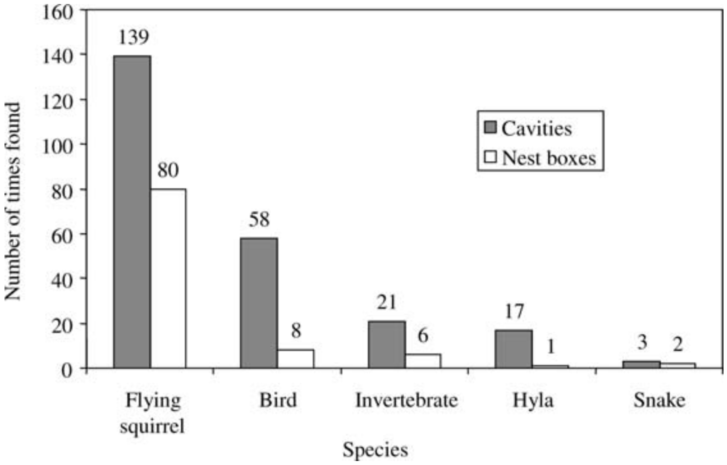

Figure 1. Number of times species were found in cavities and nest boxes at the Joseph W. Jones Ecological Research Center, Georgia, from September 2002–June 2003.

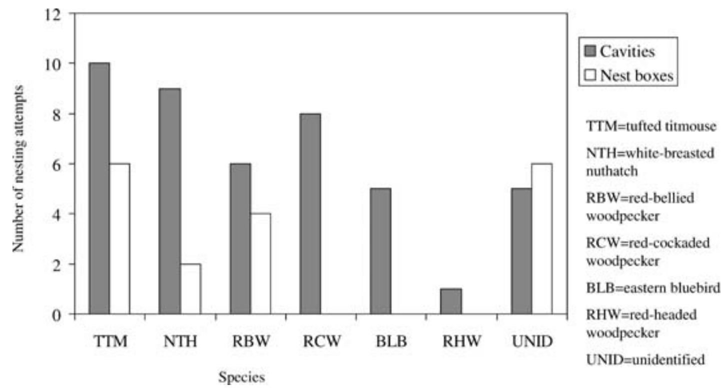

Figure 2. Utilization of cavities and nest boxes for nesting attempts by species at the Joseph W. Jones Ecological Research Center, Georgia, from September 2002–June 2003.

inhabited by woodpeckers were managed with a 1–2 year rotation of prescribed fires, flying squirrel removal, and hardwood control (physical removal of large hardwoods). Clusters also were supplemented with additional cavity inserts as needed and translocation of new birds from outside areas.

Methods

We identified 20 different study sites, each consisting of a red-cockaded woodpecker cluster with 3–6 (4.4 $\pm$ 0.2, mean $\pm$ SE; mode = 4) artificial cavity inserts. Inserts had been installed between spring 1999 and autumn 2002. Only 2 clusters had natural cavities on the periphery of the cluster (one each) but these 2 cavities had deteriorated and red-cockaded woodpeckers no longer used them. Hence, we did not include them in this study. We chose cluster sites on the basis of open midstory and $\geq$4 potential cavity trees (diameter of trees at breast height >38 cm). We separated clusters from each other by <500 m to facilitate movement among clusters by red-cockaded woodpeckers and to satisfy their social nature (USFWS 2003). We randomly assigned clusters as either treatment (nest boxes) or control clusters (no nest boxes). We added external nest boxes to each of 4 non-cavity trees within treatment clusters (n = 10). These trees were actively growing and exhibited a diameter at breast height >38 cm and were located within a maximum convex polygon that linked all cavity trees within a single cluster. If there were not 4 acceptable trees within a polygon, we selected trees closest to the cluster area. None of the trees were more than 10 m outside the polygon.

The interior dimensions of the nest boxes were 13 $\times$ 13 $\times$ 36 cm, with a 3-cm-diameter entrance hole. Nest boxes of similar design were readily used by flying squirrels in previous studies (Sonenshine et al. 1973, Brady et al. 2000). In treatment clusters, we placed nest boxes 5–7 m above the ground, at the approximate height of the internal cavities on similar surrounding trees.

We installed boxes in September 2002 and checked both boxes and cavities for occupants weekly or every other week from 26 September 2002–26 June 2003, using a Tree Top Peeper® (Sandpiper Technologies, Inc., Manteca, California.). We used a Swedish climbing ladder to access boxes and cavities if flying squirrels were present.

Understory composition (grass, forb, woody, debris, and bare cover percents) and structure (height of understory) was similar in the control (average cover percents: 30% grass, 27% forb, 14% woody, 55% debris, 20% bare; mean height = 0.71m) and treatment sites (average cover percents: 23% grass, 29% forb, 17% woody, 65% debris, 19% bare; mean height = 0. 64m). The average canopy cover (54%) of the control clusters did not differ from that of the treatment clusters (55%). We assessed midstory vegetation by measuring the basal area of small trees (only counted in a factor 5 prism, not a factor 10). Midstory vegetation was similar in control and treatment sites (0.56 m^2/ha and 0.58 m^2/ha, respectively). Such low levels of basal area of small trees are indicative of an open midstory tolerable to red-cockaded woodpeckers (USFWS 2003).

To capture squirrels from nest boxes, we blocked the nest box entrance with a cloth and removed squirrels through a wire screen in the box. We removed squirrels in cavities with a Shop-Vac® (Shop-Vac Corporation, Williamsport, Pennsylvania) modified for this purpose. We weighed and sexed all captured squirrels, and determined their reproductive condition by the method of Sollberger (1943). All captured squirrels (179) were euthanized according to the current management practices of Ichauway (Scientific Collecting Permit, Georgia Department of Natural Resources, 29-WMB-02-86). Research was also conducted per IACUC approval 1069, Utah State University. We also classified clusters according to woodpecker activity: we recorded whether red-cockaded woodpeckers used the clusters. We considered clusters active if $\geq$1 red-cockaded woodpecker roosted in a cavity within that cluster for at least part of this study. If no red-cockaded woodpecker used cavities, we considered the cluster inactive.

Clusters were the sampling unit for this study. The dependent variables were the total number of squirrels at all clusters per season, proportion of time no flying squirrels were present in any cavity in a cluster (success), the monthly average of proportion of cavities occupied by flying squirrels in a cluster per check, number of nest boxes occupied by flying squirrels in a cluster at each check totaled over the course of the study, and the number of flying

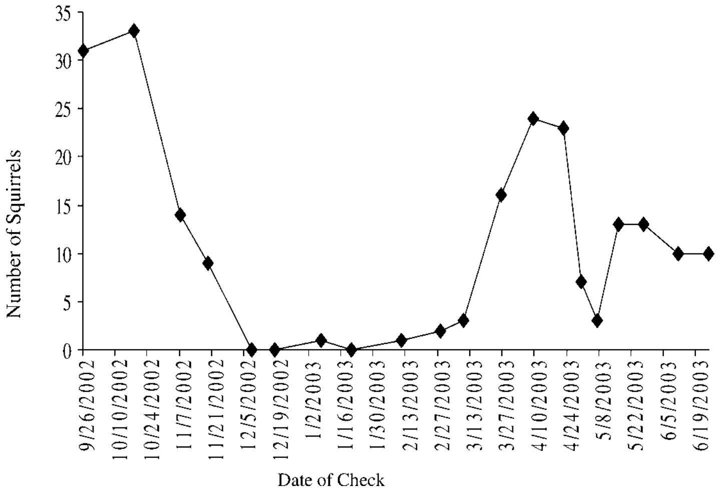

Figure 3. Total number of flying squirrels found in nest boxes and cavities in all clusters at the Joseph W. Jones Ecological Research Center, Georgia, from September 2002–June 2003.

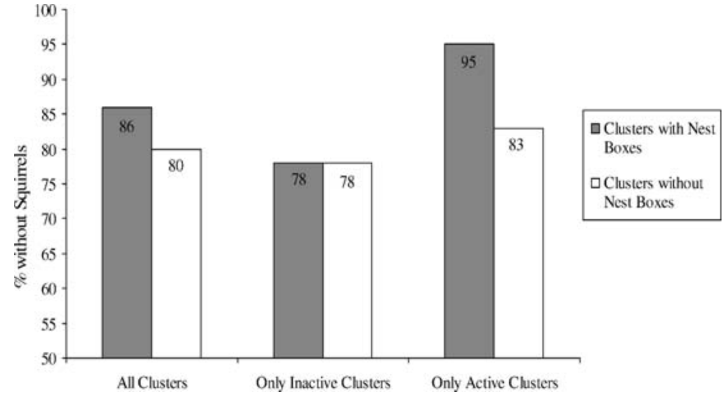

Figure 4. Percent of time no flying squirrels were found occupying cavities in a cluster at the Joseph W. Jones Ecological Research Center, Georgia, from September 2002–June 2003.

squirrels per potential roosting site (total number of cavities and nest boxes) within a cluster per month.

Though we collected these data weekly to every other week, we pooled number of squirrels and proportion of cavities used into monthly values to negate the effect of unequal timing of observations. We used a χ^2 analysis to test if squirrel use of nest boxes and cavities was seasonal (Zar 1999). We conducted a 2-way analysis of variance (ANOVA) to compare the proportion of time no flying squirrels were present in any cavity within a cluster (arcsine transformation) with the predictors being treatment and bird activity. We used a 1-way ANOVA to analyze whether the number of nest boxes occupied in a cluster differed between active and inactive clusters (Zar 1999). We used a repeated-measures ANOVA (Zar 1999) to compare the average monthly proportion of cavities occupied in a cluster (arcsine transformation) and the number of squirrels per potential roosting site (per month) within a cluster between treatment and control clusters (square root transformation).

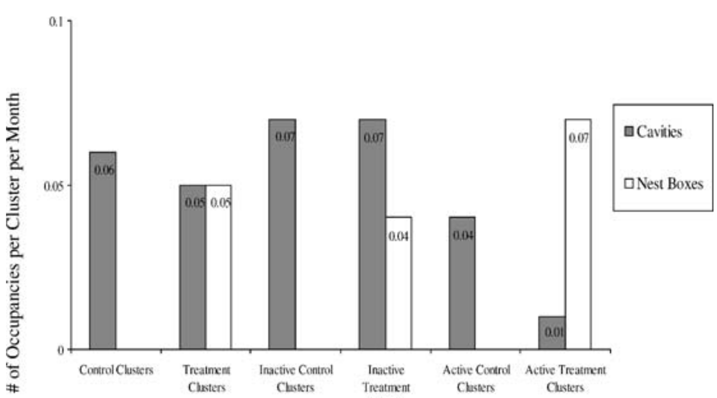

Figure 5. Number of cavities and nest boxes occupied by flying squirrels cluster^{-1} month^{-1} at the Joseph W. Jones Ecological Research Center, Georgia, from September 2002–June 2003.

Results

Eighty-four cavities and 40 nest boxes were present in the 20 clusters. Of the 10 treatment clusters, 3 were active and 7 were inactive. Of the 10 control clusters, 6 were active and 4 were inactive. Cavity and nest box occupants included flying squirrels, a variety of bird species, corn snakes (*Elaphe guttata*), a rat snake (*E. obsoleta*), frogs (*Hyla* spp.), and invertebrates (Fig. 1). We removed only snakes and flying squirrels when found in cavities or nest boxes, leaving all other species undisturbed. Tufted titmice (*Parus bicolor*), red-bellied woodpeckers (*Melanerpes carolinus*), white-breasted nuthatches (*Sitta carolinensis*), red-cockaded woodpeckers, red-headed woodpeckers (*M. erythrocephalus*), and eastern bluebirds (*Sialia sialis*) used cavities and nest boxes for nesting attempts (Fig. 2).

Use of nest boxes and cavities by flying squirrels varied seasonally with highest use in spring and autumn, and lowest in winter and summer ($\chi^2_3 = 150.9$, $P < 0.0001$; Fig. 3). The interaction between woodpecker activity and treatment affected success (proportion of time no flying squirrels occupied any cavities in a cluster; $F_{1,16} = 5.10$, $P = 0.04$; Fig. 4). This interaction was due to the treatment effect when red-cockaded woodpeckers were present. Whereas, when they were absent, there was no treatment effect. Success (proportion of time no flying squirrels were present in any cavity in a cluster) was higher in active clusters with nest boxes (95%) than those without nest boxes (83%). Success was similar in inactive clusters (success with and without nest boxes was 78% Fig. 4). Over the course of the study, flying squirrels used more nest boxes in clusters with red-cockaded woodpeckers (5.67 ± 1.67; mean ± SE) than those without the birds (2.71 ± 0.61; $F_{1,8} = 4.56$, $P = 0.07$; Fig. 5).

Only woodpecker activity affected the proportion of cavities used by flying squirrels cluster^{-1} month^{-1} ($F_{1,16} = 6.75$, $P = 0.02$). The proportion of cavities used cluster^{-1} month^{-1} in active clusters (0.03 ± 0.01) was less than that of inactive clusters (0.07 ± 0.01). The addition of nest boxes did not affect ($F_{1,16} = 0.53$, $P = 0.48$) the proportion of cavities within a cluster which were used by flying squirrels (treatment clusters, 0.05 ± 0.01; control clusters, 0.06 ± 0.01; Fig. 5). The interaction between woodpecker activity and the addition of nest boxes did not differ for the proportion of cavities used ($F_{1,16} = 2.04$, $P = 0.17$).

The number of flying squirrels per potential roosting site (cavity or nest box) found cluster^{-1} month^{-1} was not affected by whether the site was active ($F_{1,16} = 2.43$, $P = 0.14$) or the addition of nest boxes ($F_{1,16} = 1.05$, $P = 0.32$). The interaction between woodpecker activity and the addition of nest boxes also was not significant ($F_{1,16} = 0.01$, $P = 0.94$; Fig. 6).

Discussion

The observed seasonality of cluster use by flying squirrels (low winter use, high spring use) was consistent with previous observations by Loeb and Hooper (1997) and Lotter (1997). We expected this seasonality of use because flying squirrels prefer stands with little midstory in June and July (similar to cluster vegetation structure) and utilize stands with hardwood midstory during the winter months (Heiterer 1994, Lotter 1997). The switch in preference over winter may have been due to increasing number of squirrels per roosting site, requiring larger cavities generally present in hardwoods (Muul 1968, Doby 1984).

Barkalow and Soots (1965) and Burger (1969) reported that the introduction of nest boxes in hardwood-dominated ecosystems may lead to a population increase in gray squirrels (*Sciurus carolinensis*). However, Brady et al. (2000) found that flying squirrel populations did not increase following nest box addition. Our results were consistent with their study. We found no difference in the number of flying squirrels per potential roosting site in each cluster based on woodpecker activity or nest box presence. Because of the potential for flying squirrels to depredate nests or adult red-cockaded woodpeckers, any increase in flying squirrel use of an area due to addition of nest boxes would be a negative consequence for woodpeckers and would create additional management concerns.

Our results indicated that the addition of nest boxes to a cluster and the subsequent removal of squirrels from nest boxes and cavities reduced flying squirrel use of cavities. However, nest box presence was not the only factor that influenced flying squirrel use of cavities; presence of red-cockaded woodpeckers also reduced use. Nest boxes were more beneficial with red-cockaded woodpeckers present but had little effect without birds. This demonstrated that red-cockaded woodpeckers were capable of competing for cavities, and they may have been competitively excluding flying squirrels from cavities. This exclusion was even more effective if nest boxes were present, allowing for an alternative roosting site for the squirrel.

It is important to note that we coupled addition of nest boxes with removal of flying squirrels. It is difficult to say how well nest box addition would have worked without removal. At the Jones Center, Borgo (2004) evaluated the effect of removal on flying squirrel use of pseudo-clusters and found that removal had no effect on the number of flying squirrels using them. Although this particular study did not occur in active clusters, the results may shed light on why previous studies evaluating the effect of removal on red-cockaded woodpecker reproductive success have been mixed (Laves and Loeb 1999, Mitchell et al. 1999). Borgo (2004) reported that squirrel removal alone may not increase red-cockaded woodpecker use of nest cavities. For this reason and the resulting lack of clarity on whether flying squirrels negatively impact red-cockaded woodpeckers, it is difficult to conclude how influential the removal of flying squirrels was in reducing their use of cavities (Rudolph et al. 1990, Conner et al. 1996, Mitchell et al. 1999, Laves and Loeb 1999). However, given that most management practices on small, imperiled red-cockaded woodpecker populations include removal, our finding that nest boxes combined with removal is more effective at reducing flying squirrel use of red-cockaded woodpecker cavities than removal alone support this protocol.

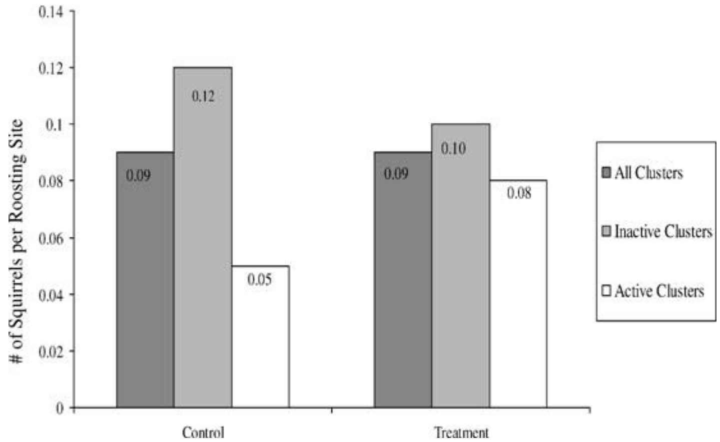

Figure 6. Number of flying squirrels per potential roosting site found cluster^{-1} month^{-1} at the Joseph W. Jones Ecological Research Center, Georgia, from September 2002–June 2003.

Further studies evaluating the effectiveness of nest boxes without removal are needed. There are ethical concerns whenever animals are sacrificed. In the case of flying squirrel management, removal often is one of the primary methods used to protect small populations of red-cockaded woodpeckers. Because of the importance of protecting populations of this endangered woodpecker, there often is a lack of willingness to experimentally evaluate whether squirrel removal works or even if squirrels negatively impact red-cockaded woodpeckers (personal communication). An experimental study would potentially put birds at risk and every individual is considered reproductively important. However, discovering if nest boxes work well without removal would be beneficial both for the squirrels and for wildlife managers due to the amount of time and money spent on squirrel management.

Management Implications

Addition of nest boxes coupled with removal of squirrels may reduce cavity usurpation by southern flying squirrels. This could be beneficial for the red-cockaded woodpecker, which only nest in tree cavities (Jackson 1978, McComb and Noble 1981, Loeb and Hooper 1997). This also may benefit other primary cavity-nesting species for which cavity usurpation by flying squirrels is detrimental. Although the literature indicating that flying squirrels negatively impact the reproductive success of other avian species is limited, anecdotal evidence exists that flying squirrels depredate avian nests and eat eggs (Bailey 1923, J. Stober, Ichauway, personal communication). It is possible that the impact of flying squirrels would be even greater in areas where cavities are limited. Our current study, along with others, has demonstrated the potential for nest boxes to reduce cavity use by flying squirrels (Loeb and Hooper 1997). Therefore, distributing nest boxes for squirrels should be considered in areas managed for red-cockaded woodpeckers or, potentially, for other primary cavity nesting species.

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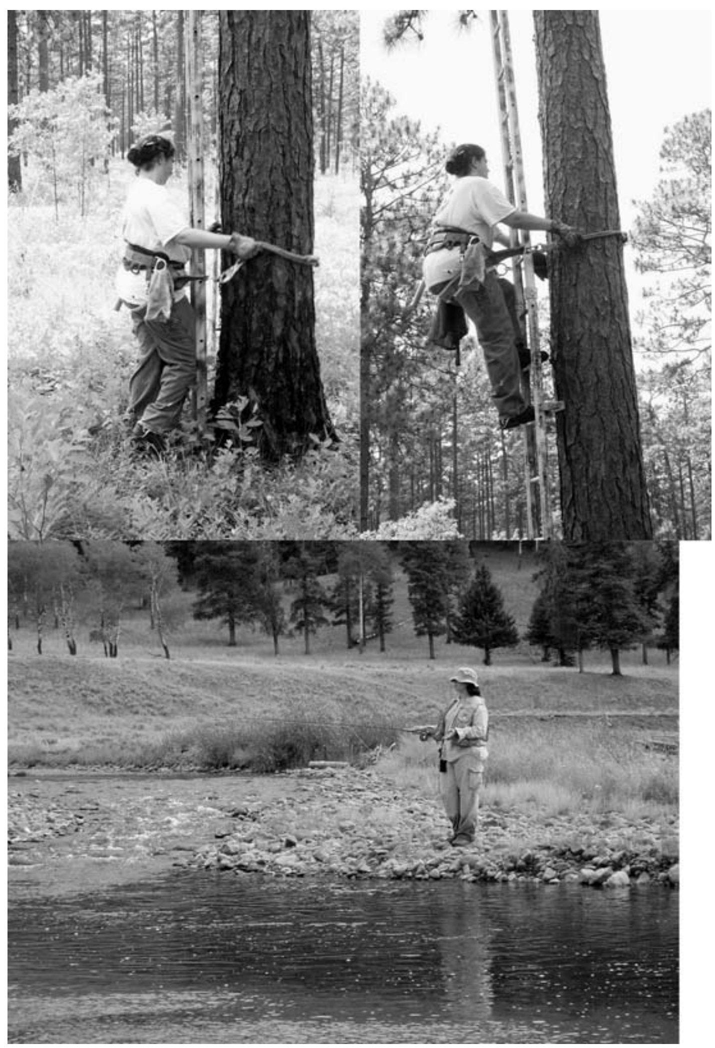

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