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The Effects of Group Selection on the Characteristics and Use of Cavity Trees and Snags

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The effects of group selection on the

characteristics and use of cavity trees and snags

(TITLE)

BY

Mary Lynn Lambert

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The Effects of Group Selection Thinning on the Characteristics and Use of Cavity Trees and Snags in Ozark Hardwood Stands

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Masters Thesis

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Charleston, Illinois

Abstract

I studied the effects of group selection tree harvest on the availability, composition, and use of cavity trees, snags and cavities in the Ozark Mountains of northwestern Arkansas. Sixteen plots dominated by oaks and hickories that were 70-102 years old were surveyed prior to harvest. Tree species, diameter, height and number of visible cavities were recorded. In addition, 192 cavity trees were marked for wildlife observations during the summer and winter. Subsequently, plots were harvested by commercial contractors to either 15 or 19 m^2/ha basal area, using either free or structural control thinning methods. A complete survey of all trees was taken after harvest, and observations of wildlife were conducted again.

Prior to harvest, plots averaged 12.2/ha cavity trees, 25.2/ha snags, and 94.3/ha cavities. Cavity trees, snags and cavities declined significantly ($P<0.001$). after cutting to 4.6/ha, 5.3/ha, and 45.5/ha, respectively. The composition and dbh of cavity trees were not changed by harvest; however, mean height was lower following harvest. The extent of thinning (15 m^2 vs. 19 m^2) did not affect the density of cavity trees, snags, or cavities. Similiarly, the method used to thin stands (free versus structural control) did not affect the number of cavity trees or cavities remaining; however, the thinning method did affect snag density with fewer snags, using the structural control method.

Wildlife use of marked trees during summer declined after harvest. This is probably due to surveys being conducted shortly after logging, which affects use by recent distrubance. However, winter use increased after cutting, probably because the few cavity trees left after harvest were marked and observances occurred months after initial disturbance. Dbh was the only significant factor influencing use by wildlife both before and after cutting. Blackgum (*Nyssa sylvatica*), red oak (*Quercus rubra*), and black walnut (*Juglans nigra*) were used most frequently and tended to be the most cavity-prone trees.

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Introduction

Our national forests provide timber, wood fiber, recreation, wildlife habitat and other ecological values (Minckler 1984). The abundance and diversity of wildlife in forests are influenced strongly by the silvicultural practices used to harvest and regenerate trees. Throughout the 1970's, clearcutting was the predominate method of harvesting and regenerating forest stands (Minckler 1991). However during the past decade, public concerns about the impacts of clearcutting on forest fragmentation, and the maintenance of stratified forest stands, have spurred forest managers to use uneven-aged forest methods such as group selection and single-tree selection to harvest and regenerate stands on eastern forests (Aplet 1994).

Group selection appears to be a very suitable uneven-aged method for improving and regenerating stands of intermediate and shade-intolerant hardwoods. These stands (including most oak-hickory stands) comprise the majority of eastern forests. By periodically harvesting small groups of trees within a stand, the group selection method creates an uneven-aged stand composed of a mosaic of small aggregations of even-aged trees (Barth 1990). Group openings usually range in size from 0.1 to 0.8 ha (Minckler 1984, Barth 1990).

Although group selection can increase the cost of timber management by increasing stand inventories, equipment costs, logging and sale contracts, proponents argue that the use of group selection in mixed hardwood stands results in a high return of sustainable forest values (Minckler 1991). Wildlife values associated with this method include: (1) the maintenance of stratified forest stands, thus increasing vertical habitat diversity, and (2) the reduction of forest edge and maintenance of larger tracts of interior forests. Further, the frequent cutting of 0.4-0.8 ha openings could benefit game species like white-tailed deer (*Odocoileus virginianus*) and wild turkey (*Meleagris gallopavo*), while increasing the alpha-level diversity of many bird and small mammal species (Grier and Best 1980, Crawford, *et al.* 1981).

A potential drawback to the use of group selection is the loss of snags and cavity trees that may occur due to the common practice of "cutting the worst first". Large, mature trees are usually cut first (since they grow slower and have a lower rate of return than small trees), as are snags, live cavity trees, and potential cavity trees (Godtel *et al.* 1978, Conner *et al.* 1975, McComb *et al.* 1986b, Miller *et al.* 1995). The loss of snags and cavities can be critical for wildlife species requiring these for nesting, foraging, and perching (McComb and Muller 1983). A second disadvantage of the group selection method is that the rotation time of harvesting stands is shorter. This means that the thinning of stands and removal of economically undesirable trees occurs more frequently and is more extensive forest-wide because the volume of timber cut in each stand is lower. This can increase the levels of disturbance to wildlife and the surrounding biological community, while increasing edge.

If snags and cavity trees are removed in greater numbers and at more frequent intervals due to group selection, these managed stands could lose these distinctive structural features of unmanaged forests and the species that rely on them (Scott *et al.* 1977, Franklin *et al.* 1980, McComb and Noble 1980, Brush 1983, Brawn 1988). The wildlife species that use cavity trees and snags are important components of oak-hickory forests, and include both game and non-game species (Hardin and Evans 1977). These species play important roles in maintaining the health, functions, and diversity of forest ecosystems (Knight 1958, Bruns 1960, Franz 1961, Solomon 1969, McCambridge and Knight 1972). Cavity trees provide nesting habitat and shelter, whereas snags are used for foraging, hunting, roosting, and courtship by numerous vertebrate species (Davis 1983).

Although group selection has the potential to reduce the numbers of snags and cavity trees, the retention of these important habitat components should be possible through careful forest management. However, before such managment can be practiced, there is a need to document the: (1) density, characteristics and quality of snags and cavity trees in unmanaged stands, (2) changes in density and composition of these due to group selection harvesting, and (3) seasonal use of these snags and cavity trees by wildlife. If wildlife use of snags and cavity trees can be associated with variables that are measurable, then the provision of suitable habitat for these species can be incorporated into forest management plans (Swallow *et al.* 1986).

The purpose of my study was to contribute to the conservation of forest wildlife on the Ozark National Forest by studying the effects of group selection silviculture on cavity-dwelling wildlife and their habitat. My objectives were to: (1) quantify the number of snags and cavity trees in typical hardwood stands before and after group selection cutting, (2) characterize these trees by species composition, diameter, height, and condition, (3) compare the number of cavity trees in stands with north or east aspects versus those with south or west aspects, (4) compare the number of cavity trees left when these stands are cut to either 15 m^2/ha or 19 m^2/ha basal area, (5) estimate the percentage of available cavity trees actually used by wildlife species in summer and winter, and (6) test whether the cavity trees used by wildlife differ from unused trees by species, dbh, height, or state of decay.

Methods

Study Site

The study areas were located on the Bayou and Pleasant Hill ranger districts in the Ozark National Forest of northwestern Arkansas. Forest stands were representive of those in which group selection regeneration methods are likely to be used. Northern red oak (*Quercus rubra*), white oak (*Quercus alba*), black gum (*Nyssa sylvatica*) and numerous hickories (*Carya* spp.) were the dominant trees on the study areas. Each district contained 8 study plots (16 total). All plots were 2.9 ha and contained dominant trees from 70-102 years old, with a basal area of at least 19 m^2/ha. The climate in this region includes relatively warm summers and mild winters. The average monthly temperatures range from 27.4° C in July to a low of 3.9° C in January. Annual precipitation averages 115.8 cm per year (Vodrazka and Winfrey 1981).

The first study area was located on the Bayou district, 44 km N of Russellville. It contained 4 plots (# 21-24) which were on N or E aspects with Nella-Enders and Mountainburg soil types and slopes from 20 to 40%. Two plots (# 25, 26) were on S aspects with Nella-Enders soil type and slopes from 15 to 20%. Plots # 27 and 28 were on S aspects with Nella-Mountainburg soils with slopes from 15 to 20% (Vodrazka and Winfrey 1981).

The second study area was located in the Pleasant Hill district. Four of the study plots (# 35-38) were located 35 km N of Clarksville. These were on S aspects with 30% slopes and Nella-Enders soil. The remaining 4 plots were located 48 km NW of

Clarksville. Plots #31 and #32 were on N or E aspects with 20% slopes and Nella-Enders soil, while plots #33 and #34 were on N aspects with a 25% slope and Enders-Leesburg soil (Garner *et al.* 1977).

Procedures

An inventory of all cavity trees and snags was conducted on each plot prior to cutting. For the purposes of this study, a cavity was defined as an opening large enough to provide shelter from the elements with an external entrance at least 2.4 cm in diameter (Carey 1983). Cavity trees were defined as any live tree at least 10 cm dbh and 3 m in height that contained a cavity. A snag was defined as any dead, standing tree at least 10 cm dbh and 3 m in height. Snags were categorized further into snags with and without cavities. The inventory was conducted after leaf fall when cavities were most visible from the ground. All trees and snags were counted, the dbh was measured with a metric dbh tape, and tree and cavity heights were estimated with a clinometer. For each cavity tree, the total number of cavities, cavity height and cavity diameter was recorded. The tree species was recorded for each cavity tree, and for snags when it could be determined.

Each plot was harvested during the summer following my inventory by commercial contractors using the group selection harvest method. All trees and stems within a 0.16-ha group opening were cut, and the remainder of the 2.9 ha plot was thinned to either 15 or 19 m^2/ha basal area, using either free thinning or structural control thinning methods. In free thinning, the forester has the freedom to select trees to be removed regardless of diameter. The objective is to leave the best quality residual stems on the plot regardless of size. The priorities of free thinning are to remove culls and defective trees first, followed by trees of low economic value and intermediate or suppressed trees of low quality or value. The goal of structural control thinning is to cut residual stands to a targeted diameter distribution between 14.2 cm and 47 cm. A complete "post-harvest" inventory of all cavity trees, snags, and cavities on each plot was conducted 3 to 6 months after this commercial harvest.

During the preharvest inventory, 12 cavity trees per plot (192 total) were selected and marked for subsequent wildlife observations. These trees were left standing by contractors during harvests so that I could compare the use of these trees by vertebrate species before and after stands were cut. Trees chosen for observation were stratified evenly among 3 dbh classes: small (15-30 cm), medium (30-45 cm), and large (>45 cm). Each tree was marked with an aluminum identification tag, and with yellow paint and a red ribbon so they could be easily identified.

Each marked tree was observed 3 times in the summer and 3 times in winter both before and after the plots were harvested. Observations were conducted for 10 minutes using binoculars or a night vision scope for a total of 12 observations per tree. During each observation period, the time of day, tree number, and all wildlife activities at the tree were noted. Any vertebrate species using the tree for foraging, perching, roosting, singing or nesting in the allotted time was recorded. In addition, any evidence of regular usage on or around the base of the tree, including wood chips and woodpecker activity, acorn hulls or obvious nests were recorded. During the winter and summer of 1994, an observer with a ladder scaled each of these trees and checked all cavities $\leq$ 5 m in height for nests or signs of wildlife use.

Paired t-tests were used to test for differences in the densities of snags, cavities, and cavity trees on study plots before and after group selection harvest. A two-sample t-test was used to test for differences in the densities of cavity trees, snags, or total cavities between plots on N or E versus S aspects before harvest. Two-way ANOVA was used to assess whether cavity tree, snag, or cavity densities differed among plots after cutting, with extent of thinning (15 m^2/ha versus 19 m^2/ha) and method of thinning (free versus structural control) as factors. Individual chi-square tests were used to test whether the cavity trees used by wildlife differed from other cavity trees in species composition, dbh, or height. A chi-square test was also used to determine whether the species composition of cavity trees changed after harvest. A stepwise logistic regression procedure was used to test whether snags and cavity trees used by wildlife differed from others in the plot (SAS Institute, Inc. 1989). This is an alternative to discriminate analysis when the two variables are not normally distributed (Swallow *et al.* 1986). All tests were conducted at the 0.05 α-level.

Results

Characteristics of cavity trees and snags before and after cutting

The mean density of cavity trees prior to group selection cutting in Ozark hardwood stands was 12.2 cavity trees/ha (Table 1). These plots averaged 25.2 snags/ha and 2.5 cavities per tree, for a total of 94.3 cavities/ha. Snags had more cavities/tree ($\bar{X}$=3.0) than cavity trees ($\bar{X}$=2.2; t=3.77; P=0.001). Cavity tree densities did not differ significantly before cutting on plots with S aspects compared to those with N or E aspects (t=0.37; *P*=0.721), nor did the number of snags (t=0.06; *P*=0.953) or cavities (t=1.73; *P*=0.085). Of the available cavity trees and snags in my stands, 30% had missing tops or crowns.

The number of cavity trees (t=6.93; $P<0.001$) and snags (t=5.24; $P<0.001$) declined significantly after group selection cutting. The density of cavity trees averaged 4.6/ha after harvest and snags were reduced to 5.3/ha, a decline of 62% and 79% for cavity trees and snags, respectively (Table 1). The density of cavities declined 52% to 45.5/ha after harvest. During my study, 24% of the marked trees fell during or shortly after harvest, even though contractors attempted to leave these trees intact.

The species composition of cavity trees did not change significantly due to harvest (χ^2=36.56; *P*=0.082). Red oak comprised 23.2% of all cavity trees before harvest, while black gum and white oak comprised 20.7% and 16.1%, respectively (Table 2). The remaining 40% of cavity trees consisted of an additional 15 species. After group selection, the same three species dominanted, however, blackgum was now the predominate species.

The proportion of cavity trees in each diameter class was not significantly changed by cutting (χ^2=0.159, P=0.924). Small diameter trees (15-30 cm dbh) comprised the largest percentage (40%) of cavity trees both before and after cutting (Fig. 1). The height distribution of cavity trees was affected by cutting (χ^2=18.337; P=0.001). Prior to cutting, trees exceeding 15 m in height comprised 60% of all cavity trees, whereas these trees comprised only 44% after harvest (Fig. 2). In contrast, the percentage of cavity trees in the 5-10 m class rose from 18% before cutting to 29% after cutting.

Effect of thinning method on cavity trees and snags

The densities of cavity trees (F=0.09; P=0.775), snags (F=0.06; P=0.812), and cavities (F=1.40; P=0.264) did not differ between plots cut to 15 m^2/ha versus those cut to 19 m^2/ha basal area. Plots cut to 19 m^2/ha averaged 4.7 cavity trees/ha and 5.4 snags/ha, while plots thinned more heavily averaged 4.5 cavity trees/ha and 5.2 snags/ha.

The method used to thin residual stands did not influence the densities of cavity trees (F=0.03; P=0.864) or cavities (F=0.65; P=0.440), but did significantly affect the snag density (F=4.79; P=0.049). Plots that were free thinned averaged 4.6 cavity trees/ha, while those thinned with structural control averaged 4.7 cavity trees/ha. Snags density averaged 6.4/ha and 4.1/ha in plots thinned by free and structural control, respectively. The interaction between the extent of thinning and the method of thinning was not significant for cavity trees (F=0.14; P=0.935), snags (F=1.61; P=0.239), or cavities (F=1.59; P=0.252).

Wildlife use of cavity trees

Use of marked trees differed before and after group selection harvesting (χ^2=4.871; P=0.027). Before harvest 55.6% of marked trees were used by wildlife, while after harvest only 43% were used. Over 30 different birds and mammals were observed using marked trees. Birds primarily used cavity trees and snags for perching, feeding or singing during the summer. Species observed included pileated woodpeckers (*Dryocopus pileatus*), eastern wood-pewees (*Contopus virens*), and red-eyed vireos (*Vireo olivaceus*). Winter use was primarily denning, nesting, and caching by squirrels (*Sciurus* spp.) and raccoons (*Procyon lotor*). Snags were also used by woodpeckers and chickadees (*Parus caroliensis*) for foraging during this period.

Prior to harvest, 24 vertebrate species were recorded using cavity trees during both seasons, compared to 21 species after harvest. Use of trees was heaviest in the summer preceeding harvest when 61% were used, compared to 39% use in the summer after harvest. In contrast, winter use of marked cavity trees was higher after stands were harvested. The percentage of trees used in winter rose from 19% before harvest to 39% after harvest.

Wildlife used cavity trees (39%) less often than snags (61%) before harvest. Use of cavity trees rose to 63% and snag use fell to 37% after harvest. Prior to harvest, the tree species used most often during both seasons were blackgum and red oak (Fig. 3). After harvest, blackgum, black walnut (*Juglans nigra*) and red oak were preferred by cavity-users in the summer, while blackgum was used most in winter months (Table 3).

Wildlife use increased with the dbh of cavity trees both before (χ^2=8.74; P<0.05) and after harvest (χ^2=6.14; P<0.05) harvest (Fig. 4). Prior to harvest, 82% of the marked trees exceeding 45 cm dbh were used, while 54% of the cavity trees in the 30-45 cm dbh class and 41% of the 15-30 cm class were used. Following harvest, wildlife used 70% of trees 30 cm or greater, but only 19% of trees less than 30 cm dbh.

Prior to harvest, the height of the cavity trees did not significantly affect use by wildlife (χ^2= 4.2; P>0.05); however there appeared to be a trend towards increased use with increasing tree height. For example, only 7% of trees in the 0-5 m height class were used, but 30% of trees >20m were used. After harvest, height of the cavity tree was a significant predictor of use, increasing as height increased (χ^2=9.32; P<0.05) (Fig. 5). For example, 3% of trees in the 0-5 m height class were used, 21% of those in the 10-15 m class and 40% in the 20+ m class were used.

Although there was not a measurable change in the composition of wildlife species using cavity trees after harvest, there did appear to be an increase in birds using the understory in the stands. The ground debris (slash) left after cutting provided habitat for the avian species typically associated with understory and ground layer habitats, including Carolina wrens (*Troglodytes ludovicianus*), red-eyed vireos, summer tanagers (*Piranga rubra*), American goldfinches (*Carduelis tristis*), indigo buntings (*Passerina cyanea*), and several species of sparrows (Evans *et al.* 1981).

A logistic model was developed using stepwise regression to test which characteristics of cavity trees (dbh, height, living or dead, and top intact or missing) were significant correlates with their use by wildlife. Dbh was the only significant predictor (χ^2=14.68; P=0.001).

Discussion

The continued existence of cavity-using species in managed forests is biologically and economically important. In the past, cavity trees have been removed during timber harvests for fear that they harbored disease and insect pests (DeGraaf and Shigo 1985). Actually, studies have shown cavity-nesting birds play an important role in the reduction of forest insect populations (Knight 1958, Otvos 1965, Solomon 1969, McCambridge and Knight 1972, Bull and Meslow 1977, DeGraaf and Shigo 1985). Further, cavity-dwelling species such as squirrels, raccoons, mice, chipmunks (*Tamias striatus*), and many birds play an important role in seed dispersal and provide an important prey base. For these reasons, it is important for forest managers to maintain sufficient cavity trees to accommodate these species (McComb *et al.* 1986a).

Cavity trees and snags are present in a variety of sizes, conditions and locations and therefore have different values (Bull 1983). Densities of these trees change as communities change (Cline *et al.* 1980, Carey 1983), suggesting that forest managers need to manage for a diverse range of snags and cavity trees and for adequate recruitment of these.

Cavity tree and cavity densities prior to harvest, tended to be higher in my stands than on other forests. This is probably because my stands were unmanaged (Carmichael and Guynn 1983), xeric (McComb and Muller 1983), and mature stands which tend to have higher densities of these trees (McComb *et al.* 1986a). However, Cunningham *et al.*

(1980) found snag density to decrease with stand age in hardwood stands in South Carolina.

Hardwood stands in Missouri averaged between 12.1 and 18.5 snags/ha (Brawn *et al.* 1984), while unmanaged second growth stands in Kentucky averaged 83.8 snags/ha. Eastern old growth stands averaged 42.8 snags/ha (McComb and Muller 1983). McComb and Noble (1980) found significantly more cavity trees and snags on unmanaged plots than managed plots. Others have reported snag densities ranging from 0.7 to 55.1 snags/ha (Table 4). As in my study, McComb and Rumsey (1983) found no significant difference in snag density on N and S aspects.

The density of cavity trees, snags and cavities decreased after commercial harvest regardless of cutsize and cuttype. In non-thinned Ponderosa pine forests of Arizona, Cunningham *et al.* (1980) reported 5.2 snags/ha before thinning, but only 0.6 snag/ha after thinning. Other studies have shown decreases in cavity trees and snags after harvest (Conner *et al.* 1975, McComb and Noble 1980). However, Cline *et al.* (1980) found snag density after thinning was similiar to control plots several years later, apparently because the removal of sound snags was offset by mechanical injury to trees leading to death and snag formation.

The species composition of cavity trees found in my study was similar to that in other studies conducted in oak-hickory forests. Black locust was found to be most prone to snag formation in Kentucky (McComb and Muller 1983), while oaks, blackgum and maples were reported to be prone to cavites in other eastern forests (Conner *et al.* 1975, McComb and Noble 1980, McComb *et al.* 1986a, McComb *et al.* 1986b, Penderson

1991). The predominance of blackgum cavity trees in my stands after harvest was probably due to the number marked and retained for wildlife observations.

The diameter of snags has been positively correlated with number of cavities. In Colorado, snags >24 cm dbh had significantly more cavities (Reynolds *et al.* 1985) than smaller trees. Cimon (1983) reported that the diameter class of a stand could be an important predictor of snag density in the coniferous forest of Oregon. However, Land *et al.* (1989) found no relationship between snag density and stand dbh.

Trees and snags with broken crowns appear to be particulary cavity prone and valuable to vertebrates (Conner 1978, Godtel *et al.* 1978, Cunningham *et al.* 1980, Brush 1983, DeGraff and Shigo 1985, Penderson 1991). If this is the case, then the 30% of trees with damaged crowns may provide important habitat on my study sites. Cunningham *et al.* (1980) reported that 32% of available snags were missing tops in Arizona, while 98% of trees with excavated cavities had broken tops in Florida (Land *et al.* 1989).

Individual vertebrate species prefer particular tree species, sizes and locations of cavity trees and snags, and these preferences may change seasonally (Conner *et al.* 1975, Bull and Meslow 1977, Brawn 1979, Morrison *et al.* 1985). My results suggest that cavity trees and snags are particularly important foraging sites for birds in the Ozarks during winter when insects are scarce and downed logs, stumps, and other substrates can be covered with snow. At this time, woodpeckers rely more heavily on snags for foraging (Conner *et al.* 1975, Bull and Meslow 1977). Snags also are important for breeding displays by resident birds (especially Neotropical migrants) in the early spring and summer. McComb and Noble (1981) found increased use of snags by birds, reptiles and amphibians during the summer and early fall in Louisiana. As in my study, Brawn (1979) found that snags were frequently by breeding Neotropical migrant birds in the spring and summer. A large proportion of his recorded activity was breeding behavior such as singing and perching by non-cavity nesters. The increase of understory birds on my plots after harvest was due probably to the increase in downed limbs and debris. Chadwick *et al.* (1986) stated that some species benefitted from tree harvesting while others did not.

Use of cavity trees and snags appears to be high in the Ozarks relative to other eastern forests. McComb and Rumsey (1983) reported that 11.8% of snags were used in central Appalachian forests, while in Mississippi the mean use of natural cavities ranged from 7.61-12.5% (McComb and Noble 1981). However, researchers in the west have reported higher rates of cavity use than I found. For example, Brush (1983) showed 73.9% use of cavities in Colorado river bottomland forests, and Sedgwick and Knopf (1992), reported 70.9-86.1% use of available cavity trees in northeastern Colorado. The decline in cavity use after group selection on my plots was probably was due to the disturbance caused by logging. Reader (1989) noted a loss of species from deciduous forests immediately following selective tree harvesting. The increased use of cavities in marked trees in the first winter after harvest may have been because marked trees comprised the majority of cavity trees left after harvest.

The frequent use of blackgum, black locust, oaks and hickories in my study parallels the species used in other oak-hickory forests (Conner *et al.* 1975, McComb *et al.* 1986a, McComb *et al.* 1986b). These species are common components of oak-hickory forests, prone to cavity formation, and apparently become sturdy and persistant snags. As such they can provide important habitat for cavity users (McComb and Muller 1983).

Different species of cavity nesters select trees in a wide range of diameter classes for nesting. The diameter of the snag usually correlates with the size of the nesting species; the larger the animal, the larger the tree (Conner *et al.* 1975). Tree diameter plays an important role in cavity selection, excavation, and may influence clutch size. An analysis of snags used for nesting versus those used for other purposes showed that nest snags were larger in diameter; and snag diameter was the most important discriminator between the two groups (Raphael and White 1986). Large diameter snags allow more space for excavation of larger cavities, and clutch size of cavity-nesting passerines has been shown to increase with cavity diameter (Karlsson and Nilsson 1977). Large diameter snags can provide a thicker insulation around the nest cavity, and remain standing longer (Cline *et al.* 1980, Dickson *et al.* 1983, Raphael and Morrison 1987). According to DeGraaf and Shigo (1985) a general rule for cavity tree management should be "the bigger the better".

Although the majority of cavity trees and snags on my study plots had smaller dbh's, larger trees were used more frequently. Swallow *et al.* (1986) reported a direct correlation between dbh and vertebrate use in central New York. Mannan *et al.* (1980) found that trees >60 cm dbh were used most often and that dbh was positively correlated with the density of cavity-nesters. Brawn *et al.* (1984) found that over 50% of cavity trees >30 cm dbh were used in Missouri. In Oregon, snags $\geq$38 cm dbh were shown to be preferred by cavity-nesters (Conner 1978).

Tree height may also influence use, prehaps because taller trees provide greater security against ground predators (Kilham 1971, Dunn 1977), and some species prefer to forage higher on the trunk than others. In general, it may be best to manage for taller snags because tall snags become shorter with time. On my stands tall cavity trees were used more frequently than short ones. Researchers in Oregon and Arizona also found that trees >15m tall were most used (Cunningham *et al.* 1980, Mannan *et al.* 1980). However, a study in Florida, McComb *et al.* (1986a) found no preference among height classes for cavity-nesters.

The physical characteristics of a cavity tree and the surrounding environment affect a cavity's suitability for nesting or denning (Conner *et al.* 1975, Hardin and Evans 1977). Although my study showed no significant relationship between use and state of decay, trees with broken tops are recommended for snag management (Conner *et al.* 1975, Godtel *et al.* 1978, Mannan *et al.* 1980, Reynolds *et al.* 1985). Nesting trees are typically more decayed than those used for foraging (Brawn *et al.* 1984). In Oregon, Bull (1983) showed that 13 out of 15 snags used for nesting by woodpeckers had missing tops. He suggested that rate of use was due to the state of decay in topless trees. An Arizona study found 66% of used trees has broken tops (Cunningham *et al.* 1980). Brawn *et al.* (1984) found nests in Missouri trees in all decay classes, but almost half were found in extremely decayed trees. It appears that the most heavily used trees in most regions are tall, large diameter trees with advanced levels of decay.

Management Implications

Both natural processes and human disturbances, such as timber harvesting, can produce cavity trees and snags by damaging healthy trees. Unfortunately, the formation of a large den tree or cavity tree can take a century or more, so substitutes are often needed. The creation of cavities can be an important and necessary tool in wildlife management (DeGraaf and Shigo 1985). McComb and Noble (1981) suggest that the loss of cavity and den trees can be partially offset by nest boxes. However, nest box installation is not economical over large areas. It has also been recommended that undesirable trees can be girdled or killed with herbicides (Conner 1978, McComb and Noble 1980) or cavities can be routed into existing trees (Carey and Sanderson 1981) to provide cavities for wildlife.

Despite our ability to create snags and artificial cavities, wildlife can benefit most if we leave natural cavity trees and snags during the commercial harvest of forest stands (Mannan *et al.* 1994, McComb 1982). Resource managers have made recommendations for the protection and maintenance of snags (Cline *et al.* 1980). Hardin and Evans (1977) suggested a minumum of 17 snags/ha for potential maximum populations of 6 species of woodpeckers in oak and hickory forests. The Forests Resources Management Plan for the Ozark-St. Francis National Forests calls for the maintenance of 5-10 snags/ha in managed stands (U. S. Department of Agriculture 1990). This recommended density has been adopted by virtually all national forests, regardless of region or forest type. However, habitat requirements vary among species and regions, therefore optimum snag densities should be determined on a regional basis (Balda 1975). Godtel *et al.* (1978) suggested that a reasonable plan for snag replacement requires leaving 2 replacement trees for every existing snag, in all diameter classes during harvest. McComb and Noble (1980) also recommends that several trees/ha should be allowed to age to maturity. Reynolds *et al.* (1985) suggested that because of the declining number of snags in managed forests, stands should be allowed to age beyond normal rotation periods. Based on previous recommendations, the unmanaged stands in my study provided relatively high cavity tree and snag densities prior to cutting; therefore, there appears to be no need for artificial cavities in unmanaged Ozark stands. However, my results suggest that this is not the case after group selection harvest. There is a need for management guidelines for the retention of cavity trees during harvest. I recommend that 10 live cavity trees/ha and 18-20 snags/ha (number includes replacement trees) be selected and marked for retention before all timber sales. Commercial contractors should avoid damaging these trees. Blackgums, black walnuts, red oaks and black locust are cavity-prone species and should be given highest priority for retention. Further, efforts should be made to retain cavity trees and snags in a variety of sizes, but highest priority should be given to trees >30 cm dbh and >15 m in height. Finally, natural resource professionals from all disciplines should be aware of the importance of cavity trees and snags in maintaining forest health and diversity, and of the need to manage and retain these resources.

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Table 1. Densities of cavity trees, snags, and cavities (no./ha) in Ozark hardwood stands before and after group-selection cutting. N is the number of plots sampled; S.E. is one standard error.

	Before cutting			After cutting		
	N	$\bar{X}$	S. E.	N	$\bar{X}$	S. E.
Cavity trees/ha	16	12.2	1.0	16	4.6	0.4
Snags/ha	16	25.5	3.8	16	5.3	0.6
Cavities/ha	16	94.3	5.8	16	45.3	3.9

Table 2. Species composition of cavity trees in Ozark hardwood stands before and after group-selection cutting.

Species	Pre-harvest	Post-harvest
Red oak (*Quercus rubra*)	23.2%	18.0%
Black gum (*Nyssa sylvatica*)	20.7	21.8
White oak (*Quercus alba*)	16.1	9.7
Unidentified species	6.4	4.4
Hickory species (*Carya* spp.)	6.3	7.3
Black walnut (*Juglans nigra*)	5.2	7.8
Black locust (*Robinia pseudoacacia*)	4.9	9.2
Red maple (*Acer rubrum*)	4.6	5.3
Black cherry (*Prunus serotina*)	3.1	3.4
Black oak (*Quercus velutina*)	2.9	4.4
White ash (*Fraxinus americana*)	1.9	3.9
Common persimmon (*Diospyros virginiana*)	1.2	0.0
Post oak (*Quercus stellata*)	0.7	1.0
American elm (*Ulmus americana*)	0.5	1.5
Sugar maple (*Acer saccharum*)	0.5	0.5
Green ash (*Fraxinus pennsylvanica*)	0.3	0.5
Sweetgum (*Liquidambar styraciflua*)	0.3	0.5
Cucumber magnolia (*Magnolia acuminata*)	0.2	0.0

Table 2. continued

Red mulberry (*Morus rubra*)	0.2	0.0
American sycamore (*Platanus occidentalis*)	0.2	0.0
Total	100.0	100.0

Table 3. Percent of cavity tree species used seasonally by wildlife before and after group selection harvest on the Ozark National Forest.

Tree species	Before harvest (%)		After harvest (%)	
Species	Winter	Summer	Winter	Summer
Blackgum (*Nyssa sylvatica*)	45.0	13.0	39.0	37.0
Black locust (*Robinia pseudoacacia*)	15.0	3.3	16.7	4.2
Red oak (*Quercus rubra*)	15.0	31.0	20.8	16.7
White oak (*Quercus alba*)	10.0	9.8	5.3	10.5
Black walnut (*Juglans nigra*)	0.0	14.7	8.3	16.7
All other species	15.0	28.2	25.0	29.1

Table 4. Comparison of cavity trees, snag and cavity densities (no./ha) on the Ozark National Forest to those in other regions of the United States.

State	Forest type	Cavity trees	Snags	Cavities	Authors
Arkansas	Oak-hickory	12.2	25.2	94.3	Lambert-this study
Missouri	Oak-hickory	____	12.1 to 18.5	____	Brawn *et al.* (1984)
Kentucky	2nd growth hardwood	____	83.8	____	McComb & Muller (1983)
Kentucky	Old growth hardwood	____	42.8	____	McComb & Muller (1983)
W. Virginia	Oak-hickory	7.0	22.4 to 55.1	____	Carey (1983)
Florida	Oak-hickory	____	11.0	____	McComb *et al.* (1986a)
Colorado	Cottonwood	2.3	0.7	4.2	Sedgwick& Knopf (1986)
Colorado	Cottonwood	____	6.5	____	Reynolds *et al.* (1985)

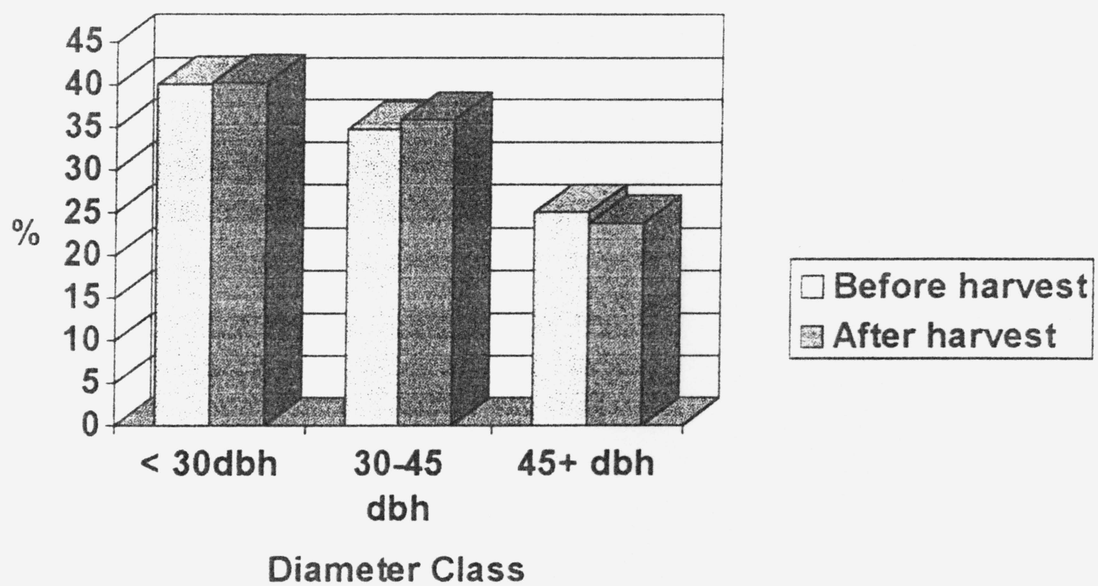

Figure 1. Proportion of cavity trees in each of 3 dbh classes (cm) in Ozark hardwood stands before and after group-selection cutting.

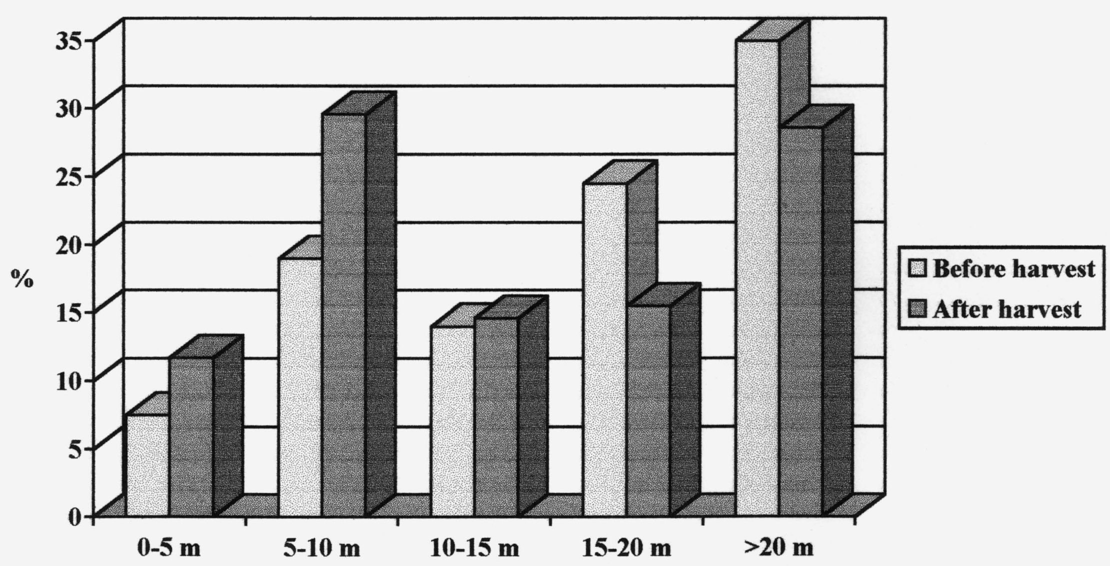

Figure 2. Proportion of cavity trees in each of 5 height classes in Ozark hardwood stands before and after group-selection cutting.

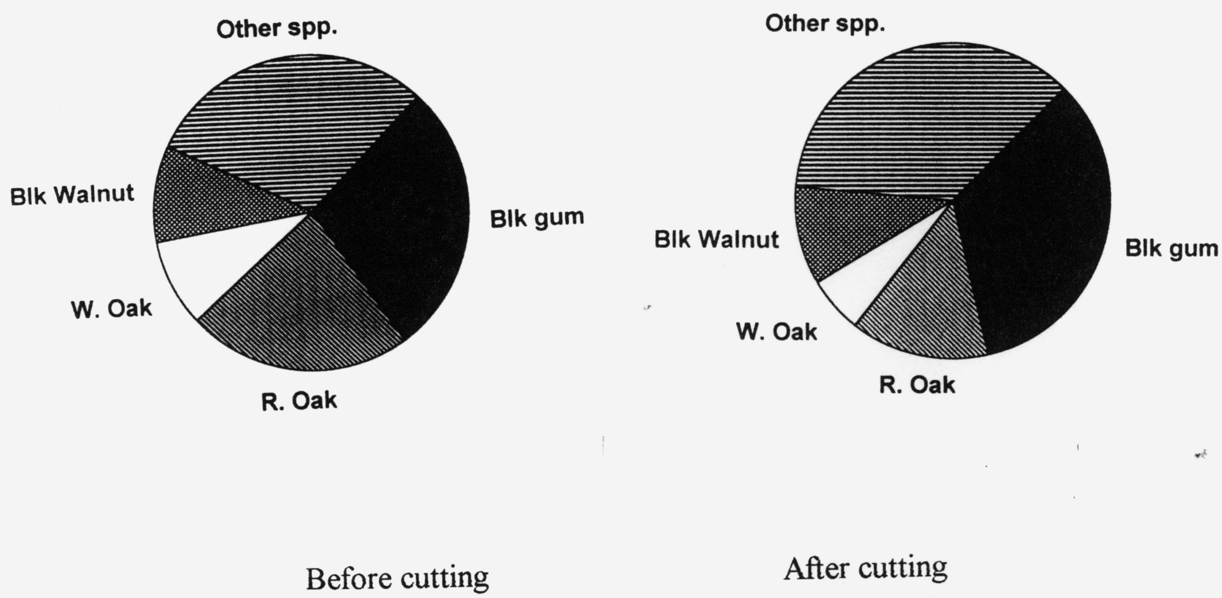

Figure 3. Species of cavity trees most frequently used by wildlife before and after group selection harvest.

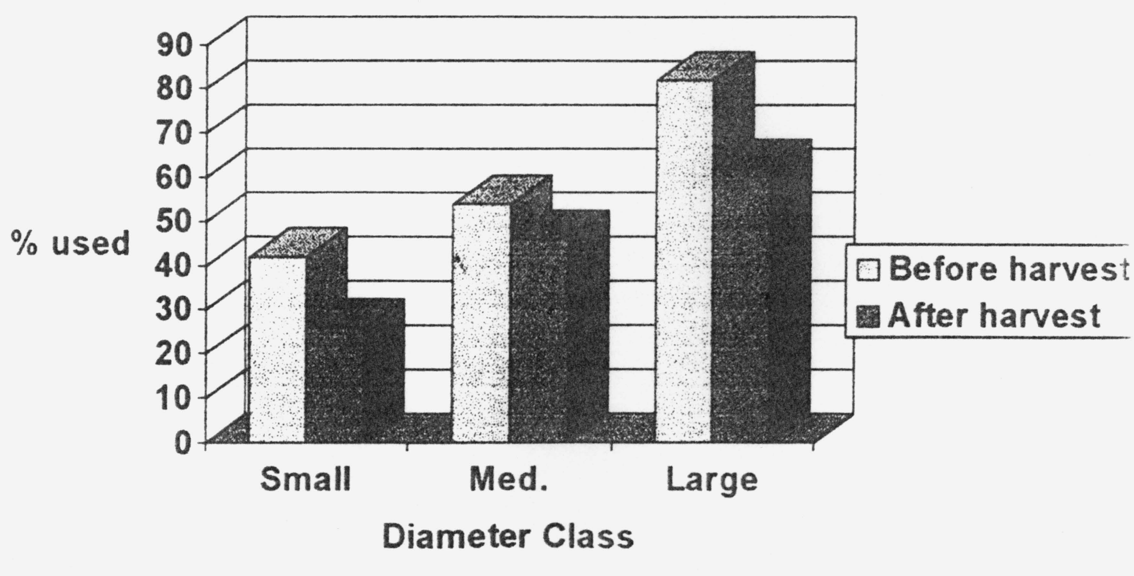

Figure 4. Wildlife use of cavity trees in each of 3 dbh classes (cm) in Ozark hardwood stands.

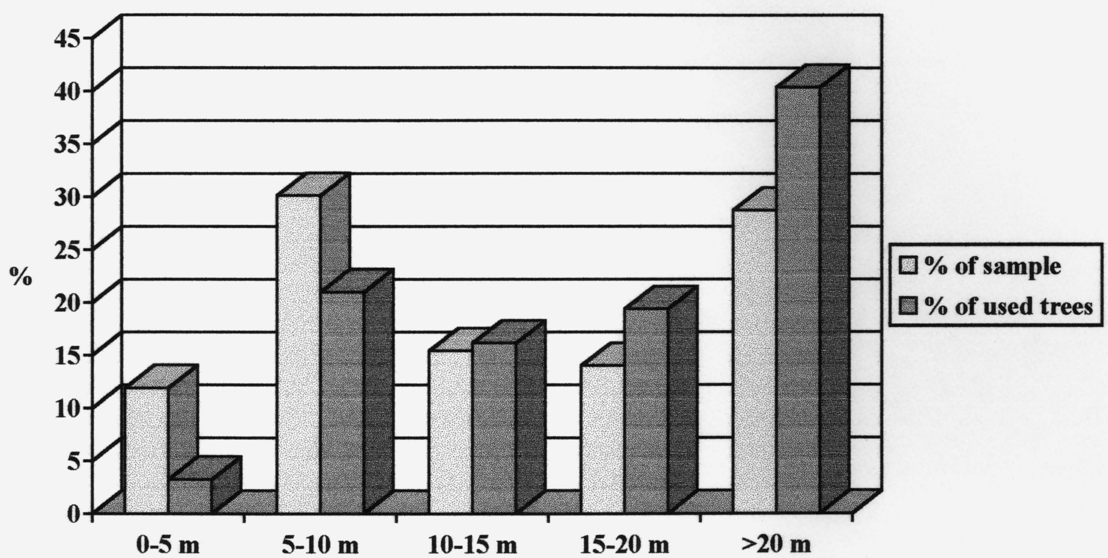

Figure 5. Post-harvest use of wildlife trees in Ozark hardwood stands classified by 5 height classes.