# PRIMARY CAVITY-SITE SELECTION BY BIRDS

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*Abstract:* Current recommendations for snag management, which focus on characteristics of individual snags or stocking levels in forests managed for timber production, not only obscure the importance of forest characteristics surrounding a potential nesting site but also fail to meet the management objectives or abilities of the small landowner. During the summers of 1978 and 1979, a random sample of 816 snags (standing dead trees) was studied in central New York. Sixty-seven percent of the sample was in mature maple (*Acer* spp.)-ash (*Fraxinus* spp.)-elm (*Ulmus* spp.), the remainder was in 2nd growth woodland. A set of 21 characteristics of snags and 19 characteristics of forest sites was analyzed to determine which best predicted bird use. Use was defined as the presence of ≥1 bird cavity in a snag or a forest site. Forest characteristics were sampled in randomly located 0.049-ha circles ($N = 61$) in 1979. Stepwise logistic regression revealed that forest characteristics (total snag basal area, tree species diversity, and number of tree species) were more reliable predictors of bird use than were snag characteristics (diameter at breast height [dbh], amount of bark, height, and species). Snag management based on selecting suitable forest sites and on maintaining or creating suitable snags within those sites is recommended. Use of logistic regression models by field managers is discussed.

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Numerous bird species, especially cavity nesters, depend upon snags for roosting or nesting sites (Scott et al. 1977). Many of these species range throughout the northeastern United States where most of the forested land is privately owned and, therefore, where maintenance of cavity-nesting bird populations depends upon the management decisions of the landowner. If avian use of snags and forest sites can be associated with some easily measured variable, management for cavity nesters can be incorporated easily into forest management strategies (Hicks 1983).

Agricultural trends in New York are typical of many northeastern states (Morris 1977). Once occupying 90% of New York lands, agricultural interests (excluding forestry) now occupy <33% of the state (Dwyer 1977). Natural reforestation has occurred on a large portion of the released northeastern farmland. Residual mature forests remain on sites least suitable for agriculture; many of these forests are riparian. In central New York, as elsewhere in the Northeast, American elms (*U. americana*) in mature forests were killed by Dutch elm disease (*Ceratocystis ulmi*) during the late 1950's and now stand as snags.

This study evaluated the utility of snags to primary cavity-nesting birds in New York forests. Objectives were to differentiate between used and unused snags, using simple criteria, and to quantify important characteristics of the forest surrounding snags used by cavity nesters.

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## STUDY AREA

The study was conducted during the summers of 1978 and 1979 at the Cornell University Biological Field Station, Shackelton Point. The station's land-use history parallels that of the Northeast, and its vegetation is typical of central New York in both species and forest structure (Wright 1956). The study area consisted of approximately 45 ha of mature riparian forest (20–25%) and 2nd growth hardwood forest (75–80%).

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## METHODS

A snag was defined as any dead, standing woody stem with a dbh ≥10.1 cm and a height ≥150 cm (Bull and Meslow 1977, Scott et al. 1977, Thomas 1979:60).

In 1978, 3 1-ha plots were established in mature riparian forest sites. These plots were located randomly as permanent plots for a long-term study of snag development and loss. All snags within the plots were tagged, and their characteristics were recorded. In 1979, snags were sampled along randomly selected, parallel transects within the study area; by chance, the 1979 sample did not traverse any portion of the plots established in 1978. Beginning at a point 25 m inside the forest edge, a search was conducted for the 1st snag within 10 m of the transect line. That snag defined the center of a 25-m-diameter (0.049 ha) circle within which forest characteristics were measured. The search then continued along the transect line to locate the next snag that was within 10 m of the transect line and at least 25 m from the previously located snag. The procedure was followed until 10 nonoverlapping circles were defined. This systematic sampling procedure assured an unbiased sample of snags and forest sites. Neither the condition of the center snag nor its use by birds was considered as a criterion in the selection process. Characteristics of all snags within a sample circle were recorded.

Visual inspection of cavities with binoculars was employed to identify roosting or nesting holes (Scott et al. 1978). No attempt was made to determine whether holes were currently occupied (von Haartman 1957, Short 1979). Because time constraints did not permit observation of individual cavities, "used" snags were defined as those containing ≥1 roosting or nesting cavity. Those containing no such cavities were considered "unused." Forest sites (0.049-ha circles) were classified as "used" if ≥1 snag in the site was used.

Twenty-one snag variables were analyzed including dbh, species, height, amount of bark remaining, loss of twigs or limbs, evidence of fungal decomposition, vine coverage, and others. The 19 forest characteristics sampled within each of 61 sites included: forest type (2nd growth or mature); species diversity and densities for tree, shrub, and herbaceous species; species diversity, density and basal area of snags; and average canopy closure. The dbh of trees and shrubs ≥7.0 cm was measured individually with a diameter tape; stems <7.0 cm were counted. Table 1 defines variables retained in final statistical models. (A comprehensive list of variables measured is available from R. J. Gutiérrez.)

Most of the variables were selected for ease of measurement or estimation to permit their use by private landowners. As expected, many of the nominal- or ordinal-scaled variables used were not distributed normally. As a result, logistic regression analysis was chosen to differentiate between the populations of used and unused snags and forest sites. Logistic regression is an alternative to discriminant analysis when the predictive variables are not distributed normally and the 2 populations have unequal covariance matrices (Hanusheck and Jackson 1977:179–245, Press and Wilson 1978). The results presented below generally agreed with separate discriminant and univariate analyses not reported here.

The signs of the logistic regression coefficients indicated the direction of the nonlinear association between a predictive variable and the probability of a snag or site being used. That is, a coefficient $b > 0$ identified that the probability of bird use increased exponentially as the predictor value, $x$, increased.

A stepwise logistic regression procedure was used to select the "best" set of predictor variables for each logistic regression model (Harrell 1980). Only variables with coefficients significantly different from zero at $P \leq 0.05$ were retained in the models. The logistic cutpoint, the probability value above which a snag (or a forest site) is predicted as used, was selected as the value where the correct classification rate was most nearly equal for snags or forest sites observed in both categories (used and unused).

Samples from which some data points were missing (<1%) were dropped from the analyses; this procedure made no substantive difference in the results. Data from 1978 and 1979 were considered in both separate and combined models because of differences in sampling techniques and the addition of several variables in 1979. This approach permitted the use of a substantially larger data base.

## RESULTS AND DISCUSSION

In 1978, 428 snags were sampled in 3.0 ha of mature forest (143/ha); 386 (90%) were elms. In 1979, 116 snags were sampled in 0.49 ha of mature forest (237/ha), and 272 snags were

Table 1. Logistic regression models for snags and forest sites sampled in central New York, 1978–79.

| Model No. | $N$[a] Used | $N$[a] Unused | $\chi^2$ ($P \le 0.01$) | Logistic regression model | Predictions (% correct)[b] Used | Predictions (% correct)[b] Unused |
|---|---|---|---|---|---|---|
| 1. Snags, 1978 and 1979 | 93 | 716 | 53.65 | XB[c] = −3.18 + 0.0440 DBH[d] − 0.244 BKAMT[e] + 0.814 ELM[f]<br>(0.572) (0.008) (0.125) (0.398) | 69.9 | 69.4 |
| 2. Snags, 1979 | 25 | 363 | 28.19 | XB = −1.63 + 0.0744 DBH − 0.551 BKAMT − 0.0112 THT[g]<br>(0.707) (0.017) (0.209) (0.005) | 72.0 | 71.9 |
| 3. Snags, 1978 | 70 | 358 | 16.04 | XB = −2.92 + 0.0396 DBH<br>(0.369) (0.010) | 58.6 | 61.7 |
| 4. Forest sites, 1979 | 20 | 41 | 29.16 | XB = −3.09 + 0.720 TSNBASAL[h] + 5.58 LTNODIV[i] − 1.25 LTREESPP[j]<br>(1.720) (0.188) (0.079) (0.556) | 85.0 | 80.5 |
| 5. Forest sites without snag variables | 20 | 41 | 13.79 | XB = −4.01 + 2.46 FOR[k] + 3.85 LTNODIV − 0.815 LTREESPP<br>(1.660) (0.906) (1.640) (0.429) | 75.0 | 68.3 |
| 6. Snags, 1979, with forest-site variables | 25 | 363 | 43.84 | XB = −2.08 + 0.0820 DBH − 0.528 BKAMT − 0.0130 THT<br>(1.400) (0.019) (0.225) (0.005)<br>+ 1.56 SNNODIV[l] − 0.956 LTREESPP + 3.52 LTNODIV<br>(0.725) (0.319) (1.290) | 72.0 | 73.3 |

[a] Procedure dropped observations with missing values.
[b] Based on the following logistic cutpoints for each model: 0.115, 0.060, 0.160, 0.255 to 0.275, 0.325 to 0.335, and 0.055.
[c] Models follow Hanusheck and Jackson (1977:187–189) and Harrell (1980); (SE in parentheses) see Management Implications
[d] Dbh to nearest 0.1 cm.
[e] Amount of bark: none = 1, <25% = 2, 25% to 75% = 3, and ≥75% = 4.
[f] Snag species: *Ulmus* spp. = 1; all others = 0.
[g] Total ht (m) of snag
[h] Total snag basal area in 1,000 $cm^2$.
[i] Shannon-Wiener diversity index (H′) for $N$ of living trees with dbh ≥7.0 cm
[j] $N$ species of living trees with dbh ≥7.0 cm.
[k] Forest type: 2nd growth = 1, mature = 2.
[l] Shannon-Wiener diversity index (H′) for $N$ snags with dbh ≥10.1 cm.

sampled in 2.5 ha of young forest (109/ha). Two hundred twenty (57%) of the 388 snags sampled in 1979 were elms; however, 89 (77%) of the snags located in mature forest were elms. A total of 179 nesting or roosting cavities were contained in 95 (12%) of the 816 snags sampled.

## Snags Used by Cavity Nesters

For 1978 and 1979 data combined, the probability of a snag being used increased with dbh and reduced bark coverage and also was higher for elm snags. The coefficients correctly predicted snags in the used and unused categories with about 70% accuracy (Table 1, Model 1).

The logistic model for snags sampled in 1979 indicated that the probability of a snag being used increased as dbh increased, the amount of bark decreased, and the snag's total height decreased (Table 1, Model 2). This predictive model classified about 72% of the used and unused snags correctly.

The logistic model for snags sampled in 1978 indicated that the probability of bird use of a snag increased with increasing dbh. The model classified only about 60% of the used and unused snags correctly (Table 1, Model 3).

The 1st 2 models indicated a negative relationship between the amount of bark and the probability of bird use. This relationship indicated that some decay (e.g., less intact bark) increased a snag's suitability for roosting and nesting. The increase in the probability of bird use with an increase in dbh indicated that large snags were preferred; however, a preference for shorter trees was primarily an indication of a preference for a decay stage (older snags likely have broken tops and reduced height) rather than for snag size. These observations on the use of snags corroborated the conclusions of previous authors (Kilham 1971, Gale 1973, McClelland and Frissell 1975, Conner et al. 1976, Scott et al. 1978, McClelland et al. 1979, Cline et al. 1980, Mannan et al. 1980). The data relating bird use and bark coverage, however, contradicted results reported by Raphael and White (1984). Loss of bark by species in their sample of snags was not a clear indicator of decay stage. Dutch elm disease accelerates loss of bark; thus, in this study bark loss was a consistent indicator that an early stage of decay was complete.

Some differences existed among Models 1–3 (Table 1). The 1978 sample (Model 3) was fairly homogeneous (90% elm snags). These elm snags were approximately in the same stage of deterioration, having died around 1960. In the less homogeneous samples (Models 1 and 2), amount of bark and the variable indicating elm snags or total height emerged as indicators of differences in decay among snags; these variables contributed little discriminatory information to the 1978 model. The combination of dbh, amount of bark, and total height or the variable indicating elm snags (Models 1 and 2) allowed the highest correct classification rate (71%) for snags as compared to dbh alone (59%) (Model 3). These 4 variables were reliable predictors of the probability of bird use.

Five potential explanations exist for the approximately 30% misclassification rates in the logistic regression models. First, misclassification is attributable to unexplained residual error. The variables measured, however, include all those found to be significantly associated with bird use in other studies (Conner et al. 1975, Conner et al. 1976, Scott et al. 1978, Evans and Conner 1979, Scott 1979, Thomas 1979, Brawn et al. 1982). Second, ignoring individual bird species requirements masks important effects (Conner and Adkisson 1977, Balda et al. 1983). The species-independent approach we present here, however, provides easy application to owner-developed management plans. Third, some snags may have deteriorated beyond optimum utility as roosting or nesting sites. If cavity nesters prefer snags in the later stages of deterioration (Brawn et al. 1982), this alternative seems very unlikely. Field observations also tended to refute this argument. A 4th explanation suggests that, unlike results from other regions (e.g., Thomas et al. 1976, Scott et al. 1978, Mannan et al. 1980), availability of suitable snags does not limit cavity-nesting species in this study area. Although this hypothesis remains to be tested, it is consistent with the land use and natural history of the region and with the abundance of snags created by Dutch elm disease (Osborne 1982). This hypothesis may be testable as beech scale (*Cryptococcus fagisuga*) and *Nectaria* canker kill large numbers of American beeches (*Fagus grandifolia*), thereby creating a pulse of forest snags in upland sites. Finally, the habitat structure surrounding a snag may strongly influence selection of the snag as a roosting or nesting site. The remaining models address this possibility.

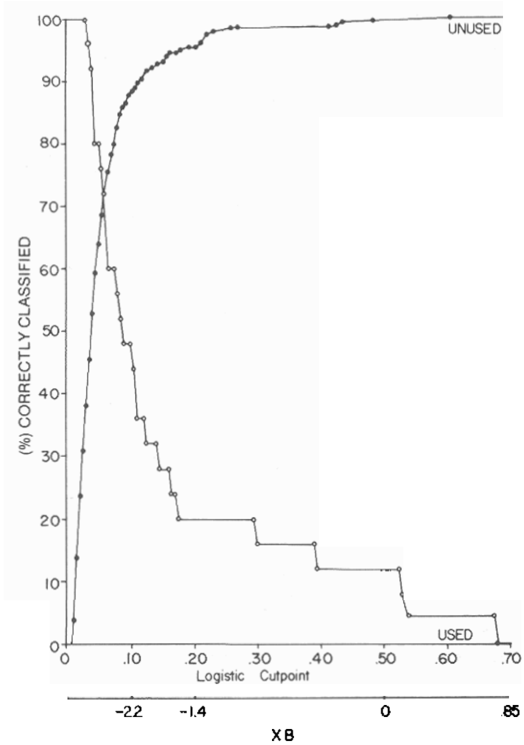


Fig. 1. Relationship of correct classification of used and unused snags to varying logistic cutpoints, based on Model 2 (Table 1), for snags sampled in central New York, 1979.

## Forest Sites and Use by Cavitv Nesters

Model 4 (Table 1) predicts the probability that a forest site includes ≥1 bird cavity. The probability of bird use in a forest site increases with available substrate for cavity excavation; i.e., increases with the total basal area of snags available. Furthermore, cavity nesters exhibit a preference for forest sites characterized by a few species of trees in a relatively even distribution; i.e., increasing diversity values and decreasing species richness. Approximately 85% and 80% of the used and unused forest sites, respectively, are classified correctly by the model.

To investigate the significance of variables related only to the living forest, all variables relating directly to snags were removed and the analysis was repeated. Model 5 (Table 1) shows the variable indicating forest maturity has replaced total basal area of snags. Thus, the probability of a forest site being used for roosting or nesting is higher for mature forest sites, as identified from land-use maps of Church (1930) and Wright (1956). These results emphasize the importance of residual mature forest as producers of suitable roosting or nesting habitat (Mannan et al. 1980).

Snag density is biased upward because the sampling technique ensured that ≥1 snag was present in every 0.049 ha sampled. Forest sites on wooded stream banks bordering released farmland have snag densities resembling mature forest, whereas the living forest is classified as 2nd growth. However, snag densities in 2nd growth sites (109/ha) are lower than those in mature sites (238/ha) under identical sampling criteria. Thus, residual mature forest sites provide a reservoir of roosting and nesting sites, whereas 2nd growth forests are just beginning to yield snags (Osborne 1982).

Use of a forest site by cavity-nesting birds is predicted correctly at a rate 10–15% higher when forest characteristics, rather than individual snag characteristics, are used. Using forest characteristics, the correct classification is less sensitive to changes in the logistic cutpoint; i.e., the slopes of the curves in Fig. 1 are steeper than the slopes in Fig. 2, generally. The 1st forest characteristic in Model 4 is snag supply. Thus, cavity nesters probably select only those suitable snags that are located in suitable forest sites. This interpretation is supported by recent research (Mannan et al. 1980, Balda et al. 1983, Brush et al. 1983).

## Snags, Forest Sites, and Use by Cavity Nesters

To test whether forest site or snag characteristics more strongly influenced cavity-site selection, characteristics of forest sites were appended to the data for each snag in the site. This merged data set included only those snag and forest-site variables that were significant at $P \leq 0.20$ in the foregoing stepwise analyses (Models 2 and 5, respectively). In the resulting model (Table 1, Model 6) forest characteristics were used to predict the probability of bird use for an individual snag. The stability of correct classification rates increased slightly when compared to Models 1 and 2. The probability of a snag being used increased with the snag's dbh and state of decomposition and increased for snags that were located in forest sites characterized by a high diversity of snag species and a few live tree species evenly represented. The significance of increased snag species diversity probably was related to availability of foraging

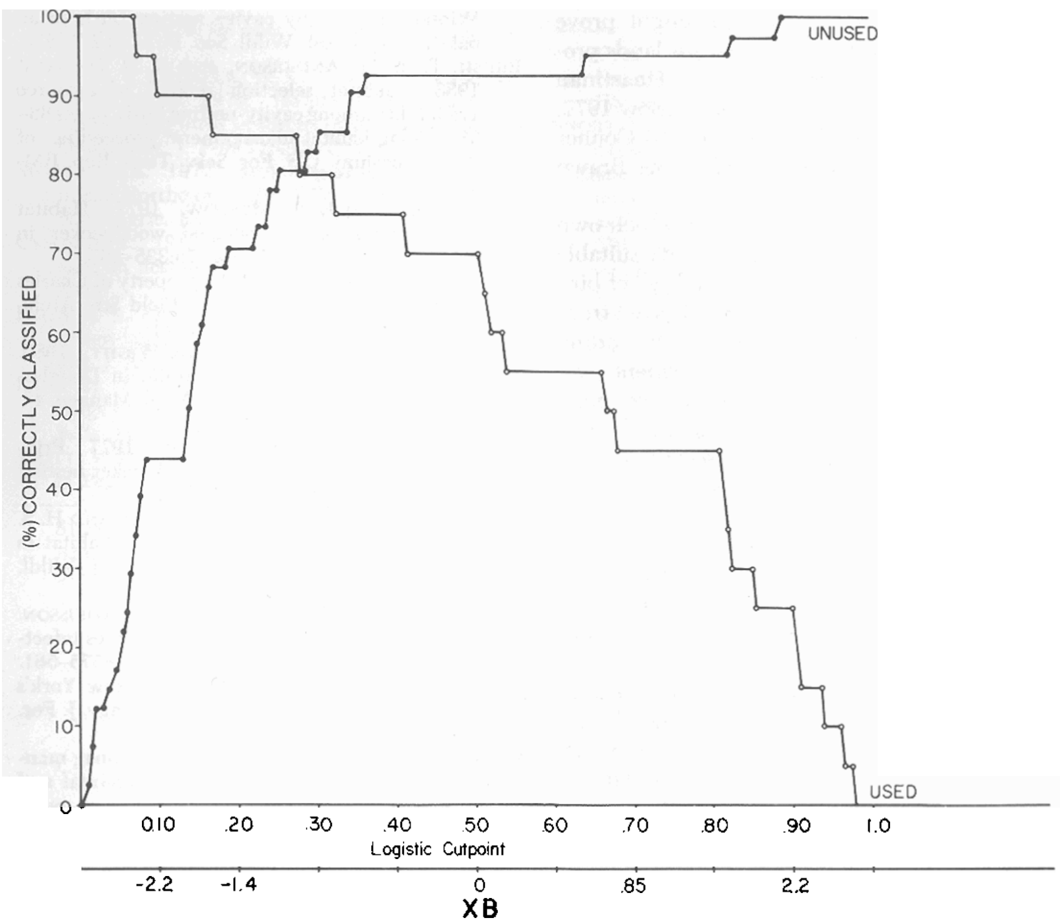


Fig. 2. Relationship of correct classification of used and unused forest sites to varying logistic cutpoints, based on Model 4 (Table 1), for forest sites sampled in central New York, 1979.

substrates. Brawn et al. (1982) suggested that cavity nesters preferred rough-barked snags as foraging sites. In this study a high snag species diversity generally indicated the presence of ash and maple along with elms, which were frequently barkless. A high diversity of snag species also may be associated with a higher diversity of cavity-nesting birds (Brush et al. 1983).

The improvement in correct classification for Model 6 indicates that forest characteristics are significantly associated with bird use of a snag even after the significant snag characteristics are exhausted. That observation strongly implicates the entire range of snag and forest-site variables in the selection process and argues for careful consideration of both in the management of forests for cavity-nesting birds. This analysis supports similar results of Raphael and White (1984).

## MANAGEMENT IMPLICATIONS

The findings of this study provide qualitative and quantitative criteria for improving the management of northeastern forests for cavity-nesting birds. Qualitatively, the model coefficients indicate the direction of relationships between bird use, snag size, deterioration stage, and forest composition. Minimally, the manager should recognize the impact of site alteration on snag suitability. The provision of natural or artifically created tracts of snag-bearing woodland remains a viable management strategy. Tract management should focus on habitat characteristics identified in this and other studies (McClelland et al. 1979, Cline et al. 1980, Mannan et al. 1980, McClelland 1980, Hicks 1983). Although this study does not explicitly address optimal tract size, casual observation suggests that tracts ≥0.1–0.2 ha might prove effective in the Northeast if adjacent lands provide supplementary resources (von Haartman 1957, Conner et al. 1975, Bull and Meslow 1977, Conner and Adkisson 1977, Evans and Conner 1979, Short 1979, Mannan et al. 1980, Brawn et al. 1982).

Quantitative managers may employ their own logistic regression equations to identify suitable tracts and snags, where the "probability" of bird use = $1/(1 + \exp[-XB])$ and XB is derived from an appropriate model; e.g., Table 1. Depending upon the degree to which a management plan favors cavity-nesting birds, the manager may raise or lower the "critical probability" (i.e., logistic cutpoint) and thereby raise or lower the number of snags and forest sites identified for intensive management. However, there are trade-offs associated with choosing a logistic cutpoint for management purposes (Figs. 1 and 2). For example, by choosing a low cutpoint managers will efficiently identify the forest sites most suitable for cavity nesters; however, greater efficiency in selecting the most suitable sites is obtained at the expense of managing a larger proportion of less desirable forest sites which are erroneously identified as prime habitat.

Finally, these results indicate that snags in the study area, and perhaps wherever Dutch elm disease occurred, may be available in numbers beyond the requirements of the cavity-nesting bird population. However, the snags in these mature riparian forest remnants are providing potentially critical habitat resources for cavity-nesting birds until such time as 2nd growth forests mature on retired agricultural lands in the Northeast. This phenomenon may be repeated in the uplands as beech scale produces another pulse of snags in northeastern forests.

In regions characterized by an abundance of snags, management should direct more effort toward nonsnag resources that limit bird populations. Management of forest-site characteristics is a 1st step toward providing these nonsnag resources.

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