NEST-SITE HABITAT SELECTED BY WOODLAND HAWKS IN THE CENTRAL APPALACHIANS

KIMBERLY TITUS AND JAMES A. MOSHER

Appalachian Environmental Laboratory, University of Maryland, Center for Environmental and Estuarine Studies, Frostburg State College Campus-Gunter Hall, Frostburg, Maryland 21532 USA

ABSTRACT.—We quantitatively describe the nest-site habitat selected by Broad-winged Hawks (*Buteo platypterus*), Red-shouldered Hawks (*B. lineatus*), Red-tailed Hawks (*B. jamaicensis*), and Cooper's Hawks (*Accipiter cooperii*), emphasizing differences among species and between each species and the surrounding forest habitat. We subjected 53 nest sites and 100 randomly selected sites to an intensive habitat analysis based upon the James and Shugart (1970) techniques. White oak (*Quercus alba*) was the most common nest tree. Distance to water, percentage nest height, distance to the nearest forest opening, basal area, and dbh of the nest tree were important discriminating variables between the hawk species. Compared with the random sample of the available forest area, Broad-winged Hawks nested closer to water and to forest openings. Red-shouldered Hawks consistently nested near water and in large trees in stands of mature forests. Red-tailed Hawks nested higher in trees than did the other species, on or near the top of ridges, and far from water and forest openings. Cooper's Hawks nested proportionally higher in trees than did Broad-winged and Red-shouldered hawks and were associated with mature forest with a well-developed understory and ground cover layer. A discriminant function analysis revealed that each species appears to select rather specific nesting areas, as characterized by the proximity of the site to various physiographic features and the structure of the nest tree.

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FEW studies of raptors have attempted to describe nest-site habitat use in forested areas quantitatively (Dietzen 1978, Hennessy 1978, Howell et al. 1978, Keran 1978, Bednarz 1979). Most habitat descriptions for raptors have been qualitative, with little comparison of sympatric species. In this study we examined the habitat characteristics associated with the nest sites of four sympatric falconiformes, Broad-winged Hawks (*Buteo platypterus*), Red-shouldered Hawks (*B. lineatus*), Red-tailed Hawks (*B. jamaicensis*), and Cooper's Hawks (*Accipiter cooperii*).

Our objectives were to (1) describe habitat characteristics at the nest sites of each species quantitatively, (2) compare differences in nest sites among the species, and (3) compare nest-site habitat for each species with available nesting habitat.

METHODS

Study areas.—The study areas, located in Garrett and Allegany counties of western Maryland, are characterized by a series of long ridges oriented northeast to southwest. The ridgetops generally have stony shallow soils and steep slopes (Stone and Matthews 1977). The valley floors are relatively narrow and typically contain small streams. Forests cover 74% of Allegany County and 69% of Garrett County, and the state forests that contain the study areas are almost completely forested, being broken only by secondary roads, trails, and small clearings.

The study areas lie within the Appalachian Province (Miller 1967), where two physiographically distinct districts are represented. One of the study areas, Green Ridge State Forest, encompassing about 14,000 ha, lies within the ridge and valley district. Elevation varies from about 200 to 600 m. The general forest cover type is oak [mainly type 52; white oak (*Quercus alba*), red oak (*Q. rubra*), hickory (*Carya* spp.), Society of American Foresters 1954]. The understory is dominated by flowering dogwood (*Cornus florida*) and saplings of the dominant trees. The second study area, Savage River State Forest, encompasses about 21,000 ha and lies on the Appalachian Plateau between 500 and 1,000 m elevation, averaging about 400 m higher than the ridge and valley study site. The vegetation is more typical of a northern hardwood forest. The most common tree species are red oak, sugar maple (*Acer saccharum*), shagbark hickory (*Carya ovata*), pignut hickory (*C. glabra*), black birch (*Betula lenta*), and white pine (*Pinus strobus*). Cool moist areas contain some stands of hemlock (*Tsuga canadensis*) and yellow birch (*Betula lutea*). Shrub species include rhododendron (*Rhododendron maximum*), mountain laurel (*Kalmia latifolia*), and flowering dogwood.

Nesting habitat description.—We conducted a systematic search of the study areas in 1978 and 1979 prior to leaf-out. Old nests were rechecked for signs of activity. These methods were adequate in locating active Red-tailed and Red-shouldered hawk nests, and rechecking after leaf-out revealed active nests of the Cooper's and Broad-winged hawks. Some nests were found while traveling to and from the study areas, and interested individuals reported other nest locations. All sites were plotted on USGS 7.5-min topographic maps and on County Soil Conservation Service maps that had been updated for recent land-use changes. The method by which a nest was found was recorded to see if any habitat variables were biased by certain methods of finding nests. For the purposes of this study, a nest site was defined as the nest tree and a 0.04-ha circular plot (11.3-m radius) centered on the nest tree.

At the end of the nesting season the vegetation at 24 Broad-winged Hawk, 10 Red-shouldered Hawk, 13 Red-tailed Hawk, and 6 Cooper's Hawk nest sites was sampled by a modification of the James and Shugart (1970) technique. Within the nest site, all woody plants over 1.75 m tall were tallied according to species, diameter at breast height (dbh), and whether their predominant foliage was part of the overstory or understory. Separate size categories were later created for understory plants and overstory trees.

Table 1 lists the 29 quantitative habitat variables that were either measured directly or created by aggregation. Height measurements were made using a Haga altimeter. Most nest heights were measured directly with a tape. A comparison of tape-measured nest heights with Haga altimeter estimates of the same nest revealed that the altimeter was accurate to within about 1 m ($\bar{x} = 0.7 \pm 0.6$m, $n = 17$).

If the plot fell at the edge of a field or other forest opening, no corrections were made, this opening being considered as part of the plot. As an example, the percentage canopy cover in that direction would be low, thereby lowering the total percentage canopy cover.

Directional exposure or aspect was quantified by the method of Mosher and White (1976). Plots with less than 5% slope were considered to be exposed in all directions. In the case of plots in a small riparian hollow or gorge with steep banks, the exposed area was considered to be bidirectional (i.e. both up and downstream).

Random sampling of forested areas was conducted throughout the two-county area. The purpose of the random sampling was to estimate available nesting habitat. The random sampling was stratified on USGS quadrangles with approximately two random plots sampled for each nest occurring in the quadrangle for a total of 100. A random numbers table was used to select two sets of three-digit numbers corresponding to vertical and horizontal scales. The random point was then plotted with the aid of a grid overlaid on the quadrangle. Once the approximate site was located in the woods, a stick was tossed, and the tree nearest to this stick was made the center point of the random sample. A tree was used as the center of the random sample plot in order to remain consistent with a nest-site sample plot. Except for the nest-tree-specific variables, the sampling was the same as that at a nest site.

The criterion for accepting a random plot was that the plot be within a forested area with a canopy height greater than or equal to 10 m. This excluded some habitat in which woodland hawks do not nest, such as fields or roads, but included some forested areas where nesting is unlikely, such as pole-stage thickets, timber-stand-improvement areas, and pine plantations. This scheme generally allowed the sampling of the total forest area without preselecting "representative" or "typical" areas (Green 1979).

The adequacy of the sample size of the random samples was checked by plotting the variance versus sample size for the habitat variables. The variances stabilized after 50–60 samples. Also, minimum sample sizes were calculated for each of the habitat variables using the criteria of remaining within 20% of the mean for 80% of the samples. These criteria were met by 19 of 25 variables with sample sizes less than 100.

Statistical methods.—Parametric statistics were used throughout the analysis. Results and explanations concerning data screening procedures and nonparametric results are reported in Titus (1980). Univariate ANOVA's were conducted on the five groups (four raptor species and the random samples) for each of 29 independent variables. A Cochran's *Q*-test (Sokal and Rholf 1969) was applied to the quantified directional exposure data.

Stepwise discriminant function analysis (Cooley and Lohnes 1971) was used to describe differences in habitat structure between the four raptor species and the random samples. Twenty-nine habitat variables were available for inclusion into the discriminant analysis. Many of these were highly correlated, indicating that they measure similar features of the habitat. Many features of the environment show varying

TABLE 1. Description of quantitative habitat variables used in analysis of raptor nest-site habitat (1 = recorded with a Haga type altimeter; 2 = based on a total of 40 ocular tube readings, 10 along each of the four transects used in SHRUBDEN). An overstory tree was a stem whose major foliage component was contained in the forest canopy layer; understory was defined as a stem whose major foliage component was below the canopy, regardless of size or height.

Mnemonic	Description
1. PERSLOP	Percentage slope of plot (1)
2. CANHT	Average canopy height of the plot in meters; the mean of five measurements taken to the top of the canopy (1)
3. ALTITUDE	Altitude of plot in meters; taken from USGS 7.5-min quadrangles
4. WATER	Distance to water in meters; when less than about 100 m, measured directly in the field; otherwise measured from 7.5-min quadrangles and/or county Soil Conservation Service maps
5. DISFOROP	Distance to the nearest forest opening in meters; measured to the nearest break in the forest continuity, such as created by a trail, road, field, etc.
6. SOIL	Soil-woods suitability; woodland classes placed into units according to their suitability for productivity of trees; class 1 indicates high productivity, and class 6 indicates low productivity; standardized by the Soil Conservation Service, USDA (Stone and Matthews 1977)
7. SITINDX	Site Index; based on SOIL and the tree species present in the plot (Stone and Matthews 1977)
8. CANEVER	Percentage evergreen canopy cover (2)
9. CANTOT	Percentage total canopy cover (2)
10. UNDEVER	Percentage evergreen understory cover (2)
11. UNDTOT	Percentage total understory cover (2)
12. GRNDEVER	Percentage evergreen ground cover (2)
13. GRNDTOT	Percentage total ground cover (2)
14. SHRUBDEN	Shrub density (James and Shugart 1970)
15. SHRUBIND	Shrub index; measured along the same transects as SHRUBDEN, except all woody stems 1–6 cm diameter and 0.25–1.75 m in height are measured; includes SHRUBDEN plus shrubs that do not intersect outstretched arms (James 1978)
16. NOSPTREE	Number of species of overstory trees in the plot
17. NOSPSHRB	Number of species of shrubs and saplings in the plot
18. NOTREES	Number of overstory trees in the plot
19. UND14	Number of understory stems 1–4 cm diameter in the plot
20. UND58	Number of understory stems 5–8 cm diameter in the plot
21. UNDGT9	Number of understory stems >9 cm diameter in the plot
22. DBHLT25	Number of overstory trees < 25 cm dbh in the plot
23. DBH2650	Number of overstory trees 26–50 cm dbh in the plot
24. DBHGT50	Number of overstory trees > 50 cm dbh in the plot
25. BASAL	Basal area in m^2/ha for overstory trees
26. DBH	Diameter breast height of the nest tree
27. NESTHT	Height of the nest in meters (1)
28. PNSTHT	Percentage nest height; calculated as: (NESTHT/HTNSTTRE) (100) = PNSTHT
29. HTNSTTRE	Height of nest tree in meters (1)

degrees of correlation, and discriminant analysis assumes independence of variables (Green 1979). To avoid potential problems in the analysis, only one of a pair of highly correlated variables ($r > 0.7$) was included in the analysis (cf. Noon in press). The variable chosen was that which was most readily interpretable in an ecological sense.

Further reduction of the number of independent variables was necessary to avoid "overfitting" small

TABLE 2. Sample means, standard deviations, and ranges of habitat variables for four hawk species' nest sites and random samples. Only variables that were used in analyses are listed.

Variable	Broad-winged Hawk (24)	Red-shouldered Hawk (10)	Red-tailed Hawk (13)	Cooper's Hawk (6)	Random samples (100)
PERSLOP	22.4 ± 10.1 (9–47)	12.1 ± 12.8 (0–44)	41.6 ± 20.5 (5–86)	16.8 ± 6.3 (8–25)	22.1 ± 15.1 (3–80)
WATER	86 ± 60 (9–211)	26 ± 24 (7–72)	288 ± 188 (28–520)	193 ± 150 (17–407)	335 ± 248 (35–1,050)
DISFOROP	63 ± 61 (3–292)	180 ± 141 (6–480)	233 ± 200 (20–550)	129 ± 124 (16–350)	229 ± 194 (8–1,110)
SITINDX	72.5 ± 8.3 (50–85)	76.0 ± 10.5 (50–85)	67.5 ± 10.1 (50–80)	74.2 ± 6.6 (65–80)	63.5 ± 11.8 (40–90)
CANTOT	75 ± 11 (40–88)	74 ± 8 (58–83)	71 ± 12 (43–85)	76 ± 13 (53–85)	76 ± 8 (43–90)
UNDTOT	59 ± 12 (30–88)	69 ± 15 (40–90)	59 ± 15 (33–80)	57 ± 7 (48–65)	54 ± 14 (18–80)
GRNDTOT	44 ± 17 (13–73)	50 ± 23 (13–78)	46 ± 20 (18–98)	58 ± 14 (43–78)	41 ± 18 (10–85)
SHRUBDEN	31.8 ± 19.2 (6–74)	42.4 ± 45.6 (3–157)	37.8 ± 20.6 (6–84)	25.2 ± 16.4 (11–54)	23.2 ± 11.0 (3–64)
UNDGT9	6.6 ± 3.5 (0–13)	11.3 ± 10.6 (3–40)	5.7 ± 3.4 (0–13)	9.2 ± 4.9 (3–15)	5.6 ± 3.4 (0–14)
DBHLT25	6.4 ± 5.4 (0–21)	3.6 ± 3.6 (0–13)	5.7 ± 5.1 (0–16)	6.3 ± 6.8 (0–19)	14.6 ± 11.8 (0–50)
DBH2650	5.9 ± 2.9 (2–15)	5.1 ± 2.1 (3–9)	3.4 ± 2.0 (0–7)	5.5 ± 3.3 (2–9)	4.8 ± 2.8 (0–12)
DBHGT50	0.3 ± 0.7 (0–3)	1.0 ± 0.8 (0–2)	1.0 ± 0.9 (0–3)	1.0 ± 1.5 (0–3)	0.2 ± 0.6 (0–3)
BASAL	19.0 ± 5.7 (9.4–36.8)	26.8 ± 4.6 (15.7–31.8)	20.3 ± 5.1 (13.2–30.5)	24.3 ± 5.0 (16.4–32.0)	20.3 ± 5.6 (3.9–34.3)
DBH	38.0 ± 9.5 (25.0–62.0)	61.5 ± 20.5 (41.0–104.0)	51.8 ± 17.3 (31.0–94.0)	44.5 ± 13.6 (31.0–68.0)	
PNSTHT	59.3 ± 8.2 (41.9–73.4)	53.2 ± 10.1 (36.2–67.7)	78.5 ± 5.4 (70.4–87.5)	67.5 ± 7.7 (53.5–73.4)	
NESTHT	13.7 ± 3.0 (9.5–20.6)	13.4 ± 3.0 (8.5–20.3)	17.6 ± 3.2 (12.9–23.3)	15.4 ± 4.1 (9.2–21.3)	

sample sizes and to achieve the least complex model that would adequately discriminate between the groups (see Green 1979). Reduction of variables beyond those eliminated by high correlation was achieved through five sets of ANOVA's on the data set, including variables in the discriminant analysis that were significant at $\alpha = 0.1$.

All statistical procedures were conducted on the Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975, Nie and Hull 1977). For the discriminant analyses, all default criteria were used; the stepwise selection criterion used was Rao's V (Klecka 1975). Cohen's kappa statistic (K_w) was calculated from the results of the classification tables based on the discriminant analysis (Cohen 1960, Wiedemann and Fenster 1978). This statistic allows one to assess how well the discriminant analysis improves prediction above chance.

Unless otherwise noted, all tests were considered significant with $\alpha = 0.05$.

RESULTS

DESCRIPTION OF NESTING HABITAT

Sample means for the quantitative habitat variables used in the discriminant analyses are listed in Table 2. No nests were found in areas with canopy heights below 15 m. Canopy height was negatively correlated with the total number of

TABLE 3. Results of one-way ANOVA's (F values) testing for significant differences of habitat variables according to five groupings (*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$; # = variables unique to nest site). Only significant variables included.

Variable	Four hawk species	Broad-wing vs. random	Red-shoulder vs. random	Red-tail vs. random	Cooper's vs. random
PERSLOP	10.48***	0.01	4.10*	17.36***	0.73
CANHT	1.19	4.97*	2.37	0.01	1.95
WATER	13.12***	23.89***	15.48***	0.44	1.94
DISFOROP	5.38**	17.03***	0.60	0.01	1.55
SOIL	1.24	9.35**	9.71**	1.17	3.86
SITINDX	1.72	12.36***	10.32**	1.25	4.75*
UNDTOT	1.56	3.66	11.18**	2.03	0.33
GRNDTOT	0.91	0.44	1.72	0.76	4.81*
SHRUBDEN	0.71	8.52**	11.74***	15.97***	0.17
SHRUBIND	0.58	3.86	8.74**	8.67**	0.81
NOSPTREE	0.08	2.80	1.06	0.64	0.44
NOTREES	1.20	10.59**	9.19**	11.06**	2.77
UNDGT9	2.35	1.25	13.91***	0.00	5.31*
DBHLT25	0.72	10.96**	8.56**	7.20**	2.88
DBH2650	2.65	2.77	0.11	3.04	0.34
DBHGT50	3.13*	0.02	15.44**	18.15***	7.99**
BASAL	5.90**	1.05	12.32***	0.00	2.84
DBH#	6.92***				
NESTHT#	5.14***				
PNSTHT#	23.61***				

overstory trees and the number of overstory trees less than 25 cm dbh and positively correlated with basal area. These four variables were all related to forest-stand structure. No nests were found in stands with an overstory tree density greater than 650 trees/ha, and most sites occurred in stands that were much less dense ($\bar{x}$ = 278 trees/ha). Areas with a high number of trees and a low canopy height were younger forests, as represented by many of the random samples.

Broad-winged, Red-shouldered, and Cooper's hawks were all found nesting in areas with a higher Site Index than the mean for the random samples (Table 3). Red-tailed Hawk nest sites were on steeper slopes than those of any of the four other groups. All Red-shouldered and Broad-winged hawk nest sites were near water (72 m and 211 m, respectively). Distance to the nearest forest opening was significant only for the Broad-winged Hawk (Table 3), the nest sites of which were closer to forest openings than those of any of the other species or than the random samples. Results of the Cochran's Q-test for directional exposure revealed that Red-tailed Hawk nest locations most frequently occurred on east-facing slopes ($P < 0.05$), while the sites of the three other hawk species and the random samples were randomly oriented.

We recorded 36 species of overstory trees on the study areas, but only 15 tree species were used as nest trees (Table 4). White oak was used as a nest tree in 20 of 53 instances. Four Red-tailed Hawk nests were in pines (*Pinus* spp.) that were isolated within a deciduous stand.

Table 2 lists the means for three of the four variables specific to the nest tree, and Table 3 provides the results of the ANOVA's on these variables. Based on Duncan's multiple range test (DMRT), the Red-tailed Hawk nested higher off the ground than the other three species ($P < 0.05$). The mean percentage nest heights were all significantly different between these species (DMRT), with the Red-shouldered Hawk nesting relatively low and the Broad-winged, Cooper's, and Red-tailed hawks nesting successively higher.

TABLE 4. Nest tree species used by raptors in the central Appalachians (BWH = Broad-winged Hawk; CH = Cooper's Hawk; RSH = Red-shouldered Hawk; RTH = Red-tailed Hawk).

Species	BWH (24)	CH (6)	RSH (10)	RTH (13)	TOTAL (53)
White oak (*Quercus alba*)	12	1	6	1	20
Red oak (*Q. rubra*)	4	1	2	2	9
Scarlet oak (*Q. coccinea*)	2	2		1	5
Chestnut oak (*Q. prinus*)	1			1	2
Sugar maple (*Acer saccharum*)	2			1	3
Red maple (*A. rubrum*)		1			1
Black locust (*Robinia pseudo-acacia*)	1			1	2
Black cherry (*Prunus serotina*)	1				1
Pignut hickory (*Carya glabra*)				2	2
Black birch (*Betula lenta*)	1				1
Short-leaf pine (*Pinus echinata*)				3	3
Pitch pine (*P. rigida*)				1	1
Tulip (*Liriodendron tulipifera*)			1		1
American beech (*Fagus grandifolia*)			1		1
Hackberry (*Celtis occidentalis*)		1			1

DISCRIMINANT FUNCTION ANALYSIS

We conducted a stepwise discriminant function analysis on the four species' nest sites (Table 5). Based on Tatsuoka's ω^2 multi, 91% of the total variability contained in the three discriminant functions was the result of group differences; this percentage may be used ". . .as a measure of the total discriminatory power residing in the discriminant function or, equivalently, in the predictory battery as a whole" (Tatsuoka 1970). The first discriminant function shows heavy weighting on distance to water and percentage nest height. Distance to the nearest forest opening shows moderate weighting. Discriminant function II has heavy weighting on basal area, dbh of the nest tree, and distance to the nearest forest opening. Along discriminant function I, Broad-winged and Red-shouldered hawks show nearly complete overlap (Fig. 1). The Red-tailed Hawk shows little or no overlap with the other three species. The only separation along discriminant function II is between the Broad-winged and Red-shouldered hawks (Fig. 1). Overall, Cooper's Hawk nest sites are intermediate between the other species.

TABLE 5. Summary of stepwise discriminant function analysis on four hawk species' nest sites.

	Discriminant function		
	I	II	III
Eigenvalue	4.983	0.726	0.165
Percentage of eigenvalue associated with the function	84.8	12.4	2.9
Canonical correlation	0.913	0.649	0.376
Chi-square statistic	115.7	32.5	7.1
Significance (degrees of freedom)	$P < 0.001$ (21)	$P < 0.001$ (12)	$P > 0.05$ (5)
Standardized discriminant function coefficients			
PERSLOP	0.1387	0.2368	
WATER	0.5173	−0.0829	
DISFOROP	0.3146	−0.3541	
DBH2650	−0.1592	0.2079	
BASAL	0.0201	−0.5185	
DBH	0.0197	−0.3714	
PNSTHT	0.4297	0.1756	

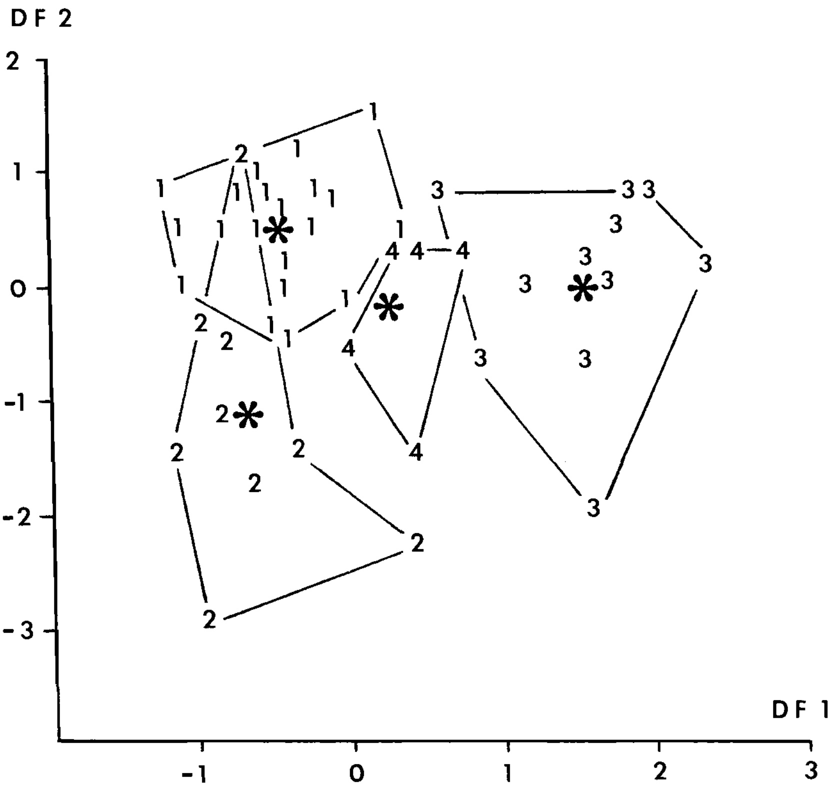

Fig. 1. Two-dimensional plots of discriminant scores indicating the nest-site habitat distributions among four species of hawks (1 = Broad-winged Hawk; 2 = Red-shouldered Hawk; 3 = Red-tailed Hawk; 4 = Cooper's Hawk; * = centroid for each species; the total number of cases for each species may not add up to the total sample size for that species, because one point may represent more than one case).

To measure the power of the discriminating variables in achieving group separation, the number of correct classifications of the individual cases was determined. The overall correct classification of species was high (87%), as was kappa, which showed a correct classification 81% above chance classification based on group sizes. Twenty-one of 24, 8 of 10, 11 of 13, and 6 of 6 nest sites were correctly classified for the Broad-winged, Red-shouldered, Red-tailed, and Cooper's hawks, respectively. No nest sites were misclassified as Red-tailed Hawk nest sites.

Broad-winged Hawk compared to random samples.—With only two groups, one discriminant function exists, and it must account for all of the discriminating power (Table 6). The associated chi-square statistic indicates that this function is highly significant. The standardized discriminant function coefficients indicate the relative power of the variables to discriminate Broad-winged Hawk nest sites from the available forested habitat. The two variables with the highest weighting indicate that Broad-winged Hawks place nests closer to water and closer to some forest opening than would be expected. Eighteen of 100 random samples were misclassified as Broad-winged Hawk nest sites. This was the largest percentage misclassification of random points for any of the hawk species (K_w = 61%), which suggests that the total available habitat has many suitable nesting areas for this species.

Red-shouldered Hawk compared to random samples.—The eigenvalue, canonical correlation, and associated chi-square statistic were higher in this analysis than for any of the other three listed in Table 6. More variables (eight) contributed to this function than to any of the others, with shrub density and distance to water showing the highest weighting. The higher basal area, more large overstory trees, and a well-developed mature understory stratum reflect the old-growth timber used by Red-shouldered Hawks as nest sites in this study. Red-shouldered Hawks had a much lower misclassification (4 of 100) and a higher kappa (K_w = 76%) than any of the other species. Based on this discriminant analysis, one might conclude that suitable nesting areas for the Red-shouldered Hawk are relatively uncommon on the study areas.

Red-tailed Hawk compared to random samples.—The sites upon which nests of Red-tailed Hawks were found had a higher percentage slope, a higher number of large trees, a higher shrub density, and a lower percentage canopy cover than did the random sites (Table 4). A moderate amount of overlap occurred with the random habitat samples, and 12 of 100 random samples were misclassified as Red-tailed Hawk nest sites (K_w = 39%).

Cooper's Hawk compared to random samples.—In comparison with random habitat samples, the nest sites of Cooper's Hawks were found in areas of larger overstory trees, a more mature understory stratum, a dense ground-cover layer, and a higher site index. Both the eigenvalue and the canonical correlation were low, indicative of relatively weak discriminating power. Seventeen of 100 random samples were misclassified as Cooper's Hawk nest sites, and kappa was low (K_w = 24%). The small sample size and the large range of discriminant scores for this species made an assessment of habitat patterns difficult.

Discussion

The four hawk species appear to select different nest-site habitats in the central Appalachians. No other studies have compared the nest sites of all these species in sympatry, although some studies have assessed one or two of these species. Bednarz (1979) quantitatively compared the nest sites of Red-shouldered and Red-tailed hawks in Iowa. Although his study was in an area of intensive agriculture, many of his results concerning nest sites were similar to those found in this study. Common separating variables included percentage nest height, dbh of the nest tree, percentage slope, and distance to water. The variables associated with Red-tailed Hawk nest sites in both this study and that of Bednarz indicated the possible importance of accessibility to the nest site. These results support the idea offered by Orians and Kuhlman (1956) that some unobstructed access to the nest is common for Red-tailed Hawks. Mader (1978) reported similar results for Red-tailed Hawks in Arizona. The 78.5% nest height for Red-tailed Hawks in this study was very similar to the 81% value found in Minnesota by Bohm (1978) and the 77% value reported by Bednarz (1979). By placing their nests high in trees and on steep slopes, the Red-tailed Hawk insures that the downslope side of the nest is usually free of obstructions.

The Red-tailed Hawk nest sites in this study were all located in relatively continuous forest and were no closer to forest openings than would be expected from the random samples. In this respect, our sample differs from most previous Red-tailed Hawk studies, which have been conducted in largely agricultural areas (Orians and Kuhlman 1956, Gates 1972, Cornman 1973, Misztal 1974, Howell et al. 1978, Bednarz 1979).

TABLE 6. Summary of four stepwise discriminant random habitat samples compared with each hawk species' nest sites.

	Broad-wing vs. random		Red-shoulder vs. random		Red-tail vs. random		Cooper's vs. random	
Eigenvalue	0.653		0.926		0.553		0.178	
Canonical correlation	0.629		0.693		0.589		0.389	
Chi-square statistic	59.8		68.1		46.5		16.7	
Significance (degrees of freedom)	$P < 0.001$ (6)		$P < 0.001$ (8)		$P < 0.001$ (4)		$P < 0.01$ (4)	
Standardized discriminant function coefficients								
	WATER	0.5571	PERSLOP	0.1552	PERSLOP	0.5358	SITINDX	−0.3075
	DISFOROP	0.3983	WATER	0.4008	SHRUBDEN	0.4907	GRNDTOT	−0.4444
	SITINDX	−0.3271	SITINDX	−0.1605	CANTOT	−0.1460	UNDGT9	−0.4503
	UNDTOT	−0.2858	UNDTOT	−0.1810	DBHGT50	0.5183	DBHGT50	−0.4946
	SHRUBDEN	−0.2748	SHRUBDEN	−0.4689				
	DBHLT25	0.1584	UNDGT9	−0.3299				
			DBHGT50	−0.2143				
			BASAL	−0.2652				

Comparing Red-shouldered and Red-tailed hawk nest sites, Bednarz (1979) was able to classify all nest sites correctly, using discriminant analysis. The same relationship held in this study, as neither species was misclassified as the other and variables such as percentage nest height and proximity to water separated these two species. Red-shouldered Hawks usually nested much farther below the top of the canopy than did the Red-tailed Hawk, as indicated by the 53.2% nest-height value calculated in this study and 66.8% and 50.2% calculated from the values given by Bednarz (1979) and Portnoy and Dodge (1979). The association of Red-shouldered Hawks with mature, moist areas was first described by Bent (1937) and Stewart (1949).

The Broad-winged Hawk is probably the most common nesting hawk in forested areas of the central Appalachians. This species appears to select sites in association with wet areas. While Burns (1911), Matray (1974), and Keran (1978) also noted the apparent association of nest sites with wet areas, they did not assess the proximity of these wet areas to random points in the forest. Burns (1911) and Keran (1978) also described the association of nest sites with some type of forest opening, and we found this relationship to be significantly different from the proximity of random samples to openings.

Nest sites have been shown to be limiting for some falcons and large eagles (see reviews by Newton 1976, 1979). Although no studies have suggested this for forest hawks, most trees are probably not suitable for nest placement, and nest trees may be a limiting factor in some otherwise suitable habitats. This is suggested in this study by the very low percentage of random sites misclassified as Red-shouldered Hawk nest sites.

The temporal aspect of habitat selection compared to the time of habitat assessment has been discussed by Whitmore (1979). He presented limited data to demonstrate changes in habitat-use overlap for pairs of grassland species based on time of habitat sampling. These changes are directly related to the specific variable(s) measured and may be more important in grassland situations, where seasonal changes in structure are proportionately greater than in forested habitats. The habitat variables measured in this study may be proximate and/or ultimate factors of habitat selection (Svärdson 1949, Hildén 1965). For example, Red-tailed Hawks were nesting more than 1 month prior to leaf-out (Janik 1980), while canopy cover at the nest site was assessed during mid-summer. In this sense canopy cover might be an ultimate factor in that it may provide shelter and protection for the young from adverse weather or from predation, while branch density or other structural features may provide the proximate cue.

As a final cautionary note, the method used to locate hawk nest sites may result in a biased sample of the population. This potential bias has been largely overlooked in other studies and may, for example, lead to the conclusion that some species are associated with forest edge simply because this is the easiest place to find nests. In this study, the 13 nests found in association with driving were significantly closer to forest openings (mainly roads or fields) than 10 nests found by systematic searching on foot ($t = 3.99$, $P < 0.001$). Systematic searching is less efficient (in terms of finding nests) than looking in "typical" nesting areas. To avoid bias and gain a better understanding of raptor-habitat relationships, however, a systematic approach to nest searching is necessary.

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The **Meandarra Ornithological Field Study Unit** (MOFSU) was formally established as a research group of the University of Queensland, Australia, in December 1980. MOFSU is active in field research in the area of Meandarra, 300 km west of Brisbane. Major emphasis is on the behavior and ecology of communally breeding species. MOFSU welcomes visitors and volunteer field assistants in its program. MOFSU is not in a position to provide financial support for students pursuing degrees, but may accept them for work on field projects. For further information contact **Dr. Douglas D. Dow, Director, MOFSU, Department of Zoology, University of Queensland, Brisbane, Australia 4067.**