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GENERAL NOTES

Habitat and snag selection by woodpeckers in a clear-cut: an analysis using artificial snags.—When a forest is clear-cut, all trees, alive or dead, are removed. The elimination of the dead trees (snags) can have drastic effects on populations of cavity nesting birds (Webb, Trans. N. Am. Wildl. Nat. Resour. Conf. 42:438–448, 1977; Dickson et al., J. Wildl. Manage. 47:799–804, 1983). For example, woodpecker density is limited by the availability of dead or dying trees because these relatively soft substrates are required for nest and roost sites (Thomas et al., pp. 60–71 *in* Wildlife Habitats in Managed Forests, J. W. Thomas, ed., USDA For. Serv. Agric. Handbook 553, 1979). Woodpecker populations may remain low until harvested tracts provide trees of adequate size for nest cavities, usually a period of 30 or more years. Species dependent on cavities excavated by woodpeckers may, in turn, decline.

Proper forest management for wildlife requires knowledge of the habitat and nesting requirements of resident species. Probably because of their potential economic importance, woodpeckers have received much attention. Picid foraging habitat (Conner and Crawford, J. Forestry 72:564–566, 1974; Conner, J. Field Ornithol. 51:119–127, 1980), nesting habitat (Conner et al., J. Wildl. Manage. 39:144–150, 1975; Conner and Adkisson, Wilson Bull. 89:122–129, 1977), and nest-tree characteristics (Conner, Auk 92:371–374, 1975; Stauffer and Best, Wilson Bull. 94:329–337, 1982) have been well-studied. Tree hardness (Kilham, Wilson Bull. 83:159–171, 1971; Conner et al., Wilson Bull. 88:575–581, 1976), slope of branch or trunk (Conner 1975; Conner, Auk 94:369–370, 1977), and weather-related variables (Reller, Am. Midl. Nat. 88:270–290, 1972; Peterson and Grubb, J. Wildl. Manage. 47:790–798, 1983) have been considered possible causes of entrance orientation. Because of the scarcity of snags, quantification of woodpecker nesting and roosting habitat in clear-cuts is lacking.

In 1982, we initiated a study to determine if woodpeckers would excavate and subsequently roost and nest in polystyrene snags placed in an area that recently had been clear-cut. Because the artificial "trees" were homogeneous and identical in composition, selection of habitat about an excavation site could be studied under conditions free of any uncontrolled variation in the shape, size, and composition of the excavation substrate itself. The purpose of our study was to characterize patterns of woodpecker colonization of snags and orientation of cavity entrances with regard to vegetation, topography, and other snag characteristics within a clear-cut.

Study area.—Observations were made on a 3.1-ha subunit of a 12-ha, 12-year-old clear-cut in the Wayne National Forest, Hocking County, Ohio. Ridge tops in the area are characterized by oak-hickory associations. Bottomland areas are dominated by American beech (*Fagus grandifolia*), sycamore (*Platanus occidentalis*), white ash (*Fraxinus americana*), and river birch (*Betula nigra*). Our site was on a steep-terrained upland site dominated by hickories (*Carya* spp.), white oak (*Quercus alba*), red oak (*Q. rubra*), chestnut oak (*Q. prinus*), maples (*Acer* spp.), flowering dogwood (*Cornus florida*), yellow poplar (*Liriodendron tulipifera*), sourwood (*Oxydendrum arboreum*), and black tupelo (*Nyssa sylvatica*). The clear-cut was densely vegetated, averaging 9250 trees/ha. Canopy height averaged approximately 8 m. The northwest and southeast sides of our plot were bordered by extensions of the clear-cut, the southwest side by a mature forest, and the northeast side by a road bordered by a forested tract (Petit, M.S. thesis, The Ohio State Univ., Columbus, Ohio, 1984). An ephemeral creek flowed southwest through the site and was bordered on both sides by relatively steep slopes. Elevation within the plot ranged from 240 to 275 m. There was little fallen or standing dead timber on the clear-cut.

Methods.—On 4 September, we placed 99 polystyrene snags, each measuring 237 × 21 × 21 cm, in the clear-cut. These dimensions are within or very near to the range of sizes of snags used by six species of woodpeckers that are found in Ohio during most of the year (Conner, pp. 120–128 *in* Management of Southern Forests for Nongame Birds, R. M. DeGraaf, tech. coord., USDA For. Serv. Gen. Tech. Rept. SE-14, 1978; Evans and Conner, pp. 214–225 *in* Management of North Central and Northeastern Forests for Nongame Birds, R. M. DeGraaf and K. E. Evans, eds., USDA For. Serv. Gen. Tech. Rept. NC-51, 1979). Although the height and diameter of the artificial snags may have been acceptable to Red-bellied Woodpeckers (*Melanerpes carolinus*), Northern Flickers (*Colaptes auratus*), Red-headed Woodpeckers (*M. erythrocephalus*), and Yellow-bellied Sapsuckers (*Sphyrapicus varius*), they were most suitable for Downy Woodpeckers (*Picoides pubescens*) and Hairy Woodpeckers (*P. villosus*). A hole was drilled lengthwise approximately 80 cm into the base of each polystyrene snag. Each snag was then painted with brown latex paint and fixed atop a 1.5-m fiberglass stake driven approximately 75 cm into the ground. Snags were positioned to face only the four cardinal directions. Because of the steep terrain and soil creep over the course of the study period, some of the artificial snags came to lean up to 20° from the vertical. The 99 snags, spaced 16 m apart, were arranged in an 11 × 9 grid pattern, and were examined at approximately biweekly intervals during the following 12 months for evidence of excavating activity by woodpeckers. A cavity was defined as an excavation at least 10 cm deep on the vertical axis from the lower lip of the entrance hole (Grubb, Wilson Bull. 94:577–579, 1982). To determine the effects of vegetation, topographical, and snag features on woodpecker cavity-site selection, we recorded 32 variables within 0.02-ha (8-m radius) circles centered on each of the snags (Table 1).

Differences between polystyrene snags with cavities and those without cavities were analyzed by using both univariate and multivariate statistical methods. Values for all variables were first tested for departure from a normal distribution (Shapiro-Wilks test; SAS User's Guide: Basics, SAS Institute, Cary, North Carolina, 1982). If nonnormal, a given variable was transformed appropriately (Steel and Torrie, Principles and Procedures of Statistics, McGraw-Hill Book Co., New York, New York, 1980). All normalized variables were tested for differences between groups by a one-way analysis of variance (ANOVA). Those variables that could not be fitted to a normal distribution were tested with the Mann-Whitney *U*-test.

Multivariate ordination techniques reduce the number of variables to one or more functions that best describe the variability within a sample set (see Morrison, Multivariate Statistical Methods, McGraw-Hill Book Co., New York, New York, 1976; Gauch, Multivariate Analysis in Community Ecology, Cambridge Univ. Press, New York, New York, 1982). Stepwise discriminant function analysis (DFA; Dixon and Brown, BMDP Biomedical Computer Programs P-series, Univ. California Press, Berkeley, California, 1979) determines those variables that best separate two or more groups (e.g., James, Wilson Bull. 83:215–236, 1971; Conner et al., Wilson Bull. 95:349–361, 1983). In our study, DFA combined the habitat variables into the discriminant function that most effectively segregated snags with cavities from those without cavities. Because the number of variables entered into the stepwise DFA must be less than the smallest sample size, we reduced the number of variables entered into the DFA. This also minimized the effect of relatively unimportant variables (Nie et al., Statistical Package for the Social Sciences, McGraw-Hill Book Co., New York, New York, 1975). Those variables that exhibited a difference of $P < 0.15$ by ANOVA or *U*-tests and that did not differ greatly from the statistical assumptions were selected for the multivariate analysis.

A chi-square test was used to test for randomness in cavity entrance orientation. For statistical analyses, alpha levels ≤ 0.05 were taken as indicating significant differences.

We placed our 11 × 9 grid of polystyrene snags in the clear-cut so that 13 snags extended

TABLE 1

VEGETATION, TOPOGRAPHIC, AND POLYSTYRENE SNAG CHARACTERISTICS MEASURED WITHIN 0.02-HA CIRCULAR PLOTS AROUND THE 99 ARTIFICIAL SNAGS ERECTED IN A CLEAR-CUT IN SOUTHEASTERN OHIO

Variable mnemonic	Description
CANCOV[a]	Percent canopy cover: the number of sightings of canopy vegetation at 20 points within the circle.
CANHT	Canopy height (m)
CCANCOV[a]	Percent coniferous canopy cover: the number of sightings of coniferous canopy vegetation at 20 points within the circle.
GRDCOV[a]	Percent ground cover: the number of sightings of ground cover (<0.6 m tall) at 20 points within the circle.
SLOPE[b]	Ground slope: a value measured at a representative point within the circle.
DISTOPEN	Distance (m) to nearest opening >100 m^2 in size.
DISTWOOD	Distance (m) to nearest mature woodland.
TREESA	Number of woody plants ≤1.0 cm DBH.
TREESB	Number of woody plants 1.1–2.5 cm DBH.
TREESC	Number of trees 2.6–8.0 cm DBH.
TREESD	Number of trees 8.1–15.0 cm DBH.
TREESE	Number of trees 15.1–23.0 cm DBH.
TREESX	Number of trees >23.0 cm DBH.
CTREESA	Number of coniferous trees ≤1.0 cm DBH.
CTREESB	Number of coniferous trees 1.1–2.5 cm DBH.
CTREESC	Number of coniferous trees 2.6–8.0 cm DBH.
CTREESD	Number of coniferous trees 8.1–15.0 cm DBH.
CTREESE	Number of coniferous trees >15.0 cm DBH.
SPTREES	Number of species of woody plants.
TOTTREES	Total number of woody plants ≥1.4 m high.
TOTCTREES	Total number of coniferous trees ≥1.4 m high.
SNAGBC	Number of snags 1.1–8.0 cm DBH.
SNAGDE	Number of snags 8.1–15.0 cm DBH.
SNAGX	Number of snags >15.0 cm DBH.
NEARTRA	Number of woody plants ≤1.0 cm DBH within a 1-m radius of a polystyrene snag.
NEARTRB	Number of woody plants 1.1–2.5 cm DBH within a 1-m radius of a polystyrene snag.
NEARTRC	Number of trees 2.6–8.0 cm DBH within a 1-m radius of a polystyrene snag.
NEARTRD	Number of trees 8.1–15.0 cm DBH within a 1-m radius of a polystyrene snag.
NEARTRE	Number of trees 15.1–23.0 cm DBH within a 1-m radius of a polystyrene snag.
NEARTRX	Number of trees >23.0 cm DBH within a 1-m radius of a polystyrene snag.
TRSLOPE	Polystyrene snag lean: the number of degrees that snag alignment departed from the vertical, estimated to the nearest 5°.
TRASPECT	Aspect of polystyrene snag lean: measured as one of the four cardinal directions.

[a] See James and Shugart (Audubon Field Notes 24:727–736, 1970).

[b] Measured with an instrument similar to that of Fovargue and Perino (Ohio J. Sci. 79:130–132, 1979).

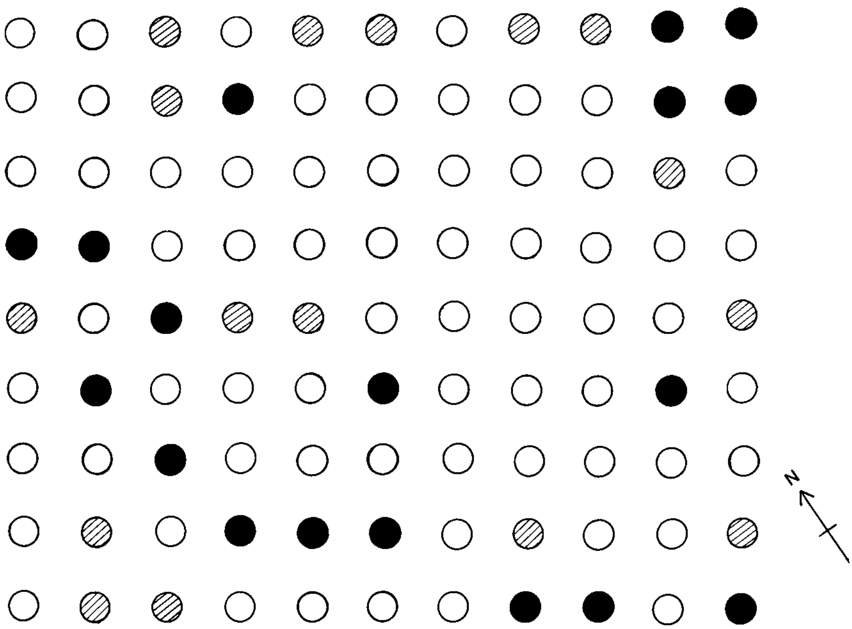

FIG. 1. Sequence of cavity excavations in the artificial snags on the clear-cut in southeastern Ohio. Cross-hatched circles represent snags excavated from October to March. Shaded circles are those snags excavated from April to September.

into the mature woodland on the southwest border. This enabled us to assess the presence of woodpeckers in an adjacent mature tract and determine if they tended to avoid the clear-cut or if there was an avoidance of the square-sided snags in general. Because of the differences in vegetation between these two areas and because there might have been seasonal or serial correlation with the choice of snag attributes, the univariate and multivariate methods for determining snag-habitat selection were repeated for four pairs of comparisons. The analyses contrasted the habitats surrounding snags with cavities (CAVITY) against the habitats around snags without cavities (NOCAVITY) for (1) snags in the clear-cut proper from October to March (CCWINTER), (2) snags in the entire plot from October to March (TOTWINTER), (3) snags in the clear-cut proper from October to September (CCYEAR), and (4) snags in the entire plot from October to September (TOTYEAR).

Woodpecker abundances.—During the 18 months after placing the polystyrene snags in the clear-cut, we conducted 40, 43, and 7 line-transect censuses in the clear-cut, and the mature woodlands on the northeast and southwest sides of the clear-cut, respectively (Petit, unpubl.). Here, we summarize briefly the relative abundances of woodpeckers. In the clear-cut, Downy and Hairy woodpeckers were detected in 20% and 10% of the censuses, respectively. No other species of woodpecker was counted within the clear-cut. In the mature woodlands, flickers (in up to 29% of the censuses), Pileated (*Dryocopus pileatus*) (up to 14%), Red-bellied (up to 29%), and Hairy (up to 40%) woodpeckers were detected regularly. In the plot on the northeast side of the clear-cut, Downy Woodpeckers were present in 49% of the censuses, but in the southwest woodland, downies were never seen during our seven

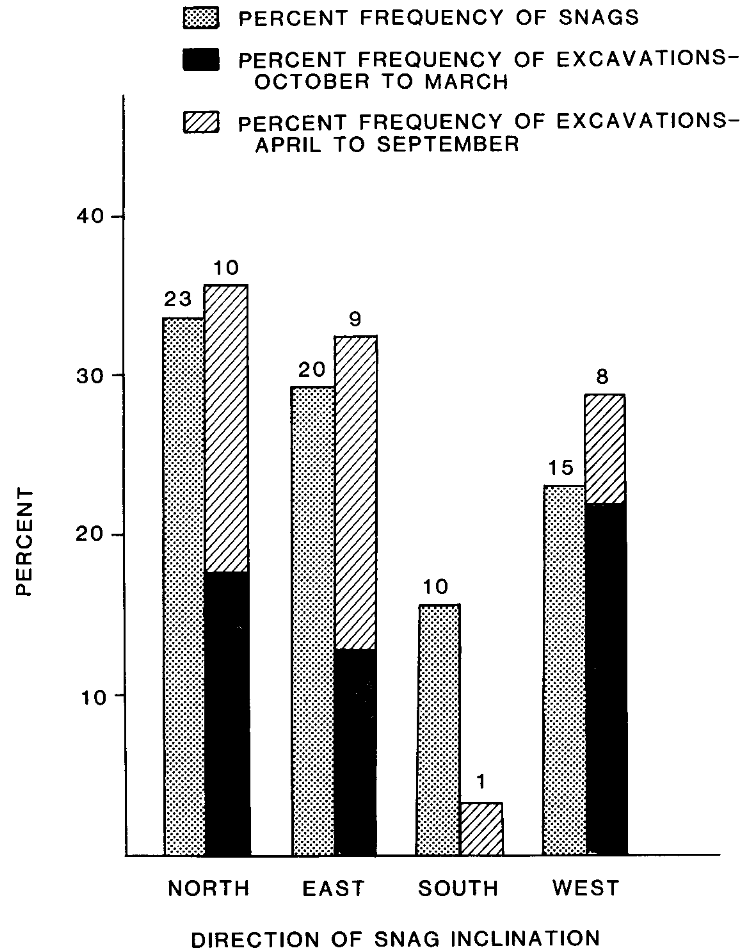

FIG. 2. The relationship between the expected use of the 68 leaning snags and the observed pattern of 28 excavations. The values above the histograms represent the number of leaning snags or the number of excavations for a given direction of snag inclination.

counts. It appears that the larger woodpeckers avoided the clear-cut altogether, and Downy and Hairy woodpeckers were less common there as compared to the surrounding mature forest. Because of these observations, our nighttime observations (see below), and the cavity entrance characteristics (see below), we believe that the woodpecker species using our artificial snags probably was the Downy Woodpecker.

Cavity entrance orientation.—The first full cavity was discovered during early October 1982, 4 weeks after the snags were placed in the clear-cut; and by 1 April 1983, 16 cavities had been dug (Fig. 1). In all instances (15 of 16) in which the snag was not exactly vertical, the entrance was on the "underside" of the snag. Snags were examined at night once in

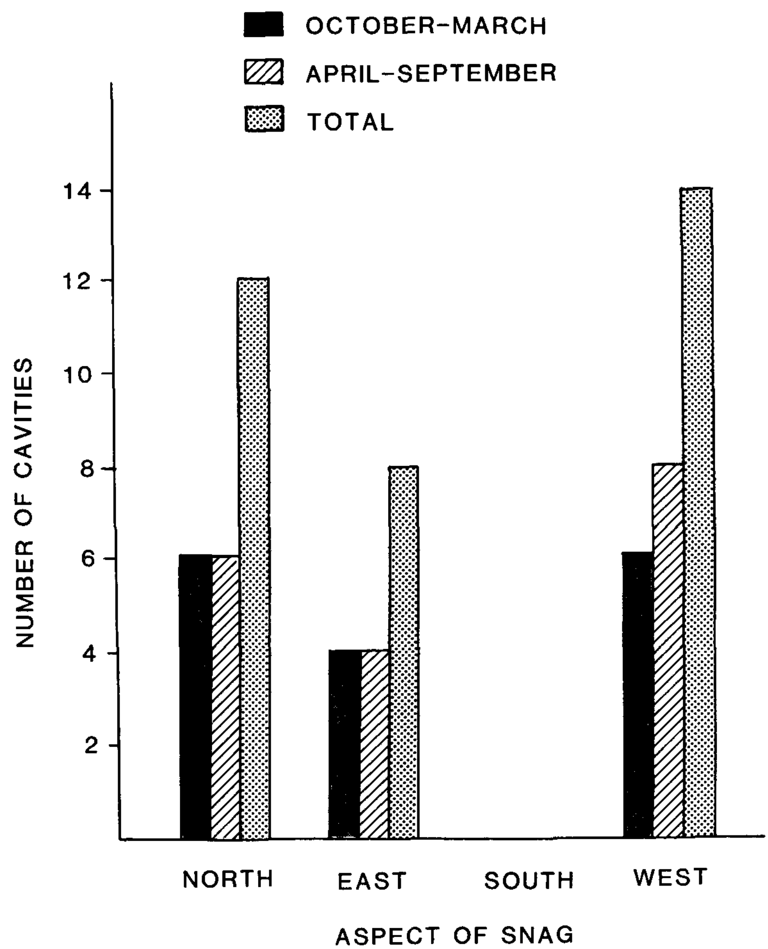

FIG. 3. Frequency of cavity entrance placement on each of the four aspects of the 34 excavated artificial snags.

December and once in February. On both evenings, two Downy Woodpeckers were found roosting in different snags.

Eighteen additional cavities were excavated from April to September (Fig. 1). Thirteen of the 18 excavated snags were nonvertical, and nine of these 13 had cavity entrances placed on the underside. A chi-square test for goodness-of-fit confirmed the relationship between direction of snag lean and cavity orientation ($P > 0.40$). To ascertain whether woodpeckers were selecting leaning snags regardless of the direction of the inclination of the snag, we calculated the proportion of the 68 leaning snags that slanted in each of the four cardinal directions and compared these proportions to the frequencies with which each of the four categories was used (Fig. 2). Woodpeckers did not excavate the inclining snags in the pro-

TABLE 2
MEAN ± SD OF CAVITY AND NOCAVITY SNAG CHARACTERISTICS SHOWING SIGNIFICANT ($P < 0.05$) DIFFERENCES FROM OCTOBER TO MARCH

Variable	Clear-cut: Snags with cavities (N = 13)	Clear-cut: Snags without cavities (N = 73)	Entire plot: Snags with cavities (N = 16)	Entire plot: Snags without cavities (N = 83)
CANCOV	88.5 ± 9.7	94.7 ± 4.2	88.8 ± 8.9	94.4 ± 4.6
DISTOPEN	35.9 ± 28.0	55.9 ± 30.9	—	—
CTREESA	0.3 ± 0.5	0.1 ± 0.2	—	—
TRSLOPE	8.8 ± 6.2	4.9 ± 4.4	8.4 ± 5.7	4.7 ± 4.4

portions present ($P < 0.05$); they rarely excavated snags that leaned toward the south. Similarly, of the 34 snags that contained cavities, none had a completed excavation on the south-facing side ($P < 0.05$, chi-square test of randomness; Fig. 3). Cavity entrance orientation did not vary seasonally (Fig. 3).

Wind and solar radiation affect the direction toward which cavity nesters orient their entrances (Ricklefs and Hainsworth, Ecology 49:227–233, 1968; Austin, Condor 76:216–217, 1974). Conner (1975) and Peterson and Grubb (1983) concluded that, in their study areas, orientation away from the prevailing wind direction prevented rain and cold air from entering the cavity. In southeastern Ohio, the predominant wind direction is from the southwest. The placement of cavity entrances in our study on the west side of snags, but not on the south side, is, therefore, difficult to interpret. Possibly, the south-facing side was more exposed to the prevailing wind than was the west-facing side because of the orientation of the valley in which the snags were situated. This valley is oriented from NNE to SSW. Wind might be funnelled up through the valley, and, therefore, might have caused the south side of the polystyrene snags to be the most susceptible to weather effects. Our results support the suggestion that tree lean is the most important factor governing woodpecker cavity entrance orientation (Conner 1975).

Cavity characteristics.—Cavity entrance area (15.1 ± 3.3 [SD] cm^2) and distance from the cylinder's top to the center of the entrance hole (45.8 ± 30.5 cm) did not vary greatly among the 34 cavities. "Summer" and "winter" cavities did not differ significantly in either of these characteristics (Petit 1984). Peterson and Grubb (1983) observed that during the warmer months woodpeckers dug larger entrances, which were thought to increase the ventilation of the cavity. The cavities excavated after March in this study, however, did not appear to receive much use (i.e., they were not soiled). More than three-fourths of the cavities were dug in the upper quarter of snags. Such higher cavities might be less noticeable and less accessible to predators.

The entrance dimensions of all but three of the 34 cavities suggest that they were dug by Downy Woodpeckers. Three snags in close mutual proximity within the band of large trees near the southwest border of the clear-cut had cavity entrances much larger than those of any other cavity (21.9, 24.0, and 25.5 cm^2). All three cavity entrances were wider than high. Northern Flickers, Red-bellied Woodpeckers, and Hairy Woodpeckers were seen foraging near these snags, and an individual or individuals of one of these species was likely the excavator.

Cavity site selection.—Snags excavated from October to March (CCWINTER; N = 13) in the clear-cut proper were not selected randomly. CAVITY snags were characterized by lower

TABLE 3

MEAN ± SD OF CAVITY AND NOCAVITY SNAG CHARACTERISTICS SHOWING SIGNIFICANT ($P < 0.05$) DIFFERENCES FROM OCTOBER TO SEPTEMBER

	Clear-cut		Entire plot	
Variable	Snags with cavities (N = 27)	Snags without cavities (N = 59)	Snags with cavities (N = 34)	Snags without cavities (N = 65)
CANCOV	91.7 ± 7.9	94.7 ± 4.3	—	—
TREESB	41.0 ± 17.2	51.3 ± 21.8	36.1 ± 18.0	49.2 ± 22.4
NEARTRC	1.2 ± 1.4	1.7 ± 1.5	0.9 ± 1.3	1.5 ± 1.5
TRSLOPE	7.1 ± 6.0	4.8 ± 4.2	6.6 ± 5.6	4.6 ± 4.2
TREESC	—	—	59.9 ± 31.1	72.6 ± 27.4
TOTTREES	—	—	153.3 ± 58.8	183.3 ± 53.8

canopy cover and distance to an opening, higher numbers of small coniferous trees, and a greater degree of inclination of the snags (Table 2). Three variables contributed significantly to the separation of the group centroids (DFA; F = 12.5; df = 3,82; $P < 0.001$). The single discriminant function is positively correlated with snag inclination and negatively correlated with percent canopy cover and distance to an opening. Thus, woodpeckers concentrated their excavating activities on inclining snags in areas of relatively sparse canopy cover close to an opening around or within the clear-cut. The ability of the discriminating variables to separate the two groups was tested empirically by a classification technique, i.e., comparing predicted group membership based only upon the discriminating variables with the observed group membership (see Nie et al. 1975). For CCWINTER, the DF correctly classified 80.2% of the artificial snags, demonstrating a high degree of cavity site selection by woodpeckers during the first six months.

The TOTWINTER comparison yielded similar results. The only two variables to show significant differences in the univariate tests (Table 2), also comprised the DF. Canopy cover and snag inclination significantly segregated group centroids (F = 13.3; df = 2,96; $P < 0.005$) and, as with CCWINTER, were negatively and positively associated with the DF, respectively. Snags with cavities were generally situated along the portion of the DF axis associated with low canopy cover and high snag lean. A high degree of snag selection by woodpeckers was indicated by the correct classification of 74.7% of the polystyrene snags.

Throughout the year, 27 cavities were excavated within the clear-cut. General univariate patterns showed reduced canopy cover, small trees (TREESB), and nearby trees of 2.6–8.0 cm DBH for CAVITY snags. Polystyrene snags with cavities leaned more than snags that had not been excavated (Table 3); however, only the nearby trees of 2.6–8.0 cm DBH had sufficient discriminating ability to be included in the DF model. Although this single-variable discriminant axis significantly distinguished between group centroids for the CCYEAR analysis (F = 5.5; df = 1,84; $P < 0.025$), group membership was predicted correctly for only 54.7% of the snags.

On the entire plot throughout the year, 34 cavities were excavated. Five habitat variables were significantly different between CAVITY and NOCAVITY snags. There were more trees of 1.1–8.0 cm DBH, more total trees, and more nearby trees of diameter 2.6–8.0 cm around snags lacking cavities, while snags with cavities leaned to a greater degree (Table 3). Group means differed significantly along the DF axis (F = 6.1; df = 2,96; $P < 0.01$), which was positively correlated with snag lean and negatively associated with nearby trees of 2.6–8.0

cm DBH. Although group distributions overlapped moderately, 67.7% of the artificial snags were correctly categorized.

Several patterns of habitat selection by cavity-excavating Downy Woodpeckers are indicated by the above analyses. First, during the autumn and winter, canopy cover was the most important habitat variable in snag selection. On at least five occasions, we saw woodpeckers (downy, red-bellied, pileated, and flickers) flying over the clear-cut from the forest on the northeast side to the woodland on the southwest border of the clear-cut. Leaves remained on the trees until late October, so the initial use of the clear-cut might have been enhanced by the reduced canopy cover around some of the snags. This might have provided woodpeckers with less obstructed access to some of the snags. Also, some of the snags might have been visible to the woodpeckers flying over the otherwise dense canopy of the clear-cut. Once Downy Woodpeckers began using these cavities as roost-sites, other snags with greater canopy cover could have been discovered during foraging movements within the clear-cut. Distance to an opening was a function of the distance to the clear-cut borders. During the "winter" period, 81.3% (13 of 16) of the snags selected were within 35 m of the clear-cut edge. Likewise, 76.5% (26 of 34) of the total snags excavated exhibited this non-random pattern. By selecting roost sites near the edge, woodpeckers could have been retaining ready access to more than one habitat type (Strelke and Dickson, J. Wildl. Manage. 44:559–567, 1983).

Woodpeckers favored snags placed in mature woodland, as they excavated 54% (7 of 13) of the snags placed in the band of large trees on the southwest margin of the clear-cut as compared to 31% (27 of 86) of the snags within the clear-cut. This result arose because woodpeckers prefer mature stands. Peterson and Grubb (1983) found that Downy Woodpeckers dug cavities in 84% of the artificial snags they placed in a mature bottomland woodlot.

The lack of trees 2.6–8.0 cm DBH (NEARTRC) close to snags with cavities might reflect an antipredator strategy. Medium-sized mammalian predators apparently had difficulty climbing the polystyrene snags (e.g., claw marks indicated that the polystyrene could not usually support a predator's weight as it climbed the snag), so a nearby tree could have provided the means by which such a mammal could have seized a roosting bird or nest-cavity contents. Trees smaller than 2.5 cm DBH probably cannot support a raccoon (*Procyon lotor*) or opossum (*Didelphis virginiana*). Trees greater than 8.0 cm DBH also were scarcer around CAVITY snags.

Our results indicate that snags used for management purposes should be placed in relatively open patches within the clear-cut. Also, at least some of the snags should be placed near the edges of the clear-cut. This placement might accelerate woodpecker colonization by providing the woodpeckers with greater visibility and access to the introduced snags. Finally, the polystyrene snags should be placed so that they lean slightly and a small area should be cleared around them.

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