Studies in Avian Biology No. 31:109–118

ECOLOGY OF THE NORTHERN GOSHAWK IN THE NEW YORK-NEW JERSEY HIGHLANDS

Thomas Bosakowski and Dwight G. Smith

Abstract. Evidence suggests that the Northern Goshawk (*Accipiter gentilis*) was once extirpated in the New York-New Jersey Highlands, but has recolonized the Highlands in the 1960s and 1970s following a dramatic reforestation in the 20th century. The reforestation produced large tracts of contiguous mature forest, which appear to be a primary habitat requirement of this species. Most goshawk nests in the Highlands were found deep in remote forest areas where nest sites are typically distant from human habitation and paved roads. Nest trees were almost always built in co-dominant or dominant trees of the stand, but were seldom built in the largest tree of the nesting stand. Canopy cover is very high (90%) and shrub cover is often reduced or nearly devoid (28.3%) at goshawk nest sites. Ruffed Grouse (*Bonasa umbellus*) appears to be the most common prey, but other predominant bird species in diets of Highlands goshawks included the Blue Jay (*Cyanocitta cristata*), Mourning Dove (*Zenaida macroura*), Rock Dove (*Columba livia*), and blackbirds. Sciurids, including eastern chipmunks (*Tamias striatus*), red squirrel (*Tamiasciurus hudsonicus*), and gray squirrel (*Sciurus carolinensis*) were also important components of goshawk diets from the Northeast. Highlands goshawks had a mean prey weight of 365.8 g, with bird prey averaging 332.3 g and mammal prey averaging 442.9 g. In the Highlands, productivity calculated from 36 nesting attempts averaged 1.4 young per nest, lower than found in two Connecticut studies (1.75 and 2.13). Although the goshawk is generally considered to be a permanent resident, dozens of northeastern hawk migration observation stations reveal a small, but distinct, fall migration during non-invasion years. Breeding bird atlas data confirm that the goshawk is rare in New Jersey, moderately rare in Pennsylvania (mostly northern), and numerous in New York. Various factors impacting Highlands goshawks are discussed including interspecific competition, lack of reserves, timber harvesting, tree diseases, and human disturbance factors.

Key Words: competition, food-niche overlap, forestry, habitat, New Jersey, New York, Northern Goshawk, productivity, migration, nest sites, site fidelity, prey.

ECOLOGÍA DEL GAVILÁN AZOR EN LAS TIERRAS ALTAS DE NUEVA YORK-NUEVA YERSEY

Resumen. La evidencia sugiere que el Gavilán Azor (*Accipiter gentilis*) fue alguna vez erradicado de las Tierras Altas de Nueva York-Nueva Yersey, pero recolonizó las Tierras altas durante los años 1960 y 1970, seguido de una drástica reforestación en el siglo 20. Dicha reforestación produjo largos espacios de bosque maduro contiguo, lo cual parece ser un requisito primordial de hábitat para esta especie. La mayoría de los nidos de gavilán en las Tierras Altas fueron encontradas hondo en áreas forestales remotas, donde los sitios de nidos estaban típicamente distantes de la población humana y de caminos pavimentados. Los nidos de los árboles estaban casi siempre construidos en árboles co-dominantes o dominantes del grupo de árboles, pero fueron raramente construidos en el árbol más grande del grupo de árboles en donde se encontraba el nido. La cobertura de copa es muy alta (90%) y la cubierta arbustiva es a menudo reducida o casi desprovista (28.3%) en los sitios de nidos de gavilán. El Grévol Engolado (*Bonasa umbellus*) parece ser la presa más común, pero otras especies de aves predominantes en la dieta de los Gavilanes Azor de las Tierras del Norte como la Charra azul (*Cyanocitta cristata*), Paloma huilota (*Zenaida macroura*), Paloma doméstica (*Columba livia*), y mirlos. Ardillas, incluyendo ardilla listada (*Tamias striatus*), ardilla roja (*Tamiasciurus hudsonicus*) y ardilla (*Sciurus carolinensis*), fueron componentes importantes de las dietas de los Gavilanes Azor. La media en el peso de las presas de los gavilanes de las Tierras Altas es de 365.8 g, con un promedio de 332.3 g para las presas aves y un promedio de 442.9 g para las presas mamífero. En las Tierras Altas, el promedio de la productividad calculada de 36 intentos de anidación fue de 1.4 joven por nido, más bajo que lo encontrado en dos estudios en Connecticut (1.72 y 2.13). Aunque el gavilán es considerado generalmente como residente permanente, docenas de estaciones de observación de migración de halcones del noreste revelan una pequeña, pero distinta migración baja durante los años de no invasión. Datos del Atlas de Reproducción confirman que el gavilán es raro en Nueva Yersey, moderadamente raro en Pennsylvania (principalmente en el norte), y numeroso en Nueva York. Varios factores que impactan los gavilanes de la Tierras Altas son discutidos, incluyendo competencia interespecífica, falta de reservas, aprovechamiento de madera, enfermedades de árboles y factores humanos de disturbio.

Following a range extension in the late 1950s, the range of the Northern Goshawk (*Accipiter gentilis*, hereafter goshawk) has moved southward into Connecticut, New Jersey, and Maryland (Root and Root 1978, Speiser and Bosakowski 1984, Mosher 1989). Possibly, the goshawk was a resident throughout all northeastern states prior to colonization by European settlers and is only recently returning to reoccupy former habitat as these states undergo a dramatic reforestation. Similarly, reforestation has resulted in recolonization of goshawks (*Accipiter gentilis gentilis*) in Great Britain (Marquis and Newton 1982, Anonymous 1989). Despite extensive deforestation in the Northeast during the past several centuries, the goshawk has persisted in remote areas of Maine, Vermont, New Hampshire, Pennsylvania, Massachusetts, and the Adirondack Mountains of New York (Bent 1937). Investigations into the breeding ecology of goshawks in the New York-New Jersey Highlands were initiated in the late 1970s by Speiser (1981) and continued with collaborative efforts throughout the 1980s by Speiser and Bosakowski (1984, 1987, 1989, 1991), Bosakowski et al. (1992), Bosakowski and Smith (1992), and Bosakowski and Speiser (1994). The Northern Goshawk is listed as threatened in New Jersey and as a species of concern in Rhode Island and Maryland (Mosher 1989), but has no special status in the remaining northeastern states.

STUDY AREA

Northern goshawk studies were conducted in the highlands physiographic region (Braun 1950) extending southwest to northeast across the New York-New Jersey border. The study area includes Passaic, Morris, Sussex, Warren, and Hunterdon counties in New Jersey, and Orange and Rockland counties in New York; this area is approximately 400,000 ha (Fig. 1) of which, approximately 192,000 ha is currently forested.

FIGURE 1. Map of the Highlands Study Area in New Jersey and New York (courtesy of USDA Forest Service).

History of Forests

Nearly all Highlands forests have been previously cut or burned within the last 200 yr (Ohmann and Buell 1968, Russell 1981). Early mining in the 1800s in the Highlands led to extensive clearcutting for charcoal production, fuelwood, and construction (Russell 1981). However, large-scale farming was never attempted in the Highlands because of thin rocky soil, and reforestation in the 20th century has progressed further in the Highlands than the surrounding lowlands and valleys (Speiser 1981). Extensive clearcutting, burning, and disease has resulted in second growth forest that is largely dominated by oaks (*Quercus* spp.) and other various sub-climax hardwood trees (Buell et al. 1966, Russell 1981). Overall, present forests contain dominant trees which are similar to the dominants of the 17th and 18th century forests, except that early forest had more chestnut (*Castanea dentata*) and hickory (*Carya* spp.) and less birch (*Betula* spp.) and maple (*Acer* spp.) than today (Russell 1981).

Present Forest Composition

The Highlands are part of the eastern deciduous forest biome (Shelford 1963). Chestnut oak (*Quercus prinus*) dominates ridgetops and upper xeric slopes, whereas white oak (*Quercus alba*), red oak (*Quercus rubra*), and tuliptree (*Lireodendron tulipera*) are common on lower slopes. Red maple (Acer rubrum), black birch (*Betula lenta*), and white ash (*Fraxinus americana*) are ubiquitous and common indicators of disturbance (Russell 1981). In areas with rich, moist soils, such as near wetlands, water courses, ravines, and broad lowland plateaus, eastern hemlock (*Tsuga canadensis*), white pine (*Pinus strobus*), sugar maple (*Acer saccharum*), American beech (Fagus grandifolia), and yellow birch (*Betula alleghaniensis*) dominate the forest. Braun (1950) considered the Highlands to be a transition zone between the oak-chestnut and white pine-hemlock-northern hardwoods region. However, due to chestnut blight, chestnut is now virtually absent except as an understory component. Wooded swamps are presently dominated by red maple, yellow birch, black gum (*Nyssa sylvatica*), white pine, hemlock, and occasionally Atlantic white cedar (*Chamaecyparis thyoides*) and black spruce (*Picea mariana*) (Russell 1981). Mature conifer plantations (planted circa 1920–1935) are sparsely distributed throughout reservoir watersheds and these are composed of various pine species including white pine, red pine (*Pinus resinosa*), Scotch pine (Pinus sylvestris), Norway spruce (*Picea abies*), and larch (*Larix* spp.). Overall, current forests are predominantly upland deciduous habitat (75%), except for limited areas of hemlock-white pine forests (20%) or mature conifer plantations (5%). Most areas are composed of a mosaic of submature (<40 yr) and mature second-growth forest (40–80 yr), older stands (>100 yr) are rare.

Overall, approximately 41% of the Highlands forests are considered potential, viable timberland available for harvesting (Michaels et al. 1992). However, the Highlands forests are rarely under much pressure for timber harvesting, because the current harvest level is only about 10% of the annual growth rate (Michaels et al. 1992). Most parcels of forest are small, 85% are <7.6 ha. Surveys have found that most landowners in the Highlands value their forestland more for its scenic value than for its timber, and no owner listed income from timber as the primary benefit (Michaels et al. 1992). Currently, thinning is the usual method of harvesting and clearcutting is rare, except for the purposes of new suburban development.

Current Land Cover Description

In 1985, forest was the predominant land cover (48%) in the Highlands, followed by residential/urban (29%) and agriculture (16%) (Michaels et al. 1992). Reservoirs and a few natural lakes account for most of the open water, although beaver (*Castor canadensis*) ponds and marshes are found in some sections. Other wetlands are typically a mix of forested wetland, brushy swamps (shrub-carr), and open marshes. Due to the higher elevations of the Highlands, temperatures are cooler and rainfall is slightly greater than the adjacent Piedmont and Kittatiny valley regions (Robichaud and Buell 1973). Public access to forests on military holdings and many private ownerships is restricted, but most city watersheds allow access with recreational permits. State and county lands are generally open to the public, as well as the few federal parks and refuges.

HABITAT ECOLOGY OF HIGHLANDS GOSHAWKS

Nest Tree Selection

In the Northeast, deciduous trees are usually favored by goshawks for nest building, even in mixed forests where conifers are abundant. Bent

(1937) reported that only 11 of 62 nests of eastern goshawks were built in conifers. In New York, Bull (1974) noted that only six of 40 goshawk nests were in conifers. In New York and New Jersey, Speiser and Bosakowski (1989) found that only five of 32 nests were in conifers and availability data indicated that the preference for deciduous trees (black birch and American beech) was significant. In deciduous trees in our study area, goshawk nests are almost always built in a primary crotch (Speiser and Bosakowski 1989). This often results placement of the nest in the lower one-third of the canopy layer (or crown height). Speiser and Bosakowski (1989) reported a mean relative nest height (nest height/nest tree height x 100) of 54.5% for the Highlands. Deciduous trees are likely preferred because they frequently provide a more stable triple or quadruple crotch for supporting the large nest (Speiser and Bosakowski 1989) with little overhead obstruction immediately above the nest platform. In contrast, conifers usually have thinner limb diameters and rarely have major crotch formations (especially low in the canopy) except in the case of deformities

Nest trees were almost always built in co-dominant or dominant trees of the stand, but were seldom built in the largest tree of the nesting stand. In the Highlands, only four of 32 nest trees had the largest diameter of trees in the nesting stand (Speiser and Bosakowski 1989). In older, taller forests, smaller sub-dominant trees are sometimes selected as nest trees probably because the goshawk prefers to nest low in the canopy.

Nesting Habitat

Although goshawks nest in a variety of forest types throughout their range in North America, the vegetative structure and topography of nest sites remain relatively consistent (see review in Bosakowski 1999). Habitat selected for nesting in the Highlands is usually in forest stands with larger basal areas and larger tree diameters than random sites (Speiser and Bosakowski 1987) which supports the findings of many studies that mature and old-growth forest is preferred (Reynolds et al. 1982, 1992, Moore and Henny 1983, Iverson et al. 1996, Squires and Ruggiero 1996). If older, taller forests are not available, the goshawk will sometimes use younger and/or denser forests with smaller trees (Doyle and Smith 1994, Bosakowski 1999).

In the Northeast, deciduous forests, mixed conifer-deciduous forests, and monoculture pine plantations are all forest habitat types used for nesting (Speiser and Bosakowski 1987, Smith and Devine 1994, Becker 2000), albeit pure coniferous forest is often scarce in the Highlands. In the Highlands, goshawk nest stands typically have a high degree of canopy cover ($\overline{x}$ = 90.0%) and shrub cover is often reduced or nearly devoid ($\overline{x}$ = 28.3%) (Bosakowski et al. 1992).

Generally, vegetation around nest sites usually appears to be similar in structure and size class to home ranges in the Highlands. Beier and Drennan (1997) found that goshawk foraging locations had significantly greater canopy closure, tree density, and large tree density, demonstrating that mature forests are not only necessary for nesting but also for foraging.

In the Highlands, nesting generally occurs on benches or bowl-like topography where the slope is generally slight to moderate, and several sites were flat with no aspect (Speiser and Bosakowski 1987). Slopes with southern aspects were avoided compared to random sites (Speiser and Bosakowski 1987).

Overall, we found goshawks to be relatively intolerant of human disturbance. They nested significantly further from human habitation and paved roads than random sites (Bosakowski and Speiser 1994), typically in the most remote forests available in the Highlands.

FEEDING ECOLOGY OF HIGHLANDS GOSHAWKS

Diets of goshawks in the Highlands were determined by examining prey remains found below goshawk nests and at prey-plucking posts following the methods outlined by Reynolds and Meslow (1984). Goshawk diets in the Highlands, as in other eastern forests, are comprised principally of birds (Meng 1959, Bosakowski et al. 1992, Bosakowski and Smith 1992; Becker et al., *this volume*). In an agricultural-woodland matrix, Meng (1959) found Common Crows (*Corvus brachyrhynchos*) to predominate the diet, whereas in contiguous forest, Bosakowski et al. (1992) found Ruffed Grouse to be the most common prey (Fig. 2). Other predominant bird species in diets of eastern goshawks included the Blue Jay, Mourning Dove, Rock Dove (*Columba livia*), and blackbirds. Sciurids, including eastern chipmunk (*Tamias striatus*), red squirrel (*Tamiasciurus hudsonicus*), and gray squirrel (*Sciurus carolinensis*), were also important components of eastern goshawk diets. All of these prey species appear to be most abundant in mature forest in the Highlands, although no field studies have been done to support this observation. Studies conducted in Minnesota (Eng and Gullion 1962) and

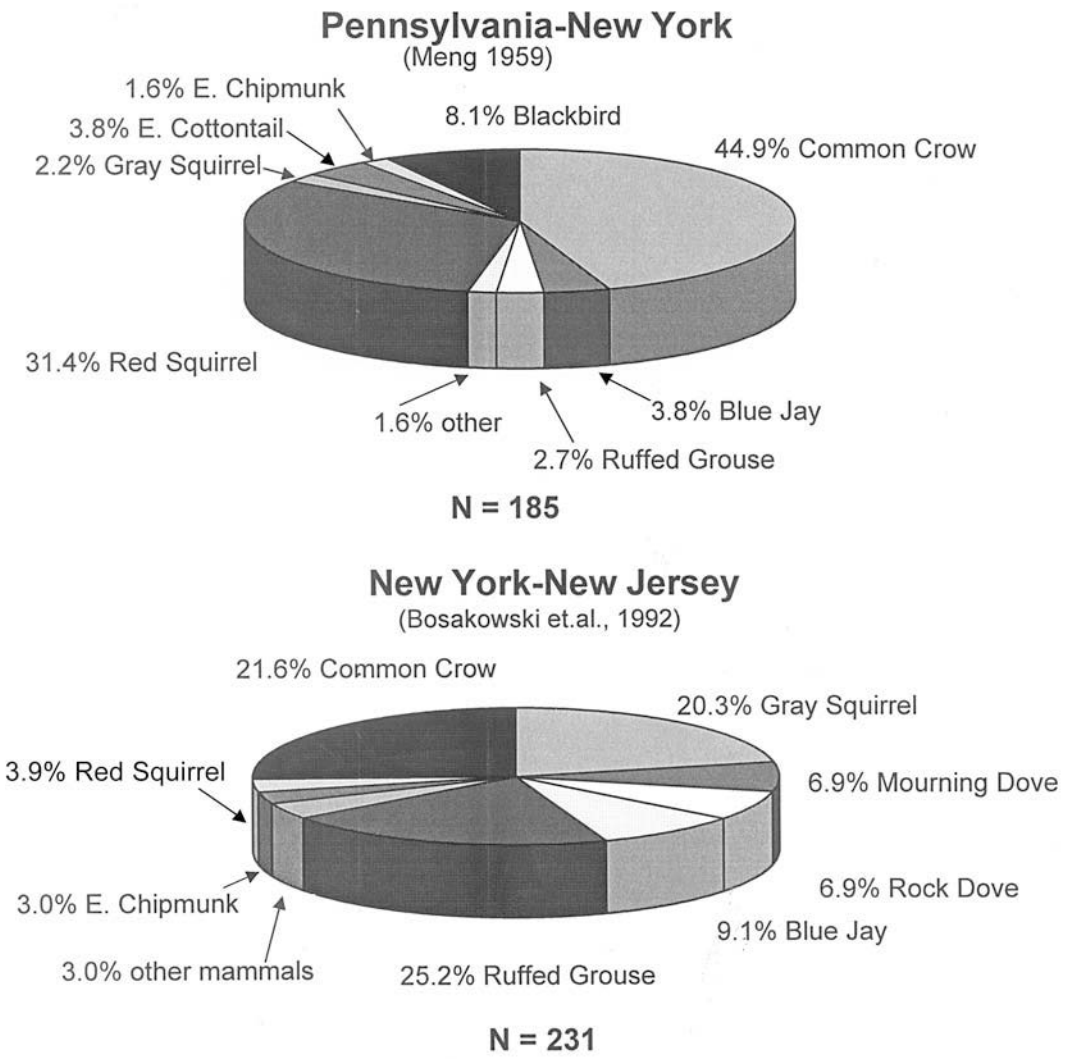

FIGURE 2. Major prey species for Northern Goshawks in the New York-New Jersey Highlands (a) and Pennsylvania-New York (b).

Sweden (Widen 1987) also showed a prevalence of grouse and tree squirrels in goshawk diets.

In comparison to other sympatric forest raptors, only the accipiters [goshawk and Cooper's Hawk (*Accipiter cooperii*)] had diets dominated by birds, whereas *Buteo* spp. diets were dominated by mammals (Bosakowski and Smith 1992). Mammals are generally less prevalent in the diet of eastern accipiters, however, goshawks took more than twice the proportion of mammals to birds (0.43) as compared to the smaller congener, Cooper's Hawk (0.17).

In western and boreal regions of North America, bird/mammal ratios differ from those in eastern populations with mammals representing a larger component of the goshawk diet. This difference can be attributed to the lack of ground squirrels and scarcity of lagomorphs (hares and rabbits) in eastern forests, prey that are more numerous in the more open western montane forests. Studies from northern Arizona, eastern Oregon and the Yukon Territories clearly show a preponderance of ground squirrels and lagomorphs in goshawk diets (Reynolds and Meslow 1984, Doyle and Smith 1992, Boal and Mannan 1994). However, in eastern Oregon (Reynolds and Meslow 1984) goshawks took a higher portion of birds compared to mammals.

Mean Prey Weight

In a study of five raptor assemblages, Jaksic (1983) found that raptor body weights were positively correlated with mean vertebrate prey weight. Analysis of prey weights for Highlands goshawks revealed a mean prey weight of 365.8 g, with bird prey averaging 332.3 g and mammal prey averaging 442.9 g (Bosakowski et al. 1992; plus errata—Bosakowski 1993). Reynolds and Meslow (1984) reported a mean prey weight of 306.6 grams for total prey with an average of 147.5 g for birds and 445.2 g for mammals in northeastern Oregon. Overall, average prey weight was significantly larger for eastern goshawks (Bosakowski et al. 1992, Bosakowski 1993) which correlates well with the larger body weight documented for eastern goshawks (Henny et al. 1985, Smith et al. 1990). For example, mean Oregon summer weights of males were significantly ($P < 0.001$) lower by 19.8% than fall weights from Wisconsin, and females were significantly ($P < 0.001$) lower by 15.6% (Henny et al. 1985). Not surprisingly, eastern and western goshawks were once considered different subspecies (Bent 1937).

Interspecific Competition

Schoener (1984) theorized that because of their elevated trophic position as terminal predators, *Accipiter* hawks should show competitively caused niche overdispersion. In comparing the goshawk with its closest North American relative, the Cooper's Hawk, Bosakowski et al. (1992) discovered that food-niche overlap by prey species was below competition levels (overlap <0.6) for New Jersey (0.47), Connecticut (0.45), and Oregon (0.47; data in Reynolds and Wight's [1984] recalculated using Schoener's overlap index). In all three cases, these results are consistent with niche overdispersion, which theoretically serves to reduce food-niche overlap. It is not known whether the niche overdispersion is the result of past or present competition levels between these two congeners (Connell 1980).

In the Highlands forests, goshawks frequently nest in close proximity to Red-shouldered Hawks (*Buteo lineatus*) and Barred Owls *(Strix varia*) as was also noted by Root and Root (1978) for northwest Connecticut. Bosakowski and Smith (1992) found that food overlap of the goshawk was very low with the Red-shouldered Hawk (*Buteo lineatus*; 0.307) and Barred Owl (*Strix varia*; 0.202), suggesting a reason for mutual tolerance of these sympatric forest raptors.

NESTING, REPRODUCTION, AND POPULATION BIOLOGY OF HIGHLANDS GOSHAWKS

Nest Building

Nest building usually begins from late February to early March. However, Speiser and Bosakowski (1991) once observed nest building as early as 1 January at a New Jersey nest site during a mild winter. When the nest is completed, fresh sprigs of greenery (usually hemlock if available) are almost always present on active nests. Occasionally, goshawks re-use and re-furbish old nests of other raptors or crows (Bent 1937), and in northwestern New Jersey we have observed a Great Horned Owl (*Bubo virginianus*) using an old goshawk nest.

Nesting Phenology

In the Highlands, the majority of goshawks return to the nest site in late February as newly added sticks and fresh greenery were generally observed on the nest by mid-March. Incubation commenced primarily (80%) during the second through fourth week in April with a mean of 23 April (Speiser and Bosakowski 1991).

Productivity

Few data are available for productivity of goshawks in the eastern US. In the Highlands, productivity calculated from 36 attempts averaged 1.4 young per nest (Speiser 1992). In northwestern Connecticut, Root and Root (1978) conducted a study on 20 goshawk nests and reported the following reproductive statistics: mean clutch size = 2.82 (N = 17), mean brood size at 4 wk = 2.06 (N = 17), nesting success = 85.0%, mean young per nest attempt = 1.75 (N = 17), and nestling mortality = 27.5% (N = 14). A more recent Connecticut study (Becker 2000) revealed an average productivity of 2.13 young per nesting attempt for 15 nesting attempts (range one–four young). The reason for the apparently lower productivity in the Highlands is unknown, but might be a function of latitude because our study area is along the southern range limit for the species.

In the Highlands, females occasionally breed in immature plumage, but only two of 35 nesting attempts were by immature females, and all breeding males were in adult plumage (Speiser and Bosakowski 1991). Similar proportions of nesting by immature-plumaged females have been reported

elsewhere (Henny et al. 1985, review by Palmer 1988).

Nest Site Fidelity

In the Highlands, nest areas were occupied from 1–8 yr with an average occupancy of 3.83 ± 3.05 (SD) yr (Speiser and Bosakowski 1991). Similar long-term fidelity has also been reported by Becker and Smith (2000) in Connecticut and in western North America by Reynolds and Wight (1978) and Woodbridge and Detrich (1994). During their occupancy, goshawks built one–five nests in the nest areas monitored in the Highlands (Speiser and Bosakowski 1991). The alternate nests in the Highlands were generally spaced within a few hundred meters of each other. However, a California study (Woodbridge and Detrich 1994) noted a maximum range of 2.1 km between alternate nests. In the Highlands, goshawks often used a new nest or different alternate nest in their nest area each year regardless of the nesting outcome of the previous year. Traditional nest site areas often remain unoccupied for many years after they are abandoned, suggesting that the goshawk population is well below saturation levels in the Highlands (Speiser and Bosakowski 1984, 1991).

Breeding Densities

No published information exists for breeding densities of goshawks in the Northeast. Speiser and Bosakowski (1984) speculated that goshawk densities in New Jersey appeared to be far below saturation levels, but systematic attempts to determine density were not made. In suitable goshawk habitat of the Highlands, nest areas were generally spaced at an average of approximately 8 km which is clearly below breeding densities reported elsewhere (Reynolds and Wight 1978, DeStefano et al. 1994a, Reynolds et al. 1994).

Dispersal, Migration, and Population Trends

In the Highlands, Speiser and Bosakowski (1991) observed goshawks in mid-winter at or near several traditional nest sites (N = 6) and others were attracted near nest sites with broadcasts of various raptor calls (N = 5), suggesting that most goshawks in the Highlands are permanent residents. However, goshawks are also frequently among the many (15+) species of raptors observed during autumn hawk migration counts in the Northeast (Heintzelman 1976). During these flights, we observed goshawks using the same migratory pathways as other hawks, flying southward along interior northeast–southwest ridgelines (i.e., flight direction is non-random). Fall migration for goshawks begins in late September and peaks by mid-October, and lasts into December in the Northeast (Heintzelman 1976). Most migrating goshawks are juveniles, except in irruption years, when large numbers of adults are observed (Bent 1937). The origin of these migrating birds remains unknown, but most are probably from the far northern boreal forest in Canada during invasion years (Doyle and Smith 1994).

A large number of hawk migration counting stations have been initiated in the Northeast, with peak numbers of observers and hawkwatches established in the late 1970s. Table 1 provides an example of the number of hawks counted during a typical non-invasion year for goshawks. The total of 297 goshawks indicates that the eastern goshawk population contains a small, but distinct, migratory component during non-invasion years. Geographically, the overall trend seems to indicate that larger numbers of goshawks appear to migrate through the interior higher ridges (Hawk Mountain, Wagoner's Gap, and Raccoon Ridge) of the Kittatiny Mountains than the lower elevation routes nearer to the coast (Skyline Ridge, Mt. Peter, and Hook Mountain) of the New York-New Jersey Highlands.

Using migration data from Hawk Mountain Sanctuary (Kempton, Pennsylvania), both Mosher (1989) and Bednarz et al. (1990) analyzed long-term trends for goshawk numbers. Mosher (1989) used a 3-yr moving average of data from 1934–1987 that showed a general increase in goshawk numbers. Bednarz et al. (1990) analyzed yearly counts from 1934–1987 and found that numbers of migrating goshawks increased during the DDT era, but no significant trend has occurred since the ban on DDT in 1973. Both studies note, however, that the periodic invasions of goshawks (Mueller et al. 1977) greatly confound the interpretation of migration data for this species. Overall, the general increase in counts of migrating hawks and the recent southern range extension provide evidence that goshawk populations may be increasing in the Northeast. Similar trends are apparent in Great Britain, where goshawk repopulation has paralleled reforestation (Marquis and Newton 1982, Anonymous 1989).

Another source of population data is the state breeding bird atlases which have been completed for most states in the Northeast. The New York state breeding bird atlas (Andrle and Carroll 1988) reported a total of 445 atlas blocks (5 × 5 km) with goshawk presence. A surprisingly large number of

TABLE 1. NORTHERN GOSHAWK MIGRATION COUNTS IN THE NORTHERN APPALACHIAN REGION FROM AUTUMN1978 (HAWK MOUNTAIN NEWS, 1979). TABLE DOES NOT INCLUDE 13 STATIONS WITHOUT GOSHAWK SIGHTINGS.

Location	Days	Hours	N Goshawks
Bear Rocks, PA	44	270	
Belfrey Mountain, NY	5	5.5	2
Chimney Rock, NJ	14	53	1
Cornwall Fire Tower	36	127	2
Hawk Mountain, PA	89	670	63
Helderberg	22	44	7
Hook Mountain, NY	57	381	6
Huntingdon Ridge [a]	21	67	1
I-84 Port Jervis, NY	2	12	3
Kittatinny Mountain [a]	76	1,038	49
Little Gap [a]	35	241	9
Little Mountain	23	154	5
Mt. Peter, NY	45	280	3
Oneida, NY	28	71	2
Pulpit	96	719	33
Raccoon Ridge, NJ	77	388	35
Skyline Ridge, NJ	74	438	5
Sunrise Mountain, NJ	18	138	8
Wagoner's Gap, PA	73	414	42
Totals	835	5,512.5	297

[a] Indicates banding station.

goshawk detections were reported for a species that has the reputation of being so secretive. However, an impressive army of 4,300 atlas workers covered all but 12 of New York's 5,335 atlas blocks in a 6-yr period (Andrle and Carroll 1988). Blocks were surveyed from 1–6 yr, usually with a minimum of 16–20 hr of survey time per year. Although variability does exist among coverage and observers, the New York Atlas represents a monumental field effort and a unique source of complete census data for the goshawk which is currently unavailable for less populated western states and Canadian provinces.

In Pennsylvania, only 120 blocks (2% of all blocks surveyed) were reported with goshawks (Brauning 1992). Although this state had almost as much forest area as New York (68,000 km^2 versus 74,000 km^2) goshawk detections were less numerous, as distribution was mostly limited to central and northern regions of the state. Atlas results from New Jersey revealed only 27 blocks positive for goshawks (Walsh et al. 1999) and were limited almost entirely to the northern half of the state with the exception of two nests found in the Pine Barrens region of southern New Jersey (Bosakowski and Smith 2002). Based on extensive fieldwork before the atlas began, it is interesting to note that Speiser and Bosakowski (1984) estimated that the state could only support about 20 pairs of goshawks.

POTENTIAL IMPACTS TO HIGHLANDS GOSHAWKS

LACK OF RESERVES

The Northern Goshawk has been recognized as an area-sensitive species in North America (Bosakowski and Speiser 1994), such that a future decrease in large, unfragmented, forested reserves could pose a threat to goshawk populations. Currently, only 6.9% of the northeast forests are on public lands, with another 3.7% classified as forest reserves, and 1.0% classified as nonproductive forest reserves (Brooks 1989). Public lands (state and national forests, state and national parks, county parks, and city watersheds) in the Northeast could be set aside for goshawk conservation, but clearly this action would not be enough protection because of the relatively small percentage of public ownership. In addition, incentives are also needed for private forest owners to ensure an adequate supply of older forests and goshawk habitat in the Northeast. Cline (1985) noted that wildlife managers have a variety of options for protecting raptors on private lands including voluntary agreements, management agreements and leases, conservation easements, acquisition of fee titles, and zoning and land-use regulations. In addition, managers could foster the adoption of changes

in legislation and tax laws to increase incentives for private landowners (Cline 1985).

Timber Harvesting

In New England, forest stands in mature size classes have recently increased 38% while sapling and seedling successional stages have decreased by a commensurate 40% (Brooks 1989). This forest maturation parallels the increasing numbers of migrating goshawks and breeding range expansion in the Northeast. Although the level of timber harvesting in the Highlands is presently low, Speiser and Bosakowski (1984, 1987) noted at least two goshawk nest sites which were lost to logging. As timber stocks continue to mature in the Northeast, industry pressure may mount to increase timber harvesting, thereby potentially impacting greater numbers of goshawks in the future. Nelson and Titus (1989) calculated that a forest growth period of 60–80 yr after clearcutting would be needed to provide suitable Red-shouldered Hawk habitat in Alleghany National Forest in Pennsylvania. We predict a similar time period would be required for goshawk habitat to regenerate owing to the close similarities in forest habitat used by goshawks and Red-shouldered Hawks.

Nelson and Titus (1989) suggested that tree cutting should not occur in goshawk nest sites, but suggested that selection cut, shelterwood (first cut only), and thinning could benefit the goshawk elsewhere in home ranges. However, Bryant (1986) noted that loss of canopy cover with a light selection harvest allowed Red-tailed Hawks (*Buteo jamaicensis*) to displace nesting Red-shouldered Hawks in Ontario. Selection harvesting is the primary method of timber harvesting in hardwood forests of the Northeast (Smith 1986), but its effect on goshawks in the Northeast is not known. Even so, Benzinger (1994) noted that if timber harvesting results in removal of >20% of the canopy, it would result in little or no reproduction of eastern hemlock, an important species in goshawk nest sites (Root and Root 1978, Speiser and Bosakowski 1987). Considering the above, the intensity and area of harvest within the home range should probably remain minor in the landscape to minimize impacts to goshawks. Studies of timber harvest impacts on goshawk populations are needed, especially including the wide variety of forest types found in the Northeast.

Tree Diseases

In addition to losses of forest area to development, logging, and fires, disease may be an increasing problem in eastern forests. Benzinger (1994), Orwig and Foster 2000), and others have reported a decline of eastern hemlock, characterized by dull foliage color, extensive needle drop, and sporadic mortality was probably due to the hemlock woolly adelgid (*Adelges tsugae*). Hemlocks are important trees in goshawk nest sites (Root and Root 1978, Speiser and Bosakowski 1987), and their loss could effect the habitat suitability and demography of goshawks in this region. Benzinger (1994) noted that the hemlock woolly adelgid and the elongate hemlock scale bug (*Fiorinia externae*) might be involved in the decline of hemlock. In addition, gypsy moth (*Lymantria dispar*) deforestation (Souto and Shields 2000) has occurred periodically throughout the Highlands in the last several decades and has resulted in some losses of large canopy trees (pers. obser.). While not a favored host, eastern hemlocks can suffer mortality up to 90% from a single gypsy moth defoliation episode (Benzinger 1994). Hemlock mortality from outbreaks of hemlock looper (*Lambdina fiscellaria* and *Lambdina. athasaria*) (Burns and Trail 2000) are currently limited to northern New England states (Benzinger 1994). In addition, acid rain threatens the stability of high elevation spruce-fir forests of the Adirondack Mountains and Vermont and New Hampshire, and may cause indirect mortality by weakening the immune system of trees.

Human Disturbance Factors

In the Northeast, reduction of human activity and disturbance may also help maintain existing breeding pairs. Recreational planners should temporarily or permanently re-route trails and activities away from traditional goshawk nests. One goshawk nest was found along the famous Appalachian Trail after hikers reported that they were attacked by a large hawk. Another goshawk nest was close to a trail in a county park, popular with joggers and walkers on a daily basis. These goshawks probably selected their nest sites during late winter–early spring when very few hikers were active and the area appeared to be free of human disturbance. Currently, the impacts of recreational activities on goshawk nesting and site fidelity in the Highlands remains unknown. However, with further encroachment of wild areas by suburban development, corrective actions could possibly improve the quality of existing goshawk territories for future nesting.

ACKNOWLEDGMENTS

We thank Michael L. Morrison and Richard T. Reynolds for inviting us to submit this paper and for

reviewing several versions of the manuscript. John Squires and Douglass Boyce also provided critical reviews of an earlier version of the manuscript and we extend our thanks to them as well. Richard Kane and John Benzinger supplied information on breeding bird atlas data and regional information on goshawks for which we are grateful.