The Northern *Goshawk* (*Accipiter gentilis atricapillus*) in the Western Great Lakes Region: A Technical Conservation Assessment

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Aimee M. Roberson[1,2] **and David E. Andersen**
U.S. Geological Survey, Minnesota Cooperative Fish & Wildlife Research Unit[3], University of Minnesota, St. Paul, MN 55108

Patricia L. Kennedy[4]
Department of Fishery & Wildlife Biology, Colorado State University, Fort Collins, CO 80523

EXECUTIVE SUMMARY

This conservation assessment is a summary of the information currently available regarding the northern goshawk (*Accipiter gentilis*) in the Western Great Lakes Region (WGLR), including the states of Minnesota, Wisconsin, and Michigan and the forested southern portion of the Canadian province of Ontario. Because relatively few scientific studies of the goshawk in the WGLR have been conducted and even fewer published, information that may be relevant from studies conducted in other parts of North America and Eurasia have also been summarized. The purpose of this assessment is to present information relevant to the formation of a conservation and management strategy for the goshawk in the WGLR. This assessment describes the species' systematics, physical characteristics, distribution, and abundance. It also includes information regarding the foraging ecology, habitat characteristics, population ecology, potential threats, and monitoring of the northern goshawk, summarizes ongoing research, and identifies additional research needs for this region.

[1]Present address: U.S. Fish and Wildlife Service, 2105 Osuna Road NE, Albuquerque, NM 87113
[2]E-mail: Aimee_Roberson@fws.gov
[3]Cooperators of the Minnesota Cooperative fish and Wildlife Research Unit: University of Minnesota, the Wildlife Management Institute, U.S. Geological Survey, and the Minnesota Department of Natural Resources
[4]Present address: Eastern Oregon Agricultural Research Center, Oregon State University, P.O. Box E, 372 So. 10th St., Union, OR 97883

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INTRODUCTION

Background

The northern goshawk (*Accipiter gentilis atricapillus*; hereafter referred to as goshawk) is listed as a migratory nongame bird of management concern by Region 3 of the U.S. Fish and Wildlife Service (USFWS) and is on the U.S. Forest Service's (USFS) Regional Forester's Sensitive Species list for Region 9 (Lewis 1998). The goshawk is listed at the state level as a species of concern in Michigan (Weise 1998), but is not listed in the other states or provinces of the Western Great Lakes Region (WGLR – northern forested portions of Michigan, Minnesota, and Wisconsin, and the southern forested portions of Ontario) where it also occurs (Dick and Plumpton 1998). The concern over this species is currently focused in the western U.S. where litigation to list goshawk populations as threatened or endangered throughout or in parts of its range has been ongoing for almost 10 years. Subsequent findings based on a status review of goshawk populations west of the 100th meridian conducted by the USFWS (1998a) determined that listing the goshawk as threatened or endangered under the Endangered Species Act (ESA) was not warranted (USFWS 1998a, b). However, the goshawk has remained a species of concern to various publics and agencies throughout its range.

Goshawks generally nest (Siders and Kennedy 1996, Squires and Ruggiero 1996) and during the breeding season hunt (Bright-Smith and Mannan 1994, Beier and Drennan 1997, USFWS 1998a) in old growth and mature forest stands. However, the association between goshawks and mature forest is not clearly delineated (Kennedy and Andersen 1999); neither optimal nor minimal levels of interspersion of habitat types and age classes needed to support goshawks and their prey are defined. Winter habitat preferences of goshawks in North America are poorly understood, but European data suggest the bird can use the same habitats year-round. Thus, they may be negatively affected by changes in habitat and prey availability due to changes in forest structure, large tree removal, and other forest developments (Crocker-Bedford 1990). These changes may be associated with timber harvest and other forest management practices, as well as, changes in fire regimes, insect and disease epidemics, and agricultural and livestock practices (Graham *et al.* 1999).

In a review of available information on goshawk populations in the U.S., Kennedy (1997) suggested that range contraction and rate of population decline, rather than population abundance or geographic range size at one point in time, may be seen as potential evidence of a species whose populations are declining. Evidence from some studies suggests that goshawk populations and reproduction may be declining in the Southwest and elsewhere in the western U.S. (Herron *et al.* 1985 *in* USFWS 1998a, Bloom *et al.* 1986, Kennedy 1989, Crocker-Bedford 1990, Zinn and Tibbitts 1990 *in* USFWS 1998a). However, Kennedy (1997, 1998) indicated that current sampling techniques might be insufficient to detect population trends. Kennedy (1997) concluded that there is no strong evidence to indicate that goshawk populations are declining, increasing, or stationary. The difficulty in accurately measuring goshawk population trends may be due to multiple factors: (1) goshawks are secretive in nature and difficult to survey; (2) many studies have small sample sizes and are temporally and spatially limited in scope; (3) potential biases exist in the nest detection methods used in some studies; and (4) research methods, data analyses, and interpretation are not consistent among studies, making comparisons across studies difficult. The development of a reliable population model is further complicated by the spatial and temporal variation in goshawk population densities (Kennedy 1997).

In response to Kennedy (1997), Crocker-Bedford (1998) stated that rate of population change for goshawk populations in the U.S. may be impossible to calculate because the species is sparsely distributed, measurements of population parameters vary with prey cycles and weather, and immigration, emigration, and survival are difficult to estimate. Crocker-Bedford (1998) suggested that instead of trying to demonstrate a decline in goshawk populations, habitat relationships of goshawks should be examined to evaluate the amount of habitat destruction or modification that has occurred or is occurring. Kennedy (1998) responded that habitat monitoring should augment demographic studies, not replace them, and suggested that once goshawk habitat is well-defined and demographic data are available from several study areas, a model (or models) that predicts the relationship between nesting and winter habitat and population trends and/or performance could be developed.

Most of the information collected on goshawk biology and ecology in the U.S. is from the West and it is unclear to what degree this information can be applied to management of goshawk populations elsewhere. Much of the information on WGLR goshawks consists of data gathered by independent researchers and volunteers and has not been published. Because many of the studies included in this conservation assessment are unpublished, written descriptions of study designs, methods, and analytical techniques are not always available for critical analysis, have not been through critical peer review as part of the scientific publication process, and should therefore be interpreted cautiously. In addition, access to unpublished information may be difficult for land management agencies and other concerned parties. Most studies from the WGLR were conducted in limited portions of one state and none have been conducted on a regional scale. With the exception of Rosenfield *et al.* (1996), most study locations were not randomly selected, which limits inference to region-wide trends (see Kennedy and Andersen 1999 for a detailed discussion of sampling considerations applicable to WGLR goshawk populations). There is clearly a need for additional research in this region.

Several researchers in the WGLR have been studying goshawk biology for decades. Erdman *et al.* (1998) summarized more than 25 years of reproductive data on breeding goshawks in northeastern Wisconsin. Evans and colleagues have been banding goshawks migrating through their banding station at Hawk Ridge, near Duluth, Minnesota since the early 1970s and have published summary reports (Evans 1981, 1983). Rosenfield *et al.* (1998) published information on the breeding distribution and nest-area habitat of goshawks in Wisconsin collected from 1977–1997.

Partially in response to the paucity of published information regarding the status and trends of goshawk populations in the WGLR, the number of symposia and meetings focused on goshawk research and management has increased over the past several years (Dick and Plumpton 1998). In 1993, regional discussions were held as part of the annual Midwest Peregrine/Raptor Symposium in Madison, Wisconsin. In 1997, the USFWS coordinated a workshop in Milwaukee (Noll West 1998) to improve communication regarding goshawk research and management across political boundaries. The purpose of the workshop was to facilitate science-based management decisions regarding the potential impact of forest management practices on goshawk habitat. The participants of the workshop initiated an extensive review and discussion of existing goshawk information for the WGLR (Dick and Plumpton 1998). The topics discussed at this meeting included: (1) current population status and biology of the goshawk; (2) status of past and ongoing monitoring and research activities that relate to goshawk biology and management; (3) information gaps and future data collection needs for the goshawk; (4) management issues that potentially impact goshawks; and (5) a course of action to address future conservation of this species (Lewis 1998). In 1998, Dick and Plumpton completed the data review entitled *Review of Information on the Status of the Northern Goshawk in the Western Great Lakes Region and Ontario*. Because it was clear from the Milwaukee workshop and from the review by Dick and Plumpton (1998) that additional regional data were needed to facilitate science-based conservation plans and adaptive management for this species, participants agreed there was a need to develop a regional research and monitoring plan for the goshawk (Noll West 1998).

Kennedy and Andersen (1999) completed such a plan. Information needs identified in that plan were addressed in part, during a three-year study of goshawk habitat use and characteristics in northern Minnesota (Boal *et al. In Review*a, *In Review*b). The focus of this study was guided by a diverse group of stakeholders facilitated by the Minnesota Cooperative Fish & Wildlife Research Unit (MNCFWRU), and includes representatives from state, federal and tribal government agencies, industry, and non-governmental organizations. Roberson *et al.* (*In Review*) conducted a test of broadcast survey methods in northern Minnesota to determine their effectiveness in detecting active goshawk nests. Smithers *et al*. (2002) are conducting a study of prey use at goshawk nests in Minnesota using video monitoring. However, data from these studies may not represent regional goshawk populations because the samples were based on known nest sites and not randomly selected.

In other parts of the WGLR, there are a few recent publications and several studies currently being conducted. Erdman *et al.* (1993, 1998), Rosenfield *et al.* (1991, 1996, 1998a, 1998b), and Doolittle (1998) are conducting or have recently completed studies in Wisconsin. In Michigan, Bowerman *et al.* (1998, 2000) and Postupalsky (1993, 1998) are conducting ongoing research on the goshawk, and Lapinski (2000) completed an M.S. thesis on habitat use and productivity of the goshawk in the Upper Peninsula of Michigan.

Approach and Scope of Assessment

This conservation assessment was written for the purpose of reviewing information pertinent to the characterization and conservation of goshawk habitat and populations in the WGLR. It will be used to develop a conservation strategy for the region. Scientists and other stakeholders have identified the population of interest as the regional breeding population in its year-round habitat in the northern forested portions of Michigan, Minnesota, Wisconsin and the southern forested portions of Ontario (Noll West 1998, Kennedy and Anderson 1999). The regional boundaries to this population are political in nature as there is no evidence that it is a biologically distinct population (Dick and Plumpton 1998, Kennedy and Anderson 1999). However, due to the similarity in landscapes across this region, the USFS has chosen to focus on information from the entire region for this assessment. This assessment is primarily based upon published literature, symposia proceedings, and unpublished management reports.

In addition to information based on data collected within the WGLR, this assessment contains information from outside the region that may be helpful in understanding goshawk biology and ecology in general. Although most research on North American goshawks has been conducted outside of the WGLR, the design and results of these studies should be considered for their relevance in helping to identify limiting factors and management strategies for goshawk populations in this region (Dick and Plumpton 1998). It is important to recognize differences in primary habitats and ecological pressures between study areas, however, careful analyses of previous and future habitat studies may lead to a broader understanding of habitat characteristics that goshawks have in common across several study areas or even throughout their Holarctic range (Kennedy 1997). Several reviews of goshawk studies have been written in recent years (Braun *et al.* 1996, Kennedy 1997, Squires and Reynolds 1997, Dick and Plumpton 1998, USFWS 1998a), providing valuable comparisons and a comprehensive scope of available information, and are cited frequently in this assessment. The structure of this assessment closely follows the structure of the *Status Review of the Northern Goshawk in the Forested West* (USFWS 1998a).

Unfortunately, there are no long-term indices of trends or estimates of goshawk breeding population size derived from standardized, widespread surveys in North America (Braun *et al.* 1996, Kennedy 1997). In addition, there is not sufficient information available to make a status determination for the entire breeding range contained in the WGLR or for any state or province within the region (Dick and Plumpton 1998).

History of Goshawk Conservation Efforts and Management

In the 1970s, several threats facing the goshawk and its nesting habitat were recognized in goshawk habitat studies (Bartelt 1977, Hennessy 1978, Reynolds 1989). Designated as a national indicator of mature and old-growth forests by the USFS in the 1980s, the goshawk was selected as a management indicator species for land management plans in at least 49 national forests (USFWS 1998a).

In the 1980s, management recommendations proposing that an 8-hectare (ha)(20-acre; ac) buffer of uncut habitat be left in timber sale areas around two active and two replacement nests per nest area were developed for western coniferous forests to protect nest areas (Reynolds 1983). An evaluation of implementations of the 8-ha (20-ac) buffer guidelines in Arizona indicated that these small buffers were not adequate to protect nest areas (Crocker-Bedford and Chaney 1988, Crocker-Bedford 1990). In 1992, the Northern Goshawk Scientific Committee, as assembled by the USFS, Southwestern Region, completed a document entitled *Management Recommendations for the Northern Goshawk in the Southwestern United States* (Reynolds *et al.* 1992). The recommendations developed by this committee included guidelines for management of 6,000-ac (2,400 ha) areas per goshawk pair, including different levels of protection at three scales: nesting habitat (12 ha; 30 ac), post-fledging habitat (168 ha; 420 ac), and foraging habitat (2160 ha; 5,400 ac).

In 1993, Kennedy and Stahlecker (1993) developed and tested a protocol for locating breeding goshawks in the southwestern U.S. using broadcast surveys that could be implemented in a systematic manner. The effectiveness of these surveys has been tested in Washington (Watson *et al.* 1999), Vancouver Island, BC (McClaren *et. al In Press*), and Minnesota (Roberson *et al. In Review*). Nests located via systematic searches may be a less biased sample of nests than those found opportunistically and may be valuable in determining population trends and for use in habitat studies.

Comprehensive management recommendations have not yet been developed for the WGLR, due in part to the lack of available information on goshawk habitat use and preferences in the region. However, all seven national forests have monitoring programs and some level of protection measures for active goshawk nests. A few have also published habitat management guidelines (Boss 1998). Dick and Plumpton (1998) summarized the management guidelines available as of 1998 from state and federal agencies in the WGLR.

In Michigan, the Department of Natural Resources (MIDNR) handles management prescriptions on an individual basis and the USFS checks timber sales for goshawk activity (Weise 1998). A woodland raptor group formed by Michigan researchers and agency personnel held hawk nest identification classes and used spring turkey hunter announcements to aid in the detection of goshawk nests (Weise 1998). The Huron-Manistee National Forest (NF) has developed recommendations for timber sale contract guidelines (Ennis *et al.* 1993) and the Ottawa NF has set guidelines for ≥121 ha (≥300 ac) buffers around active nests (Weise 1998).

The Minnesota Department of Natural Resources (MNDNR) has no nest-area protection guidelines, although internal guidelines recommend planning for retention of nesting habitat and limiting disturbance for all raptors between March and July (Baker 1997). The Chippewa National Forest (CNF) and Superior National Forest (SNF) have no set management guidelines and handle the management of each nest area on an individual basis (Dick and Plumpton 1998). On the CNF, appeal of the Third River salvage timber sale over loss of goshawk habitat resulted in modifications to the sale (Casson 1996). The MNDNR, the CNF, and cooperators have also been compiling data on goshawk nest activity and productivity since 1994. Historical nests on the SNF have been reported to various databases (Dick and Plumpton 1998) and surveys in 2000, 2001, and 2002 resulted in discoveries of new goshawk nests.

The Wisconsin Department of Natural Resources' (WIDNR) Woodland Raptor Management Guidelines call for a protection area of 65 ha (160 ac) around each nest (Dick and Plumpton 1998). The Nicolet NF listed the goshawk as a "sensitive species" in 1986 (Erdman 1993) and has protection guidelines in place following guidelines that were first developed for woodland raptors in the Eastern Region of the USFS (Zimmer 1993). The Nicolet NF also has a 16.2 ha (40 ac) clear-cut limit and gates off existing roads in goshawk breeding areas (Dick and Plumpton 1998). No nest protection guidelines exist for county or private lands in Wisconsin (Erdman *et al.* 1998) or in other areas of the region.

In Ontario, a field guide has been produced to aid personnel in locating and identifying nests. Ministry of Natural Resources staff and contracted timber surveyors report stick nests observed, which are then monitored and the species identified (Dick and Plumpton 1998). Armstrong (1998) supplied a general outline of Ontario guidelines. In addition, Naylor (1994) listed central Ontario guidelines for several species of raptors and James (1984) provided goshawk nesting area guidelines for Ontario.

NOMENCLATURE AND TAXONOMY

Common Name: Northern Goshawk
Scientific Name: Accipiter gentilis atricapillus (Linnaeus 1758)
Taxonomy:
    Order: Falconiformes
    Suborder: Accipitres
    Superfamily: Accipitroidea
    Family: Accipitrididae
    Subfamily: Accipitrinae [American Ornithologists' Union (AOU) 1998]

Approximately 10 to 12 subspecies of goshawks exist worldwide (Brown and Amadon 1968, Squires and Reynolds 1997). Originally described by Linnaeus (1758), the northern goshawk *(Accipiter gentilis*) is Holarctic in distribution, with two groups recognized worldwide: the Palearctic *gentilis* group (AOU 1983), consisting of several subspecies found in Eurasia, and the Nearctic *atricapillus* group (Wilson 1812). The *atricapillus* group occurs over much of Alaska, Canada, and the mountains of the western and eastern U.S. Although some authorities recognize 3 subspecies in North America (Johnsgard 1990), the AOU (1957) recognizes only 2: *A. g. atricapillus* and *A. g. laingi*. *A. g. apache* is not recognized by the AOU as a legitimate subspecies and the USFWS considers this issue to be unresolved (1998). *A. g. apache* is, however, recognized by some scientists (Phillips *et al.* 1964, Brown and Amadon 1968, Wattel 1973 *in* USFWS 1998a, Snyder and Snyder 1991, Hubbard 1992 *in* USFWS 1998a, Whaley and White 1994).

A. g. atricapillus, the subspecies found in the WGLR and therefore the subject of this conservation assessment, inhabits most of the North American range of the species. The Queen Charlotte goshawk, *A. g. laingi*, breeds on Queen Charlotte and Vancouver Islands (Taverner 1940), possibly extending north to Baranof Island in southeast Alaska (Webster 1988) or Prince William Sound in south-central Alaska (Jones 1979 *in* USFWS 1998a) and was listed as threatened in Canada in 2001. The debated *A. g. apache*, as recognized, is found from southern Arizona south to Jalisco in the mountains of Mexico (van Rossem 1938).

DESCRIPTION OF SPECIES

The largest and heaviest bodied of the three North American accipiters, goshawks have long, broad wings, a long, rounded tail, and stout legs and feet (Palmer 1988, Squires and Reynolds 1997). Although females are larger than males, goshawks are less dimorphic than smaller North American accipiters (Storer 1966). Average total length is 55 cm (21 in) for males and 61 cm (24 in) for females (Wood 1938). Reported averages for males range from 98 – 104 cm (38 – 41 in) wingspans and 631 – 1,099 g (22 – 38 oz) in mass, and for females from 105 – 115 cm (41 – 45 in) wingspans and 860 – 1,364 g (30 – 48 oz) in mass (Wheeler and Clark 1995, Squires and Reynolds 1997). The wingtips do not extend to the tail's midpoint when perched (Johnsgard 1990).

In adult plumage (Squires and Reynolds 1997), dorsal markings are brown-gray to slate gray, sometimes bluish. The head has a distinctive white superciliary line separating a black cap from the whitish sides of the crown. The iris is dark red to mahogany (Palmer 1988, Johnsgard 1990).

Underparts are uniformly whitish to pale gray with fine horizontal vermiculations and variable darker gray streaks on the lower breast, abdomen, and tibiae, which tend to appear as coarser barring on females. Adult females may also appear more brownish above. The tail is gray with three to five broad, dark bands, which are narrower than the intervening lighter gray. The tail tip is rounded and has a thin white terminal band. Undertail-coverts are white and may be fluffed out during courtship displays or when the bird is alarmed. The bill and the claws are bluish gray to black and the cere, tarsi, and toes are yellow.

Immature birds (Palmer 1988, Johnsgard 1990, and Squires and Reynolds 1997) possess upperparts that are dark brown to brown-black. The underparts and wing-linings are buffy white with coarse cinnamon to black-brown streaking on the throat. The dark brown tail has wavy dark brown bands with thin whitish borders that form a zigzag pattern and the undertail-coverts are usually streaked and not fluffy. The head is brown and has a pale whitish superciliary stripe and pale yellow irises, turning bright yellow during the first year, and becoming orange during the second year before turning red as adults. Tarsi and toes are greenish-gray to pale yellow.

In comparison to other North American accipiters (Wheeler and Clark 1995, Squires and Reynolds 1997), goshawks appear deep-chested with relatively broad wings, short tail, and smaller eye. Their wings appear tapered when soaring and pointed when flapping or stooping. They are obviously bigger than sharp-shinned hawks (*Accipiter striatus*), with a more protruding head in flight and a broader tail that is more rounded at the tip. Although female Cooper's hawks (*Accipiter cooperii*) may approach the size of male goshawks, distinctions can be made in the body, wing, and tail proportions described above. The tarsus of the Cooper’s hawk is feathered to only one half its length, while the goshawk’s is stouter and feathered to two-thirds its length (Brown and Amadon 1968).

In immature plumage, the goshawk can be difficult to distinguish from the Cooper’s hawk. The pale superciliary line is more distinctive in juvenile goshawks and they are more heavily streaked in the belly, underwing, and under-tail coverts, with a slightly wedge-shaped tail, and a tawny bar across the upperwing. Also, the upperside of a juvenile goshawk’s tail has a subtle pattern of fine white lines outlining the dark bands, which, when spread, appear as staggered dark bars in a zigzag pattern. In contrast, the tail of a juvenile Cooper’s hawk appears more evenly banded (Wheeler and Clark 1995, Squires and Reynolds 1997).

DISTRIBUTION AND ABUNDANCE

Rangewide

Northern goshawks are Holarctic in distribution and occupy a wide variety of boreal and montane forest habitats throughout the Nearctic and Palearctic (Johnsgard 1990). *A. g. atricapillus* breeds in North America from the boreal forests of north-central Alaska to Newfoundland, south to western and southwestern montane forests in the United States, and locally in the mountains of northwestern and western Mexico. In the east, it’s found in the WGLR and eastward to Pennsylvania, central New York, northwestern Connecticut, and locally south in montane habitats at least to West Virginia and possibly eastern Tennessee and western North Carolina (Brown and Amadon 1968, Squires and Reynolds 1997, USFWS 1998a). Factors that limit the southern extent of goshawk range are unknown (Kennedy 1997). *A. g. atricapillus* is known to winter throughout its breeding range and as far south as southern California, northern Mexico, Texas, and the northern portions of the Gulf states, rarely including Florida (Johnsgard 1990, Squires and Reynolds 1997).

Although there are few data regarding historical changes, Squires and Reynolds (1997) suggested that the distribution of the goshawk in the northern and western portions of its range is relatively unchanged since Europeans settled the area. However, they also note that the goshawk's range may have been more extensive in the eastern U.S. before the extinction of the passenger pigeon (*Ectopistes migratorius;* Jones 1979 *in* USFWS 1998a). In addition, extensive forest cutting in the eastern U.S. may have reduced goshawk populations. There is some evidence that these populations may be recovering as forests re-establish and mature (Speiser and Bosakowski 1984). Evidence that eastern goshawk populations may be expanding or reoccupying their former range should be interpreted cautiously given that such reports could merely reflect increased search effort (Kennedy 1997).

Regionwide

The WGLR is at the southern extent of the goshawk's current breeding range at these longitudes (Squires and Reynolds 1997). Thus, goshawks in the WGLR may be expected to be rarer (i.e., lower density) and have more variation in demographic parameters than populations from the center of the species' range (Caughley et al. 1988, Lawton 1993). Because density influences sampling approaches and precision of trend estimates, monitoring trends in goshawk abundance in the WGLR may be difficult (Kennedy and Andersen 1999). In addition, the meta-population dynamics between this range-boundary population and population units located nearer to cores of the species' distribution is unknown. Size of range-boundary populations may fluctuate more widely than size of core populations, which may also influence sampling approach and the ability to monitor population trends (Kennedy and Andersen 1999). Information on the historical abundance of goshawks in the WGLR is lacking or nonexistent (Rosenfield et al. 1991).

Many historical maps of breeding distributions in the WGLR are based on assumptions of what is appropriate goshawk habitat, thus a clearer delineation of range is necessary for population trend analysis (Dick and Plumpton 1998). T. Erdman has collected egg and nest data from several major museums and is in the process of summarizing these data (Dick and Plumpton 1998). As in the eastern U.S., it has been suggested that the species' range in the WGLR may be expanding southward into previously occupied areas as timber stands in the region mature (Postupalsky 1998). Only one nesting pair of goshawks has been reported in Illinois (Lux 1892) and Boss (1998) reported no historical or current nesting records on national forest lands in the states of Indiana, Iowa, Missouri, and Ohio.

Historically, Bent (1937) described the breeding range of the goshawk in Michigan as extending south to Isle Royale and Mackinaw Island. There were breeding records for seven counties in Michigan by the 1940s (Postupalsky 1991) and the species was considered a local summer resident from Roscommon County northward in the first half of the 1900s (Van Tyne 1938, Wood 1951). The Huron/Manistee National Forests have historical records of goshawk nests from each of their districts (Ennis *et al.* 1993). S. Postupalsky has documented nesting in 11 Upper Peninsula and 21 northern Lower Peninsula counties since 1971 (Dick and Plumpton 1998). In 1991, Postupalsky reported nests found in Mason, Midland, Arenac, Ottawa, Tuscola and Kalamazoo Counties and suggested that the range of goshawks in Michigan is expanding southward, but cautioned that more scientific analysis is needed (Postupalsky 1991, 1993, 1998). Ennis *et al.* (1993) also suggested that the species was undergoing a southward range expansion, but did not provide evidence.

Dick and Plumpton (1998) gathered historical records for Minnesota from a number of sources: the Minnesota Ornithological Union (MOU), the MNDNR Natural Heritage Database and nongame files, the Bell Museum of Natural History, and Janssen (1987). They found few attempts to document the extent of goshawk breeding in Minnesota during the early 1900s. As of 1982 (Johnson 1982), there were a total of 61 nesting records for the state, with the earliest reported and most southerly nest recorded in 1892 in Hennepin County (Nutter 1892). Eng and Gullion (1962) reported that the first recorded nest on the Cloquet Forestry Center, Carlton County, was in 1934. The MNDNR Natural Heritage Database lists fourteen nests in eleven counties in north-central Minnesota from 1926 to 1980 with some more recent additional records. Itasca State Park has historical records of goshawk nests dating back to the 1950s (Parmelee 1982).

Janssen (1987) approximated the Minnesota breeding range as extending from the Canadian border south to central Pine County, central Crow Wing County, and west to central Roseau and central Mahnomen Counties. Nesting has been verified since 1970 in Mahnomen, Crow Wing, Pine, Itasca, Koochiching, Lake of the Woods, Lake, Beltrami, Clearwater, and Hubbard Counties (Dick and Plumpton 1998). Since 1994, breeding has been reported in Aitkin, Becker, Beltrami, Carlton, Cass, Clearwater, Hubbard, Itasca, Koochiching, Lake, Morrison, Pine, St. Louis, and Wadena Counties (Martell and Dick 1996, Dick and Plumpton 1998, Boal *et al.* 2001). Boal *et al.* (2001) reported the following number of known occupied breeding areas in north-central Minnesota: 15 in 1998; 19 in 1999; 22 in 2000; and 14 in 2001. There were 17 known occupied breeding areas in Minnesota in 2002 (B. L. Smithers, Texas Cooperative Fish and Wildlife Research Unit, pers. comm.).

Gromme (1935) summarized the history of known goshawk nests in Wisconsin. Gromme cited Kumlien and Hollister's (1903) classification of the goshawk as a rare summer resident and listed a total of five nesting reports in Oconto (4; Schoenebeck 1902) and Rusk (1) Counties. Haug (1981) reported an active nest in Juneau County and Robbins (1991) listed published nesting records for Bayfield, Vilas, Oconto, and Ashland Counties for the years 1943 – 1958. Robbins (1991) reported the historical range in Wisconsin as encompassing the northern one third of the state. Rosenfield *et al.* (1996), however, stated that this range was presumed and not thoroughly documented.

The WIDNR has attempted to analyze the reports of northern goshawk sightings submitted through the Wisconsin Checklist Project from 1983 – 1993 (Rolley 1995). Dick and Plumpton (1998) reported, "the range in Wisconsin, as in Minnesota, probably varies temporally and is poorly delineated." The estimated range boundary in Wisconsin has extended south by reports of goshawk nests in recent years (Dick and Plumpton 1998). Counties with active nests in 1996 included: Ashland, Bayfield, Door, Douglas, Florence, Forest, Juneau, Oconto, Oneida, Price, Sawyer, Shawano, Taylor, and Vilas (Matteson 1996 *in* Dick and Plumpton 1998) and an active nest was reported in the city of Sheboygan (Sheboygan County) in 1997 (Dick and Plumpton 1998). Goshawk nests were reported as widely distributed in the northern two thirds of

Wisconsin for the years 1996 and 1997 by Rosenfield *et al.* (1998a).

Dick and Plumpton (1998) reported that little census or survey data are available from Ontario. Peck and James (1983), Weir (1988), and Duncan and Kirk (1995) suggested that goshawks breed at low density in the forests throughout most of the province, except for the extreme south, which lacks large unfragmented tracts of forest. There are no historical records of the northern goshawk nesting in the extreme south of the province (Weir 1988). Godfrey (1986) described the breeding range in Ontario as "south to Thunder Bay district, Mount Albert, north of Toronto, and Mallory Town landing on St. Lawrence River." Fyfe (1976) reported stationary population trends for Ontario and southern Quebec, with medium to high relative abundance.

FEEDING HABITS AND PREY ECOLOGY

Does Food Limit Goshawk Populations?

Prey abundance and availability are important habitat attributes and potential limiting factors for goshawk populations (Ward and Kennedy 1996, Squires and Reynolds 1997, Kennedy and Andersen 1999, Dewey and Kennedy 2001). In a review of existing literature, Squires and Reynolds (1997) reported that prey abundance strongly affects breeding area occupancy and productivity. Ward and Kennedy (1996; New Mexico) and Dewey and Kennedy (2001; Utah), however, experimentally determined that goshawks have a demographic response to a super-abundance of available food during some years, but not during other years, suggesting that food is not always limiting during the breeding season. These results have not been tested in the WGLR, but similar results from two different regions indicate they may be applicable to the WGLR. These results also suggest that if regional goshawk populations are cyclic, they may only be food-limited during periodic ecological "crunches" when cyclic prey species populations are at low densities (Kennedy and Andersen 1999). Although it is clear that goshawks in the WGLR prey upon ruffed grouse (*Bonasa umbellus*) and snowshoe hare (*Lepus americanus*; Eng and Gullion 1962, Erdman *et al.* 1998), little is currently known about the cyclic nature of goshawks breeding in this region or how dependent they are upon these cyclic prey species. Because the WGLR region is at the southern periphery of their breeding range, the suite of prey species available to goshawks may be greater than that found at higher latitudes, and therefore may result in dampened extremes in the population cycle (Postupalsky 1998).

In addition to prey abundance, it is also important to consider whether prey items are *available* to goshawks. For example, even a high abundance of hares may have low availability to goshawks in a dense aspen regeneration area where goshawks are unable to fly or hunt (Dick and Plumpton 1998). Thus, preferences in goshawk foraging habitat are likely determined, in part, by prey availability as well as abundance (Reynolds *et al.* 1992).

Based on the assumption that goshawk populations are regulated by food availability, the *Management Recommendations for the Northern Goshawk in the Southwestern U.S.* emphasizes managing the landscape to maintain habitat for typical goshawk prey items, as well as nesting, foraging, and post-fledging areas (Reynolds *et al.* 1992). In the WGLR, Casson (1996) applied this technique in the Biological Evaluation of the Third River timber salvage sale on the CNF. Forest management practices may strongly influence the availability of prey items for the goshawk, thus being a determining factor in the long-term persistence of the species (Kennedy and Andersen 1999). Beier and Drennan (1997) found that goshawks did not select foraging areas based on prey abundance, but rather selected areas that had higher canopy closure, greater tree density, and greater density of the largest trees than on contrast plots. Their results indicate "goshawk morphology and behavior are adapted for hunting in moderately dense, mature forests, and that prey availability is more important than prey density in habitat selection" (Beier and Drennan 1997). Drennan and Beier (*In press*) suggest that goshawk habitat selection may be a two-tiered process. Their results indicate that wintering goshawks expand and shift their range into habitats where they have access to a more abundant population of large-bodied prey. Thus, they hypothesize that goshawks probably do respond to prey abundance when locating a home range within a large landscape, but select for moderately dense, mature forests where they can use their maneuverability to capture prey when foraging within a home range and habitat type (Beier and Drennan 1997, Drennan and Beier *In press*).

Although Reynolds *et al*. (1992) emphasized that goshawk prey species depend on a variety of habitats distributed in a mosaic across the landscape, several studies have shown that goshawk prey such as sciurids (Carey *et al*. 1992, Carey 1995) and birds (Schwab and Sinclair 1994) are more abundant in old-growth and mature forests in comparison to younger forests or managed second growth stands. Arthropods, the prey base for many forest-dwelling insectivores, which may in turn be prey for goshawks, have been shown to be significantly less abundant along edges and in small woodlots (Burke and Nol 1998, Zanette *et al*. 2000), suggesting that food supplies may be reduced by forest fragmentation (Robinson 1998). To develop sound species conservation plans for forest-dwelling birds, it is critical to understand how forest management practices influence prey species by changing forest structure and pattern (Kennedy and Andersen 1999). This question has not been adequately addressed in the WGLR.

The evolution of smaller body size in males is thought to result from selection for optimal foraging potential during the breeding season when the modal prey size is smaller than during the winter. Some of the best support for this hypothesis was recently provided by Tornberg et al. (1999) who analyzed skin and skeletal measurements collected from 258 museum specimens of Finnish goshawks dated between 1961 and 1997. They reported that as grouse decreased in abundance and thus, in the goshawk diet, and were replaced by smaller prey during the breeding season over this 36-year period, morphological shifts were seen in both males and females, presumably as a result of selective pressures due to changes in diet. Males decreased in size, and Tornberg *et al*. (1999) hypothesized that this was due to the morphological advantage of greater agility provided by smaller size and the need to capture smaller prey during the breeding season when males do most of the hunting, providing prey for the female and their offspring. Tornberg et al. (1999) also hypothesized that increases in the size of female goshawks may be due to the fact that alternative prey used by goshawks in the winter consisted of more and more mountain hare (*Lepus timidus*), a larger prey species than grouse.

This shift in sexual size dimorphism presumably has negative consequences on male winter survival as recently demonstrated by Sunde (2002). He analyzed carcass condition of goshawks found by the public to determine if body condition was related to sex, season and latitude. Of birds killed in accidents (the largest proportion of his sample and perhaps most representative of the population), females were generally in better condition than males, and adults in better condition than juveniles. A season-by-latitude analysis indicated that males from northern latitude were in poorer condition during winter and spring than males from southern latitudes.

His results suggest that food limitation plays a relatively stronger role in northern populations, affecting young males especially. This was also supported by the fact that the sex ratio of accidentally killed birds was increasingly female biased with increasing latitudes. Sunde (2002) suggested that this demonstrates a relatively higher mortality risk of males (based on this sample of carcasses with unknown detection probabilities), that this risk is due to their smaller average body size, and that selection for starvation resistance during winter is the reason behind the clinal increase of body size documented by Tornberg et al. (1999). The applicability of these results to the WGLR is unknown but it suggests there could also be a latitudinal cline in male body size and winter mortality in North America. It also suggests that land use practices that influence availability of large prey could influence the size and survival of goshawks over relatively short time periods.

Prey Taxa and Abundance in Diets

Dependent on region, season, and availability, the goshawk captures a wide variety of prey and is classified as a prey generalist or opportunist (Squires and Reynolds 1997), typically preying on a suite of 8 to 15 species (Reynolds *et al.* 1996). As with other raptors, the food habits of goshawks have been determined by examination of stomach contents and food removed from crops of nestlings, or more commonly, direct observation of nests, prey remains, and regurgitated pellets (Sherrod 1978). Quantifying prey remains at plucking perches may be biased toward avian and large-bodied prey, as evidenced by Younk and Bechard (1994) who found that goshawks only plucked birds at plucking perches, whereas ground squirrels were taken directly to the nest. Bielefeldt *et al*. (1992) compared methods of quantifying Cooper's hawk diets and found that indirect methods, such as collection of prey remains near nests, overestimated the proportion of avian items in comparison to direct observation of prey deliveries to nestlings. Watson *et al*. (1998) found that potential biases from examining prey remains when compared to pellets reinforced the need for including direct prey delivery observations when determining the diet of nesting goshawks. Video monitoring at goshawks nests provides better quantitative information on prey selection (Groennesby and Nygard 2000). Smithers *et al*. (2002) initiated a goshawk diet study in 2000 utilizing video cameras mounted at active nests to obtain direct observations of prey deliveries to nestlings during the breeding season in north-central Minnesota.

Regionally or locally specific studies of both summer and winter diet are necessary for developing management strategies for goshawk populations at regional and local levels. Although breeding season diet composition has been studied for many populations, little is known about the winter diets of goshawk populations in North America. Beier (1997) found that winter diets were dissimilar to summer ones, in part because of the absence of hibernating species, and also noted that individual goshawks may specialize upon specific species in the winter.

Although an intensive and quantitative study of goshawk prey items in the WGLR has not been published, many records of prey items exist that were collected opportunistically at nests in conjunction with other nest observations or habitat measurements. These reports indicate goshawks in the WGLR eat a wide variety of prey species. This information should be interpreted cautiously because these prey use reports were compiled primarily from anecdotal information (with the exception of Smithers *et al*. 2002) and from a variety of sources. In addition, most prey observations in the WGLR have been made during the nesting season, thus prey use, availability, and abundance during the winter should also be examined. Table 1 lists the goshawk prey species reported in the WGLR.

Table 1. List of Goshawk prey species reported for the WGLR

Species	Study*
Mammals	
Chipmunks (*Eutamias* spp.)	Postupalsky 1998[1]
Eastern chipmunk (*Tamias striatus*)	Smithers *et al.* 2002
Eastern cottontail rabbit (*Sylvilagus floridanus*)	Eng and Gullion 1962[2], *Smithers et al.* 2002
Franklin's ground squirrel (*Spermophilus franklinii*)	Gullion 1981a[2]
Gray squirrel (*Sciurus carolinensis*)	Davis 1979[2]
Least chipmunk (*Eutamius minimus*)	Davis 1979[2]
Northern flying squirrel (*Glaucomys sabrinus*)	Eng and Gullion 1962[2], Martell and Dick 1996[2]
Porcupine (*Erethizon dorsatum*)	Gullion 1981a[2]
Red squirrel (*Tamiasciurus hudsonicus*)	Eng and Gullion 1962[2], Davis 1979[2], Dick and Plumpton 1998[2], Lapinski 2000[1], Boal and Andersen 2001[2], Smithers *et al.* 2002
Tree Squirrels	Postupalsky 1998[1]
Snowshoe hare	Eng and Gullion 1962[2], Erdman *et al.* 1998[4], Postupalsky 1998[1], Lapinski 2000[1], Smithers *et al.* 2002
Longtail weasel (*Mustela frenata*)	Smithers *et al.* 2002
Unidentified mustelid	Haug 1981[4]
Birds	
American robin (*Turdus migratorius*)	Eng and Gullion 1962[2], Postupalsky 1998[1]
American woodcock (*Scolopax minor*)	Gullion 1981a[2], Lapinski 2000[1], Boal and Andersen 2001[2]
Red-breasted nuthatch (*Sitta canadensis*)	Smithers *et al.* 2002
Blue jay (*Cyanocitta cristata*)	Eng and Gullion 1962[2], Davis 1979[2], Haug 1981[4], Postupalsky 1998[1], Dick and Plumpton 1998[2], Lapinski 2000[1], Smithers *et al.* 2002
Gray jay (*Perisoreus canadensis*)	Smithers *et al.* 2002
Blue-winged teal (*Anas discors*)	Eng and Gullion 1962[2], Haug 1981[4]
American crow (*Corvus brachyrhynchos*)	Eng and Gullion 1962[2], Davis 1979[2], Haug 1981[4], Postupalsky 1998[1], Dick and Plumpton 1998[2], Smithers *et al.* 2002
Common grackle (*Quiscalus quiscula*)	Smithers *et al.* 2002
Common nighthawk (*Chordeiles minor*)	Eng and Gullion 1962[2]
Domestic chicken (*Gallus gallus*)	Gullion 1981a[2]
Downy woodpecker (*Picoides pubescens*)	Davis 1979[2]
Eastern meadowlark (*Sturnella magna*)	Eng and Gullion 1962[2]
Green heron (*Butorides virescens*)	Gullion 1981a[2], Haug 1981[4], Boal and Andersen 2001[2], Smithers *et al.* 2002
Northern bobwhite (*Colinus virginanus*)	Errington 1933[4]
Northern flicker (*Colaptes auratus*)	Eng and Gullion 1962[2], Davis 1979[2], Postupalsky 1998[1], Dick and Plumpton 1998[2], Lapinski 2000[1]
Pileated woodpecker (*Dryocopus pileatus*)	Eng and Gullion 1962[2], Smithers *et al.* 2002[2]
Woodpeckers (*Picoides spp.*)	Gullion 1981a[2], Lapinski 2000[1]
Evening grosbeak (*Coccothraustes vespertinus*)	Smithers *et al.* 2002[2]
Pine grosbeak (*Pinicola enucleator*)	Gullion 1981a[2]
Rock dove (*Columba livia*)	Gullion 1981a[2]
Ruffed grouse (*Bonasa umbellus*)	Davis 1979[2], Haug 1981[4], Postupalsky 1998[1], Erdman *et al.* 1998[4], Dick and Plumpton 1998[2], Lapinski 2000[1], Boal and Andersen 2001[2], Smithers *et al.* 2002[2]
Sharp-tailed grouse (*Tympanuchus phasianellus*)	Gratson 1982[4], Backstrom 1991[2]

Spruce grouse (*Dendragapus canadensis*)	Duncan and Kirk 1995 (citing a personal communication from Naylor)[3]
Unidentified duck	Eng and Gullion 1962[2], Boal and Andersen 2001[2]
Wood duck (*Aix sponsa*)	Lapinski 2000[1]
Mallard (*Anas platyrhynchos*)	Smithers *et al.* 2002[2]
Broad-winged hawk (*Buteo platpterus*)	Smithers *et al.* 2002[2]
Cooper's hawk (*Accipiter cooperii*)	Smithers *et al.* 2002[2]

* Superscript number indicates study location: (1) Michigan, (2) Minnesota, (3) Ontario, and (4) Wisconsin.

Goshawks are opportunistic hunters whose diets vary among populations with seasonal and regional prey availability. More than 30 species of mammalian and 53 species of avian prey have been identified in diets from goshawk populations in North America (Squires and Reynolds 1997, USFWS 1998a). Table 2 lists the proportion of mammalian and avian prey in the diets of goshawks during the breeding season from several studies. A few prey groups are particularly important to most goshawk populations: gallinaceous birds (primarily grouse and pheasants); sciurids, including chipmunks, tree and ground squirrels; lagomorphs; corvids; and woodpeckers. The USFWS (1998a) summarized information from numerous studies and listed the following prey species as particularly important to the goshawk where they occur throughout its range: chipmunks, cottontail rabbit, snowshoe hare, Douglas squirrel (*Tamiasciurus douglas*i), red squirrel, golden-mantled ground squirrel (*Citellus lateralis*), gray squirrel, northern flying squirrel, American robin, blue jay, Steller's jay (*Cyanocitta steller*i), ruffed and blue grouse (*Dendragapus obscurus*), common crow, domestic pigeon, and northern flicker.

Table 2. Proportion of mammalian and avian prey in diets of goshawks during the breeding season (from Squires and Reynolds 1997). This table is based on studies published prior to 1995 only. Recent diet data has not been incorporated because they are not available for the WGLR.

Location	% Mammalian Prey (biomass)	% Avian Prey (biomass)	Study
U.S.			
Alaska	78 (90)	21 (10)	Zachel 1985[1]
Arizona	76 (94)	24 (6)	Boal and Mannan 1994[3]
Arizona	62	38	Reynolds *et al.* 1994[1, 2]
California	32	68	Bloom *et al.* 1986[2]
Nevada	67	32	Younk and Bechard 1994[3]
New Mexico	49	51	Kennedy 1991[1,2,3]
New York	39	61	Bull and Hohmann 1994
Oregon	42	59	Grzybowski and Eaton 1976[2]
Oregon	45	55	Reynolds and Meslow 1984[1, 2]
Utah	82	18	Lee 1981[1, 2]
Canada			
Yukon	– (86)	– (13)	Doyle and Smith 1994[2]
Sweden	21.3 (15.2)	78.6 (84.8)	Widén 1982[2]

[1]Pellet analysis.
[2]Prey remains.
[3]Direct observation.

Gallinaceous birds (primarily grouse and pheasants) may be particularly important prey for both North American (Mendall 1944; McGowan 1975; Gullion 1981a, 1981b; Gullion and Alm 1983;

Apfelbaum and Haney 1984) and European goshawks (Kenward 1979, Sollien 1979 *in* USFWS 1998a, Kenward *et al.* 1981, Lindén and Wikman 1983) at northern latitudes. Fluctuations in grouse populations have been shown to affect goshawk productivity, including number of nesting pairs, and number of young per active nest, in Finland (Lindén and Wikman 1983) and other parts of Europe (Sollien 1979 *in* USFWS 1998a). In addition, Lindén and Wikman (1983) found that goshawks killed more grouse than was expected based on abundance, suggesting that goshawks developed a search image for this prey item (USFWS 1998a).

There is evidence that at least some goshawks in Minnesota rely heavily upon ruffed grouse (Eng and Gullion 1962, Apfelbaum and Haney 1984). Apfelbaum and Haney (1984) suggested that goshawks may be alerted by courtship behaviors, and thus selectively take male grouse over females. Goshawk predation may be the most important non-human mortality factor for adult ruffed grouse in some areas of Minnesota (Eng and Gullion 1962; Gullion 1981a, 1981b) to the extent that it may have influenced the color phase composition of the Cloquet grouse population (Gullion 1981b). Eng and Gullion (1962) detailed some of the difficulties in accurately quantifying the extent of grouse predation by goshawks, including: (1) goshawks may leave signs from a single kill in multiple locations, over-representing individual kills; (2) meat is typically eaten from the bones, so bones are under-represented in castings; and (3) uncertainty in identifying the responsible predator.

Sciurids occur in most goshawk diets due to their high abundance and broad distribution (USFWS 1998a). Several studies have documented red squirrels as important prey (Mendall 1944, Meng 1959, Reynolds *et al.* 1994, Smithers *et al.* 2002) and they may be especially important during the winter when other prey are unavailable (Widén 1987).

Rabbits and hares are used extensively by goshawks (Reynolds and Meslow 1984, Kennedy 1991, USFWS 1998a). Cottontail rabbits are abundant in a variety of habitats and are distributed throughout the goshawk's range (USFWS 1998a). Snowshoe hares are also important prey, particularly in northern forests (Mendall 1944, McGowan 1975a, Doyle and Smith 1994). In the Yukon, Doyle and Smith (1994) found a positive correlation between goshawk breeding success and a snowshoe hare population peak and subsequent decline from 1987 – 1990.

Robins (Grzybowski and Eaton 1976, Reynolds and Meslow 1984), corvids (crows: Meng 1959, Eng and Gullion 1962, Gullion 1981b, Fleming 1987; and jays: Bloom *et al.* 1986, Beebe 1974 in Squires and Reynolds 1997, Kennedy 1991, Bosakowski *et al.* 1992, Boal and Mannan 1994), and woodpeckers (Schnell 1958, Eng and Gullion 1962, Erickson 1987, Allen 1978, Reynolds and Meslow 1984, Reynolds *et al.* 1994) are also common prey items found in many parts of the goshawk's range. Northern flickers are particularly important in many goshawk diets (Grzybowski and Eaton 1976, Reynolds and Meslow 1984, Bloom *et al.* 1986, Boal and Mannan 1994).

Prey Species Habitat Needs

Goshawk prey species need a variety of habitat conditions from early to mature seral stages. Reynolds *et al*. (1992) emphasized that goshawk foraging areas should include a variety of habitats and ages to support an abundant prey base. Reynolds *et al*. (1992) suggested that goshawk foraging areas in southwestern pine forests be managed for stands that are approximately 2160 ha (5400 ac), surrounding, but not including nest areas. These stands should include a mosaic of vegetation structural stages interspersed throughout the area and consisting of approximately 20% each, old, mature and middle-aged forests, 20% young forests, 10% in the seedling/sapling stage, and 10% in the grass/forb/shrub stage (Reynolds *et al*. 1992). The 60% of stands consisting of older age classes should have relatively open understories with a minimum of 40 – 60% canopy cover (Reynolds *et al*. 1992).

Although the species on which goshawks prey vary among forest types and regions, there are a few habitat features that appear to be important to a variety of prey species and thus may be important in prey abundance and availability to the goshawk in general (Reynolds *et al*. 1992, USFWS 1998a). The features identified as important to prey species in southwestern pine forests include snags, downed logs [> 30 cm (12 in) in diameter and 2.4 m (8 ft) long], large trees [> 46 cm (18 in) in diameter], openings and associated herbaceous and shrubby vegetation, interspersion (the degree of intermixing of vegetation structural stages), and canopy cover. These may also be important to goshawk prey species in the WGLR. In their compositional analysis of foraging habitat use versus availability (see section on foraging habitat), Boal *et al.* (*In Review*b) reported that foraging stands used by male goshawks during the breeding season contained from 1.6 to 2.4 km of down woody debris per ha (0.4 – 0.6 mi/ac), averaging 16.8 to 19.1 cm (6.6 – 7.04 in) in diameter. Debris was typically between 5 and 19 cm (2.0 – 7.4 in) above the ground, and mid-way through the decay process.

Reynolds *et al.* (1992) recommended that forest areas managed for goshawk prey species include large trees scattered throughout the foraging area, providing hunting perches, snags, and downed logs. This large tree component, which often occurs in clumps with interlocking crowns, provides various and unique hiding, feeding, denning, and nesting areas used during some part of the annual cycle of all selected goshawk prey species (USFWS 1998a). For example, snags provide critical resources for many species of birds, mammals, invertebrates, and plants, particularly woodpeckers and sciurids, and downed logs (> 12 inches in diameter and 8 feet long) provide cover, feeding, and nest areas for woodpeckers, chipmunks, ground squirrels and cottontails (Reynolds *et al.* 1992). Large coniferous trees are good cone producers and provide a source of seed for many species of goshawk prey (USFWS 1998a). Downed wood and woody debris (> 3 inches in diameter on the ground) are important elements in red squirrel cache areas, grouse courtship areas, and as a substrate for fungi, which is a food item for chipmunks and ground squirrels (Smith 1968, Maser *et al.* 1978, Reynolds *et al.* 1992). In conifer stands, fungi are most abundant in areas with canopy cover greater than 60% (States 1985 *in* USFWS 1998a).

Goshawks also hunt species that use early seral stages and openings. Interspersion and canopy cover have varying effects on different goshawk prey species (Reynolds *et al.* 1992). For example, red squirrels respond negatively to a high level of interspersion of structural stages and require closed older forests to attain high-density populations. Grouse, on the other hand, respond positively to high interspersion of openings and older forests. Other prey species, such as American robins, are habitat generalists and are abundant in many structural stages (Reynolds *et al.* 1992).

Reynolds *et al*. (1992) stated that small to medium openings (< 4 acres) and various seral stages scattered throughout goshawk foraging habitat enhance the availability of food and habitat resources for the prey that use them and limit the effect of large openings and fragmentation on the distribution and abundance of prey species that use interior forests (USFWS 1998a). Forests ideal for producing prey available for goshawks have well-developed herbaceous and shrubby understories associated with small to medium openings, which provide cover and food for many small mammals and birds in the form of seeds, berries, and foliage. Reynolds *et al.* (1992) also indicated these forests have developed, intact soils with organic surface layers within natural turnover rates, which provide for the sustainability of mychorrhizae.

Seasonal Dietary Shifts

Few studies have been published on seasonal dietary shifts of goshawks in North America. Drennan and Beier (*In press*) reported that in contrast to the high prey diversity killed by goshawks (n = 13) in Arizona during the breeding season, goshawks specialized in preying on only two species of large-bodied prey [cottontails and Abert squirrel (*Sciurus aberti*)] in the winter. They reported that individual goshawks specialized in only one of the two species. Goshawks located in ponderosa pine (*Pinus ponderosa*) throughout the winter specialized in killing either cottontails or Abert squirrels, but not both, and goshawks wintering in pinyon-juniper habitats were found preying on cottontails only. Younk and Bechard (1994) found that goshawks in Nevada shifted their diets to include more birds such as American robins and northern flickers when Belding's ground squirrels (*Spermophilus beldingi*) began to estivate. Seasonal trends in diet for goshawks in the WGLR are unknown.

Most information regarding seasonal changes in the diets of goshawks is based on European studies (Marquiss and Newton 1982, Lindén and Wikman 1983, Tornberg and Sulkava 1990 *in* USFWS 1998a). In general, at northern latitudes where galliformes are an important source of food, goshawks tend to rely on them heavily in the spring during nest-building and incubation, shifting to other forms of prey as migrant birds return and fledge young.

Information about winter diets is scarce and varies geographically with prey base. In Swedish boreal forests, Widén (1987) found that birds dominated diets during the breeding season, accounting for 86% of prey numbers and 91% of biomass. However, squirrels dominated both the numbers (79%) and biomass (56%) of prey in winters of both high and low squirrel abundance.

Foraging Behavior

Goshawks and other accipiters exhibit morphological and behavioral adaptations for hunting in forests (Squires and Reynolds 1997). Studies of foraging habitat used by goshawks indicate that they tend to select foraging areas with specific structural characteristics, such as flight corridors between vegetation layers and stands with a high density of large trees (Beier and Drennan 1997, Boal *et al*. *In Review*b). These structural characteristics, and perhaps others, might be selected by goshawks because they are similar to the conditions under which they may have evolved and are therefore closely linked with their foraging behavior and hunting tactics. Goshawks have short wings and long tails for maneuvering in and below forest canopy (Squires and Reynolds 1997). They have robust feet and bills that are adapted for capturing and eating a wide variety of relatively large prey (Wattel 1973 *in* USFWS 1998a). During incubation and nesting, male goshawks provide the female with food and the female primarily guards the nest (Schnell 1958, Reynolds 1972, Allen 1978, Newton 1979).

Hunting Tactics

Goshawks are short duration sit-and-wait predators, a hunting style adapted to foraging in forests with limited visibility (Reynolds *et al.* 1992). While hunting, goshawks typically make short flights to elevated perches, briefly search an area for prey, and then fly a short distance to the next perch, often moving rapidly through the forest in this manner (Kenward 1979). In one study, only 3% of goshawk attacks on prey were from hawks already in flight (Kenward 1982). In Sweden, goshawk flight activity increased with increasing time since last feeding (Widén 1984) and hawks generally captured prey at least every two days during the winter months of January and February.

Goshawks occasionally hunt by flying rapidly along forest edges and across openings (Squires and Reynolds 1997). They will crash through dense vegetation in pursuit of prey and their vigorous and sometimes reckless hunting behavior is legendary among falconers (Beebe 1974 *in* Squires and Reynolds 1997). They readily use trees, shrubs, and topographic features to hide from potential prey (Backstrom 1991) and at times stalk prey (Bergstrom 1985). Goshawks capture food through dogged persistence in addition to using surprise attacks (Westcott 1964, Brace 1983). Goshawks will even enter water when chasing prey (Schnell 1958, Fulton 1983). Depending on prey type and behavior, goshawk hunting techniques may vary from a smooth, silent, accelerating glide that ends in a strike, to rapid flapping in an attempt to increase its speed toward an animal that is being pursued (Beebe 1974 *in* Squires and Reynolds 1997).

Foraging Success, Prey Delivery Rates and Prey Caching

Foraging success and prey delivery rates vary according to type of prey, goshawk hunting experience, and habitat characteristics (USFWS 1998a). Average number of prey items delivered to 2 nests by goshawks was reported as 1.84 and 2.69 deliveries per observation day in the Adirondacks (Allen 1978), 0.25 items/hr in Arizona (Boal and Mannan 1994), and Schnell (1958) reported a prey delivery rate of 3.9 deliveries per day at one nest in California.

Prey deliveries to the nest have been observed during all daylight hours, but seem to be most common in the early to mid-morning and in the late afternoon and evening (Schnell 1958, Allen 1978). Kenward (1982) found that goshawks hunted an average of 262 minutes per kill and were successful only 6% of the time. Kenward (1979) also found that four radio-tagged goshawks in England killed an average of twice every three days during one winter.

Caching of surplus prey when nestlings are unable to consume entire prey or for future use during periods of low food availability has been recorded in many species of raptors (Newton 1979). In one study (Schnell 1958), a female goshawk was observed to cache food for nestlings until they were approximately one month old.

Foraging Distance from Nest

The distance that males hunt from their nests probably varies by habitat, nesting phenology, and prey density (USFWS 1998a). Kennedy (1988) found that male goshawks did not hunt immediately adjacent to the nest, but foraged mostly 0.8 – 8 km (0.5 – 5 mi) away from it.

Schnell (1958) reported that one female tended to hunt within a 91 – 122 m (300 – 400 ft) radius of the nest. In Minnesota, of 37 banded ruffed grouse killed by goshawks, 9 were killed approximately 1,097 – 2,515 m (0.7 – 1.6 mi) from the goshawk's nest; 26 were killed within a 1.6-km (1 mi) radius; and 32 were killed within a 2-km (1.2 mi) radius (Eng and Gullion 1962).

HABITAT

Does Habitat Limit Goshawk Populations?

Selection of habitat by goshawks may be limited by occupancy of other raptors or landscape structure and pattern (Reynolds and Hamre 1996, USFWS 1998a). In addition to nesting habitat, goshawks need habitat for foraging in both the breeding and nonbreeding periods and they use post-fledging areas where young goshawks can learn to hunt and provide for themselves and be protected from predators. Although researchers, land managers and other concerned parties agree to the importance of understanding the habitat parameters necessary for goshawk viability, many questions remain regarding the integration of goshawk conservation and forest management.

Historically labelled an old-growth indicator species by the USFS in the 1980s (Sidle and Suring 1986 *in* USFWS 1998a), recent reviews of goshawk habitat studies indicate that the nature of goshawk preference for old-growth or mature forests is not clear (Kennedy 1997, 1998). The status review conducted by USFWS "found that while the goshawk typically does use mature forest or larger trees for nesting habitat, it appears to be a forest generalist in terms of the types and ages of forests it will use to meet its life history requirements. Goshawks can use small patches of mature habitat to meet their nesting requirements within a mosaic of habitats of different age classes" (USFWS 1998a). Goshawks also appear to select mature forests for foraging during the breeding season (Austin 1993, Bright-Smith and Mannan 1994, Beier and Drennan 1997, Lapinski 2000, Boal *et al*. *In Review*b). However, prey species require varying habitat types and age classes and the degree to which these can be interspersed within the landscape and still support goshawks and their prey is not clear.

The status review was written prior to the most recent USFWS decision not to list the goshawk as threatened and points to potential biases that need to be addressed in goshawk habitat studies (USFWS 1998a). The bias common to many goshawk habitat studies pertains to the methods used for detecting nesting goshawks. Because goshawks are generally secretive and difficult to survey, nests used in habitat studies are often located in ways that may favor older-aged forests, such as detection during preparation of timber sales. In other studies, researchers have chosen areas in which to survey or search for nests based on preconceived notions of what constitutes goshawk habitat. This method also tends to favor mature and old-growth forests (Daw *et al.* 1998).

In a study of goshawk habitat in eastern Oregon, Daw *et al.* (1998) compared habitat characteristics around nests found systematically and those found opportunistically. Although both density of large trees and canopy closure were high and similar for nests found with either search method, "these results do not preclude the fact that bias can be reduced by conducting nest searches in a systematic fashion across all habitats within landscapes" (USFWS 1998a). Systematic surveys also allow for repeatability of survey methods, estimation of survey effort, calculation of reliable estimates of density, and comparability among studies and are therefore valuable for creating accurate habitat descriptions (Daw *et al.* 1998). Rosenfield *et al*. (1998) compared goshawk habitat characteristics in Wisconsin between goshawk nests found by unbiased verses potentially biased methods and reported that they failed to detect statistically significant differences between the two data sets. However, their statistical methods were very conservative and minimized the probability of observing differences unless they were extremely large. Roberson *et al*. (*In Review*) have developed a call broadcast survey technique for detecting breeding goshawks in the WGLR. Their survey design incorporates the effective area surveyed based on probability of detection and can be used to calibrate systematic searches.

Habitat preferences may be identified by careful interpretation and comparison of habitats used by goshawks to those available at the landscape level (Hargis *et al.* 1994, Johansson *et al.* 1994, McCallum 1994, Hall *et al*. 1997, USFWS 1998a). Several studies in the U.S. and Europe have compared habitat characteristics at nest areas to those available habitats within home ranges or landscapes and can be used to draw some conclusions about goshawk nesting habitat preferences (Speiser and Bosakowski 1987, Bosakowski and Speiser 1994, Hargis *et al.* 1994, Squires and Ruggiero 1996, Penteriani and Faivre 1997, Selås 1997, Daw and DeStefano 2001). A few foraging habitat preference studies (Austin 1993, Bright-Smith and Mannan 1994, Beier and Drennan 1997, Lapinski 2000, Boal *et al*. *In Review*b) and one post-fledging habitat preference study have been conducted (Daw and DeStefano 2001). The effects of changes in forest landscapes on habitat selection by goshawks are unknown and additional research is needed at larger spatial scales (USFWS 1998a).

Habitat studies in the WGLR are necessary because regional goshawk habitat cannot be effectively managed if goshawk habitat relationships are poorly understood (Kennedy and Andersen 1999). Because WGLR landscapes are different from western landscapes, available habitat information on goshawks (collected primarily in western forests) may have limited applicability to the WGLR. Data from European goshawk studies might be more applicable to the WGLR because of climatic, topographic and habitat similarities. Although data collected elsewhere may help to identify some repeatable patterns of habitat use that probably occur across the Holarctic distribution of this species, more regionally specific data are needed to develop a regional model to predict goshawk habitat (Kennedy and Andersen 1999). Boal *et al.* (*In Review*b) have recently analyzed habitat preference within breeding-season foraging areas of goshawks in north-central Minnesota and Lapinski (2000) identified habitat cover types selected and avoided by goshawks year-round in the Upper Peninsula of Michigan. However, the inference of these studies may be restricted to the sample of nests included in the studies because none of the goshawk nests studied in Minnesota or Michigan were located using unbiased sampling techniques (Kennedy and Andersen 1999, Lapinski 2000, Boal *et al*. *In Review*a, *In Review*b).

Breeding Season Habitat

Breeding season habitat includes nesting, foraging, and Post-Fledging Area (PFA) habitat. Dick and Plumpton (1998) compiled information regarding goshawk nest areas and breeding season home range habitat in the WGLR from journal notes, personal communications, agency databases, short-term study records, or records from studies covering limited portions of the region. Historically, the most frequently recorded data were nest tree species and diameter breast height (dbh), nest height, and the number of nestlings present. Indeed, vegetation and landform characteristics associated with nest area habitat are one of the most frequently recorded and best understood aspects of goshawk biology throughout its range in North America (USFWS 1998a). A lack of standardization of measurement techniques, however, may hinder comparisons in some cases (Dick and Plumpton 1998) and nests where measurements have been made may not represent the regional goshawk population.

Nest Area

The area immediately surrounding the nest tree, referred to as the nest site or nest area (Steenhof 1987), often contains alternative nests and may be reused in consecutive years (Palmer 1988). The nest area includes the forest stand containing the nest tree(s) although definitions beyond the nest stand have varied by location and study (Dick and Plumpton 1998). Reynolds *et al.* (1992) defined a nest area as the approximately 12 ha (30 ac) that is the center of movements and behaviors associated with breeding from courtship through fledging.

Daw *et al.* (1998) summarized data from goshawk habitat studies in the West and indicated that an important pattern is emerging from these studies. They 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 tree dbhs, high crown volumes, high flight space, and short distance to trails were significant predictors of goshawk nest site selection in France. Because few habitat studies have been conducted in the WGLR, the applicability of this pattern to goshawks nesting in this region is unclear. However, Rosenfield *et al.* (1998a) published data on goshawk nest trees and nest areas detected from unbiased survey methods in Wisconsin, which generally support the pattern reported by Daw *et al.* (1998). The average percent canopy closure was 81.6% and mean dbh was 29.4 cm (11.5 in) at Wisconsin nest areas (Rosenfield *et al.* 1998a).

Nest area definitions for the WGLR are variable in size and are sometimes ambiguous. Care should be taken when comparing size and composition of nest areas from different regions of the continent. The most frequent measurements reported in the WGLR are mean stem densities, mean dbh, canopy closure, basal area, slope and aspect, and distance to geographic features (such as roads and water), however, a few studies reported the vegetative characteristics of sample plots centered on the nest tree (Dick and Plumpton 1998).

Nest Tree

Goshawks nest in both deciduous and coniferous trees (Palmer 1988, Squires and Reynolds 1997) and appear to choose nest trees based on size and structure more than the species of tree (USFWS 1998a). Goshawks often nest in one of the largest trees in the stand (Reynolds *et al.* 1982, Saunders 1982 *in* USFWS 1998a, Erickson 1987, Hargis *et al.* 1994, Squires and Ruggiero 1996), with height and diameter of nest trees varying geographically and with forest type. In Wyoming (Squires and Ruggiero 1996) and California (Saunders 1982 *in* USFWS 1998a), goshawks chose nest trees that had larger diameters than other trees in the nest stand, however, in some eastern forests only 4 of 32 nests were built in the largest tree of the nest area (Speiser and Bosakowski 1989).

Using the North American Nest Cards 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. The most commonly reported deciduous tree for nesting was beech (*Fagus spp*.), followed by maple (*Acer spp*.), aspen (*Populus spp*.), and birch (*Betula spp*.). Eastern white pine (*Pinus strobus*) was the most frequently reported North American conifer followed by spruce (*Picea spp*.), fir (*Abies spp*.), western pines (*Pinus spp*.), and eastern hemlock (*Tsuga canadensis*). Nest records in this database may be subject to search biases (USFWS 1998a).

As in other regions of North America, goshawk nests in the WGLR are found in a variety of tree species. Table 3 contains a list of goshawk nest trees reported from studies conducted in the WGLR. Dick and Plumpton (1998) summarized records from the MOU Archives, the MNDNR Nongame Program Database, and Martell and Dick (1996) and found that trembling aspen (*Populus tremuloides*) was the most frequently recorded species for the region and birch, red pine (*Pinus resinosa*), and jack pine (*Pinus banksiana*) were also used. However, they also note that the number of tree species records available was skewed toward records from Minnesota and most were probably located opportunistically or by potentially biased search methods.

Table 3. Reported goshawk nest tree types in the WGLR

State/Province	Deciduous (n)	Coniferous (n)
Michigan	**Deciduous (27)**	**Coniferous (24)**
	Beech (*Fagus spp*.; 1)	Jack pine (12)
Bowerman *et al*. (1998)	Oak (*Quercus spp*.; 5)	Red pine (12)
	Paper birch (*Betula papyrifera*; 4)	
	Sugar maple (*Acer saccharum*; 5)	
	Trembling aspen (12)	
	Mean dbh = 39 cm	*Mean dbh = 25 cm*
Ennis *et al*. (1993; Huron-Manistee NF)	**Deciduous (32)**	**Coniferous (5)**
	Trembling aspen (14)	Pine (5)
	Oak (7)	
	Maple (6)	
	Other (5)	
Postupalsky (1993)	**Deciduous ***	**Coniferous**
	Paper birch	White pine
	Sugar maple	Eastern hemlock
	Trembling aspen	
	Yellow birch (*Betula alleghaniensis*)	
Minnesota	**Deciduous**	**Coniferous**
	Trembling aspen (*mean dbh = 35.7 cm*)	White pine
Martell and Dick (1996)	Basswood (*Tilia americana*)	Jack pine
	Burr oak (*Quercus macrocarpa*)	Red pine
	Birch	
Boal (Texas Cooperative Fish and Wildlife Research Unit, pers. comm., 2001)	**Deciduous (43)**	**Coniferous (2)**
	Aspen (37)	Red pine (1; *dbh = 59.7 cm*)
	Birch (5)	White pine (1)
	Red oak (1)	
	Mean dbh = 40.6 cm; SE = 2.9 cm (27)	
Ontario	**Deciduous (24)**	**Coniferous (10)**
	Aspen (7)	Pine (10)
Peck and James (1983)	Beech (3)	

	Birch (10) Maple (3)	
Wisconsin	**Deciduous (29)**	**Coniferous (8)**
	Trembling aspen (12)	White pine (5)
Rosenfield *et al.* (1998a)	Sugar maple (5)	Eastern hemlock (3)
	Yellow birch (5)	
	Black ash (*Fraxinus nigra*; 2)	
	Northern red oak (*Quercus rubra*; 2)	*Mean height: 25 m*
	Basswood (1)	*Mean dbh: 41 cm*
	Paper birch (1)	*(For both decidous and coniferous*
	Red maple (*Acer rubrum*; 1)	*trees)*

* Sample size was not reported for all studies.

Nest Structure and Location in Tree

Goshawks typically construct their nests just below the forest canopy in the upper portion of the lower one-third of the nest tree (Shuster 1980, Reynolds *et al.* 1982, Moore and Henny 1983, Speiser and Bosakowski 1987). Heights of goshawk nests are significantly correlated with nest tree heights (Kennedy 1988, Speiser and Bosakowski 1989), which vary with tree species and regional differences in tree heights (USFWS 1998a). The average height of North American nests was reported by Apfelbaum and Seelbach (1983) as 11.8 m (38.6 ft; range = 6.1 – 25.7 m; 20 – 84 ft).

Peck and James (1983) stated that nests in Ontario are bulky structures of twigs and branches reaching up to 90 cm (35.4 in) in height, with outside diameters (n = 6) ranging from 43 – 106.5 cm (16.9 – 41.9 in) and inside diameters (n = 2) of 23 and 53.5 cm (9 and 21 in). These nests had shallow cups and were lined with various items, such as fresh sprigs of hemlock, pine, or cedar, dried and fresh leaves, grasses, mosses, feathers, clay, and bark chips (Peck and James 1983). The nests (n = 29) were positioned in forks of branches at the trunk or in main crotches at heights ranging from 7.5 – 23 m (24.6 – 75.5 ft) with most (n = 15) between 9 – 12 m (29.5 – 39.4 ft).

Although canopy closure in the nest area is often cited as an important habitat feature (Squires and Reynolds 1997), the nest tree itself may be dead and offer little canopy closure (Dick and Plumpton 1998). Successful nests have been recorded in dead white pines in Minnesota (Martell and Dick 1996) and Porter and Wilcox (1941) reported a successful nest in a dead aspen tree in Michigan. Snag nesting is a common practice for goshawks nesting in the Vernal Mountains in Utah (S. R. Dewey and P. L. Kennedy, unpublished data).

Alternative Nests/Alternative Nest Areas

Typical goshawk breeding areas contain several alternative nests that are used over several years (Reynolds and Wight 1978, Speiser and Bosakowski 1987, Reynolds *et al.* 1994, Woodbridge and Detrich 1994, Reynolds and Joy 1998). Although goshawks may use the same nest in consecutive years, goshawk breeding areas often contain 1 – 5 or more alternative nests that are used by pairs over several years and are usually located within 0.4 km (0.25 mi) of each other (Reynolds and Wight 1978, Speiser and Bosakowski 1987, Reynolds *et al.* 1994, Woodbridge and Detrich 1994, Reynolds and Joy 1998). They may be found clumped in 2 – 3 adjacent stands or distributed over a much larger area (Woodbridge and Detrich 1994). Difficulties in locating all alternative nests and nest areas and differences in survey methods and nest search protocol can make fidelity to breeding areas and other productivity parameters difficult to estimate and may confound comparisons of occupancy and productivity data (Dick and Plumpton 1998).

Woodbridge and Detrich (1994) presented a method for analyzing breeding area occupancy by looking at clusters of alternative nests and nest areas. In their study conducted in northern California, the mean number of nests used by goshawk pairs was 2.6 and only 44% of nesting attempts were in nests used the previous year. The mean spacing between alternative nests was 273 m (892 ft), with a range of 30 – 2,066 m (100 ft – 1.3 mi; Woodbridge and Detrich 1994). In Arizona, 59 breeding areas that contained alternative nests had a mean spacing between them of 489 m (1,604 ft), and a range of 21 – 3,410 m (69 ft – 2.1 mi; median = 285 m; 935 ft; Reynolds and Joy 1998).

In Minnesota, goshawk nest areas monitored from 1994 – 1996 were reused in consecutive years in two breeding areas, and on two other breeding areas, three different trees were used, in three successive years (Hines 1997 *in* Dick and Plumpton 1998a). Martell and Dick (1996) found one Minnesota area had four nest structures within 200 m (656 ft) of the active nest, although occupancy of these structures in previous years was not determined. T. Erdman reported that alternative nests on his study areas in Wisconsin were within 1 km (0.62 mi) of the active nest (Dick and Plumpton 1998). Baumgartner (1938) reported three nests in the vicinity of an active goshawk nest and Ennis *et al.* (1993) reported one or two alternative nest areas found in 13 of 20 breeding areas searched in Michigan. The distances to these alternative nests were: 1 at 0 – 40.2 m (0 – 132 ft), 6 at 40.2 – 100.5 m (132 – 330 ft), 1 at 100.5 – 303.2 m (330 – 995 ft), and 11 beyond 303.2 m (995 ft; Ennis *et al.* 1993).

In northern California, the occupancy rate of nest stands was positively correlated with stand and cluster size, with smaller stands and clusters being occasionally occupied and large stands and clusters more consistently occupied (Woodbridge and Detrich 1994). Woodbridge and Detrich (1994) found that forest stands containing nest areas are often relatively small, with 1 – 5 alternative nests located in different stands. Approximately 85% of stands containing alternative nests were less than 0.7 km (0.4 mi) apart with a maximum distance between nest stands of 1.8 km (1.1 mi). Woodbridge and Detrich (1994) defined nest-stand clusters as the aggregate area of all nest stands within a territory, which ranged in total size from 10.5 – 114 ha (26 – 282 ac).

Dominant Forest Types

Forest types associated with goshawk nest areas vary geographically (USFWS 1998a). In New York, sugar maple, yellow birch, beech, and hemlock were dominant in most nest areas (Allen 1978), whereas forest types in western nest areas include all montane forest types (White *et al.* 1965, Bartelt 1977, Reynolds *et al.* 1982, Saunders 1982 *in* USFWS 1998a, Hall 1984, Reynolds *et al.* 1990, Allison 1996 *in* USFWS 1998a, Squires and Ruggiero 1996, Desimone 1997). In the interior of Alaska, stands of paper birch were used more commonly than any other forest type and paper birch was the dominant tree species in other forest types with goshawk nests (McGowan 1975a). In southeast Alaska, however, there was significantly more hemlock (81%) at goshawk nest areas than randomly available (75%; Iverson *et al.* 1996).

Boyce (1997) listed 135 historic nest areas in USFS Region 9 with 96 occurring in northern hardwood cover types, 16 in red pine cover types, 10 in oak/pine cover types and 13 in aspen cover types. Apfelbaum and Seelbach (1983) summarized 64 nest reports from various regions of North America and reported that 44% were in mixed woodlands, 34% were in deciduous forests, and 22% were in coniferous forests.

Postupalsky (1993) reported that the most frequently used nest stand types in Michigan were northern hardwood forest, aspen, or white pine stands. Ennis *et al.* (1993) listed nests on the Huron/Manistee National Forests as occurring 35% in red pine (n = 14), 28% in aspen (n = 11), 12% in oak (n = 5), 10% in northern/mixed hardwoods (n = 4) and 15% in other stand types (n = 6).

Eng and Gullion (1962) described a goshawk breeding area near Cloquet, Minnesota as heavily stocked, fairly dense, 64-year-old jack and red pine, with a few trembling aspen and paper birch scattered among the pines. Gullion (1981a) reported three nests, also near Cloquet, in the late 1970s were in hardwoods in stands dominated by jack, red and Scots pine (*Pinus sylvestris*). The nests were in smaller stands of conifers surrounded by mixed conifer hardwood and young aspen stands. Apfelbaum and Haney (1984) described a nest stand at Itasca State Park as jack pine/aspen forest. 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).

Rosenfield *et al.* (1996, 1998a) reported that goshawks in Wisconsin use a wide variety of nest area habitats in terms of tree species composition and woodland age, including four nests in pine plantations. The proximity of some nests to pine plantations has been noted by researchers in Wisconsin (Rosenfield *et al.* 1996, 1998a), Michigan (Bowerman 1998a), Minnesota (Dick and Plumpton 1998), and Ontario (Peck and James 1983).

Forest Structure and Landscape Features

Although the goshawk is considered a habitat generalist at large spatial scales, it tends to nest in a relatively narrow range of structural conditions (Reynolds *et al.* 1992, Squires and Reynolds 1997). Goshawks seem to prefer mature forests with large trees, relatively closed canopies (60 – 90%), and open understories (Moore and Henny 1983, Speiser and Bosakowski 1987, Crocker-Bedford and Chaney 1988, Kennedy 1988, Hayward and Escano 1989, Reynolds *et al.* 1992, Squires and Ruggiero 1996, Penteriani and Faivre 1997, Selås 1997, Squires and Reynolds 1997, Daw *et al*. 1998, Daw and DeStefano 2001). Due to frequent bias in goshawk nest detection methods, however, goshawk habitat selection of mature forests over other forest stages has been demonstrated in only a few studies (Kennedy and Andersen 1999). Nests are frequently found near the lower portion of moderate slopes, close to water, and often adjacent to a canopy break (Squires and Reynolds 1997). Nesting in stands that are relatively more dense than surrounding forests may reduce predation and in combination with north slopes, may provide relatively mild and stable micro-environments (Reynolds *et al.* 1982).

Stand Size, Age, Canopy Closure, Tree Size and Density. In New York and New Jersey, goshawks generally preferred extensive forest areas (Bosakowski and Speiser 1994) that contained significantly more mature trees than were randomly available (Speiser and Bosakowski 1987).

Reynolds *et al*. (1982) reported goshawks in Oregon nesting in dense, mature or old-growth conifers with a mean tree density of 482 trees/ha (195 trees/ac) and a range of 273 – 750 trees/ha (110 – 304 trees/ac). Nest areas included forests with a few mature trees and dense understory trees, forests with closed mature canopies and sparse understory trees and several variations in between. Most nest areas were in old forests, with only 5% in second growth forests and 4% in mature lodgepole pine or mixed stands of mature lodgepole and ponderosa pine. The lodgepole nest areas had relatively open, single-layered canopies (166 trees/ha; 67 trees/ac, 38% canopy closure). In their Oregon study area, Daw *et al*. (1998) found nests stands located systematically had an average of 16.4 large trees (> 53 cm dbh)/ha and a mean canopy closure of 72.4%. Daw and DeStefano (2001) compared goshawk nest stands to stands with random points in Oregon and found that goshawks nested more frequently in stands with dense canopy and late forest structure (i.e., trees > 53 cm dbh, canopy cover > 50%), but rarely in stands with mid-aged forest structure. They also found that nests were positively associated with small dry openings. They reported that average nest-stand size in older forests was about 100 ha (range = 3 – 375 ha), but emphasized that stand quality is more important than stand size, adding that forest managers need to consider the abundance of large trees across the landscape they are managing.

Siders and Kennedy (1996) described the range of stand conditions used by goshawks in northern New Mexico. They reported that goshawks used nest trees ranging from 25 – 31 m in height and 43.3 – 56.7 cm dbh. Canopy closure at the nest tree was 58 – 74% and at nest areas was 60 – 70%. Nest areas had 31 – 40 m^2/ha basal area, with an overall area density of 800 – 1,400 trees/ha and overstory trees were spaced 4.8 – 6.8 m apart. Nest areas were composed of 2.8 – 8.0% mature, 2.1 – 11.1% large, 5.2 – 32.8% pole, and 16.8 – 85.6% sapling trees. Tree densities by age class were 460 – 970 sapling trees/ha, 130 – 370 pole trees/ha, 55 – 115 large trees/ha, and 53 – 90 mature trees/ha.

In northern Arizona, Bright-Smith and Mannan (1994) found some goshawks (n = 3) preferentially selected stands with high canopy closure (selected canopy closure > 55%, avoided canopy closure <15%) at distances of > 200 m from edge for foraging during the breeding season; whereas others (n = 8) used canopy closure categories in proportion to their occurrence.

In northern California, canopy closure at nests ranged from 53 to 92% (Saunders 1982 *in* USFWS 1998a) and in northern Arizona, goshawks preferred nest areas that had the greatest canopy closure available, averaging 76%, which was 18% greater than in 360 reference areas (Crocker-Bedford and Chaney 1988). In eastern California, Hargis *et al*. (1994) reported that home range locations used by goshawks were similar to nest areas, and both had greater canopy cover, greater basal area, and more trees/ha than a random sample from the study area.

Despite differences in some habitat characteristics, high canopy closure and tree basal area at nest areas were the most uniform habitat characteristic between study areas in northern Idaho and western Montana (Hayward and Escano 1989). Tree basal area ranged from 29 to 54 m^2/ha (126 – 235 ft^2/ac), with most (60%) nest stands between 39 and 46 m^2/ha (170 – 201 ft^2/ac).

Canopy closure, stem/tree density, dbh, and basal area have been measured at a limited number of nest areas in the WGLR (Dick and Plumpton 1998). As Dick and Plumpton (1998) point out, care should be taken to closely examine methodologies before undertaking comparisons of available data for the WGLR. In some cases sample size was small and not all nests were located by unbiased means.

In Wisconsin, Rosenfield *et al.* (1998a) reported mean total percent canopy closure in nest areas as 78.7 ± 4.4% (n = 37). They used an ocular tube at 40 points per 0.04 ha (0.1 ac) plot to measure the percent occluded by overstory foliage. The mean dbh of stems was 29 cm (11.4 in), the mean tree density was 423 stems/ha (171 st/ac), and the average basal area was 30 m^2/ha (132 ft^2/ac).

Martell and Dick (1996) sampled eight nest areas in Minnesota. Canopy closure was measured using an ocular tube at 16 points on 0.08 ha (0.2 ac) plots surrounding nests. The mean canopy closure in their study was 72.5% with a range of 60 – 91%. They reported a mean dbh of 16.8 cm (6.6 in) and a mean stem density of 1153 st/ha (466 st/ac).

Bowerman et al. (1998) 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, and concluded that old-growth forests may not be a requirement for nest selection in the Upper Great Lakes area (Bowerman 1998a). Basal areas for nest areas in Michigan (Bowerman 1998a) were reported as 30 m^2/ha (136 ft^2/ac) in deciduous stands and 41 m^2/ha (187 ft^2/ac) in coniferous stands.

Peck and James (1983) described nest stands in Ontario as deciduous, coniferous, and mixed forests of various sizes. They stated that large, dense stands were favored by goshawks for nesting, and older coniferous reforestation plots were occasionally used. Sample sizes, nest location methods, and measurement techniques used in this study were not specified.

Although goshawks appear to select relatively closed-canopy forests for nesting, there are exceptions and they will nest in more open forests (USFWS 1998a). Goshawks nest in tall willow communities along major drainages in the arctic tundra (Swem and Adams 1992) and in riparian cottonwood stands (White *et al.* 1965). In Oregon, Reynolds *et al.* (1982) reported that seven nest areas had an average canopy closure of 59.8%, although three nests were located in stands of mature lodge-pole pine that were relatively open (38% canopy coverage). Also, a reported average canopy closure of 31% in nest stands in eastern California was low compared to other goshawk studies (Hargis *et al.* 1994).

Aspect and Slope. Aspect and slope in nest areas may influence microclimate and goshawk habitat selection. In the southern portions of their range, goshawk nest areas typically have northerly aspects and are located near the bottom of moderate slopes (USFWS 1998a). Studies conducted in Oregon (Reynolds *et al.* 1982), Idaho, and Montana (Hayward and Escano 1989) found that a significant number (40 – 60%) of goshawk nest locations followed this pattern, with nests on slopes with northwest to northeast-facing aspects. Bosakowski and Speiser (1994) compared goshawk nest sites to random points throughout their study area in New York and New Jersey and found that goshawks avoided nesting on slopes with southerly aspects relative to the abundance of these slopes. Average slopes in nest areas were 9% (range = 0 – 75%) in Oregon (Reynolds *et al.* 1982), 14% in northeastern Oregon (Moore and Henny 1983), and less than 50% slope in Idaho and Montana (Hayward and Escano 1989). Although goshawks nesting in New Mexico (Siders and Kennedy 1996) and Wyoming (Squires and Ruggiero 1996) did not exhibit a preference for aspect, most nests were found on moderate slopes. Goshawks nesting in northwestern California used slopes averaging 42%, which are some of the steepest slopes recorded (Hall 1984).

In contrast, most goshawks (64%) found nesting in the interior of Alaska were on slopes with southern aspects. In addition, they seemed to favor mid-slope locations with 16% on the upper portion of the slope, 46% on the middle portion, and 38% on the lower portion of the slope (McGowan 1975a,b).

Plucking Perches. Goshawks use perches on logs, stumps, old nests, and low, bent-over trees or saplings for plucking prey in nest areas (Schnell 1958, Palmer 1988). Although nests are typically found in mature forest under relatively closed canopies, plucking perches are usually located up slope from the nest in denser portions of the secondary canopy (Reynolds *et al*. 1982, Hall 1984). In California, an average of two plucking perches was found per nest area (range = 1 – 3; Hall 1984). Apfelbaum and Haney (1984) found three plucking perches, approximately 0.5 to 0.75 m (1.6 – 2.45 ft) above the ground, which were all within 100 m of a nest tree. Reynolds *et al.* (1982) found the mean distance from nests to plucking perches was 45 m (147 ft; range = 27 – 74 m; 88 – 242 ft) in Oregon and Schnell (1958) found the mean distance from 10 plucking perches to nest trees was 69 m (226 ft; range = 30 – 130 m; 98 – 425 ft) in California.

Water. Although goshawk nests are often found near permanent water sources (Bond 1942, Beebe 1974 in Squires and Reynolds 1997, Shuster 1980, Reynolds *et al.* 1982, Hargis *et al.* 1994), distances of water from nests differ regionally. Water sources vary from small streams or forest ponds to major rivers or large lakes (Beebe 1974 in Squires and Reynolds 1997). The function that water provides during nesting is unknown. However, Hennessy (1978) speculated that frequent bathing by brooding goshawks may help maintain proper humidity during incubation and Brown and Amadon (1968) stated that young goshawks might bathe or wade in water for extended periods.

Beebe (1974 *in* Squires and Reynolds 1997) reported that in British Columbia, Canada, goshawk nests were consistently found within 120 – 360 m (395 – 1,190 ft) of permanent water. Shuster (1980) found that all nests in aspen stands in Colorado, were near running water and that nests in pine stands were from 10 – 450 m (33 – 1,485 ft) from water sources. In California, permanent water sources, such as springs and small streams, were closer, on average, to nests than to random points (Hargis *et al*. 1994).

Although proximity to permanent water sources may affect goshawk nest area selection in parts of its range, goshawk nest area location is not related to proximity of water sources in all areas (USFWS 1998a). On the Kaibab Plateau, Arizona, where bodies of water averaged 3.6 km (2.23 mi) apart, only 8 of 43 nest areas occurred within 1 km (0.62 mi) of permanent water (Crocker-Bedford and Chaney 1988). Speiser and Bosakowski (1987) found no difference in distance to water between goshawk nest areas and random points in New York and New Jersey.

Forest Openings. Reports of goshawks nesting close to forest openings such as meadows, forest clearings, logging trails, dirt roads, and fallen trees are common (Gromme 1935, Reynolds *et al.* 1982, Hall 1984, Erickson 1987, Hayward and Escano 1989). Although the function of forest openings near nests is unclear, they may increase access to the nest or aid in locating nests

(USFWS 1998a). Erickson (1987) reported openings and trails being used as access corridors to the nest, with male goshawks on several occasions returning high over the forest canopy with food and then dropping into an opening or trail to deliver the prey to the female. Speiser and Bosakowski (1987) reported goshawks in eastern forests using small roads opportunistically as travel corridors, flying, perching, and plucking prey along them. In Colorado, Shuster (1980) found that goshawk nests (n = 20) were within 350 m (1,145 ft) of a 0.4 ha (1 ac) or larger natural meadow that supported populations of ground squirrels.

In California, goshawk nests had an average of one forest opening, averaging 113 m^2 (1,208 ft^2), within 15 m (49.5 ft; Hall 1984). In South Dakota, canopy openings accounted for approximately 10% of the nest area (Bartelt 1977), with the exception of only two areas that were not associated with an opening. Erickson (1987) reported in another South Dakota study that all goshawk nests were near either old logging roads (78.6%) or forest openings (21.4%) and the mean distance from the nest tree to an opening was 73.9 m (242 ft; range = 16.9 – 215 m; 55 – 703 ft).

Although extensive off-road searching was conducted, goshawks in New York and New Jersey were found nesting closer to lightly traveled roads and trails, which represented the only breaks in a contiguous forested area, than to random points (Speiser and Bosakowski 1987). Goshawks in California nested an average of 85.3 m (279 ft) from medium-use roads (Saunders 1982 *in* USFWS 1998a).

In the WGLR, there is little descriptive information on the landscape features of nest areas (Dick and Plumpton 1998). Eng and Gullion (1962) described a breeding area near Cloquet, Minnesota as having small openings in the forest within 30.5 – 61.0 m (100 – 200 ft) of the nest. Martell and Dick (1996) measured distances to maintained roads at nine active nests in Minnesota and found that although six nests were at least one km (0.62 mi) from a road (range = 1,000 – 4,000 m; 3,280 – 13,123 ft), one nest was directly over the right of way; one nest was 62 m (203 ft) away; and one was 280 m (918 ft) from a maintained road.

Breeding Season Foraging Habitat

A few studies have been conducted in North America comparing foraging habitat selection by goshawks with habitat available at the landscape level (Austin 1993, Bright-Smith and Mannan 1994, Beier and Drennan 1997, Lapinski 2000, Boal *et al*. *In Review*b). Although the wide variety of prey species that goshawks depend on require a mosaic of habitats, results from these studies suggest that goshawks use all forest types, but appear to select forests with a high density of large trees (≥ 52 cm dbh), greater canopy cover and high canopy closure, high basal area, and relatively open understories in which to hunt (Beier and Drennan 1997). Despite these preferences, however, several studies also reported goshawk tolerance for a broad range of forest structures (Kenward 1982, Widen 1989, Austin 1993, Bright-Smith and Mannan 1994, Hargis *et al*. 1994, Beier and Drennan 1997). Beier and Drennan (1997) suggested that goshawks from their northern Arizona study area use all types of forest stands in part because of the limited availability of denser stands of large trees. It is also important to note that while some habitats may be avoided by foraging goshawks, they may actually be important in terms of prey production (Boal *et al*. 2001).

In southwest Yukon, Canada, 33% of goshawk kills were in dense forest cover although only 18% of the valley contained this cover type (Doyle and Smith 1994). Hargis *et al.* (1994) found goshawks foraging in forest stands with higher basal area, more canopy cover, and more trees in large diameter classes than were randomly available. Similarly, goshawks in the southern Cascades preferred the oldest, densest vegetation type available and avoided the youngest, most open vegetation (Austin 1993). Beier and Drennan (1997) indexed prey abundance and measured forest structure at areas used by goshawks and in nearby contrast plots. They found that goshawks did not select foraging habitat based on prey abundance, but rather chose sites with higher canopy closure, greater tree density, and greater density of trees > 40.6 cm dbh than on contrast plots. They also reported a mean canopy closure of 48% on used plots; aversion to canopy closures < 40%, and a strong preference for areas with canopy closure > 80%. Beier and Drennan (1997) suggested that while 40% canopy cover may be an appropriate *minimum* (Reynolds *et al*. 1992), managers should create a diversity of canopy closures above this minimum, including > 60% canopy closures in at least 20% of the area being managed for goshawks.

In the WGLR, Boal *et al*. (*In Review*b) assessed goshawk foraging habitat preference in northern Minnesota during the breeding period. They reported that male goshawks (n = 19) demonstrated a clear preference to forage in old (> 50 yrs) early successional upland hardwood (e.g., aspen, birch) stands, mature (> 50 yrs) late successional upland conifers (e.g., red pine, white pine), and mature (> 25 yrs) early successional upland conifer (e.g. balsam fir, jack pine). They also reported that foraging male goshawks clearly avoided young (< 25 yrs) early successional upland hardwood and young (< 50 yrs) late successional lowland conifer (e.g., black spruce, tamarack). Mean canopy closure was high among all selected stand types (range = 53 – 70%) and goshawks selected stands that were remarkably similar in terms of diameter (range = 19.6 – 24.6 cm; 7.6 – 9.6 in) and heights (range = 14.7 – 16.8 m; 48.2 – 55.1 ft) of the canopy trees, canopy closure, and high stem density (570 – 1030 stems/ha: 230 – 417 stems/ac). Foraging stands were also distinguished by horizontal open spaces of 1.1 – 3.5 m (3.6 – 11.5 ft) between the bottom of the overstory canopy and the top of the understory canopy, and up to 1 m (3.3 ft) between the bottom of the understory canopy and the top of the shrub layer, and the height at which these openings occurred was consistent among stand types. Boal *et al*. (*In Review*b) suggested that these relatively unobstructed spaces between vegetation layers may serve as important flight paths through forest stands. Foraging stands also contained from 16 – 24 km (10 – 15 mi) of down woody debris per ha, averaging 17 – 19 cm (6.6 – 7.4 in) in diameter and typically located between 5 – 20 cm (2 – 8 in) above the ground.

In the Upper Peninsula of Michigan, Lapinski (2000) examined goshawk selection and avoidance of forest cover types during the breeding and nonbreeding periods. Lapinski (2000) reported that during the breeding season, when data were pooled (n = 3 females), goshawks selected cover types were hardwood/conifer mix (canopy closure > 70%) and jack pine, whereas cedar, open, and swamp fir/swamp conifer cover types were avoided. Other cover types, including aspen, hardwood (canopy closure < 70%), and red/white pine, were used in proportion to their abundance. Lapinski (2000) also reported that all of the cover types, except open, were selected by at least one goshawk and that most goshawks selected hardwood/conifer mix and avoided monotypic stands.

Goshawks have also been reported to hunt in openings and along edges. Shuster (1980) observed goshawks hunting in openings and clear-cuts in Colorado. In Nevada, three males foraged in open sagebrush away from trees (based on 13 visual observations) and along the edge of aspen groves to hunt Belding's ground squirrels in sagebrush (Younk and Bechard 1992). These studies indicate that goshawks hunt in open and edge habitats, however because they are based on a few visual observations, they may be subject to visibility bias (Dick and Plumpton 1998).

Reynolds and Meslow (1984) assigned bird and mammal prey species in forested habitat to four height zones (ground-shrub, shrub-canopy, canopy, aerial) on the basis of where each spends most of its time. They found that 40% of prey in goshawk diets were zone generalists; 35% were most often in the ground/shrub layer; and the remaining prey (25%) were evenly distributed between shrub-canopy and canopy layers. Reynolds *et al.* (1992) indicated that large-bodied prey might be more important to breeding goshawks than smaller prey. In the Reynolds and Meslow (1984) study large-bodied mammals and bird prey species were primarily associated with the lower forest strata or were zone generalists. In Arizona, Boal and Mannan (1994) found that 62% of prey was captured from the ground/shrub zone, 25% of prey was zone generalists, 13% were from the shrub/canopy and canopy zones, and highly aerial prey, such as swallows, were not observed in goshawk diets.

DeStefano and McCloskey (1997) reported that in the coast ranges of Oregon, goshawks are rare even though goshawk prey species are varied and abundant. Forests in this area contain high understory stem densities and dense undergrowth, which may make prey species difficult to capture. DeStefano and McCloskey (1997) suggested that if a relationship between vegetation structure and the availability of prey does exist, then these forest conditions might limit prey availability to goshawks.

Post-Fledging Area (PFA) Habitat

The PFA surrounds the nest area and is defined as the area used by the family group from the time the young fledge until they are no longer dependent on the adults for food (Reynolds *et al.* 1992, Kennedy *et al.* 1994). During the fledgling-dependency period the activities of young are centered near their nests, with the distances that they move from the nest increasing over time (Kennedy *et al.* 1994). PFAs may be of importance to fledglings by providing prey items on which to develop hunting skills, as well as cover from predators and prey.

Kennedy *et al.* (1994) reported that PFAs in New Mexico averaged 170 ha (420 ac) in size and suggested that this area may correspond to the area defended by a goshawk pair. The average distance fledglings moved from nests in weeks one through eight after fledging increased from 12 – 1,956 m (39 ft – 1.2 mi). During the first four weeks following fledging, 88.1% of 193 locations were within 200 m (654 ft) of the nest and 99.5% were within 800 m (0.5 mi) of the nest. During the last four weeks of the fledgling-dependency period, only 34.3% of 108 locations were within 200 m (654 ft) of the nest and 75.9% of locations occurred within 800 m (0.5 mi) of the nest.

In European goshawks, Kenward *et al.* (1993a) reported that during the first 25 days after fledging only 2% of fledgling observations were more than 300 m (0.2 mi) from the nest, whereas in the 25 – 50 days after fledging, 26% of observations were beyond 300 m (0.2 mi).

Dispersal from nest areas was abrupt and most fledglings (90%) dispersed by 65 – 90 days of age.

Daw and DeStefano (2001) recently completed the only PFA habitat study ever published. They compared PFA habitat around nest areas with that of habitat available at the landscape level in Oregon and found that within circles of 12 ha (30 ac) and 24 ha (59 ac) plots around nests, late forest structure was more abundant than around random points. They also reported that forest structure at the PFA scale was dominated by dense-canopied forest and always contained wet openings. They suggested that until telemetry studies identify specific habitat used by fledglings in a variety of forest cover types, dense canopy, late forest structure stands in patch sizes of at least 12 ha (30 ac) be maintained and that where this type of habitat exists, contiguity be maintained rather than creating smaller patches.

Nonbreeding Habitat

Winter habitat use of northern goshawks is among the least understood aspects of their biology (USFWS 1998a). The goshawk is considered a winter resident throughout its breeding range, however, some goshawks regularly winter outside their breeding areas (Squires and Reynolds 1997). Studies investigating goshawk migration and winter biology in North America are few (Doerr and Enderson 1965, Alaska Department of Fish and Game 1993, Squires and Ruggiero 1995, Drennan and Beier *In press*) and understanding of goshawk biology during the winter comes primarily from Europe (Opdam *et al*. 1977; Kenward *et al.* 1981; Marcström and Kenward 1981; Widén 1985, 1987, 1989; Kostrzewa and Kostrzewa 1991). The degree to which these results can be applied to goshawks in North America is unknown (USFWS 1998a).

Very little is known about the movements or habitat requirements of WGLR goshawks in winter (Dick and Plumpton 1998). A study of radio-tagged goshawks in north-central Minnesota has indicated that resident goshawks stay in an area relatively close to, although larger than, their breeding season home ranges (Boal *et al.* 2000). This study was conducted from 1998 – 2000; the degree to which goshawks in the region remain resident on their breeding areas over time is unknown.

Doolittle (1998) followed two goshawks using radio-telemetry during winter in northern Wisconsin and found that both the male and female stayed in Wisconsin through the winter. Doolittle (1998) reported that size of the male goshawk's use area was 32 km^2 (12 mi^2) and that 95% of his telemetry points were in swamp conifer edge cover and hypothesized that this was probably due to conifer swamps providing areas of thermal cover for most fauna during the Wisconsin winter. The female goshawk was always found within a 4-km^2 (1.5 mi^2) home range and within 3 km (1.9 mi) of a game farm. Additional research is needed in the WGLR to determine when and whether migration occurs, and to measure migration distances, winter home range size, and habitat use (Dick and Plumpton 1998).

Lapinski (2000) found that during the nonbreeding season, radio-tagged goshawks in the Upper Peninsula of Michigan (n = 2 females, 1 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.

In the winter, goshawks have been reported to use a variety of vegetation types, such as forests, woodlands, shrublands, and forested riparian strips in search of prey (Squires and Ruggiero 1995, Drennan and Beier *In press*). Wintering goshawks in the Rocky Mountains use cottonwood riparian areas (Squires and Ruggiero 1995), aspen, spruce/fir, lodgepole pine, ponderosa pine, and open habitats (Squires and Reynolds 1997). In northern Arizona, Drennan and Beier (*In press*) found that all of the female adult goshawks (n = 6) in their winter habitat study used ponderosa pine forests; whereas, most male adult goshawks (n = 6 of 7) used lower elevation, pinyon-juniper woodlands. Goshawks minimized thermal exposure and energy expenditure by caching and feeding behavior. Goshawks foraged in sites with more medium-sized trees [230 trees/ha (93 trees/ac)] and denser canopy cover (50%) than contrast plots [192 medium-sized trees/ha (78 trees/ac); 44% canopy closure]; indices of prey abundance were nearly equal in foraging areas and contrast plots (Drennan and Beier *In press*).

Stephens (2001) estimated winter home ranges of 12 goshawks breeding in the Uinta Mountains in Utah. This is the largest sample size of winter birds used in North America. He analyzed the landscapes of the home range and also collected vegetation measurements at estimated locations from ground telemetry and visual observations. The four core range habitat types were mixed-conifer forests at higher elevations composed primarily of: (1) lodgepole pine, subalpine fir, and/or Douglas fir (*Pseudotsuga menzeseii*); (2) woodlands composed primarily of pinyon/juniper and agricultural areas adjacent to the woodland; (3) a combination of the first two habitat types; and (4) lowland riparian areas adjacent to salt-desert scrub. The birds demonstrated a preference for habitats 1, 3 and 4. They used the woodland and agricultural areas in proportion to their availability in the study area. The core area of the home ranges also had a higher estimated mean patch density (1.3/km^2) than random points (0.7/km^2), but the difference was not significant. The estimated number of vegetation types/km^2 in goshawk winter ranges was higher (0.5/km^2) than in random home ranges (0.3 /km^2), but the difference was also not significant. The estimated average length of edge in goshawk core ranges and random ranges was 2.96 km/km^2 and 2.1 km/km^2, respectively. These differences were not significant. The lack of statistical significance was likely due to low power. These data indicate that these goshawks had winter home ranges that had a higher diversity of vegetation types and more patches than the rest of the study area. Stephens (2001) speculated that these areas may have supported a more diverse prey base. His data also clearly demonstrate that birds will winter in habitats not used for nesting (*i.e.*, pinyon-juniper woodland).

Widén (1989) tracked radio-tagged goshawks (n = 23 males; 20 females) in Sweden that wintered in highly fragmented forests interspersed with clear cuts, wetlands, and agricultural lands. In this study, goshawks killed more than half of their prey in large (> 40 ha; 100 ac) patches of mature forests (70 years old) and used these areas significantly more than what was proportionately available. Young and middle-aged forests were used by goshawks in proportion to abundance. Mature forests allow goshawks to hunt while remaining undetected by prey, but are also open enough for birds to maneuver when attacking prey (Widén 1989).

In England, Kenward (1982) tracked four goshawks that spent 50% of their time in and took 70% of their prey from the 12% of woodland contained within their home ranges. Another study conducted in agricultural areas of England (Kenward and Widén 1989) reported that wintering goshawks used edge habitats for foraging. Differences in habitat use may be attributed to different prey distributions (Kenward and Widén 1989). Kenward and Widén (1989) reported that in boreal forests, goshawks prey primarily on squirrels found distributed throughout the forest, whereas in agricultural areas goshawks hunt near forest edges where prey are more abundant. Goshawk home ranges in agricultural areas were smallest where prey densities were greatest, and were largest in areas that contained the least woodland edge, suggesting that prey distribution was the factor that determined the distribution of goshawks during winter (Kenward and Widén 1989).

Home Range Size

The correlation of home range size to habitat use and preference of foraging goshawks is poorly understood for North American populations (Squires and Reynolds 1997). In the WGLR, no telemetry data on home ranges during the breeding season or winter have been published, however, two studies have recently been completed (Lapinski 2000, Boal *et al.* 2001) and one of which is in review (Boal *et al*. *In Review*a). Although comparison of home range sizes may be useful, particularly on a local scale, it is also important to consider prey and foraging habitat abundance and availability, which may be influential factors in home range size (Keane and Morrison 1994). The distances traveled while foraging and the type of hunting habitats preferred and available for the breeding season, dispersal, and winter are critical to developing effective goshawk management plans (Dick and Plumpton 1998).

Squires and Reynolds (1997) reported that breeding season home range sizes in North America range from 570 – 3,500 ha (1,408 – 8,645 ac), depending on sex and habitat characteristics. Males' home ranges are usually larger than females (Hargis *et al*. 1994, Kennedy *et al*. 1994). Comparisons among studies are difficult and may not be meaningful due to differences in methodology. Shapes of home ranges vary and may be circular or almost linear depending on habitat configuration and quality (Squires and Reynolds 1997).

Lapinski (2000) reported that home range size for adults increased as fledglings matured. Mean home range size for female goshawks (n = 3) during the breeding season was 513 ha (range = 188 – 1,051 ha; 1,267 ac, range = 464 – 2,596 ac) and mean home range size during the non-breeding season for 2 females was 2,201 ha (5,437 ac) and 2,759 ha (6,815 ac) and for one male was 7,650 ha (18,896 ac; using the MCP method). Erdman (1993) reported home range sizes of over 1,000 ha (2,470 ac) for males and over 650 ha (1,606 ac) for females in Wisconsin. Sample size and methods of this study were not reported.

Boal *et al.* (*In Review*a) reported goshawk home range during the breeding season in northern Minnesota. The mean home range estimate (using the MCP method) for male goshawks (n = 19) was 3,006 ± 689 ha (7,425 ± 1,860 ac) and 2,649 ± 596 ha (6,543 ± 1,472 ac) for females (n = 11). Home range sizes were comparable between sexes, with relatively little overlap between members of a breeding pair within a breeding area. Combined home range size for goshawk pairs (n =11) was 6,454 ± 1,417 ha (15,941 ± 3,500 ac).

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 nest from drumming areas 1,097 – 2,514 m (mean = 1,664 m; 3,600 – 8,250 ft, mean = 5,460 ft) away. Davis (1979) followed a radio tagged female and one offspring during the fledgling-dependency period and reported the female's use of the habitat increased with time from 550 ha (1,360 ac) surrounding the nest to 4,200 ha (10,374 ac).

POPULATION ECOLOGY AND VIABILITY

Changes in number of animals in a population over time are a function of four demographic parameters: reproduction, survival, immigration, and emigration (Begon *et al*. 1998). Population ecology is concerned with determining how factors such as population density, distribution, age structure, resource abundance and availability, habitat distribution, competition, and climate influence these population parameters (USFWS 1998a). Understanding population ecology is critical for formulating management plans for a species because of the impact that land management practices might have on these demographic parameters via changes in habitat and prey abundance, availability, and distribution. Existing information on goshawk population ecology in the WGLR is limited to long-term monitoring of known nest areas for reproductive success in a few study areas and most of these data have not been published (Kennedy and Andersen 1999).

Definitions

An effort to standardize terminology and methodology for evaluation of breeding activity and productivity in the WGLR would facilitate compilation of data (Dick and Plumpton 1998). Standard terminology are found in Steenhof (1987).

Annual Cycle

Knowledge of the goshawk's annual cycle and breeding phenology is important in understanding population dynamics, and for designing studies, interpreting data, and conducting effective nest searches and surveys.

Breeding Period

Although there are few data available on timing of courtship, Møller (1987) reported copulations by goshawks as early as 52 days prior to egg laying in Denmark. Penteriani (2001) reported a peak in goshawk vocalizations in France during February and March, which "corresponded to initial courtship and territory establishment." Activities and behaviors associated with breeding typically occur between March and mid- to late August (Squires and Reynolds 1997). The morphology of male and female goshawks reflects the marked division of duties between the sexes throughout the breeding season. Males have larger pectoral muscles and lower wing loading than females, allowing them to carry prey longer distances, thus they are well-suited to do most of the foraging for the pair and their young (Marcström and Kenward 1981). Females are on average 1.4 times heavier than males, enabling them to incubate eggs, withstand periods of limited resources, defend the nest, and brood and feed the young (Marcström and Kenward 1981). Female accipiters may also forage during the nestling period, particularly during years of low prey availability (Newton 1986, Kelly and Kennedy 1993, Ward and Kennedy 1996).

Pre-Laying Period

Goshawks have been observed near their nesting areas in Minnesota (Roberson 2001) and other areas (Lee 1981) as early as late February, but are typically observed for the first time in early to late March (Zirrer 1947, Reynolds and Wight 1978, Widén 1984). In some areas, goshawk winter home ranges include their nesting areas (Boal *et al.* 2001, Drennan and Beier *In press*).

Squires and Reynolds (1997), Johnsgard (1990), Møller (1987), and Palmer (1988) discuss courtship rituals and mating. Møller (1987) reported that goshawk copulations in Denmark peaked twice in the pre-laying period from 31 – 40 days and from 5 – 22 days prior to egg laying. There are few observations of nest building, although Schnell (1958) and Lee (1981) reported that females do most of the nest building, with males contributing only occasionally. Females often aggressively defend the nesting area during the nestling period (Zirrer 1947) and attacks on intruders are most intense during the early stage of this breeding period (Speiser and Bosakowski 1991). The female goshawk becomes sedentary as egg-laying approaches, presumably to sequester the energy reserves necessary for egg formation (Reynolds 1972, Newton 1979, Lee 1981, Speiser and Bosakowski 1991); the male delivers prey directly to the female during this time. Penteriani (1999, 2001) reported that prior to the egg-laying period, goshawks reach an annual peak of vocal activity during courtship. Roberson *et al*. (*In Review*) found that goshawks in Minnesota were responsive to broadcasts of conspecific alarm calls during the courtship period.

Incubation Period

Timing of clutch completion ranges from early April to early June, varying among pairs, geographic areas, and years, but completed on average between late April and early May (Reynolds and Wight 1978, Henny *et al.* 1985, Reynolds *et al.* 1994). Roberson (2001) reported incubation initiation ranging from 31 March to 23 April in Minnesota. Replacement clutches appear to be rare, but have been reported at 15 – 30 days after initial egg loss (Marquiss and Newton 1982).

The incubation period has been estimated at 30 – 44 days (Brown and Amadon 1968, Snyder and Wiley 1976, Reynolds and Wight 1978, Lee 1981). Differences among estimates may be attributed to individual, geographic, or annual variation, or to measurement error (USFWS 1998a). Eggs are laid at 2 – 3 day intervals (Holstein 1942 *in* USFWS 1998a), with clutch completion time varying with the size of the clutch. Incubation usually begins with the first or second egg laid (Squires and Reynolds 1997). Because the female is typically reluctant to leave the nest during this period (Squires and Reynolds 1997), broadcast surveys may elicit little, if any response and are therefore less effective during this time (Kennedy and Stahlecker 1993).

Nestling Period

Hatching has been reported between mid-May and early June (McGowan 1975, Reynolds and Wight 1978, Lee 1981), but varies considerably. Roberson (2001) reported initial observations of nestlings at nests in Minnesota from 8 – 15 May. The nestling period varies from 37 to 45 days (Dixon and Dixon 1938, Brown and Amadon 1968, McGowan 1975, Reynolds and Wight 1978, Newton 1979, Kenward *et al.* 1993a, Boal 1994) and young generally fledge between early and late July (Reynolds and Wight 1978, Reynolds *et al.* 1994), with males developing faster and fledging sooner than females (Reynolds and Wight 1978, Kenward *et al.* 1993b, Boal 1994).

Females brood almost continually for 9 to 14 days following hatch (Schnell 1958, Boal 1994). Females do most of the brooding, but males may occasionally brood young while the female feeds (Schnell 1958, Lee 1981). The female also does most of the feeding of young, while the male does most of the hunting, at least until late in the nestling period (Squires and Reynolds 1997).

The female broods the young and only rarely attacks intruders entering the nest stand during the first few days after hatching (Speiser and Bosakowski 1991). Although there is individual and geographic variation in nest defense behavior, adult females are often aggressive toward human intruders later in the nestling period (Boal and Mannan 1994). Several studies have found response rates to broadcasts of goshawk alarm calls to be high during this period, facilitating detection of nests (Kennedy and Stahlecker 1993, Joy *et al.* 1994, Watson *et al.* 1999); however, Roberson *et al*. (*In Review*) found that in their Minnesota study area, responses to broadcast calls were highly variable among female goshawks during the nestling period.

Dewey and Kennedy (2001) reported that female nest attentiveness is a function of food availability and that the female will leave the nest to hunt during the nestling and fledgling-dependency periods. Ward and Kennedy (1996) reported that food supplementation during the nestling and fledgling-dependency periods affected young goshawk survival not by limiting starvation, but by causing the adult female goshawk to modify her behavior and spend increasing time in the nest stand, allowing more constant protection from predators.

Fledgling-Dependency Period

This period begins when the young leave the nest, continuing until they are no longer dependent on the adults for food, and has been estimated at a minimum of 6 weeks for goshawks in the U.S. (Zirrer 1947, Reynolds and Wight 1978). In New Mexico, the mean length of the fledgling-dependency period of juveniles radio-tracked until late autumn of their first year was 40 days (Kennedy and Ward *In press*). Kenward (1993) estimated a mean fledgling-dependency period of 32 days for males and 36 days for females of the European subspecies. Fledglings were first observed at nests monitored in Minnesota between 24 June and 8 July (Roberson 2001).

The fledgling-dependency period is an important period of transition during which the young learn to hunt and protect themselves (USFWS 1998a). Feather growth is not yet complete (Bond 1942, Kenward et al. 1993a), so young are initially incapable of sustained flight and may have special habitat requirements (Bartelt 1977, Kennedy 1989, Kennedy *et al.* 1994, Reynolds *et al.* 1994). For the first 3 weeks after fledging, juveniles tend to remain within 300 m of the nest, after which distance from nest tree increases with time until dispersal (Kennedy *et al.* 1994). Studies evaluating broadcast methods used for goshawk surveys have found fledglings to be responsive to conspecific juvenile food-begging calls during this time (Kennedy and Stahlecker 1993, Roberson *et al*. *In Review*). Dispersal patterns vary with food availability (Kennedy and Ward *In press*). When food availability is high, juveniles stay near the nest and when it is low dispersal is abrupt. In New Mexico, radio-tagged juveniles were independent at approximately 80 days of age (Kennedy and Ward *In press*). In Europe, Kenward *et al*. (1993a) documented that males dispersed approximately 7 days earlier than females.

Nonbreeding Period

This period begins when adults are no longer feeding juveniles and ends with the beginning of courtship. This is the least studied and understood period of the goshawk annual cycle.

Movements

Movements of birds beyond home range boundaries include migration, natal dispersal, and breeding dispersal. *Natal dispersal* is defined as movements between a bird's natal area and its subsequent breeding area, whereas *breeding dispersal* is defined as movements by adults between years among breeding areas (Greenwood 1980). Both types of dispersal are an important component of population dynamics, yet are also the least studied components of bird populations (Lebreton and Clobert 1991, Newton 1991).

Migration/Irruptions

The existence and extent of migratory behavior is geographically and temporally variable, and may be closely tied to food availability (USFWS 1998a). Information on migration patterns is derived primarily from counts at migration stations, band returns, and radio-telemetry, and indicates the goshawk is a partial migrant. 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).

Goshawks in northern areas of their range are known as irruptive or irregular migrants. Irruptive goshawk migrations are believed to be in response to rapid decreases in prey populations because more migrants are reported in years of low food abundance (Mueller and Berger 1968 *in* USFWS 1998a, Mueller *et al*. 1977, Doyle and Smith 1994), although this relationship is not fully understood. Some evidence suggests that irruptions may occur at approximately 10-year intervals and coincide with declines in indices of snowshoe hare and ruffed grouse abundance in breeding areas (Mueller and Berger 1968 *in* USFWS 1998a, Mueller *et al*. 1977). In other areas, migration counts indicate that some populations irrupt on a 4-year cycle (Hawk Mountain; Nagy 1975 *in* USFWS 1998a).

Migrations generally commence after young disperse from natal areas (Palmer 1988) and occur between mid-September and mid-December. Young typically migrate first (Palmer 1988) and adult males and females migrate simultaneously during irruption years (Mueller and Berger 1968 *in* USFWS 1998a, Mueller *et al*. 1977, Nagy 1975 *in* USFWS 1998a). However, migration of young and adults does overlap temporally and irruptions may consist mostly of adult-plumaged hawks, because in years of low prey density, few young may have been produced (Palmer 1988).

Mueller and Berger (1968 *in* USFWS 1998a) summarized band return data from North America up until 1965. However, sample sizes were too small to draw meaningful conclusions concerning migration patterns. Band return data from the European subspecies are more extensive and suggest short distance movements or wandering during the non-breeding season (Buhler and Klaus 1987 *in* USFWS 1998a) occurs for birds that reside in southern latitudes and longer-distance migrations are more common for populations from northern latitudes (Hoglund 1964 *in* USFWS 1998a). Hoffman *et al*. (2002) recently analyzed movement patterns of northern goshawks encountered at migration stations throughout the western U.S. Of the 722 goshawks captured from 1980 – 2001 at these sites only 2.3% of these birds (n = 17) were recaptured/resighted. These few returns do anecdotally support the notion that goshawk counts generally reflect relatively localized movements (*i.e.*, 400 – 500 km or less). Hoffman *et al*. note that this pattern might be disrupted every 10 years during goshawk irruptions. However, they collected data that span a 22-yr period and did not have any evidence of an irruption. Because their data suggest relatively localized movements, Hoffman *et al*. also suggest that counts of hatching-year birds at migration station may serve as an indicator of regional productivity. Researchers (Titus and Fuller 1990; Kennedy 1997, 1998) have discussed the usefulness of migration counts to estimate goshawk population trends and caution that migration data for an irruptive species may require different analytical techniques than those used for non-irruptive species (Titus and Fuller 1990).

At Hawk Ridge in Duluth, Minnesota, more goshawks are banded than anywhere else in North America (Palmer 1988). Data from Hawk Ridge indicate that 1972 and 1982 were years of heavy migration through Duluth (Evans 1983) and annual totals for the peak migration in the early 1990s (> 2,200) were not as great as those of 1982 (5,819) or 1972 (> 5,100; Evans 1982). Goshawks banded at Hawk Ridge have been recovered in northeastern British Columbia, Alberta, Saskatchewan, and Ontario (Evans 1981), and during potential irruption years in Missouri, Texas, Arkansas and Louisiana (Evans and Sindelar 1974, Evans 1981). An adult female banded at Hawk Ridge in 1972 was recaptured in 1982 at Cedar Grove, Wisconsin (Evans 1983) and an adult male banded at Hawk Ridge in 1988 as a young of the year was captured during a radio-telemetry study in north-central Minnesota in 1999 (Boal *et al*. 2001). Evans reported that the female recaptured in Wisconsin died one month later in Waukegan, Illinois at an age of at least 12 years, 6 months. The male recaptured in Minnesota died the following winter at the age of 11 years, 6 months (Boal *et al.* 2001).

Radio-telemetry studies provide information on migration but have sampled too few years to establish long-term patterns (USFWS 1998a). Observations in Alaska (McGowan 1975) and New Mexico (P. L. Kennedy, unpublished data) suggest that some goshawks can be year-round residents. In the WGLR, data from Erdman (1998) indicated that at least some goshawks were year-round residents in Wisconsin in 1996, and data from Boal *et al.* (2001) in north-central Minnesota, and Lapinski (2000) in Michigan indicate goshawks radio-tagged in these studies were year-round residents for the winters of 1998 – 2000. In 1992, goshawks in Wyoming exhibited short distance migration (range = 65 – 185 km; 40 – 115 mile; Squires and Ruggiero 1995), and Reynolds *et al.* (1994) reported altitudinal migrations of very short distances (< 20 km; <12.4 mile) in northern Arizona.

Dispersal

Information on dispersal is important for investigating issues of population isolation and demography. Dispersal and mortality may be more important than reproduction in governing population dynamics, however, these factors are difficult to measure (Braun *et al.* 1996). More information on dispersal for North American populations would be helpful in reaching a better understanding of population dynamics.

Natal Dispersal

Successful dispersal is critical to the genetic and demographic viability of populations (USFWS 1998a). Little is known about the habitats used during dispersal, dispersal direction, or dispersal distances for the goshawk. The available information comes from recapture of marked birds, band returns, radio-telemetry, and satellite-telemetry.

Based on Kenward *et al*. (1993), Ward and Kennedy (1994) and Kennedy and Ward (*In press*) defined natal dispersal as the first time a juvenile spent more than a week at least 2 km (1.25 mi) from the nest. Two records of band recoveries have been reported for the southwestern U.S., occurring in the year of banding at distances of 130 km (81 mi; Kennedy and Ward *In press*) and 176 km (109 mi; Reynolds *et al.* 1994) from the natal nest. Distances from natal nest areas, for recoveries of juveniles radio-tagged in New Mexico, ranged from 5.5 – 176 km (3.4 – 109 mi; n = 16; Kennedy and Ward *In press*). On the Kaibab Plateau, Reynolds *et al*. (2000) reported that 24 of 452 fledglings banded were recruited into the local breeding population. They reported that mean natal dispersal distance was 14.7 ± 8.2 km (SD, range = 3.4 – 36.3 km; 9.1 ± 5.1 mi, range = 2.1 – 22.5 mi) and did not differ among sexes for the recruits. Although the mean for long-distance natal dispersal was not measured due to difficulty in relocating banded birds, 5 banded juveniles found dead outside of the study area demonstrated a potential for long-distance natal dispersal (mean = 181 ± 137 km, range = 52 – 442 km; mean = 112 ± 85 mi, range = 32 – 274 mi).

Kenward *et al.* (1993) reported that natal dispersal in the European subspecies was enabled by completion of feather growth and was accelerated by food shortage, but when food was abundant, probably resulted from behavior modification as goshawks developed hunting skills. Kennedy and Ward (*In press*) experimentally examined the effect of extra food on goshawk post-fledging movements in New Mexico. They found that extra food significantly influenced post-fledging movements of juvenile goshawks. During the late fledgling-dependency period (> 65 days of age until independence) control birds were located in the natal area (< 2 km from nest tree) more frequently than supplemented birds. This pattern reversed after independence (approximately 80 days of age) when supplemented birds were located more frequently in the natal area than controls. After independence the control birds were never located in the natal area and by the end of September the controls had all left the study area (study area boundaries were > 25 km from nest tree). Supplemented birds were never located outside of the study area for the duration of the experiment. They concluded that the control birds dispersed out of the study area and the supplemented birds remained. Since the experimentally fed juveniles remained near a known food source and the controls did not, their study demonstrates that food availability influences at least the first 4 months of post-fledging movement patterns in this population. These results also suggest individuals base dispersal decisions on knowledge of their environment at a local scale, which can influence juvenile recruitment.

Very little information on dispersal is available for the WGLR. Davis (1979) radio-tracked a female and one offspring from late June through September of 1975 near Cloquet, Minnesota. The fledgling and adult met only for food exchanges, and all observations of the juvenile were within a half-mile of the nest until dispersal occurred on 26 August (Davis 1979).

Breeding Dispersal

Breeding dispersal has been defined as movements of adults between breeding areas (Greenwood and Harvey 1982). Although movements of a pair between alternative nests are not considered to be dispersal movements, they may confound detection and interpretation of movement by pairs or individuals to a different breeding area; these two types of movement can only be distinguished when individuals are marked (USFWS 1998a). Breeding dispersal could result from death of a mate, or may represent an attempt to acquire a better mate or breeding area (USFWS 1998a), and may be induced by low productivity (Reynolds *et al*. 1994).

Reynolds *et al*. (1994) reported that in northern Arizona, three birds that moved from one breeding area to another in consecutive years all produced more young after the move. Reynolds *et al*. (2000) reported results of a study of 259 banded adult goshawks breeding in northern Arizona. Six instances of breeding dispersal by males and 11 instances of breeding dispersal by females resulted in a mean breeding dispersal distance for males of 2.4 ± 0.6 km (range = 1.9 – 3.5 km) and for females of 5.0 ± 2.3 km (range = 2.4 – 9.0 km). Both male and female mean dispersal distances were close to the nearest-neighbor distance (mean = 3.8 km, SD = 3.2, n = 97), indicating that dispersers moved to neighboring territories.

In northern California, Detrich and Woodbridge (1994) reported higher rates of breeding dispersal. Over nine years, 18.2% of females (n = 22) and 23.1% of males (n = 13) were found breeding in more than one breeding area. Dispersal distances for females averaged 9.8 km (6 mi; range = 5.5 – 12.9 km; 3.4 – 8.1 mi) and for males averaged 6.5 km (4 mi; range = 4.2 – 10.3 km; 2.6 – 6.4 mi). In southeast Alaska, 4 radio-tagged adult females moved to different breeding areas, with the breeding dispersal distance ranging from 4.0 – 43.3 km (2.5 – 26.9 mi) (Alaska Department of Game and Fish 1996).

The data on natal and breeding dispersal distances should be interpreted cautiously. Accurate estimates of dispersal distance distributions are constrained by study area boundary effects for all approaches except satellite telemetry. This is particularly a problem for studies that estimate these distributions from resightings of banded birds (Koenig et al. 1996).

Spatial Structure

Spatial structure refers to the scale dependent patterns in which birds distribute themselves over the landscape in relation to food, nest areas, habitat, and conspecifics (USFWS 1998a). Two important aspects of spatial structure are dispersion, the spacing of breeding pairs, and density, both emphasizing local distribution of nesting pairs (USFWS 1998a).

Dispersion

Regular dispersion is a consistent characteristic of goshawk populations from both North America and Europe (McGowan 1975, Shuster 1976, Reynolds and Wight 1978, Widén 1985, Buhler and Oggier 1987 *in* USFWS 1998a, Kennedy 1988, Reynolds *et al.* 1994, Reynolds and Joy 1998). Mean nearest neighbor distances range from 2.5 – 6.3 km (1.5 – 4 mi) in Europe (Widén 1985, Buhler and Oggier 1987 *in* USFWS 1998a) and from 2.0 – 5.6 km in North America (1.2 – 3.5 mi; Kennedy 1997; Dewey et al. *In press*).

In Wisconsin, Erdman *et al.* (1998) reported the mean distance between nest clusters in adjacent active breeding areas as 8.8 km (5.4 mi) and a minimum distance of 1.6 km (1 mi, n = 3), observed during years of apparent peak prey densities. The range of nearest neighbor distances was not reported and it is unclear if search efforts were systematic for this study.

The regular distribution of nesting pairs documented over many areas could result from the distribution of habitat and/or territorial behavior (USFWS 1998a). The size of goshawk home ranges, however, makes defense of the entire area unlikely and it also seems unlikely the distribution of habitat is regular enough to result in such consistent spacing (USFWS 1998a). Mutual avoidance in some form seems likely (Leslie 1996) and this spacing behavior may be the mechanism by which raptor populations adjust their nesting density to resource abundance (Newton 1979). Understanding the mechanism by which goshawks distribute themselves is important because density dependence (Maguire 1992 *in* USFWS 1998a) and spacing behavior may limit the number of pairs an area can support at a level lower than what might be estimated due to availability of food or nest areas (Bernstein *et al.* 1991).

Density

Estimates of goshawk densities are based on either censuses of breeding pairs, or the distribution of nearest neighbor distances (USFWS 1998a). Searches for goshawk nests are often conducted only in "suitable" habitat; thus, many studies actually report ecological density (birds per unit of suitable habitat) rather than crude density (birds per unit area; USFWS 1998a). Both techniques rely on several assumptions, including that surveys are complete and accurate. This assumption is problematic because non-breeding birds often go undetected (USFWS 1998a). Estimating nest density by census "require(s) intensive, systematic searches of large areas for nests of goshawks and searches should be repeated over years to detect pairs that do not breed every year" (Reynolds and Joy 1998).

The methods for using census information in density estimates vary, with some studies including the number of traditional nest areas and other studies including only active nests. Also, density estimates are sensitive to the size of the area searched due to edge effects (USFWS 1998a). Regardless of how density is measured, goshawks occur at low densities compared to many avian species (USFWS 1998a). Density estimates from goshawk populations in North America range from less than one to 11 pairs per 100 km^2 (39 mi^2; Leslie 1996). Densities in the range of 10 – 11 occupied nests per 100 km^2 (39 mi^2) were reported for three study areas in Arizona, California, and the Yukon (Kennedy 1997).

Information on historical density of goshawks in the WGLR is non-existent (Rosenfield *et al.* 1991). Rosenfield *et al.* (1996) reported an estimate by T. Erdman of approximately 300 nests in Wisconsin (one pair/9,216 ha; 22,772 ac). The methods for reaching this estimate were not thoroughly explained.

Rosenfield *et al.* (1996) searched three quasi-randomly selected study areas in Wisconsin in 1996 and found one active nest in each area. Composite goshawk nesting density was reported as one pair per 3,807 ha (9,407 ac), with a range of one pair per 3,110 – 4,430 ha (7,685 – 10,947 ac).

Due to the limited number of quadrats, these data should be interpreted cautiously (Dick and Plumpton 1998).

Demographics

Several published and unpublished studies have reported various aspects of goshawk life history in the WGLR (Dick and Plumpton 1998). Siders and Kennedy (1996), Daw *et al*. (1998), Rosenfield *et al.* (1998a), and Kennedy and Andersen (1999) discuss the potential biases due to nonrandom or incomplete nest detection methods, which may apply to some of the studies conducted in this region. No studies with regional coverage concerning goshawk demographics have been conducted (Dick and Plumpton 1998).

Breeding System

Goshawks, like most raptors, are at least serially monogamous (Newton 1979, Reynolds *et al*. 1994). Studies of marked individuals indicate that most birds remain with the same mate for several years (USFWS 1998a). Fidelity to mates is difficult to measure in goshawks because fate of previous mates is often unknown and fidelity can be confounded by mate replacement due to mortality (USFWS 1998a). Estimations of this demographic parameter are confounded by low resighting rates of marked individuals. Also, because it is often difficult to locate all alternative nest areas, fidelity to breeding areas can be hard to determine. Nonrandom, non-systematic, or incomplete searches may bias results when determining breeding area occupancy.

Detrich and Woodbridge (1994) reported that although breeding adults in northern California retained the same mate 72% of the time, the 28% of cases in which adults were found paired with new mates could have been due to death of the previous mate. They also reported that in 3 breeding areas observed for 5 years, 2 males and 2 females bred in three different combinations. Reynolds *et al.* (1994) reported a mate replacement rate of 23% between 1991 and 1992 in northern Arizona (n = 30). Reynolds *et al*. (2000) verified two cases of "divorce" between 1991 – 1999 by confirming that both the male and female were alive in subsequent years. Several incidences of divorce were reported in northern California (Detrich and Woodbridge 1994).

In northern Arizona, Reynolds *et al*. (2000) reported six instances of breeding dispersal by males resulted in a rate of 4.9/100 opportunities, and 11 instances of breeding dispersal by females resulted in a rate of 6.3/100 opportunities. Only 16.7% of breeding dispersals (n = 17) were preceded by nest failure in the prior breeding season, whereas 88.2% of dispersals were preceded by non-return of a mate (Reynolds *et al*. 2000). Most goshawks, however, stayed on their previous year's breeding area despite non-return of mate. Reynolds and Joy (1998) found that breeding area fidelity of males (91.7%) exceeded that of females (78.6%) in Arizona.

In northern California, adult males and females occupied the same breeding area in consecutive years 76.5% and 71.4% of the time, respectively (Detrich and Woodbridge 1994). In southeast Alaska, 4 radio-tagged adult females moved to different breeding areas, but no males did, thus displaying greater nest fidelity than females (Alaska Department of Game and Fish 1996).

Few data are available on mate and breeding area fidelity for the WGLR. Erdman *et al.* (1998) reported breeding area use in Wisconsin for more than 20 years and evaluated mean breeding area occupancy for more than 60 nest areas. They reported mean breeding area longevity of 3.9 years (range = 1 – 28 yrs). Searches of these areas were not systematic and the entire study area was not covered in the search (Erdman *et al.* 1998). Although some nests have been shown to be active from year to year in Minnesota, pair or breeding area fidelity have not been measured with marked individuals (Dick and Plumpton 1998). In their telemetry study in north-central Minnesota, Boal *et al.* (2001) observed that a radio-tagged female goshawk moved 15 km to a different breeding area and a new mate during the courtship period of the year following the death of her mate from the previous year.

Age Structure

Based on plumage characteristics, goshawks can be placed into 3 classes during the breeding season: (1) subadults (1 – 2 years) with primarily juvenile feathers; (2) young adults (2 – 3 years) with primarily adult plumage and some juvenile feathers; and (3) adults (>3 years) with full adult plumage (Bond and Stabler 1941, Mueller and Berger 1968 *in* USFWS 1998a, Henny *et al.* 1985, Reynolds *et al.* 1994). Although subadult female goshawks have been observed breeding, no observations of breeding subadult males have been reported (USFWS 1998a) and examination of subadult male testes of the European subspecies indicates they are physiologically incapable of breeding (Hoglund 1964 *in* USFWS 1998a).

Reports of subadult females and young adults of both sexes breeding vary both geographically and temporally. Reynolds and Wight (1978) reported no observations of subadults among 70 breeding females in Oregon, whereas Henny *et al.* (1985) reported 2 subadult females (4.3%) out of 46 breeding females. Younk and Bechard (1994) reported that, in Nevada, 36% (n = 14) of breeding females were subadult in 1991, no subadults were observed to breed in 1992 (n = 22), and 4% (n = 25) were subadult in 1993. In Europe, breeding subadult females laid eggs approximately 10 to 30 days later than adults (Huhtala and Sulkava 1981). Based on proportions of subadults breeding per year and because breeding subadults in his study used only "non-traditional" nesting areas, McGowan (1975) hypothesized subadults are able to breed only in years of high prey availability. Reynolds *et al.* (1994) reported 6.8% of male and 12.2% of female breeding goshawks trapped in 1991 and 1992 were young adults. Reynolds et al. (2000) reported the mean age of first breeding for 24 young goshawks recruited into their natal breeding population in Arizona as 3.2 years ± 1.1 (range = 2 – 5 yrs) for males and 4.3 ± 1.9 (range = 2 – 8 yrs) for females. They suggested that low recruitment rates and delayed age of first breeding could indicate a stationary, saturated population of breeders on the study area.

Observations of nesting females in juvenile plumage have been reported for the WGLR (Dick and Plumpton 1998), with one female successfully fledging three young in 1978 in Minnesota (Gullion 1981b). Age structure data are not available for the WGLR.

Reproduction

Fecundity of goshawks is difficult to measure and thus, indices of reproductive success have been used. It is important to define the various terminologies used in measures of reproductive success (Steenhof 1987, USFWS 1998a). An *occupied breeding area* is defined as an area exhibiting evidence of fidelity or regular use by goshawks that may be exhibiting courtship behavior and may attempt to breed. An *active breeding area or nest* is defined as an area or nest in which eggs are laid. A *successful breeding area or nest* is one in which at least 1 young is fledged. *Nesting success* is the proportion of active nests that fledge at least one young, or occasionally the proportion of occupied breeding areas that fledge at least one young. *Productivity* is defined as the mean number of young fledged per successful nest, the mean number of young produced per active nest, or the number of young per occupied breeding area.

Biases exist in many estimates of goshawk reproductive parameters. Reproductive success is often overestimated due to the greater probability of detecting breeding versus non-breeding pairs and successful versus unsuccessful nests (USFWS 1998a, Roberson *et.al In Review*). Non-breeding pairs and pairs in which the nest attempt fails early in the nesting cycle often go undetected. In addition, goshawks may use alternative nests up to 1.6 km apart and thus, active nests often go undetected due to insufficient effort in determining occupancy (Crocker-Bedford and Chaney 1988, Dewey et al. *In press*).

Reynolds and Joy (1998) commented on the difficulties of accurately estimating goshawk demographics in their 1991 – 1996 study of dispersal, breeding area occupancy, and demography on breeding areas (n = 107) on the Kaibab Plateau in Arizona. They found a minimum of 80 – 90 breeding areas was needed to accurately estimate annual proportion of pairs laying eggs, and a minimum of 25 – 40 nesting pairs was needed to precisely estimate proportion of successful nests and annual number of fledglings produced per nest.

Proportion of Pairs Breeding

Few data exist on proportion of pairs attempting to nest annually (USFWS 1998a). Widén (1985) reported 67% of adults radio-tagged (n = 12) during winter in Sweden were later found breeding. In northern Arizona, Reynolds and Joy (1998) found the proportion of pairs (n = 478 breeding area-years) annually laying eggs declined from a high of 77 – 87% in 1991 – 93 to lows of 22 – 49% in 1994 – 96. They suggested this annual variation was related to annual fluctuations in prey populations because in years of low prey abundance a greater number of females were probably unable to secure sufficient food to form eggs.

Clutch size

In Alaska, clutch size ranged from 3.0 – 3.8 (mean = 3.2; 1971 – 1973) and no clutches of 5 or more eggs were observed (McGowan 1975). Estimates of average clutch size were 3.75 in Utah (Reynolds and Wight 1978) and 3.2 in Oregon (Lee 1981). Reynolds and Wight (1978) reported the only estimates of hatching success and found 81.2% (n = 5 nests in Oregon) of eggs laid successfully hatched. Johnsgard (1990) reported that although clutch size of goshawks may increase slightly with latitude, little regional variation in clutch size exists in North America.

Nesting Success

Most estimates of nesting success are probably biased because, in general, successful nests are more readily detectable than failed ones (Mayfield 1961, Miller and Johnson 1978, Johnson 1979, Hensler and Nichols 1981, Steenhof and Kochert 1982, Manolis *et al*. 2000). This is particularly relevant for species, such as the goshawk, whose nests are difficult to locate. Timing, duration of surveys, and variation in search effort all affect the magnitude of bias in estimating nesting success (USFWS 1998a). Estimates of nesting success range from 8 – 94% (Squires and Reynolds 1997, Lapinski 2000, Boal *et al*. 2001). Some biases can be eliminated if nesting success is estimated using the Mayfield method (Mayfield 1961, Steenhof 1987), which controls for different detection probabilities for failed and successful nests, or if nests are detected during courtship (Roberson *et. al In Review*).

Causes of nest failure include human disturbance, such as shooting of adults, recreational use of an area, and tree harvest activities (Hoglund 1964 *in* USFWS 1998a, Hennessy 1978, Buhler *et al.* 1987 *in* USFWS 1998a); avian predation (Hennessy 1978, Ward and Kennedy 1996); mammalian predation (McGowan 1975, Hennessy 1978, Doyle and Smith 1994, Erdman *et al*. 1998); disease (McGowan 1975, Ward and Kennedy 1996); and inclement weather (Hennessy 1978, Boal *et al*. 2001). Food limitation can result in higher predation rates on nestlings because female goshawks spend more time foraging and less time defending their young (Ward and Kennedy 1996, Dewey and Kennedy 2001).

Productivity

Productivity can be defined as the number of young fledged per nest where eggs were laid and is the most commonly used statistic quantifying raptor reproduction (Newton 1979). It has become acceptable to consider young observed at 80% of fledging age as surviving to fledge (Steenhof 1987) and Kennedy (1997) defined productivity as the mean number of bandable young produced per occupied breeding area. Standardization of terminology and techniques and reliable estimates of variability are important for comparisons among data sets (Steenhof 1987). Methods should be considered when comparing productivity estimates from different studies.

Productivity ranges from 1.4 – 3.9 young per successful nest in North America and 1.9 – 3.1 in Europe (USFWS 1998a). The highest estimates of productivity in North America are from the northern portion of the goshawk's range in Yukon, Canada and interior Alaska (McGowan 1975, Doyle and Smith 1994). McClaren *et al*. (2002) recently analyzed the spatial and temporal variation in productivity with long-term datasets from 3 study areas, northern New Mexico, northern Utah, and Vancouver Island, BC. Their results indicated that productivity varied annually but had little spatial variation. These results suggest that temporal patterns such as local weather and fluctuating prey populations influence goshawk reproduction more than spatial patterns such as variation in local habitat characteristics. They also concluded that nest productivity may inadequately reflect spatial patterns in goshawk reproduction and so it would be premature to assume that habitat quality for goshawks was equal among nest areas within these 3 study areas. They recommended that future research should examine spatial variability among nest areas in adult and juvenile survival rates to gain a complete picture of population responses to habitat change (McClaren *et al*. 2002).

Penteriani *et al*. (2002) reported that nest stands for male goshawks that successfully reproduced differed significantly from nest stands for males that were unsuccessful based on six parameters of nest trees and four parameters of forest stands within 1-ha (2.5 ac) plots. Krueger and Lindstroem (2001) used long-term (1975 – 1999) population data from a goshawk population in Germany to per capita population growth rate. They reported that goshawk territories that were occupied more often and earlier had a higher mean brood size, thus supporting predictions of site-dependent population regulation. They also found annual mean habitat quality was included in the most parsimonious model explaining per capita population growth rate (Krueger and Lindstroem 2001). Clough (2001) reported the number of young fledged per nest was positively correlated with the density of large-sized trees in nest areas, and negatively correlated with the size of forest openings near the nest and sapling densities in nest stands. Results from these studies suggest that habitat quality may play a factor in goshawk productivity.

Christiansen *et al.* (1998) reported one of seven breeding nests in upper Michigan produced a fledgling in 1996, and all of six breeding areas were successful in 1997. Lapiniski and Bowerman (2000) reported total productivity for 1996 – 1999 as 1.7 young per successful nest (n = 24) and 1.1 for occupied nests (n=36). Bowerman *et al*. (1999) compared productivity, falconry takes, and mammalian predation among their study sites in the Lower Peninsula of Michigan (n = 31 active nests), the Upper Peninsula of Michigan (n = 36), northeastern Wisconsin (n = 70), and northwestern Wisconsin (n = 22) for the years 1996 – 1999. The highest productivity (1.61 young per active nest) was reported in the Lower Peninsula of Michigan and the lowest (1.14) in the Upper Peninsula of Michigan. Northeastern Wisconsin productivity was 1.43 and northerwestern Wisconsin productivity was 1.36. Falconry takes for Wisconsin were 5 from the northeastern part of the state and 1 from the northwestern part. Mammalian predation at nests was highest in northeastern Wisconsin with a total of 20 incidents reported; 9 were reported for the Upper Peninsula of Michigan; 4 were reported for northwestern Wisconsin; and none were reported for the Lower Peninsula of Michigan. Bowerman *et al*. (1999) suggested that in all of these areas except the Lower Penisula of Michigan, goshawks have impaired reproduction and attributed low productivity to increased fisher (*Martes pennanti*) populations. Fishers are apparently not found in the Lower Peninsula of Michigan.

In Minnesota, Martell and Dick (1996) reported a mean of 2.4 young per successful nest (n = 5) in 1995, and Hines (1997 *in* USFWS 1998a) reported 2.2 young per successful nest (n = 5) in 1997. Boal *et al*. (2000b) reported fledglings per successful nest and fledglings per all nesting attempts in north-central Minnesota as 2.10 ± 0.23 and 1.75 ± 0.31 in 1998, 2.17 ± 0.31 and 0.87 ± 0.31 in 1999, and 1.4 ± 0.16 and 1.14 ± 0.17 in 2000. Mean number of fledglings for all three years was 1.85 ± 0.14 for successful nests, and 1.14 ± 0.17 for all nesting attempts. Boal *et al*. (2001) reported that of 17 nest failures (40.5% of total nests observed) documented over three years (1998 – 2000) in northern Minnesota, 4 were due to mammalian predation, 3 were due to avian predation, two were suspected to be due to predation, and 6 were suspected to be weather related. Six (35%) nesting failures occurred during the nestling stage (Boal *et al.* 2001).

In Wisconsin, Rosenfield *et al.* (1996) reported that 11 (85%) of 13 goshawk nests fledged at least one young in 1996, with a mean number of 1.7 fledged young per successful nest (median = 2.0). Both nest failures occurred during incubation for unknown reasons. They also noted that, from 1977 – 1982, 21 successful nests in 10 Wisconsin counties produced a mean of 2.1 (median = 2.0) young of bandable age. Rosenfield *et al.* (1996) reported that because a high proportion of nests in their study were found in the later stages of breeding when nests may be more conspicuous, their nesting success data might be skewed toward successful nests. Of the five nests they found during the incubation stage, 60% successfully fledged young (Rosenfield *et al.* 1996).

Erdman *et al*. (1998) reported productivity for goshawks nesting in northeastern Wisconsin from 1968 – 1992. Fledglings per nesting attempt ranged from a high of 3.2 in 1978 to lows of 0.8 in

1983 and 1989. A prey index was developed based on prey remains and pellets containing snowshoe hare and ruffed grouse; Erdman *et al*. (1998) found annual productivity was correlated with the prey index. Except for three years, the number of fledglings per nesting attempt was equal to the number of fledglings per successful nest from 1968 – 1982; whereas, the number of fledglings per nesting attempt was lower than the number for nesting successes for 1982 – 1992. Erdman *et al*. (1998) reported this lower productivity rate was most apparent from 1988 – 1992 when a severe drought and an outbreak of forest tent caterpillars (*Malacosoma disstria*) led to defoliation of trees in the study area. They also reported "most if not all of the productivity loss was the result of fisher predation, mainly during incubation." It is not clear in Erdman *et al*. (1998) how this source of predation was identified. Erdman (1998) also documented raccoon (*Procyon lotor*) predation on goshawk nests.

Nestling mortality rates have been estimated in only a few studies in North America. Reynolds and Wight (1978; Oregon) reported an average nestling mortality rate of 28%. Ward and Kennedy (1996) and Dewey and Kennedy (2001) estimated nestling mortlaity in their food supplementation experiments in New Mexico and Utah, respectively. In New Mexico, nestling mortality rates for controls averaged 0% in 1992 (n = 16) and 63 % (n = 8) in 1993. Treatment (birds provided with extra food) mortality was similar in 1992 (20%; n = 15) but significantly lower then controls in 1993 (10%; n = 10). Dewey and Kennedy had similar results where treatment mortality was significantly lower then controls in only 1 year of their 2-yr study (1996: controls – 11%, treatments – 7%; 1997: controls – 44%, treatments – 0%). These results support the results of McClaren et al. (2002) that productivity is highly variable temporally. They also demonstrate that productivity is limited by food availability but not in all years.

Survival and Population Growth Rate

Few data exist regarding goshawk mortality for adults, nestlings, or juveniles, and temporal trends in survival have not been adequately evaluated (Kennedy 1997). Braun *et al.* (1996) reported that a large portion of observed annual mortality occurred outside of the breeding season and was therefore not easily detected. Due to lack of sufficient survival information, population growth rates are not available for North American goshawk populations (Kennedy 1997).

Reynolds and Joy (1988) reported annual survival rates of males as 0.69 (SE = 0.06) and females as 0.87 (SE = 0.05) in northern Arizona, but found rates of population change could not be estimated in their study because they were unable to determine the survival rates of the juvenile age class. They used the capture-recapture methodology and model selection procedures outlined in Lebreton *et al.* (1992).

Using the same methodology, DeStefano *et al.* (1994) calculated adult survival rates for goshawks in northern California and reported estimates of 0.61 (SE = 0.05) for males and 0.69 (SE = 0.09) for females. The authors note that these estimates are probably imprecise due to small sample size and emigration off the study area, which contributes to low resighting values. Kennedy (1997) analyzed 12 years of mark-resighting data on 45 adults and estimated the 95% confidence interval of annual adult survival to be 0.60 – 0.96. Kennedy (1997) concluded that precise estimates of survival required large numbers of marked birds (> 100), high resighting rates, and at least five years of data.

Survival information is non-existent for the WGLR as a whole. Erdman *et al.* (1998) reported a 40% annual nesting turnover of females at nest areas in Wisconsin and calculated an estimate of annual adult survival as 0.80 based on mark-resighting data. These are also likely minimum estimates, as they do not allow for breeding dispersal outside of known breeding areas.

Longevity

Age records for wild birds include a six-year-old bird in Alaska (McGowan 1975), five- and seven-year-old birds in northern California (Detrich and Woodbridge 1994), a nine-year-old bird in New Mexico (P. Kennedy, pers. comm.), an eleven-year-old male in Minnesota (Boal *et al.* 2001), and a twelve-year-old female in Wisconsin (Evans 1981). Bailey and Niedrach (1965) reported a captive bird living 19 years and Kenward *et al.* (1999) has documented a wild bird of 19 yr.

Population Status and Viability

Biologists and managers rarely have all the information needed to conduct a fully quantitative population viability analysis (PVA; Beissinger and Westphal 1998) and this is certainly true for goshawks in the WGLR (Estabrook 2000). Graham *et al.* (1999) suggested one practical alternative is to use inventories of the quality, quantity, distribution, and connectivity of goshawk habitat as a surrogate for PVA. This has not been done for the WGLR and may be a worthwhile exercise once goshawk habitat in the WGLR is adequately described.

Because the densities and vital rates of populations vary spatially and temporally, developing a reliable goshawk population model can be difficult (Kennedy 1997). The amount of available goshawk information for different regions of North America also varies. In the WGLR, the population status of goshawks is largely unknown (Dick and Plumpton 1998). Existing information on goshawk population ecology in the WGLR primarily consists of long-term monitoring of reproductive success at known nest areas (Kennedy and Andersen 1999).

Erdman *et al.* (1998) reported that reproduction in goshawks was insufficient to maintain a stationary population and concluded that populations are declining in northeastern Wisconsin. However, another study in Wisconsin (Rosenfield *et al.* 1998a) found goshawks nesting widely throughout the northern two-thirds of Wisconsin with no evidence of range contraction, which might be expected if the state's population was declining (Kennedy 1997).

The degree of isolation between goshawk populations in the region is unknown and questions of population viability at a forest, state or regional level are affected by this uncertainty (Dick and Plumpton 1998). Available information suggests the populations in Michigan, Wisconsin, Minnesota, and Ontario are not closed (Rosenfield *et al.* 1996, Dick and Plumpton 1998). An extensive analysis of band return information from Hawk Ridge and other stations in the region may be useful in determining the degree of isolation among local populations (Dick and Plumpton 1998).

Cyclic variation in goshawk population size in the WGLR breeding populations has yet to be fully demonstrated, but must be taken into consideration when undertaking any attempts to estimate demographic parameters (Postupalsky 1998). Goshawks prey on some species that exhibit cyclic population fluctuations and their populations increase in some areas in response to increases in populations of their prey (Mueller and Berger 1968 *in* USFWS 1998a). Although migrations past banding stations, such as Hawk Ridge, do show cyclic variations in numbers, any references to population trends in the region are based on limited geographic areas and should not be considered representative (Dick and Plumpton 1998). In summarizing more than two decades of monitoring in Wisconsin, Erdman *et al.* (1998) reported the number of active goshawk nests appeared to be related to prey abundance, as indexed through snowshoe hare and ruffed grouse found in goshawk prey remains and pellets.

Postupalsky (1998) defined high and low years in the goshawk population cycle by the number of nests located per year in the Upper and Lower Peninsulas of Michigan. He noted that the amplitude of fluctuations throughout Michigan appeared to be less than those reported in some Canadian studies, but that fluctuations appeared to be greater in the Upper Peninsula than the Lower Peninsula in Michigan. Postupalsky (1998) reported that although mean brood size changed little throughout the cycle, the principal component of reproductive success that changed between high and low points of the cycles was the proportion of occupied nests that fledged at least one young. The methods and sample size that Postupalsky (1998) used to come to these conclusions is unclear.

POTENTIAL THREATS

In our opinion, there is not enough quantitative information currently available to determine if goshawk populations in the WGLR are declining, stationary, or increasing. However, there are a number of factors that have been cited by researchers and managers as being potentially detrimental to current and future goshawk viability. These include, but may not be limited to, habitat alteration, direct human disturbance, predation, competition, disease, siblicide and/or cannibalism, pesticides and other contaminants, and take of individuals.

Habitat Alteration

Biologists and land managers in the WGLR have raised concerns over destruction and modification of goshawk nesting, post-fledging, foraging, and wintering habitat (Dick and Plumpton 1998). The issues cited by researchers, agency personnel, and others as potential threats to habitat caused by various silvicultural treatments include forest fragmentation, creation of even-aged and monotypic stands, potential increase in acreage of younger age classes, and loss of tree species diversity (Anonymous 1993, Noll West 1998, MNCFWRU 1998, Dick and Plumpton 1998).

Few studies of goshawk habitat have included sufficient survey effort, sample size, or statistical power to demonstrate changes in goshawk behavior or nesting success resulting from a particular timber harvest activity. However, there is clearly some level of habitat change that will render a landscape unsuitable for occupancy and reproduction by goshawks (USFWS 1998a). In northern Arizona, Crocker-Bedford (1995) found that in selectively harvested nest areas (n = 11) reoccupancy rates declined to 9% of that found in nonharvested controls (n = 12) and nesting success declined to zero. The harvested areas were selectively harvested in 70 – 90% of 2,290 ha (5,650 ac) circles around goshawk nest clusters. Kenward (1982) reported that home range size of goshawks varied to encompass a sufficient amount of preferred foraging habitat and Crocker-Bedford (1998) has also hypothesized that home ranges are larger and breeding areas more widely spaced in landscapes where less foraging area exists in stands. Assessment of effects of timber harvest on goshawk populations should consider the spatial relationships among different functional levels of habitat use by goshawks, including nesting habitat, foraging habitat, winter habitat, and important prey species and their habitat requirements (USFWS 1998a).

Habitat quality can be reflected in goshawk fitness, nesting success and productivity, degree of fidelity to breeding area and mate, size of home range and population densities of both goshawks and prey species (Reynolds *et al.* 1994). Timber harvests can impact the structure, function and quality of both nesting and foraging habitat by removing nests and nest trees, modifying or removing entire nest stands, and removing canopy and mature trees, snags, and downed wood (Reynolds 1989, Crocker-Bedford 1990, Bright-Smith and Mannon 1994, Woodbridge and Detrich 1994, Beier and Drennan 1997, Desimone 1997, McGrath 1997, USFWS 1998a). Reduction and fragmentation of habitat may favor early successional competitors and predators such as red-tailed hawks (*Buteo jamaicensis*) and great horned owls (Woodbridge and Detrich 1994).

Forest management practices, such as the use of controlled fire and selective thinning, may improve habitat for goshawks by opening up dense understory vegetation, creating snags, down logs, woody debris, and other conditions that may benefit goshawks and their prey (Reynolds *et al.* 1992, Graham *et al.* 1999). To determine the effect of silvicultural prescriptions on potential nest habitat, expected post-harvest stand density and canopy closure should be compared to local definitions of mean structural attributes of nest area habitat (USFWS 1998a). Mean structural attributes of nest area habitat have not yet been determined for the WGLR. The relationship between these structural attributes and the ability of stands with certain structural characteristics to support sufficient prey populations and provide protection from predators also needs to be determined.

Nesting and Post-Fledgling Areas

The effect of timber harvests on goshawk nest habitat can be described as the area of potentially suitable forest that meets local definitions from nest habitat studies, and that is modified to a condition no longer meeting the definition (USFWS 1998a). Desimone (1997) suggested little or no habitat alteration within aggregate nest stands and Bright-Smith and Mannan (1994) stated that tree harvest methods that create large areas with reduced canopy cover of less than 35 – 40% may be particularly detrimental to potential goshawk nesting habitat. Reynolds (1989) stated that practices such as selective overstory removal or patch and clear-cut harvesting, resulting in either a complete removal of trees or a reduction of the stem density and canopy cover throughout management units, lower the quality of goshawk nesting habitat. Reduction of canopy closure may result in increased solar radiation and heat stress, reduced buffering from adverse weather, and increased visibility to predators, all of which may singly, or in combination, affect goshawk nesting success (USFWS 1998a).

Using a quasi-experiment, Penteriani and Faivre (2001) tested some assumptions about within nest stand harvest. They examined the effects of shelterwood harvest within goshawk nesting stands on European goshawk occupancy and productivity. During this long-term study

(1984 – 1995 in Italy and 1993 – 1999 in France) they compared trends in occupancy and productivity in logged and unlogged stands and also assessed the logging effects on the same nesting stand (n = 9 stands) before and after timber harvest. According to the authors, the forest system in both study areas is similar in terms of forest structure, scale and pattern of felling methods, method of regeneration and rotation length. In both areas, new growth is established mainly by clearance of the mature stand in successive felling steps. The harvest of mature and old-growth stands, which occurs primarily from mid-September to mid-April and represents the typical nesting habitat of goshawks in both study areas, starts with a light thinning, removing 10% of the stand trees. The regeneration process continues with 4 stages: 3 progressive steps of 20% felling, and a final 30%. The time between the first thinning and the final removal is quite different for each mature stand but was generally 10 – 15 yr where tree removal occurred once every 2 – 3 yr.

Penteriani and Faivre (2001) found no difference in productivity of goshawk pairs reproducing in unlogged vs. logged stands. When considering the same nesting stand, before and after timber harvest, they noted no short-term differences in productivity. They observed that 87.5% of goshawk pairs nesting in logged stands moved away only when the original stand structure was altered by > 30% and then they moved to the nearest neighboring mature stand. Although sample sizes were small, the results of this study suggest goshawks can tolerate some levels of timber harvesting within the nesting stand (if harvest is avoided from February through August), as long as cover reduction does not exceed approximately 30%. However, it is important to note that Penteriani and Faivre (2001) did not specify the total canopy closure in stands before and after timber harvesting and other studies have shown that goshawks appear to select nesting stands based, at least in part, on high canopy cover (Daw *et al.* 1998). The applicability of this study to North America is unknown because there are no comparable studies to the Penteriani and Faivre (2001) study in North America.

Daw and DeStefano (2001) reported that PFAs in Oregon were dominated by dense-canopied forest and always contained wet openings. Their findings support management recommendations that "call for maintaining the PFA in forest conditions intermediate between the high foliage volume and canopy cover of nest stands and more open foraging habitats" (Daw and DeStefano 2001).

Relatively few studies have addressed the patch size of forest stands that goshawks may select for nesting (USFWS 1998a). Based on observations of feathers, whitewash, and prey remains, Reynolds (1988) defined the nest area as approximately 12 ha (30 ac) of intensified use surrounding the nest. Woodbridge and Detrich (1994) suggested that although small (12 – 24 ha; 30 – 60 ac) stands were used successfully for nesting, goshawks preferred larger (34 – 80 ha; 85 – 200 ac) stands for nesting because occupancy rates of forest stands used for nesting decreased with decreasing stand size. The larger, approximately 168 ha (420 ac) area used by fledglings during the fledging-dependency period (Kennedy *et al.* 1994), further supports the theory that larger patches of mature forest surrounding goshawk nests may be important (USFWS 1998a).

Although assessment of habitat abundance for goshawk nest areas is often made at broad scales, there is evidence to suggest that landscape features such as slope, aspect, riparian vegetation, meadows, drainages, water, and other features affect location of goshawk nest areas (Allison 1996 *in* USFWS 1998a). Timber harvests associated with these physiographic features may have a disproportionate effect on habitat suitability if selection of nest areas by goshawks is at least partially dependant on them (USFWS 1998a).

Foraging Areas

Habitats used for foraging by goshawks have been documented in a small number of telemetry studies (Austin 1993, Hargis *et al*. 1994, Bright-Smith and Mannan 1994, Beier and Drennan 1997, Boal *et al*. *In Review*b). These studies suggest that goshawks select foraging areas with specific structural attributes, including old or mature forest stands with open understories, relatively high canopy closure, large trees, and high stem densities. It is possible, however, that actual foraging habitat selection occurs at spatial and temporal scales difficult to investigate using radio telemetry (USFWS 1998a). Small openings, tree fall gaps, edges, riparian zones, and rock outcrops are examples of small-scale landscape elements that may be important to foraging goshawks (Squires and Reynolds 1997).

Goshawk foraging success also depends upon the habitat requirements of important prey species (Reynolds *et al.* 1992). Much of the current literature suggests that goshawks are food limited, particularly in low quality habitats, resulting in reduced fitness and reproduction, greater interspecific competition for food, and greater susceptibility to predators (USFWS 1998a, Reynolds *et al.* 2000). Food availability may also affect the distribution and abundance of raptors, their breeding area or home range sizes, the proportion of pairs breeding, nesting success, and productivity (Schoener 1968, Southern 1970 *in* USFWS 1998a, Galushin 1974, Baker and Brooks 1981, Smith *et al.* 1991). Goshawks have been documented to forage away from forest cover in naturally open habitats if prey is available (Younk 1996 *in* USFWS 1998a, Woodbridge and Detrich 1994). It cannot be assumed, however, that adequate prey will necessarily be available in openings created by timber harvests, which often result in dense re-growth where goshawks would be unlikely to detect or capture prey (USFWS 1998a). Also, populations of many prey species are linked to structural attributes such as snags, large logs, large trees, soil organic horizon depth for fungi, and hardwoods for mast, which may not be maintained under silvicultural prescriptions, unless prescriptions are specifically designed to maintain them (Reynolds *et al*. 1992, USFWS 1998a).

Goshawk habitat can be maintained or restored through means such as protection of specific areas, control of tree spacing, length of tree-cutting cycles, and management strategies that sustain the structure, function, and ecological processes of forests that are important to goshawks (Reynolds *et al*. 1992, USFWS 1998a).

Human Disturbance

Human disturbance associated with timber practices and other activities may affect goshawks and can cause nest failure, especially during incubation (Boal and Mannan 1994, Squires and Reynolds 1997). Camping near nests has also been determined to cause nest failure (Speiser 1992). Disturbances associated with research are usually of short duration, and appear to have little impact on nesting birds (USFWS 1998a). Observations of nests for short periods of time following hatching of young and trapping of adults for banding or attaching radio transmitters during nesting has not been documented to cause desertion (Austin 1993, Squires and Reynolds 1997). The USFWS (1998a) reported that “disturbance generally does not appear to be a significant factor affecting the long-term survival of any North American goshawk population."

Predation

Predation is a natural mortality factor in raptor populations. It is unknown if predation of goshawks is increasing due to increased forest fragmentation from forestry practices nor if predation rates are significantly reducing survival. However, studies on passerines suggest that at some level of fragmentation and/or reduction of canopy cover predation rates increase (Brand and George 2000, Manolis *et al*. 2000, Zanette and Jenkins 2000). Goshawks are occasionally killed by large raptors, such as eagles (Squires and Ruggerio 1995), great horned owls (Rohner and Doyle 1992), and conspecifics (Boal and Bacorn 1994), as well as mammals, such as pine martens (*Martes americana*), fishers, and raccoons (Paragi and Wholecheese 1994, Doyle 1995). Several studies have indicated predation may increase during periods of low food availability because females may spend more time away from the nest foraging instead of protecting young (Zachel 1985 *in* USFWS 1998a, Rohner and Doyle 1992, Ward and Kennedy 1996, Dewey and Kennedy 2001).

Due to its wide distribution within the goshawk's geographic range, its size, abundance, and capacity for preying on large raptors, the great horned owl is one of the most important predators of goshawks (Orians and Kuhlman 1956, Hagar 1957, Luttich *et al.* 1971, Houston 1975, McInvaille and Keith 1974). Goshawks aggressively defend their nests against predators during the day. However, they are less capable of doing so at night and most reports of predation by great horned owls are losses of nestlings, although adults are occasionally taken (Rohner and Doyle 1992). The effect of great horned owl predation on goshawk populations is unknown (USFWS 1998a), but predation rates as high as 49% on nestling red-tailed hawks has been reported. This suggests the owl's potential to impact goshawk nestling survival is great (Luttich *et al.* 1971). Great horned owls begin nesting earlier than goshawks and occasionally lay eggs in goshawk nests, forcing goshawks to construct or use alternative nest areas (Reynolds *et al.* 1994, Woodbridge and Detrich 1994). Alternative nest sites are often in close proximity, which may increase the potential for reciprocal predation between the goshawk and owl (Gilmer *et al.* 1983, Rohner and Doyle 1992).

Predation on goshawks by avian and mammalian predators has also been reported in the WGLR. Erdman *et al.* (1998) suggested that fisher predation is a major cause of nest failure and incubating female mortality in northeastern Wisconsin with annual turnover rates of nesting females exceeding 40%. Metal baffles have been used on nest tree trunks in this area since 1988 to reduce predation by mammals (Erdman *et al.* 1988), but the effectiveness of this technique has not been tested. Erdman *et al.* (1998) also reported a great horned owl feeding a female goshawk to its young (Erdman 1993). Erdman *et al.* (1998) and others (Anonymous 1993, MNFWRU 1998, Noll West 1998, Bowerman *et al*. 1999) have suggested that in the WGLR, nesting goshawks, their eggs and young may experience increased susceptibility to fisher and raptor predation as a result of habitat modification and increased predator densities (Dick and Plumpton 1998).

Postupalsky (1993) reported predation by great horned owls on goshawks in Michigan. Also in Michigan, Bowerman *et al.* (1998) reported three of eleven banded young died due to predation and five breeding areas failed during the nestling period due to mammalian predation

(Bowerman *et al.* 1998). Duncan and Kirk (1995) reported that great horned owl, raccoon and fisher are the most significant predators of goshawks in Canada. Boal *et al.* (2001) reported that out of 5 adult goshawks depredated during the breeding season (four females, one male) during 1998 – 2000, 2 deaths were caused by mammalian predation, 2 were caused by great horned owls, and one was caused by a diurnal raptor.

Little is known about the extent of predation on goshawks during winter. Squires and Reynolds (1997) reviewed reports of predation on goshawks, including instances by eagles (Squires and Ruggiero 1995) and martens in winter (Paragi and Wholecheese 1994).

Competition

The extent to which interspecific competition for habitat and prey affects goshawk habitat use is not well understood. Fragmentation of forested habitats can make the affected areas more accessible and attractive to competing species such as red-tailed hawks and great horned owls, potentially decreasing habitat available to goshawks (USFWS 1998a). In addition, these potential competitors also function as potential predators (see previous section) making the effect of their presence difficult to interpret. Goshawks may be excluded from nest areas by other raptors, although it is not uncommon for goshawks and other raptors to nest close to one another (Reynolds and Wight 1978). Great horned owls, spotted owls (*Strix occidentalis*), and great gray owls (*Strix nebulosa*) often breed in nests previously built by goshawks (Forsman *et al.* 1984, Bryan and Forsman 1987, Buchanan *et al.* 1993). In Minnesota, great gray owls have been observed using nests previously used by goshawks, with the goshawk pair building a new nest or using an alternative nest nearby (n = 3; A. M. Roberson, U.S. Fish and Wildlife Service, unpublished data).

Although Cooper's hawks and goshawks have a similar preference for nest habitat (Reynolds *et al.* 1982, Moore and Henney 1983, Siders and Kennedy 1994), and nest in the same stands (P.L. Kennedy, Oregon State University, unpublished data), Cooper's hawks are smaller than goshawks and begin nesting later (Reynolds and Wight 1978); thus they are unlikely to be effective nest site competitors. This has also been demonstrated for the common buzzard (*Buteo buteo*) which is a smaller-bodied raptor nesting sympatrically with the European goshawk. Krüger (2002) recently did a multivariate discriminate analysis of nest site characteristics of the common buzzard and European goshawk (392 nests of both species combined). His results showed substantial overlap between the two species and he concluded this is good evidence for competition for optimal nest sites. The utility of niche overlap data for evaluating competition is debatable, but it suggests the buzzard (the smaller bodied species) might be constrained by the larger-bodied European goshawk in its nest site selection. Krüger (2002) experimentally examined the behavioral interactions between common buzzard (*Buteo buteo*) and European goshawk and their effects on buzzard breeding success and brood defense using dummies and playback calls. Buzzards had a significantly lower breeding success when presented with a goshawk dummy compared to control broods but there was no effect of buzzard dummies on buzzard reproductive success. European goshawks were far more aggesive against an intraspecific dummy than buzzards. Krüger concluded buzzards perceive a goshawk more as a potential predator rather than a competitor.

Several species of hawks and owls, and numerous mammalian predators can potentially compete with goshawks for prey (USFWS 1998a). The red-tailed hawk and great horned owl prey on many of the same species as goshawks (Fitch *et al.* 1946, Luttich *et al.* 1970, Janes 1984, Bosakowski and Smith 1992), although neither has the same degree of dietary overlap with goshawks as does the Cooper's hawk, which also forages in the same habitat (Storer 1966, Reynolds and Meslow 1984, Bosakowski *et al.* 1992). Because both the red-tailed hawk and great horned owl are more abundant in open habitats, such as meadows, edge, forest openings, and woodlands (Spieser and Bosakowski 1989), "the extent to which they coexist and compete for food with goshawks probably varies by the openness of forest types and extent of natural and anthropogenic fragmentation of a forest" (USFWS 1998a).

A variety of mammalian carnivores, including foxes (*Vulpes spp*.), coyotes (*Canis latrans*), bobcats (*Lynx rufus*), Canada lynx (*Lynx canadensis*), weasels (*Mustela frenata*), and pine martens are sympatric with goshawks in most North American forests and feed on some of the same prey species as goshawks, such as rabbits and hares, tree and ground squirrels, grouse, and other birds (USFWS 1998a). Erlinge *et al.* (1982) demonstrated that the combined consumption of large numbers of small vertebrate by numerous sympatric species of carnivores, owls, and hawks in Sweden resulted in food limitations.

Disease

Although disease has been documented in goshawks in the WGLR (Redig *et al.* 1980), it is not believed to be one of the primary threats to goshawk populations in the region (Dick and Plumpton 1998). In addition, the USFWS found that there were no data to show that disease has a significant effect on the likelihood of long-term goshawk persistence in the U.S. West (USFWS 1998a). Mortality from diseases may be exacerbated by food shortage (Newton 1979).

Redig *et al.* (1980) reported aspergillosus (*Aspergillus fumigatus*) in 53% of 49 goshawks trapped in 1972 and 7% of 45 in 1973 during migration at Hawk Ridge in Minnesota. They suggested that the trapped goshawks were birds emigrating from northern forests due to low prey abundance, and that the epizootic was the result of increased stress on the hawks due to increased agonistic interactions, reduced prey availability, and migration (Redig *et al.* 1980).

Internal parasites are common and heavy infestations of ectoparasites like lice (*Degeeriella nisus vagrans*) may occur in weakened birds (Keymer 1972 *in* Squires and Reynolds 1997, Lierz et al. 2002b). Greiner *et al.* (1975 *in* USFWS 1998a) estimated that 56% of North American birds had blood parasites, including Leucocytozoon, Haemoproteus, Trypanosoma, and microfilariae. Trichomoniasis can be transmitted to raptors that ingest infected prey, usually columbids, which are hosts to *Trichonomonas gallinae*, a parasitic protozoan. It is apparently common in falconry birds (Szymanski and Houszka 2002). T. Erdman (personal communication to Dick and Plumpton 1998) reported trichomoniasis among goshawks in areas where pigeons are abundant in Wisconsin. Ward and Kennedy (1996) reported the cause of death of a nestling in New Mexico as heart failure due to severe fibrinous pericarditis on the heart caused by *Chlamydia tsittaci* and *E. coli*. Lierz et al. (2002a) reported antibodies against falcon herpevirus in European goshawks found injured or debilitated and Lierz et la. (2002b) identified a new fluke (*Hovorkonema variegatum*) in raptors in a rehabilitated goshawk. The potential impact of west Nile virus (a newly observed avian disease in the WGLR) on WGLR goshawk populations is unknown.

Siblicide/Cannibalism

Siblicide and cannibalism appear to be infrequent and associated with food deprivation (Schnell 1958). Estes *et al*. (1999) presented evidence based on observations of siblicide at control nests during a food supplementation study that are consistent with the idea of siblicide as a mechanism for brood reduction when food availability is low. Two observations of cannibalism of goshawk nestlings have been reported at nests in Minnesota, but in both cases the factors influencing the cannibalism were unknown (Dick and Plumpton 1998, Boal *et al*. 2001).

Pesticides and Other Contaminants

In the early 1970s, pesticide levels were high in raptors in the U.S., such as peregrine falcons (*Falco peregrinus*), osprey (*Pandion haliaetus*), and sharp-shinned hawks (*Accipiter striatus*), but were low in goshawks (Snyder *et al.* 1973). It is possible that the goshawk is less susceptible to pesticide accumulation than other accipiters, such as the Cooper's hawk, because the goshawk's prey species tend to accumulate less pesticide in their tissues (Rosenfield *et al.* 1991). Goshawks wintering in Illinois during the 1972 – 1973 irruption year contained less organochlorine and PCB residues than did other raptors (Havera and Duzan 1986). These birds were probably from nonagricultural northern forests. The USFWS concluded that pesticides and other contaminants appear to have not significantly affected goshawks in the U.S. West (USFWS 1998a).

Falconry

Although take of goshawks through shooting, trapping, poisoning or other means is generally illegal, falconry is one means by which live goshawks can be legally taken (USFWS 1998a). In an Environmental Assessment (EA) on falconry and raptor propagation regulations, the USFWS (1988) concluded that falconry is a small-scale activity that has no significant biological impact on raptor populations. Mosher (1997) examined data reported by Brohn (1986) and falconers' annual reports and concurred with the conclusions reached by the USFWS.

The impact of falconry on goshawk populations in the WGLR has been discussed at several meetings by biologists and land managers (Dick and Plumpton 1998). No data are currently available to evaluate the number of goshawks that can be sustainably harvested from regional populations. However, Erdman *et al.* (1998) and others at various meetings in the WGLR (Anonymous 1993, MNCFWRU 1998, Noll West 1998) have cited take of goshawks for falconry as a potential threat.

MONITORING

There have been no attempts to estimate the population size of goshawks across the WGLR (Dick and Plumpton 1998). At a workshop concerning the goshawk in the Midwest, Andersen (1998) reported on the development of raptor monitoring strategies beyond the scale of single study areas and examined the current state of goshawk knowledge in the region in terms of monitoring. Some issues of importance to the development of a regional goshawk monitoring program were listed by Andersen (1998) as follows and should be considered in developing a monitoring program for the region:

- The WGLR is at the southern extent of the current breeding range of northern goshawks. This has important implications for population dynamics and, in turn, population monitoring.
- Northern goshawks over much of this region likely forage on prey species whose populations may be cyclic (hare and grouse). This has important implications for population dynamics of goshawks.
- Little is known about the ecology of goshawks outside of the breeding season. Factors affecting survival and physical condition outside the WGLR may have impacts on population dynamics.
- Fall/winter invasions of goshawks from populations that breed farther north in the boreal forest of Canada and Alaska may influence population dynamics of Great Lakes goshawks.

The monitoring of goshawks in the WGLR has been limited primarily to checks of known nest areas during the breeding season. Without long-term population data, trends in population and their significance are difficult to evaluate (Dick and Plumpton 1998). In their research and monitoring plan for goshawks in the WGLR, Kennedy and Andersen (1999) identified the survey method and the demographic method as the two general approaches to monitoring population trends. They also stress the importance of calculating and considering statistical power in designing a monitoring program so that the probability of detecting population trends is known (see also: Taylor and Gerrodette 1993, Journal of Wildlife Management 1995, Stiedl *et al.* 1997, Gerrard *et al.* 1998). Taylor and Gerrodette (1993) demonstrated that given a fixed amount of effort, the survey approach has a higher probability of detecting a decline in population size when densities are higher and that the demographic approach has higher statistical power at lower densities. Kennedy and Andersen (1999) further discussed the pros and cons of various population monitoring techniques. They suggested that if habitat models are developed and validated to predict goshawk population performance, habitat-monitoring approaches could be used in conjunction with periodic population-based monitoring.

Survey Approach to Population Monitoring

The survey approach to population monitoring attempts to estimate population size, or some index of population size, directly over several years and determine whether or not the estimates indicate a trend over time. Because it is not possible to census, or completely enumerate, the entire population of most bird species, population monitoring is almost always based upon surveys of a sample of the breeding population (Kennedy and Andersen 1999). Surveys of breeding raptor populations are generally designed to monitor changes in distribution, occupancy of a sample of nests over time, and changes in breeding densities (Kennedy and Andersen 1999).

Possible methods for locating nests to be used in monitoring programs include broadcast surveys, which can also be used to monitor area of occupancy or changes in distribution and densities. Roberson *et al.* (*In Review*) reported that detection probability functions should be incorporated into survey designs to help researchers and managers calibrate the results of extensive surveys. Differences in detection rates among studies conducted in different areas of the goshawks' range indicate that these functions should be calibrated based on local probabilities of detection (Roberson *et. al In Review*). For broadcast surveys in Minnesota, their results indicated that the effective area surveyed at each broadcast point has a radius of 356 m (90% bootstrap C.I. = 255 –

846 m; 1167 ft, 90% bootstrap C.I. = 836 – 2,775 ft) during the courtship phase and 331 m (90% bootstrap C.I. = 271 – 518 m; 1,086 ft, 90% bootstrap C.I. = 889 – 1,699 ft) during the fledgling-dependency phase. Thus, surveys during these two phases could have broadcast stations spaced at 712 m (90% bootstrap C.I. = 510 – 1,692 m; 2,335 ft, 90% bootstrap C.I. = 1,672 – 5,550 ft) and 662 m (90% bootstrap C.I. = 542 – 1,036 m; 2,171 ft, 90% bootstrap C.I. = 1,778 – 3,398 ft), respectively (Roberson *et al. In Review*). Additionally, when conducting systematic, grid-type surveys, their results suggest that during the courtship phase, transects could be separated by approximately 617 m (2,024 ft), with stations on adjacent transects offset by approximately 356 m (1,168 ft); during the fledgling-dependency phase, transects could be separated by approximately 573 m (1,879 ft), with stations on adjacent transects offset by approximately 331 m (1,086 ft) (Roberson *et al. In Review*). Foot surveys can also be effective in locating nests and may be combined with broadcast surveys. Aerial surveys may also have potential for finding goshawk nest in the WGLR (Kennedy and Andersen 1999). Each of these nest location methods has pros and cons, which are discussed in greater detail by Kennedy and Andersen (1999).

Ecological density, or the number of individuals per area of usable habitat, cannot be estimated in the WGLR until after the range of habitats used by the goshawk in the region is identified (Kennedy and Andersen 1999). Abundance, a “crude” density estimate of number of individuals per unit of area, could be measured in a number of ways. Using simple tallies of nests to create an index to population size or to estimate breeding density in a study area produces biased estimates of population size (Gould and Fuller 1995).

One way to estimate population size and breeding densities is to use capture-recapture data and Jolly-Seber models for a well-defined study area. In order for this method to produce accurate population estimates with the desired statistical power, studies must be carefully planned and organized to ensure that study areas and number of goshawks pairs are large enough and that sampling effort and intensity are consistent among years (Kennedy and Andersen 1999). Gould and Fuller (1995) described the application of this approach to raptors.

Quadrat sampling, where the number of individuals within an area is counted and then divided by the size of the study area, may be the simplest way to estimate density (Kennedy and Andersen 1999). Rosenfield *et al*. (1996) used this approach in northern Wisconsin and it could be repeated throughout the region with quadrats of similar size (or larger) randomly located within the ecoregions of the WGLR (Kennedy and Andersen 1999). Kennedy and Andersen (1999) investigated the statistical power of this approach for detecting trends in regional breeding populations of goshawks. They found that statistical power in estimating population trends was sensitive to breeding density of goshawks, plot size, number of plots monitored, and years of monitoring. They stated that if the density estimates reported by Rosenfield *et al*. (1996) are representative of the region, the 3,800 ha (9,386 ac) plot-size used in their study would be a minimum size needed to attain adequate power to detect increasing or decreasing population trends. Kennedy and Andersen (1999) suggested that five years of monitoring may not be adequate to achieve the desired statistical power and that any monitoring program for goshawks in the WGLR must be long-term. In addition, if the goshawk population on the WGLR is cyclic or irruptive, these complex dynamics reduce power and add complexity to data interpretation. Kennedy and Andersen (1999) stated that if goshawk populations are cyclic, a minimum of two cycles would have to be monitored before trends became apparent, which might substantially increase the time interval necessary to monitor populations.

Another approach that could be used to monitor goshawk populations would be the probability of detection-area occupied technique (Bart and Robson 1995, McLeod and Andersen 1998). Roberson *et al*. (*In Review*) found that using broadcast surveys of goshawks in north-central Minnesota resulted in a high probability of detection during the courtship and fledgling-dependency periods of the breeding season. Their results may be useful in developing a technique to monitor breeding density if the relationship between estimates of area occupied and breeding density can be evaluated.

The utility of trends in migration counts for monitoring population trends has been much debated (Fuller 1996, Kennedy 1998, Smallwood 1998). One of the problems with migration counts is that they are indices that have not been calibrated with any estimate of demography. Therefore, these indices are difficult to interpret. Trends in migration counts could reflect distributional changes and changes in residency patterns rather than changes in population size, particularly in species such as the goshawk, whose migrations are characterized by irruptive invasions (Kennedy and Andersen 1999). However, migration counts can be used as an addendum to demographic studies to determine if the counts reflect demographic changes in the regional goshawk breeding population (Kennedy and Andersen 1999).

Demographic Approach to Population Monitoring

The demographic method involves monitoring trends in survival and fecundity, and using these data to calculate the finite population growth rate (λ). λ can be calculated based on reproduction and survival of individual age classes, or can be estimated through simulation based on annual variation in cohort survivorship and reproduction. Advantages of the demographic method over the survey method are that it provides some explanation for observed population trends and it has higher statistical power when animal densities are low (Kennedy and Andersen 1999).

Braun *et al.* (1996) indicated that models designed to predict increases or declines in goshawk populations based on reproductive activity or survival alone have little validity because population trends are based on the cumulative effects of survival, reproduction, and dispersal. McClaren *et al*. (2002) examined whether the number of young fledged varied spatially among northern goshawk nest areas within 3 study sites where long-term reproductive data from goshawks were available: (1) Vancouver Island, British Columbia; (2) Jemez Mountains, New Mexico; and (3) Uinta Mountains, Utah. A mixed-model ANOVA analysis indicated there was minimal spatial variation in the number of young fledged among nest areas within the 3 study locations. However, variability in the number of young fledged/nest area each year was high within each study site and the temporal patterns were not consistent among the three study areas. These results suggest that temporal patterns such as local weather and fluctuating prey populations influenced northern goshawk reproduction more than local spatial patterns such as habitat characteristics. They also concluded that monitoring reproductive success in the absence of monitoring survival and/or recruitment has limited utility in monitoring programs unless reproductive success is being monitored in the framework of a quasi-experiment.

In analyzing temporal trends in reproductive success for two western goshawk populations, Kennedy (1997) found that reproductive success was not correlated with population abundance and therefore monitoring reproductive success by itself is not a good index of population trends.

Similarly, a meta-analysis of northern spotted owl datasets indicated that reproductive success, compared to survival, had little relationship to abundance (Burnham *et al*. 1996, Raphael *et al*. 1996). Seven years of data on broad-winged hawk (*Buteo platypterus*) breeding density and reproduction also found no statistically significant or apparent relationships between reproductive success or productivity and breeding density in north-central Minnesota (D.E. Andersen unpublished data). Kennedy and Andersen (1999) also suggested that monitoring goshawk population trends using demographic methods requires monitoring survival and reproduction or recruitment. They emphasized that reproductive success should be determined by monitoring a representative and sufficiently large sample of nests that represent the larger population to which inferences are to be made. Precise survival estimates can be estimated by mark-resighting data from at least five years if sample sizes of marked birds and resighting rates are high (DeStefano *et al.* 1994, Kennedy 1997). Survival can also be estimated from telemetry data using the Kaplan-Meier (1958) procedure or other survival estimators (Pollock *et al*. 1989).

Habitat-based Monitoring

Kennedy and Andersen (1999) suggested that if goshawk habitat can be well-defined and demographic data are available from several study areas for an analysis of population trends, a model (or models) that predicts the relationships between preferred breeding season and winter habitat and population trends and/or performance could be developed for the region. The rationale for switching to habitat-based monitoring has been clearly articulated by Roloff and Haufler (1997) and Lint *et al*. (1997) and includes cost effectiveness in emphasizing the ecosystem rather than specific species and the ability to develop a more proactive management program (Kennedy and Andersen 1999).

Although extensive data on goshawk habitat preference is not available for the WGLR, preliminary regional habitat models based on the information available from the WGLR and the considerable information available from other regions and countries could be developed and parameterized to predict goshawk habitat (Kennedy and Andersen 1999). These models could be independently validated and modified once more extensive regional data become available. Kennedy (1997, 1998) has suggested that the most efficient way to identify consistent patterns in data collected in multiple studies is to conduct meta-analyses of the existing habitat literature. *If* models can be developed to predict goshawk population performance, then monitoring programs could switch emphasis from population-based to habitat-based monitoring. Reich *et al*. (*In prep*.) have recently developed a method to predict the location of goshawk nests on the Kaibab NF by modeling the spatial dependency between nest locations and forest stand structure. In the same area, Joy *et al*. (2000) have modeled small-scale variability in the composition of goshawk habitat on the Kaibab NF and plan to link these models with point-process models and a ranking of territories of northern goshawks with the purpose of identifying determinants of goshawk habitat quality.

Although goshawks may select habitat on the basis of structural characteristics and prey availability, they are also at the mercy of unpredictable factors such as drought, severe storms, or predation (Boal *et al*. 2001). If habitat models do not adequately predict population performance and it is determined that habitat features do not drive goshawk population dynamics, a strictly habitat-based monitoring program may have limited ability to predict changes in goshawk demographic performance and population-based monitoring would need to be continued

(Kennedy and Andersen 1999).

ONGOING RESEARCH AND RESEARCH NEEDS

It is clear from the symposia and meetings held in the WGLR in the past few years regarding the goshawk that more information is needed to facilitate science-based conservation plans and adaptive management for the goshawk (Kennedy and Andersen 1999). The *Review of Information on the Status of the Northern Goshawk in the Western Great Lakes Region and Ontario* (Dick and Plumpton 1998) further supports the need for additional data on goshawks in the region.

In order to develop a better understanding of goshawks in the WGLR as a whole and to develop conservation plans for this region, it would be useful for individual researchers and managers to share data summaries and results from survey and monitoring efforts. Standards should be developed for estimating habitat and demographic parameters so that data from different studies are comparable (Kennedy and Andersen 1999).

Ongoing Research

A comprehensive report on research and monitoring needs and protocol for the goshawk in the WGLR was completed by Kennedy and Andersen (1999), and is available from the MNCFWRU. Information needs identified in that report have begun to be addressed through new or ongoing research. A study on habitat use and characteristics of goshawks in northern Minnesota was conducted during the 1998 – 2000 field seasons and a final report with analysis and summary of the data has been completed (Boal *et al.* 2000b). An evaluation of broadcast survey methods for goshawks conducted in the same area during the 1999 and 2000 field seasons is in review (Roberson *et al. In Review*). B. Smithers, a Graduate Research Assistant working with the MNCFWRU and Texas CFWRU, initiated a diet study of prey use and delivery rates using video cameras at active nests during the 2000 breeding season and will continue to collect data through 2002. Cooperators and sponsors on these projects include Boise Cascade, the Leech Lake Band of Ojibwe, Potlatch, USFWS, USFS, MNCFWRU, MNDNR, The Raptor Center at the University of Minnesota, the National Council for Air and Stream Improvement (NCASI), the Minnesota Falconers' Association (MFA), the National Fish and Wildlife Foundation (NFWF), and the National Forest Foundation (NFF).

Research projects are underway or have been recently completed in other parts of the region. Researchers in Wisconsin (Doolittle 1998, T. Erdman personal communication to Dick and Plumpton 1998) have initiated preliminary use of radio-telemetry and Geographic Information Systems (GIS) and the WIDNR continues to conduct plot and aerial nest searches. Bowerman *et al.* (1998), Doolittle (1998), Erdman *et al.* (1993, 1998), Postupalsky (1993, 1998), and Rosenfield *et al.* (1991, 1996, 1998a, 1998b) continue to collect and analyze goshawk data in the WGLR. T. Lapinski, a Graduate Research Assistant at Northern Michigan University, has recently completed an M.S. thesis on habitat use and productivity in goshawks in the Upper Peninsula of Michigan (Lapinski 2000). A graduate student in Ontario is preparing a thesis on goshawk nest area analysis (Naylor pers. comm. to Dick and Plumpton 1998). S. Christiansen, a graduate student at Northern Michigan University, has completed a thesis investigating goshawk ecology in Upper Michigan. In addition, W. Bowerman, T. Doolittle, T. Erdman, S. Postupalsky and others have formed a working group to coordinate goshawk research in Michigan and Wisconsin (Bowerman *et al.* 2000).

Research Needs

As is evident from this and other (Dick and Plumpton 1998, Kennedy and Andersen 1999) information summaries relative to goshawks in the WGLR, considerable additional information is desirable regarding goshawk population dynamics, population monitoring, goshawk-habitat relations, and goshawk-prey interactions. Kennedy and Andersen (1999) polled regional management agencies and non-governmental organizations concerned with goshawk conservation, and identified a preliminary list of information needs for the region. Current and past research efforts have provided information relative to some of these needs, but considerable additional information is needed before goshawks can adequately be incorporated into management plans at larger (*e.g.*, regional) scales. The following is an overview of information and research needs regarding goshawks in the WGLR.

Population Dynamics

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). Erdman *et al.* (1998) have been working with a population model in Wisconsin, however, a reliable regional model will require data from regional, systematic studies conducted over the long term (Dick and Plumpton 1998). In the WGLR, no regional estimates exist for survival or mortality, dispersal movements are unknown, populations have not been adequately defined, and problems exist with current productivity estimates (Dick and Plumpton 1998, Kennedy and Andersen 1999). Data necessary to estimate population growth rates are not available for the WGLR or for any other North American goshawk population (Kennedy 1997).

Information on dispersal is important for investigating issues of population isolation and demography. Dispersal and mortality may be more important than reproduction in governing population dynamics, however, because they occur mainly outside of the nesting period, these factors are difficult to measure (Braun *et al.* 1996). Information on dispersal for regional populations would be helpful in reaching a better understanding of population dynamics.

The regular distribution of nesting pairs documented over many areas could result from the distribution of suitable habitat, territorial behavior, and/or some form of mutual avoidance. Understanding the mechanism by which goshawks distribute themselves over the landscape is important for management because density dependence (Maguire 1992 *in* USFWS 1998a) and spacing behavior may limit the number of pairs an area can support below that dictated by availability of food or nest areas (Bernstein *et al.* 1991, Smith *et al.* 1991).

Population Monitoring

Kennedy and Andersen (1999) indicated that population monitoring based on a static sample of breeding areas is not sufficient to adequately monitor regional goshawk populations. Monitoring of breeding areas needs to include a strategy that results in a sample representative of the regional breeding population of goshawks. Kennedy and Andersen (1999) suggested that this could be accomplished using stratified random sampling with an ecological basis for stratification. In addition, if preliminary results indicate goshawk densities are as high or higher than what has been reported for Wisconsin (Rosenfield *et al*. 1996), monitoring breeding densities using quadrat sampling and/or call broadcast surveys and the area-occupied technique may be feasible. This approach would require a significant commitment of resources, but has the highest potential to track population changes and result in representative regional samples of goshawk breeding areas that could be used to evaluate demographics and factors affecting demographics. Well-designed sampling to locate breeding areas or to estimate breeding density should result in a representative sample of breeding areas, which could be used to characterize breeding habitat for goshawks.

Habitat Relationships and Models

There are currently not sufficient regional data to develop a regional habitat model to predict suitable goshawk habitat (Kennedy and Andersen 1999). If preliminary models, based on the information that is available for the WGLR and relevant information from other parts of the goshawk's range, are developed and validated, any range-wide habitat patterns identified could be combined with silvicultural information for the WGLR, and used to develop management guidelines for regional goshawk populations similar to the southwestern guidelines developed by Reynolds *et al.* (1992). As noted by Fuller (1996) "the concept of Reynolds *et al.* (1992) could be used as a model, for assessments and strategies in other areas and for other species. The concept is good because it incorporates the best available ecological and management information and considers a variety of species and forest conservation issues." Guidelines for the WGLR could be developed in an adaptive management framework and modified, as regional data become available (see Kennedy and Andersen 1999 for suggested approaches for habitat data collection in the WGLR).

Kennedy and Andersen (1999) identify the following questions as ones that habitat studies in the WGLR should focus on answering:

1) What is the structure and composition of breeding and wintering habitat at a variety of spatial scales?
2) What proportion of the total landscape is goshawk habitat?
3) What is the relationship between forest structure and prey availability?
4) What is the distribution of sizes of habitat patches?
5) What is the distribution of distances (connectivity) between habitat patches?

The purpose of addressing questions 4 and 5 is to evaluate the degree of habitat fragmentation that occurs in goshawk habitat and to identify minimum (and maximum?) patch sizes and landscape conditions used by goshawks in the WGLR.

Goshawk Diet and Habitat Requirements of their Prey

In addition, an understanding of how goshawks and their prey species are influenced by changes in forest structure and pattern resulting from forest management practices is critical to the development of sound goshawk conservation plans. Thus, it is important to determine goshawk prey use in the WGLR both in the breeding and non-breeding periods, and examine how prey species respond to changes in forest structure and landscape pattern, in terms of both abundance and availability (Kennedy and Andersen 1999).

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