Characteristics and Use of Cavity Trees and Snags in Hardwood Stands

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Abstract: A 3-year study was conducted to evaluate the availability and use of cavity trees and snags in hardwood stands regenerated using the group selection method. A survey of cavity trees and snags was completed before and after group selection harvest in 16 2.9-ha plots in the Ozark National Forest, Arkansas. Cavity trees and snags were identified to species, and the height, dbh, state of decay, and number of visible cavities recorded. We marked and measured 66 cavity trees and 126 snags with cavities, and observed the use of these cavities by wildlife. Use of cavity trees was observed seasonally and before and after group selection harvest. Plots averaged 12.2 cavity trees/ha and 25.5 snags/ha before harvest. Densities did not vary between plots with northeast and south aspects. Species composition of cavity trees and snags did not reflect overall stand composition. Black gum (*Nyssa sylvatica*), red maple (*Acer rubrum*), and black walnut (*Juglans nigra*) were most likely to develop cavities. Cavity trees and snags declined after group selection harvests to 4.6/ha and 5.3/ha, respectively. Harvesting changed the species composition and relative size of cavity trees. Over 30 species of vertebrates used cavity trees. The percent use of cavity trees dropped from 53% before to 30% after harvest. The 3 species of cavity trees used most frequently by wildlife were black gum (66%), black walnut (63%), and red oak (*Quercus rubra,* 60%). Large diameter (>45 cm) and tall (>20 m) cavity trees and snags were used most frequently, regardless of the species of tree.

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Cavity trees and snags are important components of wildlife habitat in forests, providing sites for nesting, roosting, and foraging (Scott et al. 1977). Over 100 species of birds and mammals are known to use tree cavities for nesting and shelter, including game and nongame species (Scott et al. 1977, Conner 1978). The provision of habitat for cavity-dwelling wildlife in managed forests is both ecologically and economically important. Numerous studies have shown that cavity-dwelling, insectivorous birds

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play an important role in maintaining healthy forests by reducing forest insect populations, preventing insect outbreaks, and reducing the loss of forest productivity caused by herbivorous insects (Bruns 1960, Franz 1961, McCambridge and Knight 1972, Kroll and Fleet 1979, Marquis and Whelan 1994). Further, cavity-nesting mammals such as squirrels, mice, and chipmunks play an important role in seed dispersal and provide an important prey base.

Some public land management agencies recognize the importance of snags and have established guidelines for retaining minimum densities in managed stands (Thomas et al. 1979, Bull et al. 1986). Requirements on the Ozark-St. Francis National Forests, Arkansas, call for a minimum of 5 to 10 snags/ha (U.S. For. Serv. 1990). Nevertheless, managers must still decide which snags to leave, and quantitative information on which snags are most important is lacking for hardwood forests in the central United States.

Retaining optimal numbers of cavity trees and snags can be difficult because of the dynamic nature of cavity recruitment and turnover (Morrison and Raphael 1993). Further, cavity trees and snags are usually culled or may be accidentally damaged during the thinning and logging of stands. If group and single-tree selection systems of regenerating forests become more common in the eastern United States, loss of cavity trees could increase because harvests and thinning operations are conducted more frequently and across more stands (Murphy et al. 1993). This could reduce the availability of cavities for wildlife and limit populations of wildlife species that depend on this resource (McComb and Noble 1980).

This study evaluated the availability, characteristics, and use of cavity trees and snags in mature oak-hickory stands on the Ozark-St. Francis National Forests, Arkansas. The objectives were to: (1) quantify the densities of cavity trees and snags before and after group selection harvest, (2) characterize cavity trees by species, diameter, height, and condition, (3) estimate the percentage of cavity trees used by wildlife, and (4) test whether the species, dbh, or height of cavity trees used by wildlife differed from unused cavity trees. Funding for the study was provided by a grant from the USDA Forest Service, Southern Forest Experiment Station, Monticello, Arkansas.

Methods

The study was conducted on the Bayou and Pleasant Hill Ranger Districts of the Ozark National Forest, Arkansas. Sixteen 2.9-ha plots were established in well stocked, mature oak-hickory stands representative of site and stand conditions designated for uneven-aged management by the U. S. Forest Service. Stands were 70–102 years old, at least 19 m^2/ha basal area, and dominated by northern red oak, white oak (*Quercus alba*), black gum and various hickories (*Carya* spp.). All stands had a site index of 70 for northern red oak at 50 years. Eight of 16 plots were located on each ranger district. Four plots in each district were on northeast-facing mountain slopes, and 4 were on south-facing slopes.

A survey of all cavity trees, snags, and cavities on each plot was conducted prior to cutting. Surveys were conducted in winter so that cavities would not be obscured by foliage. We defined cavity trees as living trees ≥3 m in height and ≥10 cm dbh, with visible cavities large enough to shelter wildlife or openings ≥2.5 cm in diameter. Snags were defined as standing, dead trees ≥3 m in height and ≥10 cm dbh. Snags may or may not contain cavities. For each cavity tree and snag, we recorded the species (when identifiable), dbh, height, extent of deterioration, and number of visible cavities. The diameter and dimensions of each cavity with openings ≥2.5 cm were estimated for cavities below 5 m in height. We recorded only the size of the external opening of higher cavities. Because we do not know if the internal dimensions of some of these higher cavities were sufficiently large to be inhabited by wildlife, the cavity densities we report here are presented as maximum densities of cavities visible from the ground.

Each plot was harvested 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. A survey of cavity trees, snags, and cavities on each plot was repeated 3 to 6 months after cutting.

To assess the use of cavity trees and snags by wildlife, 8 cavity trees and 4 snags with cavities per plot were tagged for seasonal observations. Trees were stratified into 3 dbh classes: 15–29 cm, 30–44 cm and ≥45 cm. Within each dbh class, 4 cavity trees or snags in each plot were tagged for observation. Each tagged tree was observed 3 times each in summer and winter, both prior to and after harvest. During each observation period, a tree was scanned for a 10-minute interval using binoculars or a 10x night vision scope. Afterwards we searched cavities and the ground under the tree for sign of use. A tree was considered to be used if nest material or food was found in or protruding from a cavity, sign of foraging (empty seed hulls) was evident beneath the tree, or a cavity-using wildlife species was observed inside or on the tree.

We used paired *t*-tests to compare densities of cavity trees, snags, and cavities on study plots before and after group selection harvest. Student's *t*-test was used to compare plots on northeast versus south-facing slopes, and plots thinned to 15 m^2/ha versus those thinned to 19m^2/ha. Chi-square tests were used to assess whether species composition, dbh, or height differed between cavity trees used and not used by wildlife. A stepwise logistic regression procedure was used to test the effects of dbh, height, species, and condition of cavity trees on whether or not they were used by wildlife (SAS Inst., Inc. 1989).

Results and Discussion

Cavity Tree and Snag Densities

Plots averaged 12.2 cavity trees/ha (SE = 1.0) and 25.5 snags/ha (SE = 3.8) prior to cutting. Cavity trees averaged 2.2 cavities/tree (SE = 0.1) and snags with cavities averaged 3.0 cavities/tree (SE = 0.2), resulting in a mean density of 94 cavities/ha (SE = 5.8). The density of cavity trees did not differ between plots with a north or east aspect versus plots with a south aspect ($t = 0.37$; $P = 0.72$), nor did the density of snags ($t = 0.06$; $P = 0.95$).

Snag densities are higher in younger, xeric (McComb and Muller 1983), and unmanaged (Carmichael and Guynn 1983) stands. Our plots in the Ozarks were in mature, somewhat xeric stands that had received little management prior to the study. Accordingly, it is surprising that density of cavity trees and snags recorded were relatively low compared to other southern forests. Average snag densities in Missouri oak-hickory stands ranged from 12.1/ha to 18.5/ha (Brawn 1984). McComb and Muller (1983) reported high snag densities in mixed mesophytic stands in eastern Kentucky. Density of snags ≥10 cm on their study sites averaged 83.8 snags/ha in unmanaged 35-year-old second-growth stands, and 42.8 snags/ha in old-growth stands. Carmichael and Guynn (1983) found densities of 50.3/ha and 31.2/ha for upland hardwood and pine-hardwood stands, respectively, on the Clemson Forest, South Carolina. They noted that these densities were higher than had been reported for managed stands, on the nearby Francis Marion National Forest, where snags were removed soon after detection (Harlow and Guynn 1983).

Prior to our study, we suspected that density of snags would be higher on plots with south aspects because these stands were more xeric. McComb and Muller (1983) found highest density of snags in all diameter classes on xeric sites. Our results did not support this hypothesis, perhaps because white oaks and hickories which were dominant on ridges and south aspects are relatively drought tolerant (Braun 1950). Density of cavity trees did not vary widely among our study plots, because plots were purposely placed in stands of similar forest type, age, and fertility. Carey (1983) reported highly variable cavity tree densities in Appalachian deciduous forests, and noted that much of the variability was unrelated to age, dbh, site index, or other stand features.

The density of cavity trees declined after group selection harvest ($t = 6.93$; $P < 0.001$), as did the density of snags ($t = 5.24$; $P < 0.001$). Density of cavity trees was reduced by 62%, and density of snags declined by 82% after harvest. The mean post-harvest density of cavity trees was 4.6/ha (SE = 0.5), while snags averaged 5.3/ha (SE = 0.8). The cavity trees and snags left standing in plots averaged 4.3 cavities/tree, a mean total of 42.6 (SE = 4.1) cavities/ha. Density of snags was not lower in plots where the residual stand had been thinned to 15 m^2/ha (5.2 snags/ha; SE = 0.9) versus plots thinned to 19 m^2/ha (5.4 snags/ha; SE = 0.7). Density of cavity trees averaged 4.6 trees/ha (SE = 0.5) on plots thinned to either density. Previous studies have suggested adverse effects of timber harvest on the densities of snags, cavities, and snag-using birds (Conner et al. 1975, McComb and Noble 1980). Our data also show a decline in density of cavity trees and snags following group selection harvest.

The species composition of cavity trees did not reflect overall plot composition (Table 1). Prior to cutting, cavity trees were predominately 3 species: red oak, black gum, and white oak. Sixteen additional species comprised the remaining 40%. White oak comprised 36% of the total basal area on plots, much higher than reflected in composition of cavity trees. Red oaks and hickories were found at approximately the same proportions between cavity trees and living trees. Black gum, black walnut, red maple, and black locust (*Robinia pseudocacia*) comprised a disproportionate number of cavity trees relative to their dominance among living trees. Black gum, in particular,

Table 1. Percent species composition of overstory trees and cavity trees in hardwood stands before and after group selection.

Species	All overstory trees	Cavity trees Before harvest	Cavity trees After harvest
White oak (*Quercus alba*)	36.4	16.1	9.7
N. red oak (*Q. rubra*)	23.5	23.2	18.0
Black oak (*Q. velutina*)	9.4	2.9	4.4
Hickories (*Carya* spp.)	7.9	6.3	8.3
Black gum (*Nyssa sylvatica*)	7.0	20.7	21.8
Red maple (*Acer rubrum*)	1.6	4.6	5.3
Black cherry (*Prunus serotina*)	1.1	3.1	3.4
Black walnut (*Juglans nigra*)	0.8	5.2	7.8
White ash (*Fraxinus americana*)	0.6	1.9	3.9
Black locust (*Robinia pseudoacacia*)	0.3	4.9	7.2
Other species	11.4	11.1	10.2

was likely to contain cavities. This species comprised only 7% of the basal area of the study plots, but 21% of cavity trees. Others have found black locust, red oak, red maple, blackgum, sycamore (*Platanus occidentalis*), and sweetgum (*Liquidambar styraciflua*) to be tree species prone to cavity formation (Bellrose et al. 1964, Sanderson et al. 1975, McComb and Muller, 1983, Melchiors and Cicero 1987).

Characteristics of Cavity Trees

Small diameter cavity trees and snags (15 to 30 cm dbh) were most common (40.1%), while trees in the 30 to 45 cm and ≥45 cm classes comprised 34.8% and 25.1% of cavity trees, respectively. Large cavity trees and snags were not uncommon prior to cutting, averaging 9/ha (SE = 0.9). Height varied considerably, but the majority of trees (60%) were taller than 15 m. Many cavity trees (26%) had broken crowns, apparently the result of wind, ice, and senescence.

Group selection harvest altered both the species composition and size distribution of cavity trees (Table 1). Specifically, the percentage of cavity trees that were red or white oaks decreased from 39% to 28%, while the percentage of hickories and white ash (*Fraxinus americana*) increased from 8% to 12%. Although 67% of the large diameter cavity trees were removed during harvest, large diameter cavity trees were not removed at a rate greater than smaller trees; thus, the relative distribution of cavity trees in each diameter class was unchanged by harvest ($X^2 = 0.2$; $P = 0.924$). Harvesting did affect height distribution by removing the tallest cavity trees. Trees taller than 15 m comprised 60% of the preharvest inventory, but only 44% of the post-harvest inventory ($X^2 = 18.3$; $P < 0.01$).

Wildlife Use of Cavity Trees and Snags

The number of marked cavity trees and snags that were used by wildlife declined from 21.0/ha before harvest to 5.3/ha after harvest. This decline during the first year after harvest resulted largely from lower cavity tree and snag densities, but also from site disturbance immediately after harvest. Over 30 species of birds and mammals were observed using marked trees. During the summer, birds primarily used cavity trees for nesting and snags for foraging display, and courtship. Species using the marked trees commonly observed during the summer included pileated woodpecker (*Dryocopus pileatus*), eastern wood-pewee (*Contopus virens*), and red-eyed vireo (*Vireo olivaceus*). Winter use of cavity trees primarily consisted of denning, nesting, and caching by gray squirrels (*Sciurus carolinensis*), and denning by raccoons (*Procyon lotor*). Snags were used by woodpeckers and chickadees (*Parus carolinensis*) for foraging and roosting during the winter.

Use of cavity trees prior to harvest was high regardless of species (Table 2). Tree species that were used most frequently were black gum (66%), black walnut (63%), and red oak (60%). Use was heaviest during the summer, primarily due to nesting by songbirds. Although all species of cavity trees had a lower percent use after harvest, the relative rank of each species did not change.

Large diameter cavity trees and snags were used more often and appeared to be particularly valuable to wildlife. Thirty-seven of the 45 (82%) trees > 45 cm dbh were used by wildlife prior to harvest, whereas 41% and 54% of the trees in the 15- to 30-cm and 30- to 45-cm dbh classes were used, respectively. A model developed using logistic regression to assess the relative importance of species, dbh, height, and level of decay as predictors of cavity tree use by wildlife indicated that only dbh was a good predictor ($P < 0.05$) of use; however, use of trees generally increased with the height of the tree. For example, 71% of the trees taller than 20 m were used, while only 37% of the trees less than 5 m in height were used. No difference was found in the use of cavity trees versus snags with cavities, as 60% of cavity trees and 53% of snags were used ($X^2 = 0.25$; $P = 0.615$). In an analysis of snags used for nesting versus those used for other purposes, Raphael and White (1986) showed that snag diameter

Table 2. Percentage of cavity tree species used by wildlife before and after group selection harvest in hardwood stands.

	Before harvest				After harvest			
Species	*N*	Summer	Winter	Annual use[a]	*N*	Summer	Winter	Annual use[a]
Black gum (*Nyssa sylvatica*)	44	46	48	66	38	8	39	45
N. red oak (*Quercus rubra*)	40	53	13	60	30	10	17	27
White oak (*Quercus alba*)	22	32	14	41	11	9	18	27
Black walnut (*Juglans nigra*)	16	63	6	63	16	25	13	38
Black locust (*Robinia pseudoacacia*)	15	33	40	53	11	9	18	27
Red maple (*Acer rubrum*)	7	29	29	57	6	0	33	33
Black oak (*Q. velutina*)	6	17	17	17	5	20	0	20
Black cherry (*Prunus serotina*)	6	83	17	83	5	0	40	40
White ash (*Fraxinus americana*)	6	50	0	50	6	33	17	33
Other species	30	30	0	30	18	0	0	0

[a]Percentage of trees used in either summer or winter.

was the most important discriminator between the 2 groups. Large diameter snags allow more space for excavation of larger cavities, provide more insulation around nest cavities, and remain standing longer (Cline et al. 1980).

In 1983, a committee of biologists from the Missouri Department of Conservation and the Mark Twain National Forest convened to recommend management guidelines for snags and den trees in Missouri's forests (Titus 1983). After reviewing literature on the habitat requirements of 89 species of vertebrates known to require snags or den trees in Missouri, the committee recommended optimum cavity tree and snag densities of 15/ha and 13/ha, respectively, for forest interiors (Titus 1983). Our study plots exceeded this recommended density of snags and approximated this density of cavity trees prior to harvest; however, after group selection harvest, snag and cavity tree densities provided only 30% to 40% of these optimum densities. Optimum densities of cavity trees and snags could be provided on the Ozark National Forest by unmanaged, older stands (≥70 years). Such densities might be expected in riparian zones, wilderness tracts, and stands set aside as unsuitable for commercial harvest. Our data indicate that managed stands are unlikely to contain optimum densities in and of themselves. By following National Forest guidelines for snag retention in harvesting operation, however, these strands could provide from 30% to 60% of the optimum density of snags. Presently there are no guidelines for leaving adequate number of cavity trees.

Our data suggest that cavity trees and snags >30 dbh and taller than 15 m are particularly valuable to wildlife and should be given highest priority for retention. While wildlife species demonstrate individual preferences for tree species, the probability of cavity formation is greatest in black gums, black walnuts, black locusts, and red oaks, making these species particularly valuable to cavity-dwellers in Ozark forests.

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