The Condor 89:387–394

NEST SITE SELECTION BY NORTHERN GOSHAWKS IN NORTHERN NEW JERSEY AND SOUTHEASTERN NEW YORK[1]

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Abstract. Vegetational and topographical factors of 22 nest sites of the Northern Goshawk (*Accipiter gentilis*) were compared to random forest plots. Goshawks selected sites with greater basal area, fewer saplings, and significantly greater numbers of trees 20 to 40 cm in diameter. The relative dominance and relative density of oak (*Quercus* spp.) was significantly less at nest sites whereas that of eastern hemlock (*Tsuga canadensis*) was significantly greater. Goshawks did not use southern slopes for nesting and nests were often found at higher elevations than random sites. Nest sites were significantly further from human habitation, but were significantly closer to swamps and woods roads (or discernable trails) than random sites. Despite the significant preference for conifers in the nest sites, deciduous hardwoods were more often used as nest trees (82%) with American beech (*Fagus grandifolia*) and black birch (*Betula lenta*) being used more than expected.

Key words: *Northern Goshawk;* Accipiter gentilis; *nesting habitat; nest; raptor; habitat selection; nest site selection; woodland hawk.*

INTRODUCTION

The discovery of Northern Goshawks (*Accipiter gentilis*) nesting within 50 km of New York City prompted an investigation of the recent range expansion into this region (Speiser and Bosakowski 1984). Preliminary observations of nest sites revealed a similarity of several habitat features, suggesting that goshawks select specific habitats for nesting. Published accounts of goshawk nesting in eastern North America are few and mostly qualitative (Farley 1923, Sutton 1925, Bent 1937, Todd 1940, Meng 1959, Root and Root 1978), but some quantitative habitat information from 12 nests in the Adirondack Mountains of New York was obtained by Allen (1978).

This study presents a detailed quantitative description of goshawk nest sites and randomly selected forest plots. The objectives of our study were to: (1) document the various vegetational and topographical factors of nest sites and nest trees, (2) examine differences and similarities between the nesting habitats and those available, and (3) explain why certain habitat features were more strongly associated with goshawk nest sites.

STUDY AREA

The study was conducted in the Highlands, a belt of granitic rolling hills which form the major part of the Reading Prong of northern New Jersey and southern New York. This region forms an ecotone between the hemlock–white pine–northern hardwoods (*Tsuga canadensis–Pinus strobus–Betula alleghaniensis, Fagus grandifolia, Acer saccharum*) Region and the oak–chestnut (*Quercus–Castanea*) Region as delineated by Braun (1950). Chestnut has since almost completely vanished due to chestnut blight, being replaced by various oak species and other hardwoods. Our study area of approximately 1,900 km^2 included Morris, Sussex, Passaic, and western Bergen Counties in New Jersey, and Orange and northern Rockland counties in New York. Elevations ranged from 460 m to about 175 m in many valleys and near sea level at the Hudson River. Nearly all forest vegetation has been entirely cut and/or burned within the last 200 years (Keatinge 1967, Ohmann and Buell 1968, Russell 1981). This disruption has resulted in a mosaic of different aged stands of second growth forests (Russell 1981); old-growth stands are very scarce.

Forests in the study area were predominantly oak in composition (Buell et al. 1966, Russell 1981). Chestnut oak (*Quercus prinus*) dominates ridgetops and upper xeric slopes with red oak

[1] Received 9 June 1986. Final acceptance 13 October 1986.

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(*Quercus rubra*) more common along the lower slopes. In limited areas, where richer, deeper soils and moisture have accumulated (ravines, plateau-like areas, water courses), the northern hardwoods birch–beech–maple thrive and are sometimes mixed with eastern hemlock. Other conifers, such as white pine, red pine (*Pinus resinosa*), and Norway spruce (*Picea abies*), are much less abundant than hemlocks and are mainly the result of plantations around reservoirs or abandoned homesteads. Red maple (*Acer rubrum*), black birch (*Betula lenta*), and white ash (*Fraxinus americana*) are ubiquitous. Predominant understory species include witch hazel (*Hamamelis virginiana*), flowering dogwood (*Cornus florida*), mountain laurel (*Kalmia latifolia*), blueberry (*Vaccinium* spp.), serviceberry (*Amelanchier* spp.), and saplings of the dominant tree species.

Although the Highlands is sparsely populated, developments, reservoirs, lakes, highways, and other rights-of-way fragment the region into habitat blocks of various sizes.

METHODS

A five-year (1976 to 1980) breeding bird survey in the Highlands was conducted by Speiser (1981) during which 13 goshawk nests were located. We located nine additional nests from 1981 through 1985. Our efforts were enhanced by collaboration with other field workers such that intense coverage of the study area and all its habitat types resulted during the 10-year period (1976 to 1985). A total of 13 distinct goshawk "breeding areas" was recognized from 22 nests. A breeding area is defined as a traditional nesting territory used over the course of several years where one or more nests are in close proximity (Grier 1982).

We surveyed a circular plot (0.145 ha, 43 m in diameter) centered on the nest tree and defined this area as the nest site. This plot size was chosen qualitatively after careful visual inspection of 13 nest sites. Our plot was approximately 3.5 times larger than the standard 0.04-ha plot (James and Shugart 1970) which we considered to be too small to accurately assess habitat for a bird as large and mobile as the goshawk. All trees in the plot were counted, identified to species, and measured for diameter at breast height (dbh) with calipers (<50 cm) or measuring tape (>50 cm). Saplings less than 2.5 cm dbh were not recorded. From these measurements, we calculated tree densities, basal area, relative dominance (the percentage for each species of total basal area), and relative density (the percentage for each species of the total number of trees) (Curtis and McIntosh 1951).

Height measurements of nests and nest trees were made with a homemade triangulation instrument (Bakst 1967), field tested and accurate to 0.3 m. Distances to swamps, streams, lakes, woods roads, discernable trails (>2 m width), and human habitation were measured with tape (<30 m) or paced (>30 m) from the nest tree. Mason's cord and line level were used to measure degrees of slope; the maximum amount and its direction (aspect) through the nest tree were noted. Slopes less than 2° were considered to have no aspect. Elevations and long distance measurements (>0.5 km) were obtained from standard 7.5′ USGS quadrangle maps along with field checking.

Twenty random sites were marked on appropriate USGS maps of the study area using computer generated random coordinates. Vegetation sampling was conducted only at the first 10 sites but topographical measurements were made at all 20 random sites. Since all goshawk nests occurred in extensively forested areas, we increased the discriminating power of our random sites on the basis of three qualifying parameters. Random sites were rejected if: the canopy height was less than 10 m (after Morris and Lemon 1983), the stand was partially clear-cut or thinned, or the site was located within 0.45 km of human habitation (our minimum distance for a goshawk nest was 0.5 km).

For statistical comparison, we selected the most active nest from each of the 13 breeding areas; vegetation data were not obtainable from two of these breeding areas because they were logged. Habitat data were subjected to nonparametric statistical analysis on the RS/1 software system (BBN Software Products Corporation, Cambridge, Massachusetts) using a two-tailed Mann-Whitney *U*-test (Seigel 1956). A chi-square goodness-of-fit test (Seigel 1956) was used to compare the frequency of nests in each cardinal direction quadrat (aspect) for nest sites and random sites. In this case, we used all goshawk nests from all breeding areas since several sites had no true aspect and could not contribute to the analysis.

RESULTS

NEST STAND DESCRIPTION

All goshawk nests were located in contiguous forest land: 17 were in stands of mature or old-growth mixed forests (hardwood-hemlock), two

were in submature hardwood stands containing a few overmature trees, two were in groves of mature white (0.6 ha) and red pine (2.7 ha) surrounded by mature mixed hardwood forest, and one was in a dense cedar swamp (*Chamaecyparis thyoides*) surrounded by mature mixed forest.

NEST SITE VEGETATION

Nest sites and random sites were significantly different for 11 of 31 habitat variables tested at the $P < 0.05$ level (Table 1); three other variables were significant at the $P < 0.10$ level. Overall tree density (>10 cm dbh) was not significantly different between nest sites and random sites for both live and total (live and dead combined) trees. However, a significantly greater tree size (dbh) was found at nest sites as shown by the larger basal area (live and total, both $P < 0.001$) of nest sites versus random sites. This result is explained by the extremely truncated distribution of tree sizes in random sites with most of the trees falling into the smaller diameter class categories (Fig. 1). In comparison, nest sites showed a more even distribution with significantly more trees in the larger diameter classes.

Nest sites contained significantly less oak trees (relative density) and oak basal area (relative dominance) than random sites (Fig. 2). This was mostly the result of the preponderance of hemlock ($P < 0.01$), pine (sites B1, G1), and cedar (site A1) in the nest sites. Most nest sites had a higher relative dominance and density of northern hardwoods than random sites but the difference was not significant. Species richness at nest sites was generally lower ($P < 0.10$) than random sites. No significant difference in the amount of dead standing timber (decadence) was found.

NEST SITE TOPOGRAPHY

No difference in slope was found between nest sites and random sites, but southern aspects were used significantly less for nesting (Fig. 3). Nest sites were generally situated on lower gentle slopes and flat bench-like areas, frequently ($P < 0.10$) at higher elevations than random sites (Table 1). The distance to human habitation was significantly further ($P < 0.005$) for nest sites than random sites. This result is even more striking given that random sites within 0.45 km of human habitation were rejected from our analysis. Nest sites were usually closer to swamps ($P = 0.06$) than were random sites, but not to streams or lakes (Table 1). Nest sites were significantly closer to woods roads or discernable trails ($P < 0.05$).

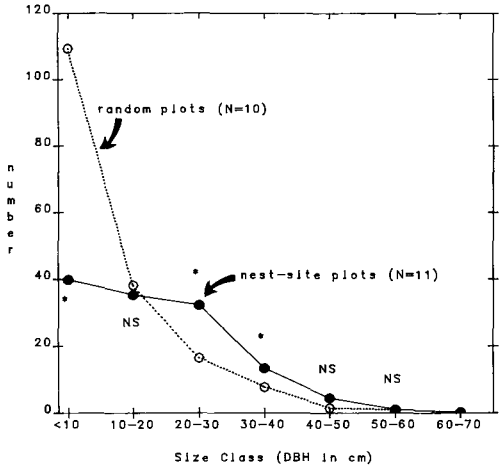

FIGURE 1. Mean tree diameter size class distribution at Northern Goshawk nest sites and random sites. * Indicates a statistically significant difference (see Table 1 for test statistics and probability levels).

This result was not considered an artifact of "trail bias" (Titus and Mosher 1981) since the fieldwork was almost always done without regard to trails. To illustrate this point, we sometimes found nests first before discovering on closer examination that a woods road or trail was nearby.

NEST TREES

The majority of nests (82%) were built in deciduous hardwood trees rather than conifers (Table 2). American beech (27%) and black birch (23%) were used significantly more than expected on the basis of their relative densities (Fisher Exact Test, $P = 0.06$, $P = 0.01$, respectively). Oaks were only used twice, but this result was not different than expected (Fisher Exact Test, $P = 0.61$).

All nest trees were alive and generally large in diameter (mean = 38.3 cm) when compared to those available (mean was among top 15% shown in Fig. 1). Nest height averaged 12.0 m above ground and was positively skewed ($P < 0.10$, Shapiro-Wilk Test for Normality). The mean percentage of nest height above ground to tree height of 53.7% supported our observations that most nests were built at the bottom of the canopy. Nests were usually constructed in large primary crotches (triple or quadruple supporting branches) of deciduous hardwoods, or at the base of horizontal limbs in conifers.

DISCUSSION

Goshawks selected extensively forested areas with significantly more mature timber than random

TABLE 1. Habitat variables of Northern Goshawk nesting sites and random sites in the Highlands of northern New Jersey and southeastern New York (means ± SD).

Nest site variables	Nest sites $n = 11$	Random sites $n = 10$	MWU statistic	P (Critical Value 84)
1. Live trees (>10 cm)/ha	537.1 ± 119.8	438.6 ± 150.2	73	>0.20
2. Total trees (>10 cm)/ha	662.3 ± 310.0	482.7 ± 153.2	73.5	>0.20
3. Live basal area (m^2)/ha	33.2 ± 7.9	19.2 ± 5.1	105	<0.001***
4. Total basal area (m^2)/ha	36.7 ± 9.3	21.3 ± 4.8	107	<0.001***
5. Decadence (%)	6.4 ± 2.8	10.1 ± 7.6	67.5	>0.20
6. Live trees (<10 cm)/ha	273.0 ± 160.7	751.1 ± 357.4	103	<0.001***
7. Live trees (10–20 cm)/ha	243.0 ± 85.3	262.5 ± 132.8	59	>0.20
8. Live trees (20–30 cm)/ha	222.4 ± 100.8	113.4 ± 63.1	90	<0.02*
9. Live trees (30–40 cm)/ha	91.8 ± 44.6	48.1 ± 32.1	85.5	<0.05*
10. Live trees (40–50 cm)/ha	30.6 ± 25.6	10.3 ± 8.7	77	<0.20
11. Live trees (50–60 cm)/ha	6.2 ± 6.5	5.5 ± 6.3	58.5	>0.20
12. Live trees (60–70 cm)/ha	1.2 ± 2.8	0	65	>0.20
13. Rel. dom. of oaks (%)	15.3 ± 15.7	54.6 ± 29.8	96	<0.005**
14. Rel. dom. of pines (%)	12.9 ± 28.6	0	70	>0.20
15. Rel. dom. of hemlocks (%)	17.5 ± 23.9	0	95	<0.01**
16. Rel. dom. northern hardwoods (%)	24.3 ± 32.5	9.2 ± 12.0	66	>0.20
17. Rel. dom. ubiquitous hardwoods (%)	13.2 ± 9.6	22.1 ± 19.1	69	>0.20
18. Rel. dom. other (%)	16.9 ± 22.0	14.1 ± 13.3	58	>0.20
19. Rel. dens. of oaks (%)	11.4 ± 13.2	44.7 ± 32.1	96	<0.02*
20. Rel. dens. of pines (%)	13.2 ± 29.5	0	70	>0.20
21. Rel. dens. of hemlocks (%)	19.8 ± 27.3	0	95	<0.01**
22. Rel. dens. northern hardwoods (%)	25.9 ± 33.6	12.0 ± 14.5	66.5	>0.20
23. Rel. dens. ubiquitous hardwoods (%)	14.3 ± 11.8	28.3 ± 24.9	75	<0.20
24. Rel. dens. other (%)	15.5 ± 23.6	15.0 ± 14.3	61.5	>0.20
25. Species richness (number)	10.3 ± 2.0	12.5 ± 3.6	79.5	<0.10+
26. Slope (degrees)	9.0 ± 10.5	9.7 ± 6.2	63.5	>0.20
Distance variables	$n = 13$	$n = 20$	(Critical Value 184)	
27. Elevation (m)	347.2 ± 49.1	304.4 ± 74.4	176	=0.10+
28. Dist. to stream/lake (m)	172.1 ± 114.6	219.5 ± 169.1	146.5	>0.20
29. Dist. to swamp (m)	275.5 ± 382.2	514.2 ± 448.8	182	=0.06+
30. Dist. to woods road trail (m)	118.8 ± 182.9	268.8 ± 302.9	186	<0.05*
31. Dist. to human habitation (m)	1,334.6 ± 567.7	772.5 ± 385.8	211.5	<0.005**

Abbreviations: MWU = two-tailed Mann-Whitney U-Test, P = probability that nest sites and random sites come from the same population, *** = statistically significant at $P < 0.001$ level, ** = $P < 0.01$, * = $P < 0.05$, + = $P < 0.10$, Rel. dom. = relative dominance, Rel. dens. = relative density, Dist. = distance.

sites in the study area. Consistent with mature forest growth, nest sites showed reduced growth of saplings probably because of shading from large canopy trees. Mature forests provide more suitable nest trees and the open understory affords flyway space which can enhance prey vulnerability and hunting success (Devereux and Mosher 1984). Investigations of goshawk nesting habitat from western North America (Schnell 1958, Shuster 1980, Reynolds et al. 1982, Moore and Henny 1983, Hall 1984) and Europe (Hoglund 1964, Dietzen 1978, Marquiss and Newton 1982) confirm the preference for mature and old-growth forest. The maturation of eastern United States forests has been suggested as a major factor in the recent southern range extension of the goshawk (Bull 1974, Postupalsky 1975, Speiser and Bosakowski 1984). Conversely, Mannan and Meslow (1984) reported that *A. gentilis* has been nearly extirpated from northeastern Oregon due to destruction of old-growth forest stands.

A distinct preference for mixed stands dominated by conifers (hemlock, pine, cedar) and northern hardwoods was observed. We observed goshawks on territory in late winter prior to deciduous tree leaf-out. Therefore, the presence of conifers in or near the prospective nest site may be very important in site selection. Barrows (1981) noted that in summer, Spotted Owls (*Strix occidentalis*) selected the cooler microclimate of dense fir (*Abies concolor*)–cedar (*Calocedrus decurrens*) stands over more open, hotter, oak for-

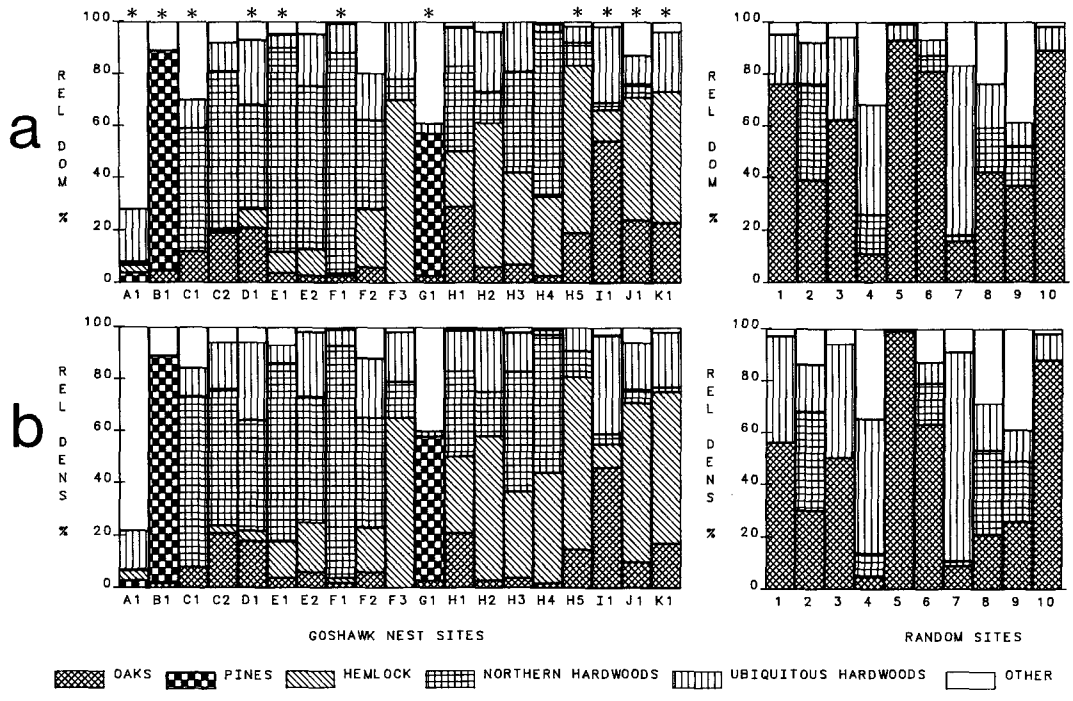

FIGURE 2. Tree species composition of Northern Goshawk nest sites and random sites expressed in terms of relative dominance (a) and relative density (b). Ubiquitous hardwoods include black birch, white ash, and red maple. Northern hardwoods include American beech, yellow birch, and sugar maple. Pines include white and red pine. Oaks are represented primarily by chestnut, red, black (*Q. velutina*), and white (*Q. alba*) oak. Nest site A1 was dominated by Atlantic white cedar (relative dominance 72% and relative density 65%) but was included in the "other" category because it was not found at any other sites. * Indicates nest sites used for statistical comparison with random sites in Table 1.

ests. Similarly, Reynolds et al. (1982) and Hall (1984) suggested that goshawks were sensitive to the amount of insolation at nest sites.

The tracts inhabited by goshawks were large in extent as exemplified by the comparatively long distances to human habitation. Nest sites were also more often found at higher elevations because wilderness areas are more common at higher altitudes in the study area. The closer proximity of nests to swamps may be associated with moisture and soil conditions which appear to favor the growth of conifers and northern hardwoods in otherwise oak dominated areas. We also noted that swamps generally had very little human disturbance of any kind and usually appeared to have a greater density and diversity of prey species than xeric oak woodlands. In Connecticut, Root and Root (1978) also noted a tendency for goshawks to nest near wetland systems. Distance from water sources other than swamps (streams and lakes) did not differentiate nest sites from random sites, although the maximum distance for nest sites was only 390 m. Reynolds et al. (1982) stressed a preference for sites near water, but admitted it was apparently not required. Similar to the observations of Shuster (1980) and Reynolds et al. (1982), we noted that goshawks did not nest directly adjacent to loud rushing streams.

Goshawks generally nested on flat bench-like areas, lower gentle slopes, or in depressions ("frost-pockets"). In selecting nest sites, goshawks avoided slopes with southern aspects. Data from goshawk studies in temperate climates (Allen 1978, Dietzen 1978, Shuster 1980, Reynolds et al. 1982, Moore and Henny 1983, Hall 1984) also show an obvious avoidance of southern slope aspects. Conversely, in the boreal forests of interior Alaska, McGowan (1975) found that the majority (64%) of goshawks nested on southern slopes.

Despite our intensive off-trail searches, gos-

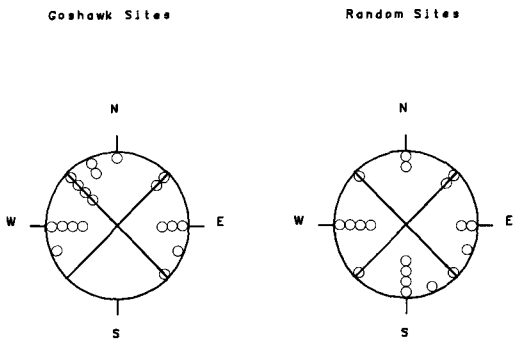

FIGURE 3. Slope directional aspect of Northern Goshawk nest sites and random sites. In the goshawk distribution, the south quadrat was significantly avoided ($\chi^2 = 3.99$, df = 1, $P < 0.05$) when compared to the frequency of nests located in the remaining three quadrats. An avoidance of the south quadrat was not found in the random site distribution when the same test was applied ($\chi^2 = 0.12$, df = 1, NS).

hawk nests were found closer to woods roads (or discernable trails) than random sites: six nests were very close (<22 m) and 11 out of 22 were within 65 m. An association with woods roads and trails was noted at other nests of goshawks (Gromme 1935, Hald-Mortensen 1974, Heintzelman 1979) while clearings (Dementiev and Gladkov 1966, Shuster 1980) were considered important at others. In our study, woods roads often represented the only break in deep contiguous timber. We believe that they may serve as landmarks providing orientation to the nest. Perhaps nest trees are difficult to find in areas without obvious landmarks, thus favoring the use of nests that are constructed near them. In dense contiguous timber, woods roads also seem to resemble corridors perhaps aiding the hawks with improved flyway space. On several different occasions, we observed goshawks flying, perching, and plucking prey along woods roads in the study area. Although woods roads did not exist prior to European settlement, we believe that goshawks are opportunistic, favoring these habitat modifications where present. Moreover, there are numerous examples (published and unpublished) of other raptors which have exploited various man-created habitats, e.g., sanitary landfills, farmland, cemeteries, golf courses, and highway shoulders.

Goshawks preferred to build their nests in large canopy-sized hardwood trees, showing a signif-

TABLE 2. Nest tree characteristics of 22 Northern Goshawk nests.

Nest no.	Tree species	DBH (cm)	Height (m)	Nest height (m)	% Nest height
A1	*Acer rubrum*	31	18.0	10.8	60
B1	*Pinus resinosa*	24	17.7	8.6	49
C1	*Quercus rubra*	38	31.0	12.7	41
D1	*Acer saccharum*	35	19.8	10.7	54
D2	*Acer rubrum*	29	18.5	10.1	55
E1	*Fagus grandifolia*	41	24.3	12.6	52
E2	*Fagus grandifolia*	42	21.6	11.9	55
F1	*Fagus grandifolia*	53	29.7	12.4	42
F2	*Fagus grandifolia*	52	27.0	13.5	50
F3	*Tsuga canadensis*	33	20.8	11.6	56
G1	*Pinus strobus*	31	18.7	11.1	59
H1	*Betula lenta*	44	24.7	14.8	60
H2	*Acer rubrum*	34	18.6	10.6	57
H3	*Betula lenta*	36	19.8	12.8	65
H4	*Fagus grandifolia*	63	35.5	18.0	51
H5	*Fagus grandifolia*	43	25.3	9.7	38
I1	*Betula lenta*	23	14.3	10.6	72
J1	*Betula lenta*	37	23.7	11.9	50
K1	*Betula lenta*	38	25.3	13.6	54
L1	*Tsuga canadensis*	*			
L2	*Pinus strobus*	*			
M1	*Quercus rubra*	*			
Mean:		38.3	22.9	12.0	53.7
CV %:		26.0	23.3	17.4	15.2
Skewness:		+0.82	+0.74	+1.21	+0.07

* Nest site lost to logging operations, no measurement data available.

icant overuse of American beech and black birch. Conifers were rarely used as nest trees despite the preference for conifers in the nest sites and nest stands. Conifers have a different growth form than hardwoods and seldom have large triple and quadruple primary crotches. The distribution of nest heights above ground was positively skewed which implies that a minimum threshold exists for acceptable nest heights. Goshawk nests were always situated below or in the bottom quarter of the canopy. This tendency was noted in all previous goshawk studies mentioned and probably represents a "stereotypic preference" (Klopfer 1965). This claim is supported by our mean percent nest height for the goshawk (53.7%) which was significantly different ($P < 0.05$, Student's t-test, 2-tailed) from three of four woodland hawk species studied by Titus and Mosher (1981) in the central Appalachians (our mean = *Buteo lineatus* 53.2% < *B. platypterus* 59.3% < *A. cooperii* 67.5% < *B. jamaicensis* 78.5%). Low nest placement probably affords easier accessibility to goshawks approaching the nest below the canopy since the nest sites we studied typically had little or no understory. Furthermore, *A. gentilis* is probably under less selection pressure to conceal its nest than its smaller congeners *A. cooperi* and *A. striatus*. Like the observations of Shuster (1980), we also found that most nests had a conspicuous open space immediately adjacent to at least one side of the nest tree (although the canopy usually remained unbroken). Apparently, this feature provides an unobstructed flight path to the nest which would be advantageous to the adults while making numerous trips with nesting material (large sticks) and food, and to the young while making their initial flight attempts.

Reynolds (1983) hypothesized that goshawks choose nest sites on the basis of the stands' overall structural characteristics, and then focus on a particular nest tree. Favorable habitat structure and topography probably trigger the "settling reaction" (Hilden 1965). Moore and Henny (1984) point out the additional importance of past experience (success or failure) to nest site selection, but at least for first-time nesters, the role of early experience (Klopfer 1963) and imprinting to the natal habitat (Hilden 1965) may be of primary importance to goshawks. Additional factors such as prey density, prey accessibility, competition, and the presence of predators (e.g., *Bubo* owls) need to be addressed in future studies of nest site selection by goshawks.

ACKNOWLEDGMENTS

We thank the following individuals for their help in providing information or assisting with fieldwork: Pete Both, John Benzinger, Robert Eriksen, Richard Kane, Walter Lehnes (in memory of), Robert Deed, Peter Devers, John Sima, Thomas Koeppel, Bill Boyle, Frank Weber, and Neil Weiss. We are also indebted to Robert Martin, Gloria Dyer, Dwight G. Smith, and James A. Mosher for reviewing early drafts of this paper and providing useful references. We also thank Marc J. Bechard for his critical review of the final manuscript. This research was funded in part by generous grants from the National Audubon Society (Highlands Audubon Chapter, Oakridge, New Jersey) and Fyke Nature Association (Ramsey, New Jersey).

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