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Resource Ecology

MACROHABITAT SELECTION BY NESTING NORTHERN GOSHAWKS: IMPLICATIONS FOR MANAGING EASTERN FORESTS

THOMAS BOSAKOWSKI AND ROBERT SPEISER

Abstract. Macrohabitat data from 16 Northern Goshawk (*Accipiter gentilis*) nest sites and 70 random sites in the New York–New Jersey Highlands were analyzed. Variables included distances to human habitation, paved road, water, wetlands, and forest openings, elevation, and slope, slope location, and slope aspect. Univariate tests revealed that macrohabitat was important to nest site selection in goshawks, since several variables were significantly different than random sites (distance to human habitation, paved roads, and elevation). In addition, slope aspect data revealed that nesting on southern aspects (SW, S, SE) was avoided. A full-model discriminant function analysis (DFA) was used to determine the extent of overlap between random sites and nest sites. The DFA was able to correctly classify 69% of nest sites and 79% of random sites, further demonstrating that macrohabitat plays an important role in nest site selection. A management model using stepwise DFA revealed that distance to paved road and elevation were the most important discriminating variables. These variables indicated that the goshawk may be an area-sensitive species, since smaller forest tracts bounded by paved roads were not used for nesting.

Key Words: *Accipiter gentilis*; area sensitive species; discriminant function analysis; macrohabitat; nest site selection; Northern Goshawk.

Most habitat studies of Northern Goshawks (*Accipiter gentilis*) in western Northern America have emphasized microhabitat features of the nest site, such as basal area, stand densities, canopy cover, or shrub cover (Hennesey 1978, Reynolds et al. 1982, Hall 1984, Moore and Henny 1983, Crocker-Bedford and Chaney 1988, Kennedy 1988, Hayward and Escano 1989). In the eastern deciduous forest biome, Speiser and Bosakowski (1987) found that macrohabitat (landscape level) features were also important parameters in nest site selection of Northern Goshawks when compared to random sites. Macrohabitat was also found to be an important component of nest site selection for Red-tailed (*Buteo jamaicensis*) (Speiser and Bosakowski 1988) and Red-shouldered hawks (*B. lineatus*) (Bosakowski et al. 1992a). In the East, wilderness forests are typically much smaller and are impacted more by highways, rights-of-way, and suburban development. As such, the suitability of nest sites may be highly influenced by the presence of these macro features of the environment. Thus, management plans based on microhabitat alone may include many unsuitable areas for nesting.

In this paper, we present an analysis of goshawk nest sites in the Northeast to determine which macrohabitat features are important components of nest site selection.

STUDY AREA AND METHODS

The study area was in the Highlands Physiographic Province of northern New Jersey and southeastern New York (315,780 ha) and was described in detail in Speiser and Bosakowski (1987) and Bosakowski et al. (1992b). Goshawk nests were located in the study area from 1976–1989. In addition to our own searches, we pursued all reports of possible goshawk nesting from *Records of New Jersey Birds*, local naturalists, and forestry personnel.

Habitat data were collected as described in Bosakowski et al. (1992b) for 16 Northern Goshawk nests and for 70 random sites described in Speiser and Bosakowski (1988). Macrohabitat variables included distances to human habitation, paved road, water, wetland (>0.5 ha), and forest opening (>1 ha), and elevation, slope (over a 150-m baseline centered through the site), slope location rating (0 = no slope, 1 = lower slope, 2 = middle slope, 3 = upper slope) and slope aspect (8 classes).

All data were analyzed on a personal computer using NCSS software version 5.03 (Number Cruncher Statistical Software, Kaysville, Utah). Univariate tests were run separately for each variable comparing nest sites and random sites with an F-test and t-test. An unequal variance t-test was used (Winer 1971) when F-test results indicated significant differences in variance ($P < 0.05$). All variables were tested for normality using the test described by D'Agostino (1990). Random site variables were found to be non-normal, so all data were square root-transformed. This transformation normalized the data set prior to multivariate analysis.

The first stage in model building was to construct a correlation matrix to determine any problems of collinearity among variables. Titus and Mosher (1981) used a cut-off value of $r < 0.6$ to eliminate multicollinearity. Because the highest simple correlation in this study was only 0.54, all variables were retained for inclusion in a full-model discriminant function analysis (DFA). Discriminant scores were automatically

TABLE 1. MACROHABITAT VARIABLES FROM RANDOM SITES AND NEST SITES OF NORTHERN GOSHAWKS WITH UNIVARIATE COMPARISONS

	Random site (N = 70)		Nest site (N = 16)			
	$\bar{X}$	SD	$\bar{X}$	SD	F-test P value	t-test P value
Distance to (m)						
Paved road	501.9	± 452.7	1170.6	± 652.3	0.079	0.000
Human habitation	730.1	± 516.5	1052.2	± 634.7	0.314	0.034
Water source	250.8	± 201.9	212.2	± 106.2	0.004	0.288
Wetland	564.2	± 552.0	326.8	± 370.0	0.080	0.084
Forest opening	238.1	± 210.0	263.8	± 116.8	0.008	0.508
Elevation (m)	273.1	± 84.2	342.9	± 62.8	0.155	0.003
Slope (degrees)	8.67	± 5.84	9.50	± 8.15	0.108	0.637
Slope location (rank 0–3)	1.14	± 1.12	1.06	± 0.77	0.074	0.786

rescaled to a probability scale (0–1) by the NCSS program and were plotted to show the extent of group separation.

RESULTS

STATISTICAL RESULTS

Nest sites and random sites were significantly different for several macrohabitat variables (Table 1). Distance to paved road, distance to human habitation, and elevation were significantly different when comparing means. Unequal variances were found for distance to water and distance to forest opening, with nest sites showing lower variation in each case. Goshawks nested in all but southern aspects (SW, S, SE) (Fig. 1), resulting in a significantly different distribution from random sites (Kolmogorov-Smirnov Test, 2-tailed, $D = 0.875$, $P < 0.05$).

FULL-MODEL DISCRIMINANT FUNCTION ANALYSIS

Full-model DFA of the macrohabitat variables correctly classified 78.6% of the random sites and 68.8% of the goshawk nest sites. Conversely, there were 15 misclassified random sites (21.4%) and 5 misclassified nest sites (31.3%) (Table 2). Discriminant scores from all sites were plotted to show the pattern of separation between the groups as well as to demonstrate the pattern of overlap that resulted in misclassified sites (Fig. 2).

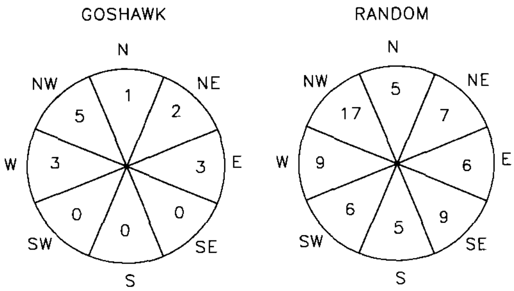

FIGURE 1. Slope aspects of Northern Goshawk nest sites and random sites. No aspect was determined for two nest sites and six random sites on level ground.

MANAGEMENT MODEL

Following the suggestion of Mosher et al. (1986), we also used a stepwise DFA to determine the most important discriminating variables in habitat selection. This test revealed that two of the original eight variables retained nearly the same Wilks' lambda value (Table 3), and that the prediction (classification) accuracy was also nearly the same. In this case, the nest site predictions remained the same, but one less random site was misclassified as a nest site.

DISCUSSION

Our results with discriminant models showed that goshawks do not select macrohabitat at random, as the majority of nest sites and random sites were correctly classified. Since random sites should include the whole spectrum of available habitat (suitable, marginal, and unsuitable habitat), a certain degree of overlap is expected between random site data and nest site data (Fig. 3). This overlap region includes all of the sites that the models had difficulty segregating between random and nest sites, which are typically known as misclassified sites (Fig. 2). Thus, the misclassified random sites included habitat that was both suitable and marginal for goshawk nesting, whereas the misclassified nest sites represented sites with marginal habitat for goshawks.

Overall, these results suggest that goshawks are selecting certain macrohabitat features for nesting in eastern forests, which means that nest site selection is not based entirely on forest stand

TABLE 2. SUMMARY OF FULL-MODEL DISCRIMINANT FUNCTION ANALYSIS OF SQUARE ROOT-TRANSFORMED MACROHABITAT VARIABLES FROM NORTHERN GOSHAWK NEST SITES AND RANDOM SITES

	Canonical coefficients		
Variables	Random site	Nest site	F-Prob
Distance to			
Paved road	0.286	0.427	<0.001
Human habitation	0.088	0.080	0.858
Water source	0.206	0.179	0.669
Wetland	0.329	0.316	0.727
Forest opening	0.029	0.097	0.308
Elevation	2.544	2.870	0.031
Slope	1.236	0.968	0.370
Slope location	−2.085	−1.992	0.440
(Constant)	−30.80	−39.69	
Wilks' Lambda = 0.7065			

characteristics. Additional investigations of Red-tailed Hawks (Speiser and Bosakowski 1988) and Red-shouldered Hawks (Bosakowski et al. 1992a) in the same study area also showed significant macrohabitat selection by these sympatric raptors, albeit each species exhibited different macrohabitat preferences. For the goshawk, this selectivity results in only a fraction of the total study area that is suitable macrohabitat for nesting, an important point for management and conservation in eastern forests. If the avoidance of southern aspects for nesting that we noted for 16 nests is verified with larger sample sizes, it may be possible to eliminate approximately 37.5% of management areas from future nest searches or habitat management.

The remote nature of goshawk nest sites was characterized by significantly longer distances to paved roads and human habitation. Higher elevations were also selected, possibly because the largest wilderness areas occurred only at higher elevations in the study area. These results indi-

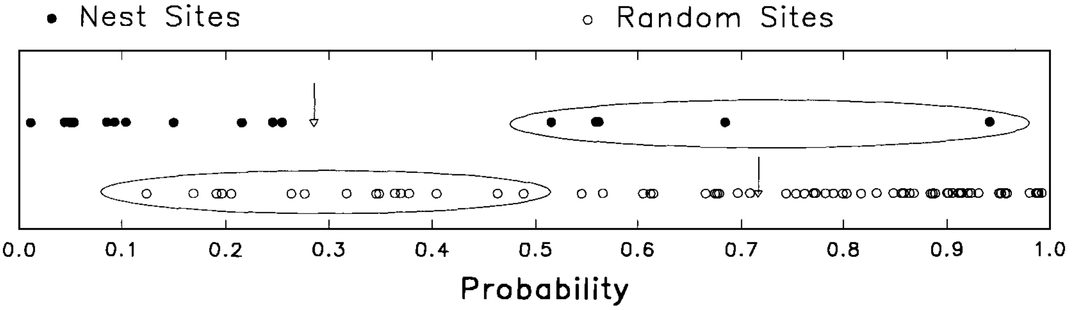

FIGURE 2. Discriminant score distribution for full-model DFA macrohabitat model of nest sites (N = 16) and random sites (N = 70). Data indicate probability of a site being a random site with arrows indicating group means. Circled sites represent the misclassified sites.

TABLE 3. SUMMARY OF STEPWISE DISCRIMINANT FUNCTION ANALYSIS (MANAGEMENT MODEL) OF SQUARE ROOT-TRANSFORMED MACROHABITAT VARIABLES FROM NORTHERN GOSHAWK NEST SITES AND RANDOM SITES

	Canonical coefficients		
Variables	Random site	Nest site	F-Prob
Distance to paved road	8.06	11.84	<0.001
Elevation	114.2	119.7	0.004
(Constant)	−144.7	−167.5	
Wilks' Lambda = 0.7253			

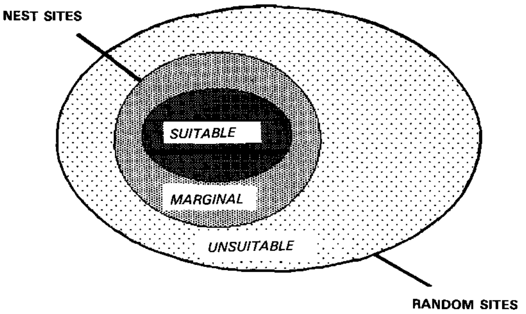

FIGURE 3. Random site and nest site domains for discriminant models in relation to habitat suitability.

cate that the goshawk is an area sensitive species, requiring large blocks of forested habitat since the study area was very nearly covered by contiguous forest. Robbins et al. (1989) demonstrated that area sensitivity was a phenomenon for many breeding bird species in the eastern deciduous forest. In our study, goshawks rarely nested in smaller forest tracts, which underscores the important effect of macrohabitat on breeding bird occurrence in eastern forests. In eastern forests this effect appears to stem from encroaching urbanization.

As a management model for eastern forests, the stepwise DFA indicated that only two of the original eight variables (distance to paved road and elevation) are needed to predict suitable macrohabitat for nesting goshawks. This reduction in the number of variables could speed the search for suitable macrohabitat and managers could apply these two variables to a sampling grid-system of random points on study area maps. With the advent of Geographic Information Systems and digital elevation models, rapid identification of suitable nesting areas is now possible and there may be less need to eliminate variables from consideration. Once suitable macrohabitat blocks have been identified, it would be prudent to conserve these areas from logging and development to preserve mature and old-growth stands which are preferred for nesting (Speiser and Bosakowski 1987).

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