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NORTHERN GOSHAWK ECOLOGY IN THE WESTERN GREAT LAKES REGION

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Abstract. A substantial amount of research has been conducted on Northern Goshawks (*Accipiter gentilis*) in recent years, but the majority of this research has been conducted in western North America and Europe. Little information has been published concerning goshawks in the western Great Lakes region, including the states of Minnesota, Wisconsin, and Michigan, and the forested southern portion of the Canadian province of Ontario. We present an overview of the regional information available on Northern Goshawks in the western Great Lakes region which draws heavily on our recent studies in Minnesota, but also includes published and unpublished information from across the western Great Lakes region. Inclusion of this information on productivity, breeding-season food habits, breeding-season habitat use, residency status and migration patterns, and breeding season mortality provides a broader understanding of the ecology of goshawks in this region. Our recommendations for additional research needed to enhance management of western Great Lakes region goshawks include development of a collaborative sampling program to identify goshawk nest sites and monitor survival, mortality, and productivity at subsamples of nests across the region; identification of winter habitat and prey use; and monitoring of goshawks in silvicultural treatment areas to assess responses to forest management.

Key Words: Accipiter gentilis, ecology, food habits, foraging habitat, Minnesota, nesting habitat, western Great Lakes, Wisconsin.

ECOLOGÍA DEL GAVILÁN AZOR EN LA REGIÓN OCCIDENTAL DE LOS GRANDES LAGOS

Resumen. Una substancial cantidad de investigación acerca del Gavilán Azor (*Accipiter gentilis*) ha sido conducida en los últimos años, pero la mayor parte de esta investigación ha sido conducida hacia el oeste de Norte América y Europa. Poca información ha sido publicada acerca de los gavilanes en la región oeste de los Grandes Lagos, incluyendo los estados de Minnesota, Wisconsin, y Michigan, así como la porción sureña del área forestal de la Provincia Canadiense de Ontario. Presentamos una visión global de la información regional disponible acerca de Gavilanes Azor en la región occidental de los Grandes Lagos, la cual se basa fuertemente en nuestros recientes estudios en Minnesota, pero también incluye información publicada y no publicada a lo largo de la región occidental de los Lagos del Norte. La inclusión de la información en productividad, hábitos de alimentación durante la época de reproducción, hábitos de uso durante la época de reproducción, estado de residencia y patrones de migración, y mortandad en la época de reproducción, provee de un entendimiento más amplio de la ecología del gavilán en esta región. Nuestras recomendaciones acerca de la información adicional que se necesita para reforzar el manejo del gavilán de la región occidental de los Grandes Lagos, incluye el desarrollo de un programa de muestreo de colaboración, para identificar nidos de gavilán y monitorear supervivencia, mortandad, y productividad en submuestras de nidos a través de la región; identificación del hábitat de invierno y utilización de la presa; así como el monitoreo del gavilán en áreas con manejo de silvicultura, para evaluar respuestas al manejo forestal.

The Northern Goshawk (*Accipiter gentilis*) is a large raptor associated with mature deciduous, coniferous, or mixed forests (Bright-Smith and Mannan 1994, Siders and Kennedy 1996, Squires and Reynolds 1997). It breeds throughout northern temperate and boreal forests in northern North America, Europe, and Asia (Squires and Reynolds 1997). In North America, potential conflict between goshawk habitat requirements and timber harvest practices has led to concern for the status of the species (Kennedy 1997), which has been proposed for listing several times under the U.S. Endangered Species Act. The species' status continues to be the object of considerable litigation (Peck 2000; Squires and Kennedy, *this volume*) and as a result, over the last decade, numerous studies have addressed goshawk population ecology and status (see Block et al. 1994, Squires and Reynolds 1997; Squires and Kennedy, *this volume*). The vast majority of these studies, however, have been conducted in the western US and western Canada, with fewer studies in western Europe. Results of these studies have been incorporated into management plans designed to maintain goshawk populations in a variety of landscapes.

Existing goshawk management plans (Reynolds et al. 1992) generally focus on managing forest structure and landscapes to provide nest sites, foraging habitat, and prey species habitat. Such management plans, however, presuppose a thorough understanding of the species' habitat use and resource needs (Garshelis 2000). Even for western North America, an understanding of goshawk habitat preferences and resource requirements is often lacking or is very limited in scope and scale. Thus, existing data may not be relevant to the range of environmental conditions and forest management practices found across the species' distribution. Goshawks in western North America typically occupy areas of high elevation (1,200–3,900 m) and substantial topographic relief, with generally warm, dry summers and cool, wet winters (Kennedy et al. 1994, DeStefano and McClosky 1997, Keane 1999). In contrast, the western Great Lakes region (WGLR) of North America is of lower elevation (330–560 m), has relatively little topographic relief, and typically experiences cool, wet summers and cold, dry winters (Tester 1995). Forest-harvest practices in the western US typically focus on large tracts of land administered by a single public agency or landowner, whereas harvest practices in the midwestern and eastern US focus on smaller tracts of land under a mixture of public and private ownerships (Mannan et al. 1994). This has led to increased forest heterogeneity in midwestern and eastern deciduous forests and, in some cases, an increase in the extent of early-successional forest types, relative to pre-settlement landscapes (Whitcomb et al. 1981, Minnesota Forest Resources Council 2000, Reich et al. 2001). For these reasons, the existing information on goshawk habitat use and resource requirements, primarily from western North America and western Europe, may not directly apply to other regions of North America.

Here we provide an overview of the ecology of goshawks in the WGLR. Our emphasis is on Minnesota and draws extensively on our own research. Other areas within the WGLR are not as well represented because few published papers have been produced on goshawk populations outside of Minnesota. Roberson et al. (2003) recently reviewed the available published and unpublished literature for the WGLR and we rely heavily on this document for our summaries of the unpublished literature. We approach the interpretation of these unpublished data cautiously, but without including these forms of data, our overview would be almost entirely limited to our own work in Minnesota and a small number of published reports from Wisconsin and Michigan.

PRODUCTIVITY

Activities and behaviors associated with breeding goshawks typically occur between March and mid- to late August (Squires and Reynolds 1997). However, goshawks have been observed near their nesting areas in Minnesota as early as late February (Roberson 2001, Roberson et al., unpubl. data), possibly because their winter home ranges include their nesting areas (Boal et al. 2003). Initiation of incubation occurs from 31 March–23 April in Minnesota, with initial observations of nestlings from 8–15 May (Roberson 2001; Roberson et al., unpubl. data). Smithers et al. (2005) estimated mean hatch and fledging dates at goshawks nests in Minnesota in 2000–2002 as 28 May and 4 July, respectively.

In Minnesota, Boal et al. (2005a) reported 26 (62%) of 42 nesting attempts were successful, with 1.14 ± 1.07 (SE) young fledged per nesting attempt and 1.85 ± 0.73 young fledged per successful nest. In Michigan, Lapinski (2000) reported goshawks fledged 1.14 and 1.71 young per active and successful nest, respectively, among 36 nesting attempts. Rosenfield et al. (1996) reported 11 (85%) of 13 goshawk nests in Wisconsin fledged at least one young, with a mean number of 1.7 fledged young per successful nest. Erdman et al. (1998) reported higher productivity in their study area in Wisconsin, with an average of 1.7 fledglings and 2.2 fledglings per nesting attempt. In general, productivity among successful nests in the WGLR fell slightly lower than the average, but within the range, of that reported in 16 studies from western North America (Squires and Kennedy, *this volume*).

NEST FAILURE AND NESTLING MORTALITY

In North America, the most common nest predator of goshawks appears to be the Great Horned Owl (*Bubo virginianus*; Moore and Henny 1983, Rohner and Doyle 1992). A wide variety of mammals are also known to prey upon goshawk nestlings (Squires and Kennedy, *this volume*). In Minnesota, inclement weather accounted for failure of 6 (13.9%) of 43 goshawk nesting attempts (Boal et al. 2005a). Another 21.0% of goshawk nesting failures were due to depredation by Great Horned Owls and mammalian predators (e.g., fishers [*Martes pennanti*], martens [*Martes americana*]). Elsewhere in the WGLR, Erdman et al. (1998) reported that predation by fishers was the primary cause of nesting failure among goshawks in Wisconsin, but did not provide details as to how they arrived at this conclusion or the number

of nesting failures due to fisher depredation. This is not an exhaustive list of potential goshawk predators in the WGLR but it does suggest that, similar to other areas, goshawks in this region are subjected to both avian and mammalian predation.

FOOD HABITS

Goshawks are considered prey generalists with diets varying by region, season, and availability (Squires and Reynolds 1997; Squires and Kennedy, *this volume*). Local studies of food habits are necessary for developing management strategies for goshawk populations at regional and local levels (Reynolds et al. 1992).

A number of anecdotal records of prey items collected opportunistically at goshawk nests in the WGLR, provide a prey list rather than any quantitative assessment of food habits (Roberson et al. 2003). The video monitoring of prey deliveries to goshawk nests in Minnesota by Smithers et al. (2005) is the only quantitative food habits study conducted to date in the WGLR. Smithers et al. (2005) identified 576 (88.3%) of 652 prey items delivered to 13 goshawk nests in Minnesota as mammal or bird. Red squirrels (*Tamiasciuris hudsonicus*) accounted for 202 (42%) and eastern chipmunks (*Tamias striatus*) accounted for 95 (19.8%) of 479 prey deliveries identified to family or finer taxonomic resolution. This suggests sciurids are a key breeding-season prey species for goshawks in Minnesota. Other prey species accounting for ≥5% of identified prey included hares and rabbits (7.9%), American crows (*Corvus brachyrhynchos*, 7.7%) and Ruffed Grouse (*Bonasa umbellus*, 6.9%).

Mammals and birds accounted for 61% and 39% of biomass delivered, respectively, to goshawk nests in Minnesota (Smithers et al. 2005). Snowshoe hare (*Lepus americanus*, 25.5%), red squirrel (23.6%), and chipmunk (5.0%) accounted for 54% of mammalian biomass delivered to nests, while Ruffed Grouse (11.5%), crows (9.0%) and diving ducks (7.1%) accounted for 28% of avian biomass.

Several studies have documented red squirrels as important prey for goshawks (Squires and Kennedy, *this volume*) throughout their range, and they may be especially important during the winter when other prey are unavailable (Widén 1987). Squirrels dominated Swedish goshawk diets in terms of number (79%) and biomass (56%) during winters of both high and low squirrel abundance (Widén 1987). Winter food habits information for goshawks in the WGLR is not available, but the extensive use of red squirrels during the summer (Smithers et al. 2005) and the patterns of squirrel use during winter in other areas (Widén 1987) suggest this species may be of year-round importance to goshawks in the region.

Rabbits and hares are also used extensively by goshawks throughout their range (Squires and Kennedy, *this volume*). In Minnesota, 25.5% of prey biomass delivered to nests was from snowshoe hares (Smithers et al. 2005). Ruffed Grouse comprised 5% of prey deliveries and 11.5% of biomass delivered to goshawk nests during a 3-yr period (2000–2002) of low grouse abundance (Smithers et al. 2005). There is some evidence that at least some goshawks in Minnesota may rely more heavily on Ruffed Grouse during some time periods (Eng and Gullion 1962, Apfelbaum and Haney 1984). Erdman et al. (1998) suggested that goshawk productivity was probably related to cyclic abundance of Ruffed Grouse and snowshoe hares in Wisconsin but it is unknown how he arrived at these conclusions since he did not describe goshawk diet. Eng and Gullion (1962) focused on Ruffed Grouse mortality, and did not assess proportional use of grouse in the diet of goshawks, and Apfelbaum and Haney (1984) reported on prey remains collected at only one nest in northern Minnesota. Because of the difficulties in accurately quantifying the extent of grouse predation by goshawks (Eng and Gullion 1962) and the biases associated with determining raptor diets based on prey remains (reviewed in Boal 1993), the results of these studies need to be interpreted cautiously. The importance of Ruffed Grouse in goshawk diets in the WGLR region through periods of varying grouse abundance is not known but they may be important prey item in the WGLR. Gallinaceous birds (primarily grouse and pheasants) are well documented as important prey of North American and European goshawks at northern latitudes. Fluctuations in these grouse populations have been shown to affect goshawk productivity, including number of nesting pairs, and number of young per active nest (Squires and Kennedy, *this volume*).

NESTING HABITAT

Nest Tree

Goshawks are thought to choose nest trees based on size and structure more than tree species (USDI Fish and Wildlife Service 1998a). Goshawks often nest in one of the largest trees in the nest stand, although height and diameter of nest trees vary geographically and with forest type (Reynolds et al. 1982, Hargis et al. 1994, Squires and Ruggiero 1996, Squires and Reynolds 1997). In Minnesota,

goshawk nests were placed in the tallest and largest diameter at breast height (dbh) trees available in nest stands (Boal et al. 2001). However, height and dbh of goshawk nest trees in our study were among the lowest reported from 10 studies reviewed by Siders and Kennedy (1994). We suspect that available trees in northern Minnesota are smaller than those available in other study areas possibly due to shorter growing seasons (Tester 1995).

Using the North American Nest Card Program, Apfelbaum and Seelbach (1983) found that goshawks nested in 20 tree species or species groups, with deciduous trees reported twice as often as conifers throughout North America and nine to one over conifers in the Midwest. In a review of studies in the WGLR, the majority of known goshawk nests were placed in deciduous tree species (Roberson et al. 2003). In our research in Minnesota, we found 46 goshawk nests placed in aspen (*Populus* spp., 80%), birch (*Betula* spp., 19%), white pine (*Pinus strobes*, 4%), red pine (*Pinus resinosa*, 2%), and red oak (*Quercus borealis*, 2%) trees (Boal et al. 2001). Deciduous trees were clearly the dominant species (94%), even in conifer-dominated nest stands (Boal et al. 2001). Rosenfield et al. (1998) also found one of four goshawk nests in aspen trees within Wisconsin pine plantations. Thus, conservation of large deciduous trees in all stand types may be important for goshawk management in the WGLR.

Aspect and slope at nest sites may influence microclimate and goshawk habitat selection. Several studies have demonstrated clear associations between goshawk nest placement and slope, but slopes are highly variable (9–75%; Reynolds et al. 1982, Moore and Henny 1983, Hayward and Escano 1989, Siders and Kennedy 1996, Squires and Ruggiero 1996). Goshawk nests are also usually associated with a northerly aspect (Reynolds et al. 1982, Hayward and Escano 1989, Bosakowski and Speiser 1994). However, aspect and slope probably are inconsequential in Minnesota due to the lack of topographical relief on the landscape; most goshawk nests in Minnesota were on sites that were so level that slope and aspect could not be reliably determined (Boal et al. 2001).

Nest Area

In a review of goshawk habitat studies, Daw et al. (1998) concluded that goshawks tend to select nest stands that are characterized by relatively large trees and relatively high canopy closure (>50–60%), regardless of region or forest type. Penteriani et al. (2001) also reported that high dbhs, high crown volumes, and flight space were significant predictors of goshawk nest site selection in France. These patterns were consistent with data from the few nest habitat studies conducted in the WGLR. Nest stands in Minnesota consisted of canopy trees that were both taller and greater in diameter than the average in stands where goshawks were foraging (Boal et al. 2001). Similarly, canopy closure at Minnesota and Wisconsin goshawk nests stands (Martell and Dick 1996, Rosenfield et al. 1998, Boal et al. 2001) were within the range (59.8–95.0%) reported by Siders and Kennedy (1994) for other areas.

Penteriani et al. (2001) suggested a distribution-wide commonality among goshawk nest stands is a variable, but typically low, stem density. In contrast, the 1,153 stems/ha (Martell and Dick 1996) and 1,196 stems/ha (Boal et al. 2001) observed at goshawk nest stands in Minnesota are among the highest reported for the species (Siders and Kennedy 1994, Penteriani et al. 2001). High stem density at goshawk nests in Minnesota was coupled with a multistoried canopy. However, there were distinct open layers between the foliage of the canopy and understory, and between the understory and shrub layers. We suspect these relatively unobstructed layers may be important as flight corridors for goshawks, particularly in stands with high stem densities.

In Minnesota (Boal et al. 2005b) we found goshawks nested primarily in early-successional upland deciduous stands (58%) and late-successional upland conifer stands (26%). Fewer nests were located in late-successional upland deciduous stands (12%) and early-successional upland conifer stands (5%). Elsewhere in Minnesota, Gullion (1981a) reported that three nests in the late 1970s near Cloquet were in hardwood trees in small stands dominated by jack pine (*Pinus banksiana*), red pine, and Scots pine (*Pinus sylvestris*), and surrounded by mixed conifer hardwood and young aspen stands. A goshawk nest in Itasca State Park was located in a jack pine-aspen forest (Apfelbaum and Haney 1984). Nests reported by Martell and Dick (1996) were found in aspen-balsam fir (*Abies balsamea*), red pine-aspen, mixed hardwood, and jack pine-aspen stands (Dick and Plumpton 1998).

Elsewhere in the WGLR, Ennis et al. (1993) reported nests on the Huron-Manistee National Forests were placed in red pine (35%), aspen (28%), oak (12%), northern-mixed hardwoods (10%), and other (15%) stand types. Postupalsky (1993) reported northern hardwood forest, aspen, or white pine stands as the most frequently used nest stand types in Michigan. Bowerman et al. (1988) reported most nests examined (62%, N = 45) in Michigan were

located in early to mid-successional stage deciduous or mixed stands, with the remainder (38%) in red pine plantations. Peck and James (1983) described typical nest stands in Ontario as dense stands of deciduous, coniferous, and mixed forests. Rosenfield et al. (1998) reported that nest stands in Wisconsin varied in tree species composition and woodland age, including four nests in pine plantations. The proximity of some goshawk nests to pine plantations has been noted by researchers in Wisconsin (Rosenfield et al. 1996, 1998), Michigan (Bowerman et al. 1988), Minnesota (Dick and Plumpton 1998), and Ontario (Peck and James 1983).

BREEDING SEASON FORAGING HABITAT

The few studies on breeding-season foraging habitat of goshawks have been conducted in western North America (Austin 1993, Bright-Smith and Mannan 1994, Beier and Drennan 1997) and Europe (Kenward 1982, Widén 1989). Collectively, results from these studies suggest goshawks use a variety of forest types, and appear to select forests with a high density of large trees, high canopy cover and closure, high basal area, and relatively open understories (Kenward 1982, Widén 1989, Austin 1993, Bright-Smith and Mannan 1994, Hargis et al. 1994, Beier and Drennan 1997).

Until recently, information on goshawk foraging habitat during the breeding season in the WGLR was not available. Boal et al. (2005 b) assessed foraging habitat use relative to availability and found that breeding male goshawks in Minnesota preferentially used early-successional upland deciduous stands (aspen or birch) ≥50 yr old. Goshawks also used this stand type in the age range 25–49 yr old at least proportional to availability, but clearly avoided stands <25 yr old. Late-successional upland conifer stands (white pine and red pine) of all ages were also a clearly preferred stand type. Late-successional upland deciduous stands (maples and oaks) ≥50 yr old were used proportional to, or greater than, availability (depending on scale of assessment), whereas late-successional lowland deciduous stands (ash) were used proportional to availability. Late-successional lowland conifers (tamarack and lowland black spruce) were one of the most widely available stand types in goshawk home ranges, but were avoided. Wetlands and open and cut-over areas were also used less than was proportionally available. Elsewhere in the WGLR, Lapinski (2000) reported three female goshawks in the Upper Peninsula of Michigan foraged in mixed hardwood-conifer stands and jack pine, but avoided cedar, open, and swamp fir-swamp conifer cover types.

Similar to other parts of the goshawk's range, the landscape of north-central Minnesota has changed in the past several decades, with the ratio of forested land to non-forested land apparently declining from 1.72 in 1977 to 1.63 in 1990 and a shift from stands of white and red pines to stands of aspen (Minnesota Forest Resources Council 2000). It is clear that breeding male goshawks in Minnesota foraged in mature and old forested stands, especially upland conifer and upland deciduous stands (Boal et al. 2005b), but the influence the changes in vegetation communities may be having on goshawk populations is unknown.

The demonstrated preference for older age class stands by foraging male goshawks in Minnesota (Boal et al. 2005b) is consistent with reports on breeding-season foraging habitat use by goshawks in coniferous forests of the western US (Austin 1993, Bright-Smith and Mannan 1994, Beier and Drennan 1997), non-breeding goshawks in boreal forests of Sweden (Widén 1989) and Finland (Tornberg and Colpaert 2001), and year-round habitat use in coniferous forests of southeast Alaska (Iverson et al. 1996). However, even if goshawks do not typically venture into stand types that are used less than expected, the possible importance of those stand types to prey production in a goshawk's home range should not be overlooked (e.g., young aspen stands and Ruffed Grouse, Gullion and Alm 1983). Boal et al. (2005 b) also stressed that their data and assessments were limited to the breeding season and relative use of different stand types by goshawks may vary seasonally due to factors such as seasonal changes in prey availability or additional requirements for thermal or escape cover during the non-breeding season.

HOME RANGE

In a summary of goshawk studies in North America, (Squires and Reynolds 1997) found breeding-season home range sizes were between 570 and 3,500 ha. Their summary did not include information from the WGLR, although Eng and Gullion (1962) reported some of the first foraging area data collected for goshawks in North America. By examining the remains of marked grouse found at goshawk nest areas in northern Minnesota, they determined that nine banded male grouse were brought to the nests from drumming areas 1,097–2,514 m ($\bar{x}$ = 1,664 m) away. Also, in one of the first studies of goshawks using radio-telemetry, Davis (1979) found a nesting female goshawk in Minnesota with a home range size of 4,200 ha. In the Upper Pennisula of Michigan, Lapinski (2000)

reported that breeding season home ranges of three female goshawks averaged 513 ha.

Recently, Boal et al. (2003) reported that mean breeding-season home range sizes for 17 male and 11 female goshawks in Minnesota were 2,593 ± 475 ha and 2,494 ± 631 ha, respectively. Although Hargis et al. (1994) and Kennedy et al. (1994) reported males' home ranges as larger than females', Boal et al. (2003) found negligible gender differences in home range sizes. However, even though gender differences were small, the combined home-range size of goshawk pairs (N = 10 pairs, $\bar{x}$ = 6,376 ± 1,554 ha) was on average 55 ± 5% greater than that of individual male and female members of pairs (Boal et al. 2003). Boal et al. (2003) speculated that a goshawk pair may exploit a larger area to meet the increasing food demands of growing nestlings. The combined home-range size of pairs may therefore be a better measure of the area required for successful brood rearing. This would suggest that management plans based on estimated home-range sizes of individual goshawks may underestimate the area actually required for successful nesting (Boal et al. 2003).

Variability in home range size estimates among studies may be partially explained by different estimation and data collection methods. Variability due to sex of goshawk and local environmental conditions, however, suggests home ranges need to be assessed at a local or regional scale. Home range size likely varies as a function of regional differences in forest conditions, spatial distribution of forest stands, climate, topography, and local prey availability.

RESIDENCY

The ecology of goshawks during the winter is one of the least understood aspects of the species ecology (Squires and Kennedy*, this volume*). Very little is known about winter movements or habitat requirements of goshawks in the WGLR (Dick and Plumpton 1998). In Minnesota, 26 (93%) of 28 radio-tagged goshawks remained within 7 km of their nest stands, one female moved 87 km, and one female was not relocated during the winter (Boal et al. 2003). With few exceptions, during the period 1999–2001 breeding adult goshawks in Minnesota appeared to be year-round residents, and remained close to their nest stands through the winter (Boal et al. 2003).

Elsewhere in the WGLR, Doolittle (1998) found that two radio-tagged goshawks remained in Wisconsin through the winter, and reported that the size of the male goshawk's use area was 32 km^2 and the female's was 4 km^2. Over 95% of the relocation points for the male were in the edges of conifer swamps; Doolittle (1998) speculated that conifer swamps may provide areas of thermal cover for prey during the Wisconsin winter. In the Upper Pennisula of Michigan, Lapinski (2000) reported that two females and a male selected hardwood-conifer mix and swamp fir-swamp conifer cover types and avoided aspen, cedar, hardwood, jack pine, and red-white pine cover types during the non-breeding season.

The pattern of winter residency among goshawks is variable across the species' distribution and this variability suggests goshawks are partial migrants where some individuals maintain year-round occupancy of breeding areas and breeding-season home ranges while other individuals in the population undergo seasonal movements to wintering areas. The proportion of individuals that migrate can vary from 0–100% depending on winter conditions (Dingle 1996). Winter ranges of 18 goshawks in California included nest stands from the previous breeding season (Keane 1999), whereas goshawks in Wyoming moved from their breeding areas (Squires and Ruggerio 1995). In Sweden, male goshawks radio-tagged in late summer and fall near their breeding area tended to remain in the area through the winter, while female goshawks tended to move away (Kenward et al. 1981b, Widén 1985b). It appears that goshawks in the WGLR tend to remain as year-round residents. Although data on winter ecology of goshawks is almost nonexistent in the region, breeding-season and winter habitat, and prey use may differ (Boal et al. 2001). Additional acquisition of region-specific winter data for goshawks remains an important missing component of our understanding of goshawk ecology in the WGLR and throughout the species distribution.

MIGRATION

Data on goshawk migration patterns is derived primarily from counts at migration stations, band returns, and radio-telemetry. These data also suggest goshawks are partial migrants. Sample sizes in migration studies to date, however, have been inadequate to fully understand patterns or routes for North American goshawk populations (Squires and Reynolds 1997, Hoffman et al. 2002). Hoffman et al. (2002) recently analyzed movement patterns of Northern Goshawks encountered at migration stations throughout the western US. Of the 722 goshawks captured from 1980–2001 at these sites only 2.3% of these birds (N = 17) were recaptured

or resighted. This low resighting probability is one of the reasons researchers have doubted the utility of using migration counts to estimate goshawk population trends (Titus and Fuller 1990, Kennedy 1997, Kennedy 1998; but see Smallwood 1998 for an alternative view).

Given the caveats associated with migration counts, it is interesting to note that more goshawks are banded at Hawk Ridge in Duluth, Minnesota, than anywhere else in North America (Palmer 1988). Goshawks banded at Hawk Ridge have been recovered in northeastern British Columbia, Alberta, Saskatchewan, Ontario, and Minnesota (Evans 1981, Boal et al. 2003), and during potential irruption years in Missouri, Texas, Arkansas, and Louisiana (Evans and Sindelar 1974, Evans 1981). A female banded at Hawk Ridge in the fall of 1972 was recaptured in the fall of 1982 at Cedar Grove, Wisconsin (Evans 1983) and a male banded at Hawk Ridge in the fall of 1988 was re-captured as a breeding bird in north-central Minnesota in 1999 (Boal et al. 2001).

MORTALITY

The majority of information on causes of mortality among adult goshawks is anecdotal (Squires and Reynolds 1997). Furthermore, a large portion of annual mortality occurs outside the breeding season and therefore is not easily detected (Braun et al. 1996). Still, the primary cause of mortality among free-ranging goshawks appears to be depredation and starvation (Kennedy 2003). For example, Ward and Kennedy (1996) found radio-tagged juveniles goshawks in New Mexico succumbed to predation (50%), accidents and injuries (17%), and disease (8%). Conversely, Dewey and Kennedy (2001) found that most deaths of juvenile goshawks in a Utah population were from starvation or siblicide (a consequence of low food supplies).

Published mortality data for goshawks in the WGLR are based almost solely on females found killed at Wisconsin nests (Erdman et al. 1998) and relocated radio-tagged goshawks found throughout the year in Minnesota (Boal et al. 2005a). Five (56%; four females and one male) of nine (eight radio-tagged) goshawk mortalities in Minnesota occurred during the breeding season (Boal et al. 2005a). Three goshawks were depredated by avian predators and two were preyed upon by mammals (Boal et al. 2005a). Erdman et al. (1998) identified fishers as the cause of mortality for four nesting adult female goshawks in Wisconsin.

Of four winter mortalities documented in Minnesota, one goshawk had been shot, the recovered radio of another had been obviously cut from the body of the goshawk, and the causes of mortality of the remaining two were not determined (Boal et al. 2005a). Furthermore, goshawk mortality in Minnesota occurred with equal frequency in the breeding and winter seasons and, although depredation appeared to be the most significant mortality factor, human persecution may still be a factor affecting goshawk survival despite legal protection (Boal et al. 2005a).

Discounting the single non-radio-marked female, the estimated annual survival rate (estimated using the modification by Pollock et al. [1989] of the Kaplan-Meier [Kaplan and Meier 1958] survival model) of 32 radio-marked goshawks was 74% ± 7.8% (SE) (Boal et al. 2005a). Although their sample size was relatively small for conducting survival analysis, the estimated annual survival rate is quite similar to mark-recapture estimates in California (61–69%; DeStefano et al. 1994b), New Mexico (60–96%; Kennedy 1997) and northern Arizona (69–87%; Reynolds and Joy 1998). All these authors indicate imprecision in their studies due to a variety of reasons, and Kennedy (1997) concluded that precise estimates of survival require large numbers of marked birds (>100), high re-sighting rates, and at least 5 yr of data. Such data have not been collected in the WGLR and are not likely to be collected in the future.

SUMMARY

When comparing goshawks in western North America to those in the WGLR, some differences are immediately apparent. The primary difference is in nesting habitat features due to the differences in landscapes. Goshawks in western North America primarily build nests in conifer trees situated in conifer stands on mountain slopes (Squires and Reynolds 1997). In the WGLR, goshawks typically build nests in deciduous trees in mixed or conifer dominated stands. Although exceptions occur, typically little or no slope exists at nests sites due to the generally level terrain of the region. Nest site canopy cover is similar between the regions, but nest trees in the WGLR appear to be smaller than in the West, probably due to regionally different patterns in species and growing seasons. However, similar to western North America, goshawks in the WGLR build their nests in the largest trees available in stands. In most other respects, the available information suggests little difference between the regions. Similar to western studies (Squires and Reynolds 1997), goshawks in the WGLR appear to remain reasonably close to their breeding areas year-round (Boal et al. 2003).

Productivity in Minnesota was also within the range of that reported for numerous studies in western North America (Squires and Reynolds 1997). Although very few data exist, that available suggests annual survival of goshawks in Minnesota (Boal et al. 2005a) is similar to the West (DeStefano et al. 1994b, Kennedy 1997, Reynolds and Joy 1998). Finally, similar to most other studies (Squires and Reynolds 1997), goshawks in the WGLR appear to have diets dominated by sciurids and leporids, especially red squirrels (Smithers et al. 2005).

RESEARCH NEEDS

A comprehensive report on research and monitoring needs for the Northern Goshawk in the WGLR was prepared by Kennedy and Andersen (1999). Information needs identified in that report have begun to be addressed through recent research, much of which has been summarized in this overview. Development of a more comprehensive understanding of goshawks in the WGLR would be facilitated by sharing results among investigators conducting current survey and monitoring efforts in the region. This would be further enhanced if standards for estimating habitat and demographic parameters were comparable across the region (Kennedy and Andersen 1999). However, as is evident from this paper and other information summaries on goshawks in the WGLR (Dick and Plumpton 1998, Kennedy and Andersen 1999), information on goshawk population dynamics, goshawk-habitat relations, and goshawk-prey interactions is sparse for the region. If this lack of information is to be addressed, research and monitoring priorities for goshawks in the WGLR should include:

1. A region-wide sampling program to locate goshawk nest sites and assess nesting and foraging habitat use. Survey methods developed by Roberson (2001, Roberson et al., unpubl. data) may facilitate nest detections. Radio-telemetry studies from other areas of the WGLR are needed to assess habitat use at local and regional scales. Habitat-use studies require stand-scale information across the region. Although some entities, such as the USDA Forest Service, possess stand age and structure data at a resolution relevant to understanding landscape-level patterns of goshawk habitat use, our study area was comprised of a myriad of land ownerships. The only available landscape data encompassing all ownerships are derived from remote sensing (e.g., LandSat Thematic Mapper). Thematic mapper data provide information only at the resolution of tree-species composition; this is inadequate for examining stand age and structure patterns of goshawk habitat in the WGLR. For example, a goshawk may be interpreted as avoiding a given stand type when, in reality, the hawk avoids it because it is available only at an unsuitable age class. Until stand age and structure data are available for the entire region, assessment of landscape patterns in habitat use will be possible for only a few goshawks, which might unpredictably bias inferences. Developing and compiling landscape level databases that detail stand structure and age should be a priority (Squires and Kennedy, *this volume*).
2. An emphasis on year-round management. Current evidence suggests goshawks are year-round residents in the WGLR (Boal et al. 2003). Thus, conservation plans for goshawks in the WGLR should not be limited to the breeding-season. However, regional winter habitat-use information is non-existent. We suggest radio-telemetry studies be initiated to identify stand characteristics of foraging goshawks year-round and to facilitate location of kill sites to determine winter prey use (Drennan and Beier 2003).
3. An experimental evaluation of the effects of forest management on goshawks (DeStefano 1998, Kennedy 1998). With some planning, we think silvicultural treatments in the vicinity of nests should be used as quasi-experiments (Penteriani and Faiver 2001). Radio telemetry could be used to monitor pre- and post-harvest movements and habitat use of goshawks. Monitoring could include multiple years following treatment to assess goshawk response to forest succession. Such an experimental examination would greatly enhance our ability to predict goshawk responses to silvicultural treatments than has thus far been provided by correlative studies (Kennedy 2003).
4. A collaborative, region-wide approach to monitoring demographics. Existing data are inadequate to determine if WGLR goshawk populations are declining, stationary, or increasing, or to identify habitat conditions that result in sources of goshawk recruitment or in population sinks (Dick and Plumpton 1998). Nest monitoring and methodologies used among projects and researchers have been inconsistent. We suggest that a collaborative effort using a consistent strategy for

monitoring samples of goshawk nests across the WGLR would facilitate an understanding of survival, mortality, and productivity in the region. Greater resolution of population dynamic assessments at the regional scale will require substantial research effort (Kennedy 1997, 1998). The applicability of suggestions by Hargis and Woodbridge (*this volume*) for monitoring goshawks at bioregional scales should be explored for the WGLR.