Conservation Assessment for Northern Goshawk *(Accipiter gentilis)* Linnaeus in the Western Great Lakes

Photo credit: Phil Detrich, USFWS

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EXECUTIVE SUMMARY
TBD

ACKNOWLEDGEMENTS
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INTRODUCTION

The northern goshawk (*Accipiter gentilis*) is a large, forest-dwelling bird of prey with a circumpolar distribution. In the Eastern Region of the National Forest Service (Fig. 1) the northern goshawk (hereafter goshawk) is among 370 Regional Forester Sensitive Species (RFSS) (January 2007; http://www.fs.fed.us/r9/wildlife/tes). The U. S. Forest Service Manual (FSM) (2670.15) defines Sensitive Species as "those plant and animal species identified by a Regional Forester for which population viability is a concern as evidenced by significant current or predicted downward trend in numbers or density" and..."habitat capability that would reduce a species existing distribution.".

Figure 18. The Eastern Region of the USDA Forest Service

The criteria used by the Eastern Region for inclusion of a species on the RFSS list and the associated ratings for the Western Great Lakes Region (WGLR) National Forests are shown in Table 1.

According to the Eastern Region RFSS Framework (USFS, Milwaukee, WI, February 2002), RFSS "'must receive special management emphasis to ensure their viability and to preclude trends toward endangerment that would result in Federal listing' (FSM 2672.1). Conservation assessments provide a means to gather the current state of knowledge to design approaches for conservation and recovery."

The RFSS process alone is sufficient to justify developing a conservation assessment for the goshawk in the WGLR. There are, however, additional factors to consider in the case of the goshawk that make the need for this conservation assessment greater than the factors listed above would call for. Beginning in the 1990s, some researchers suggested that the goshawk population in the western U. S. was in decline and this set in motion a series of actions that culminated in the U. S. Fish and Wildlife Service denying a petition to list the species as Threatened west of the 100th meridian on the basis of insufficient evidence (Andersen et al. 2005).

Table 2. Criteria used by the Eastern region of the Forest Service foe inclusion of goshawk as a Regional Forester Sensitive Species

Criterion	Status
U.S. Fish and Wildlife Service and/or National Marine Fisheries Service candidate for Threatened and Endangered species listing and species delisted in the last five years	None
The Nature Conservancy G1-G3, T1-T3 and N1-N3	G5 – Secure N4B, N4N (United States) – Apparently secure, breeding and non-breeding
States	
Minnesota	SNRB, SNRN – unranked, breeding and non-breeding State Endangered, Threatened, Special Concern - None
Wisconsin	S2B, S2N – **imperiled, breeding and non-breeding** State Endangered, Threatened, Special Concern – **Special Concern**
Michigan	S3 **– vulnerable** State Endangered, Threatened, Special Concern - **Special Concern**
Documented occurrence within the proclamation boundary of an Eastern Region NF	Yes
Designated RFSS on WGLR Forests	**All**

In response to the petition and ensuing decision, the Raptor Research Foundation, Inc. and The Wildlife Society jointly commissioned a review of available information on the status of the goshawk. A summary of the report prepared by the Technical Committee on the Status of Northern Goshawks in the Western United States published in 2005 Andersen et al. (2005) included the following conclusions: 1) existing data are insufficient to assess the status of the goshawk population in the west; 2)there is no genetic evidence to suggest differences among recognized or alleged goshawk subspecies of the western United States and Canada *and* that the genetic distinctiveness of goshawks in eastern and western North America is unknown; and, 3) based on current understanding of goshawk-habitat relationships, it is not appropriate to assess the status of goshawks solely on the distribution of late-successional forest habitat. Of course, the negative nature of these conclusions (i. e., 'data are insufficient', 'no genetic evidence', 'not appropriate to assess') did little to resolve this contentious issue. This conservation assessment draws on the information presented in Andersen et al. (2005) as well as myriad other sources, many of which have been only recently published, to meet the goals of the Eastern Region RFSS Framework.

Approach, Scope and Methods of Assessment

The goal of this document is to provide the Forest Service's analysis and documentation of the current status and distribution of the goshawk in the WGLR. It provides what is known and unknown about the goshawk and it identifies what is needed to develop a plan of action to conserve the species (such as a recovery or conservation strategy). The intended audience is Forest Service biologists, managers, rangers and, just as importantly, the interested public. As such, I use a style of writing that is (hopefully) less intimidating to the lay reader than traditional scientific reportage.

What is known and unknown about the goshawk differs by region and even continent. Focus on goshawks in the WGLR has been, for the most part, local. Exceptions are a workshop held in Madison, Wisconsin in 1993 and a Raptor Research Foundation meeting in 1995 at Duluth, Minnesota in which a number of goshawk papers were presented (West 1998a). In 1997, a workshop entitled “Status of the Northern Goshawk in the Midwest” was held at the Midwest Regional Raptor Management and Peregrine Symposium in Milwaukee, Wisconsin West (1998b).

I collected all available pertinent information on goshawks from peer-reviewed literature, government reports, theses and dissertations, and anecdotal notes published in regional bird journals. I also made use of the internet to collect raw data on various aspects of goshawk ecology. Throughout the process of writing I conducted personal communications with a large number of biologists, ecologists and academics that shared an interest in goshawk ecology.

This assessment is not meant to be a comprehensive study of the goshawk across it’s entire range. I limit my enquiry to those aspects of goshawk ecology that are pertinent to the WGLR in general and the Forest Service in particular. If the reader is interested in a more comprehensive study of goshawk I recommend in Avian Biology Numbers 31 (2006: *The Northern Goshawk: a Technical Assessment of its Status,*

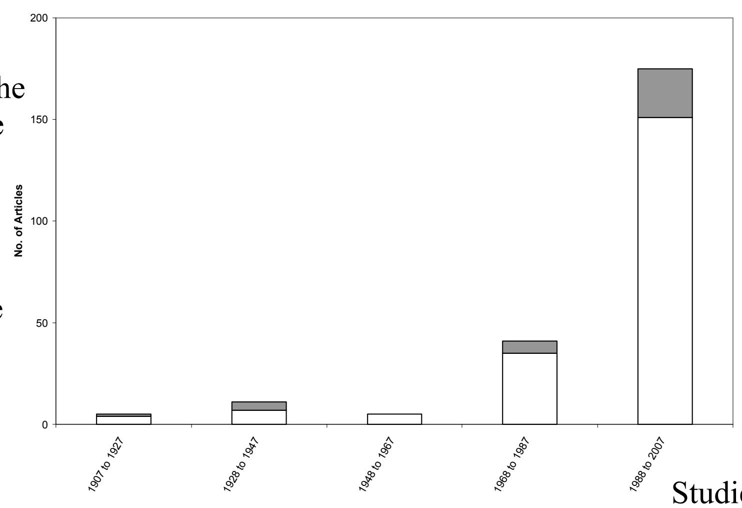


Figure 19. number of papers published by time period with 'goshawk' in title. Shaded areas represent WGLR Studies

Ecology, and Management) and 16 (1994: *The Northern Goshawk: Ecology and Management*), Bosakowski (1999), Anderson et al. (2004), and for the WGLR Dick and Plumpton (1999).

The Data

I collected electronic or hard copies of about 400 references, of which 44 were not peer-reviewed. Not all of these sources dealt directly with goshawks, many concerned related topics such as prey species or vegetation dynamics. I collected papers from as far back as the early 1900s, but the bulk of information is from the last 20 years as interest in and availability of goshawk research has exploded (Fig. 2). Not surprisingly, most of the information is from areas of the goshawk's range outside of the WGLR. About half of all goshawk papers published globally since 1975 are from Europe with most of the remainder from North American studies (Kenward 2006).

Studies of WGLR goshawks have increased over time, but they still represent a small proportion of all goshawk work (Fig. 2). So, whereas globally every aspect of goshawk ecology has been addressed to some extent, the pool of knowledge for the WGLR is still somewhat shallow. For this assessment, I address this limitation by first relying on available WGLR data with comparisons to similar studies in other regions when context is important. Lacking local data I use North American data and/or Eurasian data to explore the known limits of parameters under investigation. There are dangers to this approach. Differences between regions can influence goshawk ecology. For example, Boal et al. (2003) point out that goshawks in the west typically occur in areas of high elevation, substantial topographic relief with warm dry summers and wet, cool winters whereas goshawk in the WGLR are found in lower elevation, low topographic relief areas with cool wet summers and long dry cold winters. Similarly, at the community-level, bird communities in the Pacific northwest are less effected by diminishing forest patch size and distance to edge than in the Eastern deciduous forest (Hansen and Urban 1992).

Structure and Layout of this Assessment

An assessment of the distribution and abundance of a species and how the distribution and abundance are affected by interactions between the species and its environment (i. e., ecology) is actually a cataloguing of two things (Hansen and Urban 1992):

- The life history of an organism; which sets constraints on the resources that can be used profitably
- Behavioral plasticity; which allows organisms to adjust to environmental factors

With this in mind, the structure of this assessment will consist of five sections (not including the introduction, cited literature, etc.). First, the defining characteristics of the goshawk. At the most fundamental level this is the DNA of the species, but that is outside of the scope of this assessment. This section includes physical description, pre-settlement distribution, reproductive physiology, etc. Parameters that do not vary significantly over the species' range. Second, the habitat. This will be as specific as possible to the WGLR. However, a survey of the variety of habitats that goshawks use is included to measure the magnitude of the behavioral plasticity mentioned above. Third, population dynamics. This is how the DNA meets the constraints of the environment. This will include factors that promote or limit the increase in abundance of the species. Fourth, the human-goshawk interaction. How our species has coexisted with the goshawk. Finally, the fifth section covers the research and monitoring needs and management implications of the preceding information. A key result of a conservation assessment is to identify what is needed to develop a plan of action to conserve the species.

Throughout this document there are text boxes set apart from the body of the text. These contain discussions of subjects that are important to understanding the ecology of the goshawk in the WGLR, but are too complex to describe fully in a few paragraphs.

THE GOSHAWK

Nomenclature and Taxonomy

The Northern Goshawk (*Accipiter gentilis*) takes its common name from Old English “gos”, meaning goose, therefore “goose hawk”. The binomial (Linnaeus 1758) is *Accipiter* (“birds of prey” Latin) *gentilis* (“of the people” Latin).

Table 3. Current taxonomy of the goshawk.

Kingdom	Animalia
Phylum	Chordata
Subphylum	Vertebrata
Class	Aves
Order	Ciconiiformes
Family	Accipitridae
Genus	Accipiter
Species	Accipiter gentilis
Subspecies	Accipiter gentilis atricapillus
Subspecies	Accipiter gentilis gentilis
Subspecies	Accipiter gentilis laingi

The latter referring to the availability for falconry of this species to priests and yeoman, as opposed to the gyrfalcon (*Falco rusticolus*), peregrine falcon (*Falco peregrinus*)and saker (“sacred”) falcon (*Falco cherrug*) used by the nobility (Grossman and Hamlet 1964).

Figure 20. Adult goshawk

The current taxonomy of the northern goshawk is displayed in Table 2. The earliest taxonomy listed the adult and immature northern goshawk as separate species because of differences in plumage (Mayr 1940). As with many widely distributed species, *Accipiter gentilis* has been subdivide into varying numbers of subspecies. Currently 10 subspecies are recognized worldwide, with two North American subspecies in addition to *A. g. gentilis* (Table 2). Another subspecies, *A. g. apache*, is recognized by some authors, but not by the American

Ornithologist's Union (American Ornithologist's Union 1983, Squires and Reynolds 1997).

The saga of differentiating 'races' of goshawks in North America is reviewed in Taverner (1940). In that paper, the author discusses Ridgeway's original description of the western goshawk ([*A. g.*] *striatulus* Ridgeway) then shows that the delineation is artificial. Taverner (1940) goes on to show that the Queen Charlotte goshawk (([*A. g.*] *laingi*) known from the islands of the British Columbian (Canada) coast is, indeed, a valid subspecies from *A. g. gentilis* based on morphological characteristics.

Description

A complete description of the goshawk is presented in Squires and Reynolds (1997) and various field guides give adequate information for identifying goshawks in nature. For our purposes, the following information will serve as sufficient.

The largest accipiter in North America; long, broad wings and long, rounded tail allow for agility in flight through forests. As is usual for raptors, female larger than male, but difference is much less pronounced than in other accipiters (Storer 1966). Average total length, male 55 cm, female 61 cm; wing-span, male 98–104 cm, female 105–115 cm mass, male 631–1,099 g, female 860–1,364 g. For full measurement data see Squires and Reynolds (1997). Upperparts of adult brown-gray to slate gray; head with black cap and pronounced white superciliary line. Undertail-coverts white, often quite fluffy, especially during courtship or when alarmed. Tail dark gray above with inconspicuous broad, dark bands (3–5). Female similar to male but browner above and more coarsely marked below, sometimes appearing barred. Partial albinism may occur (Evans 1978). Adult plumage grows in after 2 years, for hatchling and juvenal plumage, see Squires and Reynolds (1997).

Global/North America Pre-settlement Distribution

Figure 21. North American resident and summer range of the goshawk.

In the context of conservation biology the spatial and temporal structure of a species' distribution is the combined product of life history traits and ecological processes. Given that many ecological attributes have been dramatically altered by humans, the current distribution of a species may be far from that under which the species evolved. For our purpose it is important to understand if: 1) the current distribution of goshawks represents the internal structure (e. g., connectivity, opportunity for genetic exchange, population source/sinks) that allows for a secure population across its range; and 2) if the current edges of the goshawk's range are ecologically determined or if they are artifacts of recent human activities.

The goshawk has a circumpolar distribution (Grossman and Hamlet 1964, Squires and Reynolds 1997). The northern goshawk has three closely related allospecies in Africa, Madagascar and New Guinea (Amadon 1966). For a dated but detailed discussion of the species' palearctic distribution see Gladkov (1941).

In North America, the distribution of the goshawk covers most of Canada, Alaska and the Rocky Mountains, extending south into Mexico. In eastern North America, the distribution extends south to the northern Great Lakes and much of the Appalachian Mountains (Fig. 4).

Within this coarse-scale distribution, the greatest part of the breeding distribution consists of boreal and boreal-hardwood forests in Canada. The Canada Wildlife Service ranks the goshawk as being of medium concern because of vulnerability and population trend, and high responsibility because the majority of the species' North American range is in Canada (Dunn et al. 1999). The data used for this determination are not available. Figure 5 shows the proportion of the goshawk's North American breeding range covered by major Partners in Flight physiographic areas(Rich et al. 2004).

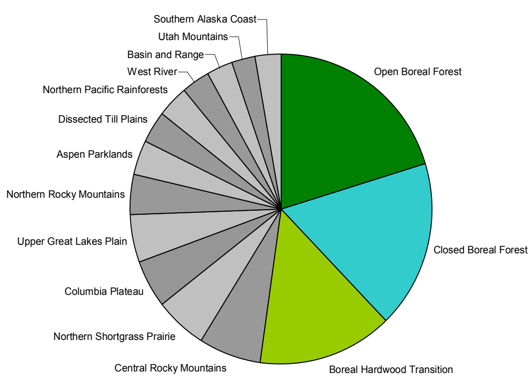


Figure 23. Proportions of coarse-scale North American goshawk distribution covered by PIF physiographic regions. Graph represents only the cumulative 75th percentile (excluding tundra).

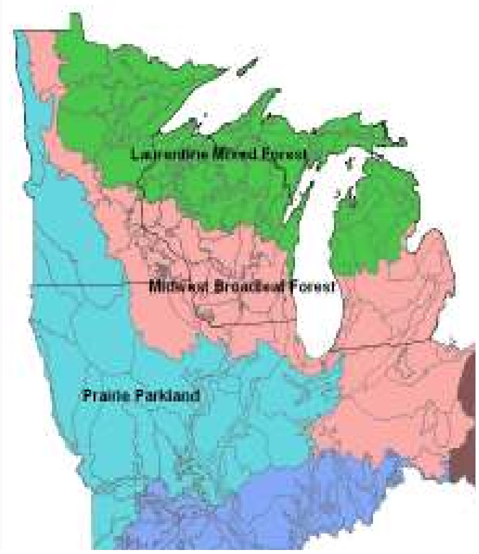


Figure 22 Western Great Lakes states and ecological provinces (from Cleland et al. (2007))

At the continental scale Figure 4 shows an integrated distribution for the goshawk in North America with the possible exception of the Mexican range. Unfortunately, breeding bird data are rare from much of the goshawk's core range in Canada primarily due to the sparse human population (Kennedy et al. 1999). Therefore, we can make no inferences on the internal structure of the goshawk's range. Understanding a species' range size/abundance relationship (e.g., decreases in overall abundance result in smaller ranges) can be a powerful tool in developing conservation strategies (Gaston and Curnutt 1998); accruing data and developing this concept for goshawks in North America, although not a research priority, would be helpful in our efforts. A discussion of the goshawk's current distribution is presented in a later section.

Populations behave differently at the edges of their ranges than elsewhere (Curnutt et al. 1996). It is important, therefore, to determine if the edge of the goshawk range, currently running across the WGLR states (Fig. 4), is ecologically or artificially derived.

Figure 6 shows the ecological provinces of the WGLR (Cleland et al. 2007). Each province is composed of sections and sections are composed of subsections. In considering the nature of the edge of the goshawk's range the province scale is appropriate.

Most early records of goshawk in the region are from Wisconsin (but see The Natural Heritage database: 14 historic nesting records for Minnesota dating back to 1892; and Manville (1948) for Michigan's Upper Peninsula). I could find no records of goshawks in the WGLR from before the late 1800s. The earliest goshawk records for the WGLR, therefore, coincide with the period of greatest human-caused change in the area. Beginning in the mid-1800s and accelerating until the early 20th century logging and human-mitigated wildfires destroyed most of the forests in the WGLR (Stearns 1997). We can assume that the goshawk was resident in the pre-European laurentine mixed forest of the WGLR. Stearns (1997; p. 1) description of that region as seen by the first Europeans seems like a goshawk paradise:

> The northern forests appeared as vast areas of hardwoods and conifers within which were found many lakes, impenetrable swamps, patches of scrubby pine or oak, open bogs, and scattered areas of burned or windthrown timber. These forests were diverse in species ranging from pines on the sandy soils or hardwood and mixed hardwood-conifers of the more fertile loams to the swamp forests of cedar, spruce, and larch. They varied in age from young stands largely of aspen/birch, pine, or maple, to older stands mostly of pine, hemlock, or northern hardwood that ranged in age from 250 years to over 400 years. These forests were not uniform and were always subject to change as a result of increasing age, natural succession, wind, fire, or other disturbance.

In fact, the earliest scientific records describe the goshawk in Wisconsin as " formerly common. Becoming rare now" (Schoenebeck 1939). The author goes on "In the year 1891, I found 4 nests of this hawk, but since the timber is being removed rapidly from this country, this bird is going farther north." Richter (1939) reported that his last breeding record was near the east edge of the Peshtigo marsh area (near Green Bay, Wisconsin) in 1934. A thorough treatment of Wisconsin nesting data up to the mid 1930s can be found in Gromme (1935).

The preference by goshawks for the laurentine mixed forest province is pronounced in Wisconsin where, of about 95 known historical territories, only four fall in the state's other province – Midwest broadleaf forest (James Woodford, Wisconsin DNR, unpubl. data). Nesting records exist for various Wisconsin counties (Kemper 1969, Knudson 1978, Haug 1981, Dick and Plumpton 1999).

We can safely assume that the laurentine mixed forest constituted goshawk breeding range in the WGLR. Determining whether the adjacent province to the south and west –

the Midwest broadleaf forest – was originally a part of the goshawk breeding range is more problematic. In addition to the four territories listed above there exists only Kumlien and Hollister's (1903; *in* Gromme [1935]) description of the goshawk as "a rare summer resident…" but acknowledging insufficient data for the "northern portion" of the state; and Lux (1892; *in* Gromme [1935]) reporting a nesting record in northern Illinois. To the south, including Indiana, Ohio, Missouri, Illinois, Iowa and Arkansas, all goshawk records pertain to migration or wintering activity (Black 1935, Gromme 1935).

It appears that the Midwest broadleaf forest province may represent a transition zone at the very edge of the goshawk's range. The edge of the goshawk range then could be characterized as a "ramp" (as opposed to a "step" – an abrupt edge) *sensu* Caughley et al. (1988). At a ramp, an attribute(s) of the population (e. g., density, fitness) is low at the periphery and increases toward the center of the range. Typical factors that would cause a ramp profile are climate, resources (consumptive, preemptive, and unmodifiable), and a facultative predator, parasite or pathogen (Caughley et al. 1988). More research is needed to test this hypothesis.

Over the last several decades of the 20th century, Postupalsky (1998) claims that the goshawk has gradually extended its breeding range southward in Michigan. The same has been noted for Wisconsin (Gibson 2003 and T. Erdman, [Richter Mus. Nat. Hist.], pers. comm.). Range expansion has also been recorded in New York and New Jersey (Speiser and Bosakowski 1987). All of the above authors agree that the goshawk is recolonizing areas where forests were removed ca. 100 years ago and are now being reforested by ecological succession.

The historic and current edge of the goshawk's range cuts across all three states in the WGLR (Figs. 4 and 7). As mentioned above, the population dynamics at the edge of a species' range have certain qualities that are diminished or lacking in the center (Curnutt et al. 1996). We would expect that the population density is lower toward the edge; that the population is more variable over time (when adjusted for abundance [Taylor 1961]) and that the core and edge of the range serve as population source and sink, respectively. Therefore, goshawk breeding territories winking in and out over time in the WGLR may be simply an attribute of the spatial distribution of the entire goshawk population and is not cause for alarm. Applying the source/sink paradigm (Pulliam 1988), conservation of the goshawk in the WGLR is more dependent on highly productive goshawk populations to the north and west than on the individual territories in the WGLR states (Curnutt et al. 1996).

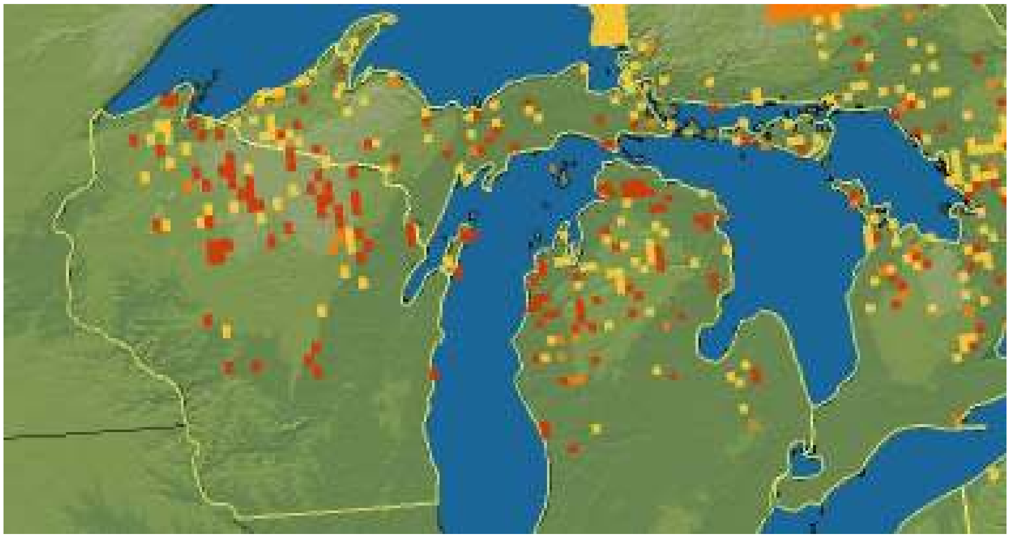


Figure 24. BBA data for the WGLR except Minnesota showing goshawk occurrences: confirmed ; probable ; and, possible .

Habits, Nesting and Reproduction
In addition to the preceding topics, the following aspects of goshawk ecology are more or less standard across the species' range, indicating an evolved rather than contemporary foundation.

Foraging
Goshawks usually forage in forests by series of short flights, punctuated with brief periods of prey searching from elevated hunting perches (short duration sit-and-wait predatory movements; Squires and Reynolds 1997). Other methods (e. g., walking, stalking, paddling in water) have been observed and are doubtless opportunistic in nature (Bent 1937, Bergstrom 1985, Opdam et al. 1977, Schnell 1958, Kenward 1982).

The list of species that goshawks have taken for prey is overwhelming. As I collected references for this assessment I kept track of prey species reported in the literature. For just North America I catalogued over 50 actual species with numerous genus-level observations as well (Deane 1907, Grzybowski and Eaton 1976, Allen 1978, Beier and Drennan 1997, Andersen et al. 2005)and others). A ten year (1950 – 1960) study of goshawks in Europe showed the diversity of species taken as prey: 57 species of birds and 9 species of mammals (Brüll 1964). For the WGLR the list is more manageable (Appendix I), but still shows that the goshawk is not an obligate predator on any prey taxon (WGLR prey analyses are below under **Habitat**).

Prey Selection
So what determines prey selection in goshawk foraging? At one end of the spectrum is the energy gained per unit effort – some things are too small to exert energy on capturing. For example, in Finland, grouse chicks were preyed upon by goshawk only late in the summer after the chicks grew to a size profitable for hunting (Reif and Tornberg 2004). Storer (1966) analyzed optimum prey size for the goshawk as compared to sharp-shinned (*Accipiter striatus*) and cooper's (*A. cooperii*)hawks and determined that the larger size

of the goshawk along with the relative lack of sexual dimorphism results in a more limited number of potential prey species and that these species, being generally larger, occur at lower densities than those used by the other two hawks. There are conditional exceptions. Passerine nestlings accounted for the largest part of the goshawks summer diet in the Sierra Nevada (Schnell 1958). As an individual prey item this doesn't seem to make sense, but consider how foraging goshawks will return repeatedly to a location with multiple prey items (e. g., chicken coop, duck nest; Bacon 1983, Deane 1907) and the cost per item is much lower.

The upper weight limit of prey taken by goshawks has not been studied systematically. Size differences between males and females suggest the effect of size on prey selection. In Britain, females catch proportionally more rabbits (large) and fewer pigeons (small) than males. Also, in areas with both gray (*Sciurus carolinensis*) and red squirrels (*S. vulgaris*), gray squirrels are taken only by female goshawks – being nearly twice the weight of red squirrels, gray squirrels are apparently too large for males to catch successfully (Kenward 1981).

Being catholic in their tastes, goshawks have a potentially wide dietary breadth (Steenhof and Kochert 1988). In fact, goshawk populations tend to have a few predominant taxa in their diets (Squires and Reynolds 1997). Which species dominate the goshawks' diet differs across the goshawk's range. In the WGLR the three most prominent prey species are the red squirrel, ruffed grouse (*Bonasa umbellus*) and the snowshoe hare (*Lepus americanus*) (Boal et al. 2006). A more complete discussion of prey in the WGLR is presented below. Spatial and temporal differences in prey choice are related to differences in the composition of local faunas – in other words, whatever is most common will be the most common prey item (Opdam et al. 1977). Abundance of a prey species is not enough in all cases; prey availability, which is a factor of both abundance and habitat, has been shown to be a more powerful predictor of goshawk nest site selection than density (Beier and Drennan 1997). Beier and Drennan (1997) showed that goshawk foraging activity in northern Arizona did not correlate with prey abundance and suggested that prey availability was more important. Their findings, however, failed to reach statistical significance.

THE GOSHAWK AND THE PASSENGER PIGEON

"The fierce Goshawk inhabits deep woods, and with the Passenger Pigeon (*Ectopistes migratorius*)as an available food, was *perhaps* much more numerous in earlier days." (https://www.nyhistory.org)

"However, the goshawk's range may have been more widespread in the eastern US before the extinction of the Passenger Pigeon in the early 1900s, because the pigeon *may have been* an important prey species" (Squires and Kennedy 2006). [emphases mine]

The earliest citation of goshawks preying upon passenger pigeons was Bent (1937) who, in reporting the decline of the goshawk in Pennsylvania, suggested that the extinction of the passenger pigeon may have played a role. As for actual evidence that goshawk's preyed upon passenger pigeons – eye-witness accounts, prey remains, etc. there is none to my knowledge. The closest thing to an eyewitness account is implied by John James Audubon (Audubon 1950):

> *Although the flight of our Passenger Pigeon is rapid and protracted almost beyond belief…, that of the Goshawk or of the other species of this group so very far surpasses it, that they can overtake it with as much ease as that with which the pike seizes a carp.*

There are five extant memoirs of North American explorers along the Eastern seaboard, dating back to 1524. John Smith's (Smith 1907) 1612 memoir was the first to mention passenger pigeons, and not in the unimaginable numbers that would be told of later. That would occur in the mid-1650s (Josselyn 1865). The first record of the "wild pigeon" in the WGLR is Chicago in spring 1675 (Marquette 1917); the four previous memoirs from the area dating from 1623 don't mention it. By 1681, passenger pigeons are noted as summer migrants to the mouth of the St. Lawrence winter. In 1749, Kalm (1773) would note that during some winters the species is abundant in Pennsylvania, and that the pigeons were more common then ever. Finally, a Native American midden at the west end of Lake Erie, dated ca. 1000 YBP had remains of a goshawk and a "surprisingly rare" occurrence of passenger pigeons (Mayfield 1972).

The pre-European distribution of passenger pigeons is a puzzle to be solved by an effort far greater than I can apply to this story. It seems feasible, however, that the distributions of the pigeon and the goshawk didn't overlap very much. Why is it important to know? Because if the goshawk evolved with a virtually limitless food supply, as would have been the case with the clouds of passenger pigeons, our understanding of the goshawk and our attempts to conserve it would be dramatically different than they now are. It is hard for me to believe that the goshawk, with its territoriality, method of hunting, and breeding system evolved with so many passenger pigeons. I think it is more likely that the huge pigeon population was a result of an ecological release, short-lived and ultimately fatal.

Seasonal Shifts in Diet

The availability of data on goshawk foraging is skewed heavily to the nesting season (Linden and Wikman 1983, Tornberg 1997, Salafsky et al. 2005, Lewis et al. 2006). For the few studies that incorporated year-round data on goshawk foraging we must depend on work from Europe. Shifts in goshawk diet have been reported at two temporal scales – within the breeding season and breeding *v* non-breeding season. In best study to my knowledge, a marked seasonal shift in goshawk prey species occurred where a goshawk population nested and wintered in forests surrounded by open fields and agriculture (Opdam et al. 1977). In winter, prey was predominantly open-field bird species taken from the agricultural lands. During the breeding season nearly all prey was forest-dwelling bird species – especially in the form of poulii from forest bird nests during late May to early July (28 – 48%). In another European study, this one conducted over 10 years, goshawk prey included 57 species of birds and 9 species of mammals (Brüll 1964). This study also revealed a seasonal shifts in diet, presumed by the authors to be driven solely by abundance and availability of different prey species (or different ages of individuals within species) at various times of year. For example, species of Corvidae were commonly preyed upon during their nesting season when both nestlings and adults were taken by goshawks, but not during the winter when these species form large flocks in the area. Also, goshawks took a large number of starlings (*Sturnus vulgaris*) early in the post-fledging period of the latter as these birds formed large flocks foraging for prey in meadows. And finally, goshawks took large numbers of fieldfare (*Turdus pilaris*) when the local population was very high due to the arrival of migratory flocks.

During the breeding season prey selection is driven by a number of factors. Most simply, since the smaller male does all of the hunting during nesting, smaller prey (thrushes vs pheasants) are taken selectively (Opdam et al. 1977). Vulnerability (for the prey, availability for the goshawk) changes through the season as well (Widen 1987). Schnell (1958), citing Sulkuva contends that goshawk [avian] food habits during the nesting season can be divided into two parts: 1) prey taken by goshawks during nest building and incubation (predominantly adult birds); and, 2) the period of juvenile goshawk development (predominantly nestling birds). Furthermore, that these nestling development phases are coincident in time.

Nesting and Reproduction

Dates and tree species may differ between regions, but there are other aspects of goshawk nesting and reproduction that are constant across space. For a much more comprehensive discussion of the nest, nest structure, and dimensions see Squires and Reynolds (1997).

Nests

As for the nest itself, all reported goshawk nests were built in trees, there are no incidences of ground nesting (as sometimes occurs with other raptors [Curnutt and Robertson 1994]). Although not reported universally, goshawks seem to build stick nests below or in the bottom quarter of the canopy (Speiser and Bosakowski 1987) and in the crooks of large obtuse branches (Squires and Reynolds 1997). Many goshawks build and maintain alternate nests within a nest area. One nest may be used in sequential years, but often an alternate is selected. Importance of alternate nests is unknown; nest switching may reduce exposure to disease and parasites (Squires and Reynolds 1997). For example, in one of the most complete studies of a goshawk nesting population (Reynolds et al.

2005) determined a mean number of about 3 alternate nests per territory. In that study on the Kaibab Plateau (Arizona), the cumulative proportion of alternate nests showed about 75% occurred within 0.5 km of the territory centroid and 95% occurred within 1 km of the centroid. Over the 12 year study, the frequency of use of alternate nests was high with 64% breeding goshawks moving to an alternate nest at some time.

The Breeding Cycle

For the purposes of this conservation assessment it is not necessary to catalogue every aspect of goshawk breeding. For a comprehensive discussion on this topic see Squires and Reynolds (1997) and Roberson et al. (2003)

There are surprisingly few data on the chronology of goshawk nesting in the WGLR aside from general statements such as "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" (Andersen et al. 2005). I could find no data for Michigan or Wisconsin. For Minnesota, Roberson (2001) recorded dates for 1999 and 2000 as shown in figure 8. Environmental factors (e. g., weather) may effect the onset of breeding (Squires and Reynolds 1997).

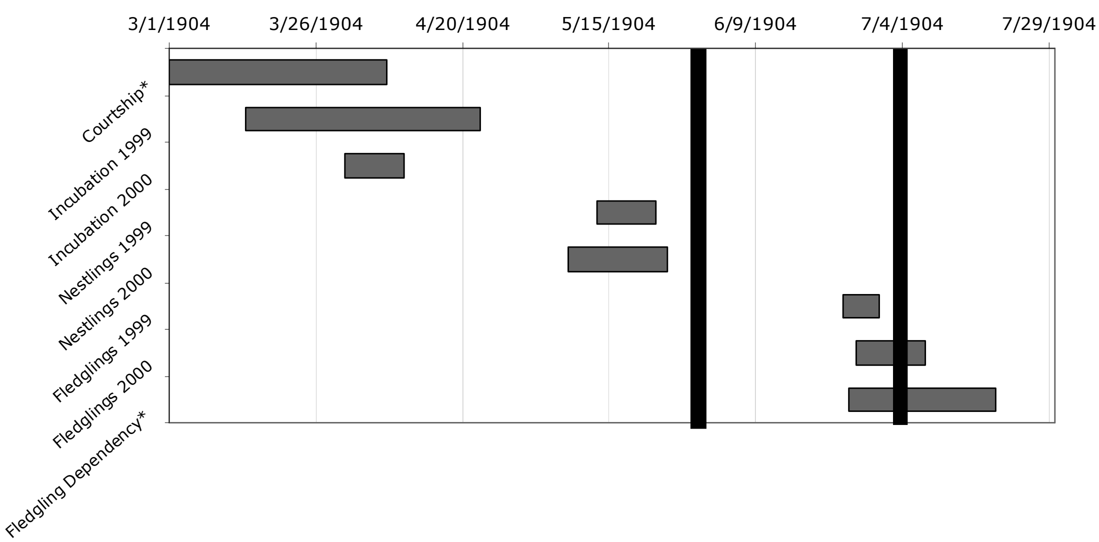


Figure 25. Observed breeding cycle dates from Roberson (2001). Asterisk denotes estimated dates. Thick lined indicate mean hatching (left) and fledging (right) dates in a Minnesota study from 2000 – 2002 (Smithers et al. 2005a)

Determining the onset of courtship is difficult because some goshawks reside in the breeding area year-round (Squires and Reynolds 1997). From egg-laying to fledging the female becomes increasingly aggressive in defense of the nest (Lapinski 2000). The ferociousness of a female goshawk when defending a nest is often learned inadvertently by happening upon a nest: "It is hard to imagine more pent-up fury and power in any being of her size" (Gromme 1935). During the entire breeding period the male does little to defend the nest, but provides about 85% of prey deliveries (Schnell 1958). Prey delivery frequency is positively correlated with nestling growth rate (Schnell 1958).

Extra-pair fertilization is common in many bird species (Burley et al. 1996). For goshawks, any extra-pair fertilizations should take place just before and during egg laying when females are left alone at the nest (Gavin et al. 1998). Although difficult to observe, a study on goshawks on the Kaibab Plateau by Gavin et al. (1998) using genetic evidence showed that extra-pair fertilization was extremely low, only 1 of 39 (2.6%) clutches sampled. The authors attribute this low incidence to goshawk life history characteristics, i. e., social monogamy, non-colonial and territorial nesting areas, and synchronous breeding.

The female goshawk lays a single clutch of 2 to 4 eggs (range = 1 – 5, North American average 2.7 [Squires and Kennedy 2006]). Replacement of a lost clutch seldom occurs (Squires and Kennedy 2006). Prey abundance has been reported to correlate positively with clutch size (Mueller et al. 1977). Conversely, in Michigan Postupalsky (1998) reported that brood size was unaffected by the prey population cycles.

Incubation is primarily by the female (Zirrer 1947) and lasts 30 to 44 days (Kennedy 2003). Weather can cause nesting failure during incubation. In Minnesota, 35% of nest failures observed one year by Boal and Andersen (2005) were due to 10-11 days of steady rain. A severe winter and late spring may have contributed to egg failure and/or decrease in available prey in Lapinski's (2000) Michigan study. After the chicks hatch brooding is done mostly by the female (Squires and Reynolds 1997).

In a rare study of goshawk fledgling survival that included an experimental and control treatment, nestlings from territories with artificial food supplementation were larger and heavier than the ones from the un-supplemented control nests, but not significantly so (Ward and Kennedy 1996), the same is true of early survival rates. However, there was a higher overall survival rate for treatment nests compared to control during one year of the study. This is attributed in differences in predation; in the presence of abundant food, the female adult goshawk was at the nest more often, thereby limiting opportunities for predators to take young goshawks (Ward and Kennedy 1996).

In Finland, Kenward et al. (1993) tracked 221 goshawks from 1980 to 1987, monitoring the behavior of fledglings. The young birds were almost always within 300 m of the nest during the first 25 days after fledging. From about 25 days to 65 days the fledglings spread farther from the nest but remained within the general area (< 1.5 km from the nest). At 62 to 66 days after fledging an important physiological stage is reached. This is when the fledglings primary feathers and retrices finish growth and harden their bases. This age coincides with the beginning of natal dispersal (i. e., final departure from the nest area). Most goshawks (90%) had dispersed by 90 days post-fledging. The authors supplemented food supply and removed parents from some territories to test if food shortage or parental aggression influenced dispersal age. Removal of parents had no effect. Birds with supplemented food available remained in the area 4 to 7 days longer than the control group, but even these birds dispersed by around day 95. Taking all of the evidence together, Kenward et al. (1993) suggest that: 1) a dispersal window opens as soon as the fledglings' primary feathers are fully grown and hardened; 2) the window closes due to behavioral maturation of the hawks around 95 days post-fledging; and 3) food shortages cause earlier dispersion within the window.

Summary

The goshawk is a forest raptor with a circumpolar distribution. The edge of the goshawk's range cuts across the three states of the WGLR – Minnesota, Wisconsin, and Michigan. The global conservation of the goshawk will be little served by any actions or inaction that occurs at this edge. Goshawks prey on any number of species, the primary determinant being availability. Even so, most regional populations have one or two primary prey species. In the case of the WGLR these are ruffed grouse and snowshoe hare. The breeding cycle in the WGLR begins with courtship around the first of March and ends with dispersal of fledglings some time in late July.

GOSHAWK HABITAT

Of all the aspects of goshawk ecology, habitat – specifically breeding season habitat – has been most studied. Of my 400 or so goshawk references, fully one third address or refer to habitat. I believe there are two primary reasons for this bias in attention. First, it's the easiest part of a wild animal's ecology to study. The vegetation doesn't fly off and once a breeding site is found the study area is almost self-defined. The second, and more important, reason is that the habitat is something that is influenced by human behavior.

Table 4. Goshawk habitat variables measured in some North American and European studies.

Nest	**Nest Site**
nest height	patch size
relative nest height	patch shape
no. of branches for nest	down woody material
	number of overstory trees
Nest Tree	age structure of tree layer
species	standing dead trees
height	stem density
DBH	height of understory top
Canopy closure	height of understory bottom
crown height	height of canopy top
crown cover	height of canopy bottom
crown volume	DBH of neighboring trees
vigor	tree density
Distances to	**Landscape**
human disturbance	number of tree species
water	dominant tree species
next tree	Forest edge length
next stand edge	forested area
nearest forest edge	number of habitats
	area covered by clearings
	slope
	slope position
	altitude above sea level
	soil moisture
	topography
	signs of recent cutting

Our ability to affect change in goshawk habitat (see **Humans and Goshawks** below) has, to some extent, burdened us with the responsibility to create and maintain said habitat. This in turn has led to the countless studies of what constitutes 'goshawk habitat' with the inferred goal of developing a 'habitat recipe' to make goshawks. But how many ingredients are in this recipe? We can't tell how many dimensions constitute a species' niche (Hutchinson 1959); so we will never know when we have all the data we need. (There are still studies of what constitutes white-tailed deer habitat, e. g., Deperno et al. [2002]). Also, the goshawk exhibits a great deal of plasticity in habitat selection which means that we can never really abandon systematic searches for nests (Daw et al. 1998). A cursory review of goshawk references reveals the extent to which researchers have engaged the goshawk habitat issue (Table 3). Many of these studies were done at the behest of management agencies. Of course, not every study measured all of these variables, and in discussing habitat across studies it is difficult to compare results because different units of measure have been used. For instance, Reineke's stand density Index (SDI) (Reineke 1933) was used by (Lilieholm et al. 1993) to define the range of stand conditions that qualify as goshawk nesting habitat; whereas Gibson (2003) deduced stand conditions by comparing various habitat measurements.

Krüger (2002) brings up a very important consideration in studying habitat characteristics of long-lived birds (e. g., many raptors): if a species prefers certain habitat features for nest sites, as opposed to nesting randomly within its habitat, is the mere cataloguing of nest site parameters sufficient to measure this preference? Krüger (2002) asserts that the true measure of nest site preference can only be made when occupation rate or reproductive success is also taken into account. Using 25 years of data on 79 goshawk nests in Germany, he found that 30.6% of nests built by goshawks were never used. A stepwise forward multiple regression model of productivity at nest sites with 43 variables produced one determinator variable that correctly classified occupied nests 63.3% of the time – successful nests had more forested area within a 500m radius of the nest.

Goshawk habitat, as mentioned in the introduction, can vary greatly by location, over time, perhaps even by the temperaments of individual birds. For example, this 'forest raptor' has a well-established breeding population within the city of Hamburg, Germany – human population 1.7 million (Rutz et al. 2004). In order to avoid a mind-numbing catalogue of every permutation of habitat variables observed in goshawk studies, I will try to keep the following discussion focused on the WGLR with reference to other regions where appropriate.

Breeding season habitat

Nest tree

Spatial Scale: one tree

Goshawks in the WGLR have built nests in most species of large trees with growth patterns that provide a stable nest platform, including Aspen (*Populus sp.*; Richardson and Bach 2002, Rosenfield et al. 1998), beech (*Fagus grandifolia*; Gibson 2003), white pine (*Pinus strobus*; Dick and Plumpton 1999), white oak (*Quercus alba*; Haug 1981), and others. Nests have been constructed and successful in dead white pines and dead aspen (Dick and Plumpton 1999). DBH and tree height measurements in themselves are more or less useless because goshawk nest tree preference is comparative rather than absolute (e. g., Rosenfield et al. (1998) reported mean tree density at 28 nest sites as 353 stems/ha).

Figure 26. Goshawk nest in aspen tree on the Chippewa

In general, deciduous trees are much more commonly used than conifers for nesting by goshawks in the WGLR (Boal et al. 2006). Larger aspens are preferred throughout the WGLR (Postupalsky 1998, Rosenfield et al. 1998, Maya Hamady, Minnesota DNR, pers. comm.) probably owing to their forming multiple crotches within the crown. For the same reason, in the Upper Peninsula of Michigan, beech trees were used selectively to nest in Hiawatha NF (West Unit) by goshawks; and preference was shown for sugar maple (*Acer saccharum*) and yellow birch (*Betula lutea*) (Gibson 2003). Beech is often the largest tree in these areas and the structure is favorable for nest placement (Gibson 2003).

In Gibson's (2003) study of three sympatric raptors in the west unit of the Hiawatha NF, goshawks selected trees for nesting that were significantly larger (DBH) than random, but compared to the red-shouldered and red-tailed nest trees, goshawk trees also showed a high degree of variability in nest tree size.

Alternative nests have been shown to be important to goshawks in the Kaibab Plateau (Reynolds et al. 2005). In the WGLR the literature is relatively silent on this aspect of goshawk nesting. An exception is Ennis et al. (1993) who reported on approximately 40 territories in the Huron-Manistee NF. Of these territories half were searched for and, of those, 13 had one or two alternative nests. Of the 19 alternative nests located, 11 were greater than 300 m from the active nest and 6 were between 40 m and 100 m away.

Nest site/Nesting area

Spatial Scale: 8 – 39 ha (Newton 1979, Reynolds et al. 1992, Finn et al. 2002)

Once the spatial scale of analysis is increased beyond the actual nest tree the problem of terminology becomes apparent. The *nest site* is generally taken to be the immediate area around a nest including any alternate nests. A *nesting territory* is a collection of nest sites known from historical breeding records to belong to a pair of birds which were distinct from all neighboring pairs (Watson et al. 1992). This is comparable to a *breeding territory*, defined by Reynolds et al. (2005) as an area exclusively occupied by a pair of goshawks during the breeding season. Another common term is *nest stand – stand* being a forestry term meaning a group of trees occupying a given area and sufficiently uniform in species composition, age, etc. so as to be distinguishable from the forest on adjoining areas. Stands are often defined by edges that have nothing to do with the ecology of the goshawk and are, therefore, highly variable (Reynolds et al. 2006). Reynolds et al. (2006) use the more encompassing term *nest area*: the "area surrounding a nest that includes the hawk's roosts and prey plucking sites, and the nest stand". I will use this last definition in the ensuing discussion.

Studies describing forest characteristics of nest areas seem to be represented inordinately in the modern literature on goshawks. Perhaps, just as early North American records were primarily restricted direct observations of locations and effects on domestic chickens (e.g., Deane 1907, Bunker 1917), current studies nearly always use GIS and available digital landscape data.

Typically, these studies include some number of active nest sites and compare habitat characteristics (structure, mage, canopy cover) at various spatial scales with the same measures at randomly selected points. Resource selection is determined by either used versus unused or versus available. For example, in Oregon, Daw and DeStefano (2001) compared forest age and structure at 22 active nests versus random points and found that goshawks selected dense canopy, late-forest structure for nesting.

A review of the literature by Reynolds et al. (2006) revealed that, although goshawks most often use mature and old forests with relatively closed canopy for nesting, mid-aged to young forests, forests adjacent to meadows, and open scrub or tundra areas with only scattered patches of trees have also been used. Witness the urban goshawks mentioned above; or the pair of goshawks that nested successfully for only one year above the treeline in Alaska, the nest in the tallest willow (*Salix alexensis*) of a riparian area (Swem and Adams 1992); or the highest recorded density of breeding goshawks (less than 10 km^2 per pair) in an area of central Germany with only 12 – 15% woodland, the remaining area being agricultural (and highly productive for prey species) (Kenward 1981).

I will spare the reader once again the interminable catalogue of goshawk nest areas described across the hemisphere and focus on the WGLR. In the Upper Peninsula of Michigan, Lapinski et al. (2002) found that goshawks showed no selection for any forest habitat during the breeding season. The goshawks, however, did prefer the presence of aspen, cedar (*Thuja occidentalis*) and open habitats. To the authors, the goshawks appeared to choose habitat that coincided with that of its suspected favorite prey – snowshoe hare and ruffed grouse rather than any vegetation variable. In the Hiawatha NF, goshawk nest stands averaged 30.35 ha and represented relatively high basal area and canopy cover for the area (Gibson 2003).

In Michigan's Lower Peninsula, goshawks typically nest in mature forests, but pole-size timber is also used as long as the stand is open below (Postupalsky 1998). In the Huron-Manistee NF 16 of 21 active nests discovered in 2000 – 2001 were within red pine (*Pinus resinosa*) plantations (Fig. 10); of the remaining nests, three were in mature aspen stands, one in lowland hardwood dominated by maple and ash (*Fraxinus sp.*), and one in a stand dominated by red maple (*Acer rubrum*)and yellow birch (Richardson and Bach 2002). The authors compared plantation nests to other nests for 23 habitat variables within 0.04 ha circular plots centered on the nest tree. None of the differences calculated between the two types of nest site were significant. This is important because much of Michigan's forested federal lands contain large tracts of pine plantations (Richardson and Bach 2002).

Figure 27. Red pine plantation on the Huron-Manistee NF.

Overall, combining references reported in Boal et al. (2006) with Postupalsky (1998, Dick and Plumpton (1999), Richardson and Bach (2002), and Gibson (2003) the picture of goshawk nesting habitat in the WGLR appears as: 1) relatively high canopy cover (60-90%); 2) larger basal area than surrounding forest with some trees of the size and shape to support stick nests; and, 3) an open layer between the bottom of canopy crowns and tops of understory plants.

One other variable of goshawk nesting areas that has been measured repeatedly is patch size or core area. These terms refer to the size (patch size) of the stand in which the nest is built; especially that portion of the stand that is labeled 'interior forest' (core area:

usually forest > 200 m from an edge). In New York and New Jersey, goshawk nests were located in the largest available contiguously forested areas (Speiser and Bosakowski 1987). In the western Upper Peninsula of Michigan core area was not a predictor of goshawk habitat in a stepwise linear regression (Gibson 2003).

Even though the above description of habitat may be nebulous these conditions are well represented across the WGLR, and, therefore, attains a key objective of this assessment. Incorporating more data across a wider spatial realm results only in more generalization. For example, Reynolds et al.'s (2006) conclusion that structure is more important than species composition for goshawk choice of nesting areas may be correct but it is of little use to most place-based land managers. After discussing goshawk breeding habitat at the landscape scale and the attributes of habitat for goshawk prey below we will try to address Kennedy's (1988) proposed functions that drive nest site selection goshawks: 1) proximity to hunting areas with dense prey populations, 2) availability of prey in the nest site during thee fledgling dependency period, (3) historic nesting success, (4) home range size requirements, and (5) the gross vegetative structure of the site.

Caveats for Interpreting the Research

At this point in our discussion – the transition from the scale of the nest area to that of the landscape – it is important to review the shortcomings of many goshawk habitat studies. These are: 1) how the habitat is delineated; 2) the value assigned to different habitat areas; and, 3) the interpretation of results.

1) The standard practice for measuring goshawk breeding habitat is to delineate a circle at some distance from a nest and sample within the circle (e. g., Speiser and Bosakowski 1987, Kennedy 1988, Siders and Kennedy 1996, Beier and Drennan 1997, Richardson and Bach 2002, Gibson 2003); often comparing the results to those of randomly placed circles. There is no reason to assume that the use of an area by goshawks should be uniform across some artificially determined shape (e. g., see Dzialak et al. (2005) for peregrine falcon). In fact, radio-telemetry studies (Reynolds et al. 2004) show that within an area occupied by goshawks there are regions actively selected for foraging (Beier and Drennan 1997), breeding season habitat use (Lapinski et al. 2002), and social interactions (Kenward et al. 2001). Furthermore, radio-telemetry can discriminate between core areas (Samuel et al. 1985) and less important areas of a home range.

   Obviously, goshawks built the nests where they did for some reason, no doubt related to habitat. In using the generic circle method, however, any habitat 'signature' (Holling and Allen 2002) will be at least partially hidden by the noise of unrelated habitat variables. At best this will cause a decrease in certainty, at worst it will lead to spurious results. Goshawk habitat studies in the WGLR include various methods. Until hypotheses are tested at the appropriate scale (i. e., the goshawk-defined scale) it would be wise to interpret results as general indications rather than valid facts.

2) Although it is yet to be shown for the WGLR, in other regions goshawks exhibit a type of self-limiting breeding behavior called Ideal Preemptive Distribution (IDP) (Pulliam and Danielson 1991), wherein the "best" (i. e., most productive) breeding territories are occupied first and later occupations are in less productive territories. Krüger and Lindström (2001), using a 25-year dataset of goshawk breeding in

Germany, found that in low goshawk density years, most occupied territories were of high quality. In years of intermediate or high goshawk nesting density, the number of intermediate and low quality territories occupied increased accordingly. Furthermore, as occupancy increased to include lower quality territories overall productivity (measured by brood size) decreased. Krüger and Lindström (2001) concluded that goshawks exhibit IDP in the spatial distribution and productivity of breeding.

Now, let's say a graduate student identifies 10 goshawk nests in an area. Pains are taken to make sure they are actively being used for breeding. The circles are drawn and the habitat data are collected and analyzed and results produced. In pooling the data across the nests, what can be determined, given that there are no data on the quality of these nest sites? If significant variables are identified in this process do they represent "good" goshawk breeding habitat? In the absence of further data the only conclusion can be that the variables represent a value that is above some minimum for goshawk habitat.

Unfortunately, the amount and quality of data needed for a study like Krüger and Lindström's (2001) exist for only a few goshawk populations in the world. In North America, Reynolds et al. (2005) have such a dataset for the goshawks of the Kaibab Plateau in Arizona. They state that the amount of temporal and spatial variation in goshawk reproduction at their study area required as many as 8 years of repeated nest searching to identify a population of breeders. Once territories are known, annual searches of the 1.4-km radius around territory centers are necessary for reliable estimates of the reproductive status of territorial pairs (to identify and sample alternate nests).

3) This last caveat is not limited to goshawk studies. When a study includes a large number of variables and a computer loaded with readily-available multivariate statistical programs the author often uses the "shotgun approach" to statistical analysis (Block and Brennan 1993). While this is often useful as a heuristic tool to help formulate hypotheses, too often the derivatives that result from these analyses are presented as ecologically significant when they aren't.

Speiser and Bosakowski (1987) point out the danger of attributing goshawk selection of nest sites to derivative habitat parameters. In their 10-year study of goshawk breeding in New York and New Jersey they found the following parameters at nest sites significantly differed ($p<0.05$; + = positive correlation, - = negative correlation) from random sites:

Parameter	**Nests v Random**	**Narrative: Goshawks…**
Relative dominance and density of oaks	-	prefer sites with a large component of hemlock and, therefore, a smaller proportion of oak
Relative dominance and density of hemlocks	+	
Distance to human habitation	+	prefer larger blocks of forest. Often these undeveloped sites are at higher elevations, near wetlands and, therefore, farther from human habitation.
Elevation	+	
Distance to swamp	-	

Instead of accepting the significant parameters at face value, they suggested a narrative for how these parameters interact. The difference in narrative can have profound implications for managers.

Goshawk Habitat at the Landscape-scale

Spatial Scale: 570-3,500 ha (reviewed in Squires and Reynolds [1997])

There are two or three areas (depending on definitions) important to breeding goshawks at the landscape-scale: post-fledging area, home range, and foraging area. Since they are all centered on the nest they overlap considerably.

Post-fledging Area

Home range and foraging area are well-established metrics of breeding bird biology, but post-fledging area (PFA) is not acknowledged universally. I find this curious since all birds fledge. A cursory search on the journal archive JSTOR (www.jstor.org) for the terms 'post-fledging area" and "habitat" yielded 320 articles; removing "goshawk" reduced this to 276. Unfortunately, this search returned articles with only 'post-fledging" as well as the original search terms. In short, I found a few studies where post-fledging habitat differed significantly from that of the nesting area (scarlet macaw (*Aro macao*), [Myers and Vaughan 2004]; wood thrush (*Hylocichla mustelina*), [Vega Rivera et al. 1998]), but for the most part, articles that quantified post-fledging dispersal and survival had no reference to a delineated PFA (e. g., prairie falcon (*Falco mexicanus*), [McFadzen and Marzluff 1996]; white-crowned pigeon (*Patagioenas leucocephala*), [Strong and Bancroft 1994]; black-throated blue warbler (*Dendroica caerulescens*), [Sillett and Holmes 2002]).

According to Kennedy (2003) the PFA was conceptualized by Reynolds et al. (1992) 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. Theoretically, PFAs may be important to fledglings by providing prey items on which to develop hunting skills, as well as cover from predators and prey. Empirical support for this hypothesis has been limited to movement patterns of goshawk families (see Kennedy [2003]). To my knowledge there have been no comparisons of capture rate by fledglings in differing PFA habitats; and, while mortality to predation increases with age out of the nest for goshawk fledglings (Ward and Kennedy 1996) and other birds (Anders et al. 1997), no studies link mortality rate to characteristics of the PFA.

In fact, all of the attributes assigned to the PFA can be more simply conferred on the home range of the adult breeding pair. Given that the center of the PFA is the nest area, and that the PFA is intermediate in size to the nest area and the home range, one would expect a gradient of dissimilarity as one travels outward from the nest. Just so, in measuring heterogeneity the PFA is found to be intermediate between the nest area and the home range (Finn et al. [2002] *in* Kennedy [2003]). Since the authors did not account for spatial autocorrelation (by using detrended correspondence analysis or non-metric multidimensional scaling [Gauch 1982]) the same result can be explained by spatial beta diversity (Ricklefs 1979). Similarly, Johansson et al.'s (1994) models to predict potential goshawk nesting sites in Utah used elevation and vegetative characteristics of the nest stand. Adding the vegetative characteristics of the PFA (per Reynolds et al. [1992])

increased the predictive ability only slightly compared to the two original parameters in combination.

McGrath et al. (2003) compared goshawk nesting habitat in the Cascade Mountains across multiple scales. Of the seven spatial scales they analyzed they found the best model for discrimination between nest and random sites was 83 ha. The authors justified inclusion of this scale by applying the body-size/home range size relationship described in Holling (1992). Eighty-three ha falls between the scales of nest area and home range and may represent some ecologically-significant unit of study, but this isn't made clear in McGrath et al. (2003). The PFA has been compared to the female nesting goshawk's core area. Fig 11 shows the average area of fledgling dispersal from the nest over time reported in Kennedy et al. (1994). In that study, the authors defined the PFA as 168 ha. This falls well within the female home range reported in the same study. It would be safe to assume that an area with sufficient habitat to support a female's home-range (let alone a male's [Fig. 11] would provide adequate habitat for a PFA. Harrower et al. (2005) provide an insight into the mechanism behind this correlation of fledgling movement and breeding female home-range. Intensive tracking of fledgling goshawks revealed that after fledging but before dispersal the young, the adult female provides prey directly to the young birds. Much of the post-fledgling movements then, result from following the females (who provide most of the food at this stage) or flying out to intercept adults returning with prey. Given that the objective *raison d'etre* for PFAs is questionable, Occam's razor calls for us to simplify our analyses of goshawk breeding habitat by removing PFA and concentrating instead on the sex-specific home ranges of nesting adult goshawks. Since, however, many readers will expect a discussion of PFAs for the WGLR goshawk I will provide one for the sake of continuity and comparison.

In British Columbia average fledgling home range was 0.20 ha (± 0.18 SD, n=6) (Harrower et al. 2005). In that study only 4% or radio-tagged birds were located beyond 500 m of their nests before final dispersal. This is a very restricted pattern compared to other studies of post-fledgling movement (e. g., 91% of locations within 800 m of nest in Kennedy et al. [1994]) and may be the result of the fragmented habitat in the British Columbia study (Dzialak et al. 2005). The consensus is that PFA habitat is similar to that of the nesting area and can be differentiated from random areas by the dominance of more mature, larger trees (reviewed in Finn et al. [2002]). This generalization holds true in the WGLR as reported in Ennis et al. (1993). In the Huron-Manistee NF about 32% of trees are over 30 years old, in PFAs the proportion is 85%. Titus et al. (1999), however, found a much more complex landscape. They delineated hypothetical, circular post-fledging areas with a radius of 1,500 m, approximating the average distance moved prior to dispersal by a sample of radio-tagged juveniles in Southeast Alaska. Their analysis of 136 of these 707-ha PFAs found, on average, medium- and high-volume old growth covered 39 percent, non-forested and non-commercial forest covered 45 percent, low-volume forest covered 8 percent, and clearcuts covered 4 percent.

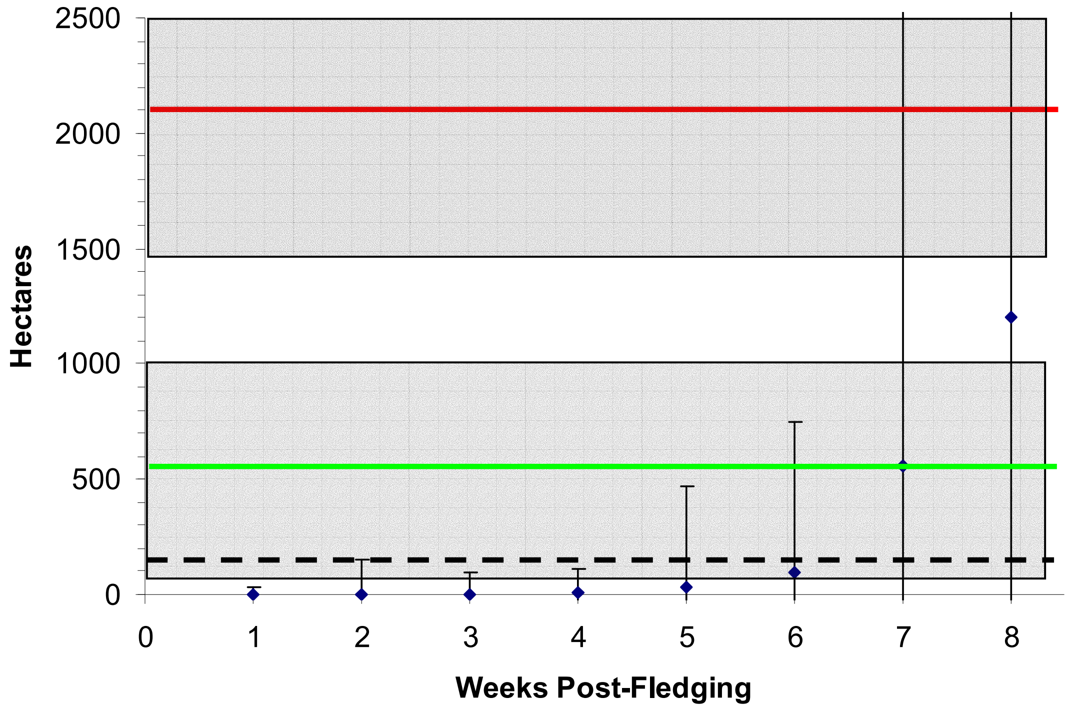


Figure 28. Using data from Kennedy, Ward et al. (1994), mean distance fledglings traveled from the nest site at each week post-fledging converted to area (vertical lines represent 1 SD); compared to PFA (green line), male and female home ranges (gray).

Home Range/Foraging Area

Home range has been defined as: "…that area traversed by the individual in its normal activities of food gathering, mating, and caring for young." (Burt 1943). Breeding season home range is the area used by a pair of breeding goshawks for foraging, resting and caring for young (Hargis et al. 1994). Goshawk breeding home range consists of the nest area, the post-fledging area and foraging areas. The first two are discussed above. According to this approach, the home range, exclusive of the nest area, is defined by foraging activity. Goshawk home ranges can overlap (Reynolds, personal communication *in* Woodbridge and Hargis [2005]), but this is prevalent only in dense breeding populations and has not been observed in the WGLR.

Structure - Boal and Andersen (2005) used radiotelemetry to examine foraging habitat preferences of 17 breeding, male northern goshawks in Minnesota. They found that early-successional upland conifer stands, early-successional upland deciduous stands, late-successional upland conifer stands, and late-successional upland deciduous stands were selected for while early-successional upland deciduous and all ages of late-successional lowland conifer stands were selected against. In Michigan's Upper Peninsula, Lapinski (2000) found goshawks preferred mixed hardwood/conifer and jack pine (*Pinus banksiana*) forest types for foraging. Across vegetation communities, goshawk foraging areas share structural similarities with high canopy and understory stem densities, high canopy closure, substantial shrub cover, and large amounts of woody debris (Boal and Andersen 2005).

In the west Unit of the Hiawatha NF, Gibson (2003) developed a stepwise linear regression model of goshawk foraging macrohabitat selection at various spatial extents. Of more than 60 variables entered and removed from the model, discrimination of goshawk nest sites from random sites was attained for the 314 ha extent with two variables: increased edge of coniferous forest patches and little variability in size and shape of all patch sizes; at the 1256 ha extent there were three variables: patches of open water with smooth edges, deciduous patches in close proximity to each other, and deciduous patches of varying size. Correct classification for these models was around 70% (but see James and McCulloch [1990] for a discussion of stepwise regression use). On the Chippewa NF, foraging of breeding goshawks occurred in habitat types at the same frequency as availability, that is, no preferred habitat (Ludwig, unpl. ms., no date).

Productivity - In her review, Kennedy (2003) reported on comparisons of occupied and unoccupied goshawk territory landscapes. Historical sites were more likely to be occupied in landscapes with large uniform patches and reduced early-succession cover. These differences were most apparent with increasing spatial scale. Desimone and DeStefano (2005) compared activity at nest site discovered from 1992 to 1994 in south-central Oregon with historical sites (1973 – 1992). Although the authors' assumptions concerning territory occupancy are not supported by other work (e. g., Reynolds et al. [2005]) the results they show for the 46 nest sites they studied are convincing. Occupied sites had significantly more late structural stage forest while 'unoccupied' sites had more early stage forest. Canopy cover > 50% also contributed positively to the occupancy rate.

Size - Goshawk home range/foraging area has been estimated to be about 2,000–3,000 ha (Boyce et al. 2006, Finn et al. 2002). The interpretation of these values calls for another caveat; this one on measures of home range size. Measures of home range size for animals are dependent on methodology (Kenward et al. 2001). This makes questionable the value of comparing of home range results from different studies. For example, the minimum convex polygon method of delineating home range is sensitive to outlying points that may or may not reflect important use of a resource. Kenward et al. (2001) suggest using cluster analysis to define the 'outlier-exclusive core' which would more accurately delineate the area of 'normal use' referred to by Burt (1943). Even an accurate measure of a bird or pairs' core area is of limited application outside of the birds that were measured. The home range is ultimately a measure of the landscape pattern that provides necessary resources to the birds.

Home range sizes in the Upper Peninsula of Michigan were small compared to those measured in western states (Lapinski et al. 2002). Lapinski et al. (2002) suggest that this small home range size found in the Upper Great Lakes is due to increased prey availability in conjunction with the snowshoe hare/ruffed grouse population cycles. In Minnesota, Eng and Gullion (1962) studied the effect of one goshawk family on the local ruffed grouse population. They calculated the foraging area of the nesting goshawks as about 5 miles^2 (1295 ha). Also in Minnesota, 28 radio tagged goshawk (17 male, 11 female) were followed to estimate breeding season home range size over three years, with comparisons between male, female and pair home ranges (Boal et al. 2003). Differences between male and female home range sizes weren't significant: 2593 ha and 2494 ha, respectively, using minimum convex polygon; 3927 ha and 5344 ha, respectively using 95% fixed kernel method. However, the authors' found that among breeding pairs overlap between male and female home ranges were less than 50%, therefore, combined home ranges for a pair were significantly larger than those for individuals. Boal et al. (2003) suggest that basing goshawk conservation measures on individual home range size estimates would underestimate the required area for a breeding pair.

Forest openings – Goshawk nest sites are usually (always?) found near openings, either natural (e. g., stream beds), or artificial (e.g., clear cuts). In the western U. S., nest are normally within 0.4 km of an opening in the forest that is 0.04 – 0.4 ha in size (Lilieholm et al. 1993 and citations within). In New York and New Jersey, where goshawks prefer large contiguous forests for nest sites, nests were significantly closer to forest roads and discernable trails than would be expected by chance (Speiser and Bosakowski 1987). Many authors include the presence of small openings in their recommendations for goshawk habitat (Reynolds et al. 1992, Graham et al. 1994, Squires and Kennedy 2006). Reynolds et al. (1992) refer to the openings and other habitat features (e. g., snags, downed logs) as critical for goshawk prey species (see **Prey Habitat** below). These openings and their associated edges may also serve to facilitate foraging by goshawks (Squires and Reynolds 1997). The occurrence of bodies of water in goshawk home ranges has been noted. Water is not a great physiological need because goshawks are able to concentrate Na^+ and Cl^- in nasal secretions; allowing for conservation of water in the body (Cade and Greenwald 1966). There was no significant relationship between goshawk nest sites and open/running water in New York and New Jersey (Speiser and Bosakowski 1987). Bodies of water define edge habitat and this may be the more important aspect of the landscape for goshawks.

Goshawk Winter Habitat

Goshawk in the WGLR are primarily resident and spend both summer and winter in the same habitat (Boal et al. 2003). There may be some short movements in response to prey availability (Drennan and Beier 2003, Rickman et al. 2005), but in our region we do not witness the seasonal changes in distribution and behavior shown by populations that are regular migrants (e. g., Opdam et al. 1977, Kenward 1982)).

Collecting data on birds outside of their breeding seasons is difficult, especially when the species is secretive and occurs at low densities. The only reliable data on winter goshawks in the WGLR come from radiotelemetry studies, and these are in short supply. In Wisconsin, two goshawks were tracked through the winter (Doolittle 1998). The male used an area of 32 km^2 and was nearly always located near the edges of conifer swamps; the female spent most of her time within only 4 km^2 but was apparently attracted to the presence of a game farm, once the farm closed the female dispersed. In Michigan's Upper Peninsula, Lapinski et al. (2002) analyzed locations of three radiotagged goshawks with respect to habitat. The birds preferred hardwood/conifer mixed and fir/conifer swamp forests and avoided cedar, jack pine and open habitat types.

Conifer stands seem to be important to wintering goshawks in the WGLR. Doolittle (1998) suggested that goshawks may depend on these stands for thermal cover. A similar suggestion was made by Speiser and Bosakowski (1987). They observed goshawks on their future nest sites in late winter prior to deciduous leaf-out and suggested that the presence of conifers provides thermally insulated microhabitat for goshawk.

Our knowledge of goshawk ecology in the WGLR is nowhere as thin as in the area of winter habitat, prey selection, and physiology. I agree with Boal et al.'s (2006) call for more research in this area.

Goshawk Prey Habitat

Unlike some species of birds that nest and forage in the same habitat (e. g., many warblers and vireos [Martin 1988]), the goshawk preys on many species that inhabit much younger habitat than its preferred breeding area. Although there have been countless studies of goshawk breeding season habitat, I am not aware of any that address specifically the potential of nesting habitat to provide sufficient prey availability to successfully rear a brood. In the WGLR, where every landscape has been altered entirely by humans, this may seem an academic point. But in order to more completely understand the ecology of the goshawk this heuristic exercise may prove useful. For now, though, we must limit our analyses to the data we have at hand – the species presented in Appendix I.

Goshawk are opportunistic predators of birds and mammals (Boal and Mannan 1994, Squires and Kennedy 1994, Krüger 2007). Whereas specialist predators are assumed to be restricted to the same habitat as are their prey; opportunistic predators are able to take advantage of a variety of spatial and temporal changes in a landscape to secure different prey species depending upon their availability (Ryall and Fahrig 2006). So, the first question to address when discussing goshawk prey habitat is 'which prey'?

Throughout its range, goshawks prey upon Sciurids, lagomorphs, song birds, gallinaceous birds, corvids and woodpeckers (USFWS 1998). In many areas one or two species are predominant prey during goshawk breeding (e. g., blue grouse [*Dendragapus obscurus*] and red squirrels in Southeast Alaska [Lewis et al. 2006]). There have been few studies of goshawk food habits in the WGLR. Smithers et al. (2005b) conducted a well-designed study using video cameras at 13 nests from 2000 to 2002 in Minnesota. The only other study that I could find with actual numbers of prey was conducted by Richardson and Bach (2002) on the Huron-Manistee NF in Michigan (21 nests from 2000 to 2001). This study was based on prey remains collected from nests and, as such, shares many of the pitfalls associated with that method (Rutz 2003, Lewis et al. 2004). For the purposes of this assessment these two sets of results will serve to highlight the nature of goshawk foraging needs in the WGLR.

Figures 12 and 13 show the percent of prey items and percent of biomass by species for each study. I did some quick calculations on the numbers provided in Smithers et al. (2005b) and Richardson and Bach (2002) to get numbers of prey items by species and total biomass by species using values posted on Natureserve.org so that the data will be more comparable to each other.

Sciurids (squirrels) account for the highest percent of items and the largest percent of biomass from both studies (figs 12 and 13). For Minnesota, the only other species that claims more than about 5% of items is the eastern chipmunk (*Tamius striatus*); for Michigan, chipmunks, ruffed grouse, blue jays and mourning doves each account for more than 5% of the items recorded. Biomass may be a better indicator of prey importance, but it doesn't take into account prey availability. Figure 13 includes only those species that accounted for more than 1% of the total biomass and the inference is easier to make. In both studies squirrels are the dominant species for biomass (red for Minnesota, gray for Michigan) followed by ruffed grouse. The third most important species differ between the areas – for Minnesota it is chipmunks, for Michigan it is cottontail rabbits.

The years of these studies represent declining ruffed grouse numbers after a peak in the grouse population cycle around 1999, but the bottom of the cycle was not reached yet (see PREY CYCLES Box). Ruffed grouse, then, may be slightly more important prey items for goshawk in the WGLR than figures 12 and 13 indicate. Either way, the answer to the question asked above as to habitat for which prey species should we be concerned with can be answered as Sciurids, ruffed grouse, eastern chipmunks, and lagomorphs (rabbits). Habitat for these species follows:

Sciurids

Pine (red) squirrels prefer boreal coniferous forests that provide abundant conifer seeds, fungi, and interlocking canopies for efficient foraging and escape from predators. Suboptimal habitats include planted coniferous stands, aspen, and mixed coniferous-deciduous stands (Steele 1998). Herbaceous density, canopy cover, and proximity to tree cavities, underground burrows, and logs are important habitat factors (Steele 1998).

Eastern gray squirrels are most common in mature continuous woodlands >40 ha with a diverse woody understory (Koprowski 1994). Densities are highest in habitats composed of tree species that produce winter-storable foods such as oak, hickory, and walnut. Due to the variability in seed production, a diversity of nut trees is important to support high densities (Koprowski 1994). Availability of den trees can be a limiting factor addressed by silvicultural techniques (Sanderson 1975).

In Wisconsin, habitat specialization determines differences in distribution of red and gray squirrels. Densities of red squirrels are highest in fir-cedar stands and in pine stands in months following high production of cones. Densities of gray squirrels are highest in mature stands of maple-oak throughout the year and were correlated with tree size of red oak (Riege 1991).

Ruffed grouse

According to Rusch et al. (2000), ruffed grouse are closely associated with aspen woodlands year-round. In the WGLR, highest densities are reached in aspen-dominated forests. Aspen provides an abundant and reliable winter food resource (Svoboda and Gullion 1972). In Minnesota, dense sapling and pole stands of aspen provide the best cover for ruffed grouse while mature aspen provides high-value winter food (Gullion and Alm 1983). With this high-value winter food condition, however, comes the increased risk of predation by goshawks, especially if there is a larger age-class of conifers present (Gullion and Alm 1983). Optimal year-round cover consists of a mixture of young and older forest,

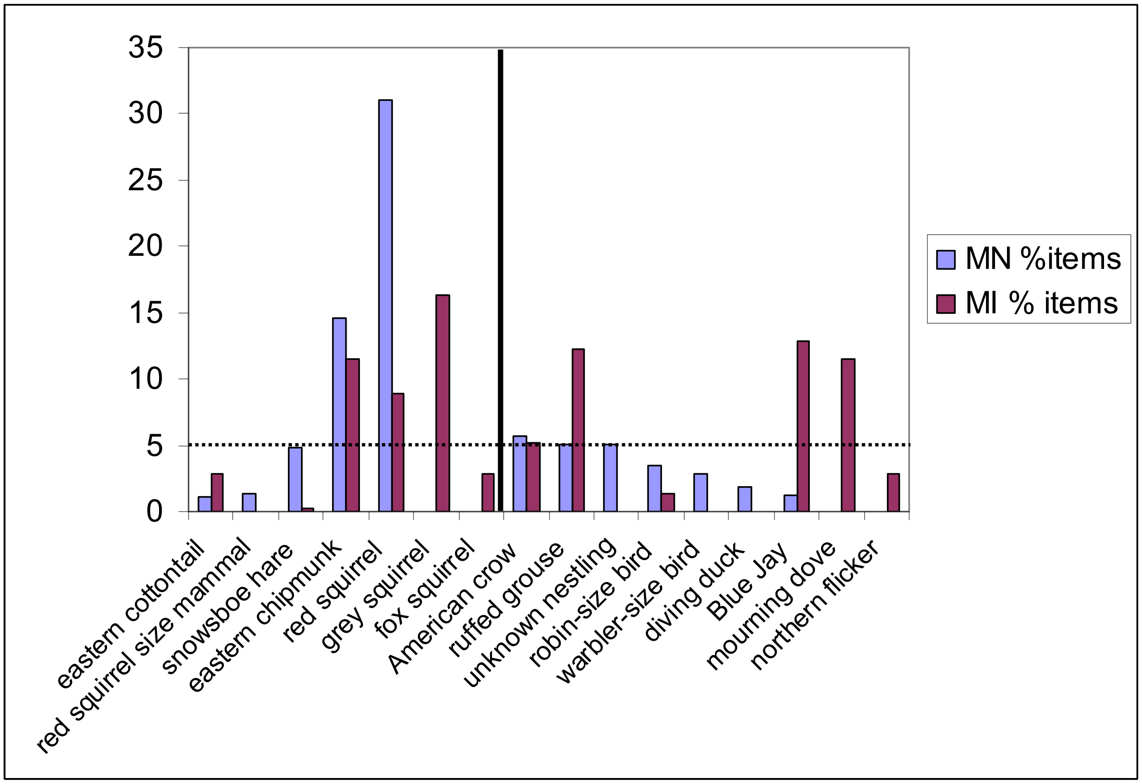


Figure 29. Percent goshawk prey items reported by Smithers et al. 2005 for Minnesota and Richardson and Bach 2003 for Michigan.

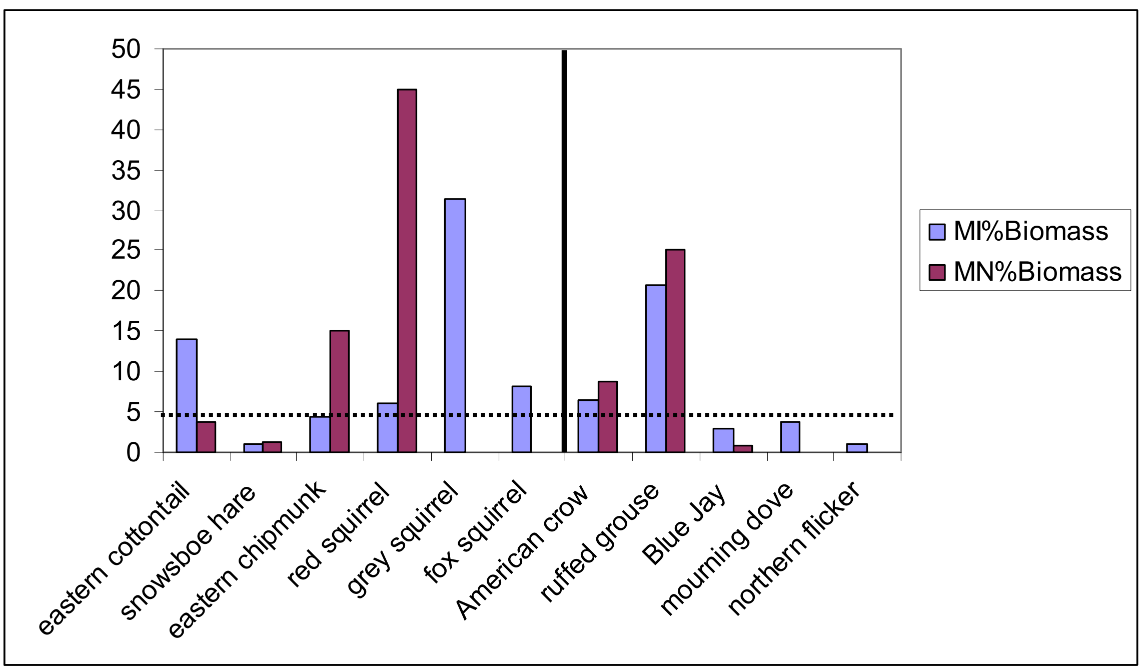


Figure 30. Percent biomass of major goshawk prey items for Minnesota and Michigan (see figure 8).

providing cover and food (Rusch et al. 2000). Blocks of hardwoods or conifers that shade understory growth provide marginal habitat and may be occupied only at edges. Nests in hardwood or aspen stands with open understories (Rusch et al. 2000). Fearer and Stauffer (2003) suggest that landscapes containing small (0.5-5 ha), regularly shaped patches with high interspersion of preferred habitat types and an extensive amount of high contrast edge will decrease ruffed grouse home range size and movement. Such landscapes may contain ruffed grouse habitat requirements within smaller areas, thereby reducing travel costs, decreasing exposure to predators and increasing survival.

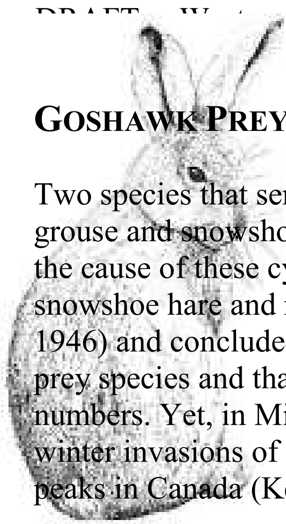
Figure 31. Wildlife clearing on the Huron-Manistee created through timber removal.

Small clearings (<0.4 ha) are important for reproduction and food (Sharp 1963) (Fig. 14). Gullion (1990) states that in conifer plantations ruffed grouse benefit if "islands" of aspen regeneration at least 0.4 ha in size are permitted to develop within or adjacent to the plantation.

Over time, small openings as described above will convert to forest and, therefore, lose their value as ruffed grouse habitat. In a field experiment, Sharp (1963) noted that by seven years after creation (via clearcut) openings began losing the herb and other ground-layer vegetation because of shading and, consequently, grouse brood use began to decline. By the end of 10 years, the openings were filled in by a dense brushy canopy and were of little value as brood feeding grounds. Areas with impenetrable ground cover, caused by thick vegetative growth, logging slash, or windthrown trees and brush, have proven to be unsuitable for grouse (Gullion 1990). Maintenance of clearings can be achieved by fire (natural or prescribed). Dessecker and McAuley (2001) state that, in the absence of fire, commercial timber harvests and other proactive habitat management practices should be implemented approximately every 10 years to ensure a continuous supply of quality ruffed grouse habitat on the landscape.

Eastern chipmunk

Primarily deciduous wooded areas; it occurs in open bushy habitats as well as mature forests (Snyder 1982). Probably because of predators, chipmunks prefer ample cover. Abundant crevices and coarse woody debris are important to chipmunks, especially in areas with open canopies and thick shrubs (Zollner and Crane 2003). For many small mammals specific microhabitats are necessary, but no data exist on the requirements of the chipmunk in the WGLR (Dueser and Shugart 1978). In Minnesota, Forbes (1966) reports that aspen and jack pine stands supported the largest numbers of eastern chipmunks. Disturbed or early succession forests also provide quality habitat.



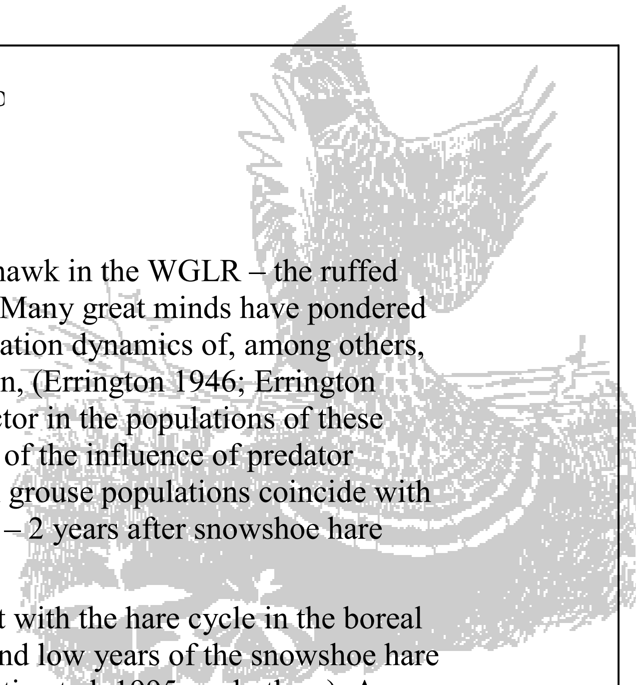


Figure 1: A male ruffed grouse drumming on a log.

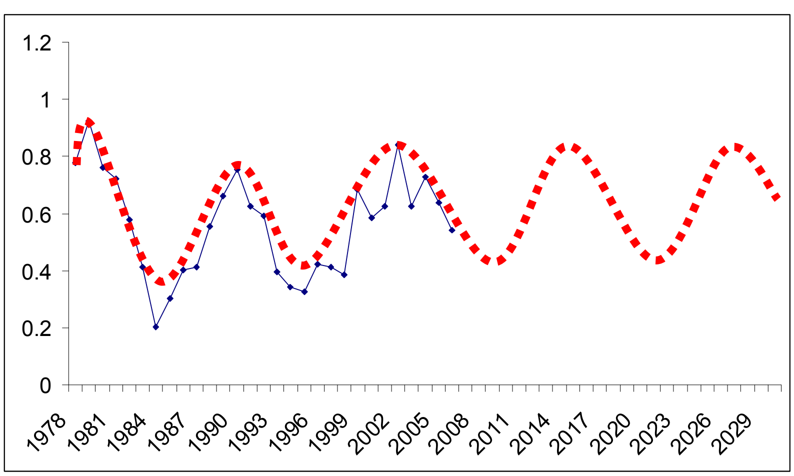
GOSHAWK PREY CYCLES

Two species that serve as important prey items for goshawk in the WGLR – the ruffed grouse and snowshoe hare – exhibit population cycles. Many great minds have pondered the cause of these cycles. Errington reviewed the population dynamics of, among others, snowshoe hare and ruffed grouse in relation to predation, (Errington 1946; Errington 1946) and concluded that predation is not a limiting factor in the populations of these prey species and that population cycles operate outside of the influence of predator numbers. Yet, in Minnesota and Wisconsin, declines in grouse populations coincide with winter invasions of goshawks and great horned owls, 1 – 2 years after snowshoe hare peaks in Canada (Keith and Cary 1991).

The invasion of goshawks into the WGLR is coincident with the hare cycle in the boreal forests of Canada. There the difference between peak and low years of the snowshoe hare cycle may be 15 to 100-fold (Keith *in* Wolff 1980; Boutin et al. 1995; and others). As one moves south the amplitude of the hare cycle dampens (Smith 1983). Wolff (1980) suggests that the relatively mild fluctuations in snowshoe hare populations across the 10-year cycle in the south compared to the northern parts of the range are due to the lack of establishment by dispersing hares in sub-optimal habitat in the south – possibly the result of higher predation. The hare population in the WGLR seems to have stopped cycling all together, something Bulmer (1975) noted for many species. He attributed it to habitat disturbance and hunting pressure.

The ruffed grouse still cycles in the WGLR. Since the population dynamics of goshawk are tied to the grouse cycle to some extent, studies should consider when in the cycle the data are collected.

I calculated the same prey availability (actually *abundance*) index used in Erdman et al. (1990) with data from the Wisconsin DNR (hare track count index and grouse drumming index). The prey index is calculated as $(\text{Snowshoe Hare Index}^2 \text{*Ruffed grouse Index})^{1/3}$. The graph below shows the index values up to 2006 and an unscientific projection of the cycle (red).



Hares and Rabbits

The snowshoe hare inhabits intermediate-aged aspen stands adjacent to conifer or alder swamps, old burns, young jack pine stands, and hardwood stands near coniferous cover. They use hollow logs, willow (*Salix sp*.) clumps and fallen trees for resting cover. In lower Michigan, Conroy et al. (1979) found that high degrees of habitat interspersion correlated with high densities of hares. Accessible cover in the form of cedar-fir, oak-pine, and alder (*Alnus sp.*) stands is preferred within 400 m of clearcuts. The authors also suggest that vegetation management for hares should emphasize the interspersion of upland and lowland habitats. In Minnesota, Fuller and Heisey (1986) found that snowshoe hare prefer vegetation providing low, dense cover (balsam fir [*Abies balsamea*], white spruce [*Picea glauca*], cedar) in winter. At times of high hare density other, less favorable cover is used (red pine, white pine). Also in Minnesota, Pietz and Tester (1983) report that snowshoe hares are restricted mostly to swamp conifers and thicket habitats during years of low density, but they are found in all forest or shrub habitat types when they are abundant. The overall preference for lowland and edge types probably reflected year-round availability of both cover and browse, and suggests that these habitats are critical for snowshoe hares. In the Yukon, the goshawk is an important hare predator. There, Doyle and Smith (1994) found that, whereas the other primary predators (lynx [*Lynx canadensis*], coyote [*Canis latrans*], great horned owl [*Bubo virginianus*]) typically capture hares in open spruce forest, one third of kills attributed to goshawks were in dense forest cover, although this comprised only 18% of habitat. Goshawk are able, therefore, to capture hares in dense cover, where they are relatively safe from their other major predators in winter.

The eastern cottontail is so wide ranging and so common across its range that Chapman et al. (1980) state: "No single habitat type may be classed as preferred cover. Habitat preferences vary from season to season, between latitudes and regions, and with differing behavioral activities.". Some studies have determined how to increase cottontail density in some areas. Habitat has been 'improved' by interspersing old fields and briar thickets and creating edge in large, continuous parcels of monotypic habitat (Chapman et al. 1980). Morgan and Gates (1983) report that cottontails respond to vegetative structure that allows a clear view of their surroundings and permits quick movement under cover. Thus, management should stress cover structure that allows use of these escape mechanisms.

Ensemble

There is somewhat of a dichotomy in the habitat needs of the species listed above. For the squirrels, large blocks of relatively mature forest support the highest numbers. Conversely, ruffed grouse, snowshoe hare and cottontails do best in non-contiguous blocks of early and later stage habitat. The chipmunk falls somewhere between these two.

We need better data on the foraging habits of goshawks across space and time, but the information above can fit into the reigning paradigm of goshawk breeding habitat (i. e., a central nesting area of relatively dominant forest with habitat heterogeneity increasing away from the nest [Kennedy 2003]): squirrels closer to the nesting area and grouse and lagomorphs more abundant in the outer home range. As to what proportions of these different types of habitat would best constitute "ideal" goshawk habitat, the science hasn't captured that. Furthermore, each species (with the exception of the cottontail, perhaps) has its particular habitat needs: mast production for gray squirrels; abundant conifer seeds for red squirrels; aspen and small clearings for ruffed grouse; and, coarse woody debris and downed logs for chipmunks and snowshoe hare. All of this, of course, must occur in a vegetative structure that allows for goshawks to successfully forage; that is, enough edge/open understory for successful implementation of goshawk hunting tactics (see above).

The above analyses do not address the potentially significant temporal factor of prey species that are important within and between years. Virtually every breeding season goshawk food study mentions nestling and recently fledged birds as prey (e. g., Schnell 1958, Reynolds and Meslow 1984, Tornberg 2000, McCallum and Hannon 2001, Rutz 2003, Lewis et al. 2004, Lewis et al. 2006). The fledging of many forest birds coincides with the time of highest food demands of nestling goshawks. Goshawk prey habitat may require robust and diverse populations of nesting birds.

The population of ruffed grouse (and to a lesser extent, snowshoe hare) exhibit an approximately 10 year cycle in the WGLR (see PREY CYCLES Box). There haven't been any long-term food habit studies that address the direct effect of this cycling on goshawk in our region, but Salamolard et al. (2000) provide good surrogate information. Their study of Montagu's Harrier (*Circus* pygargus) population response to cyclic prey availability offers a clue to how goshawk in our region may respond. In Fennoscandia, increasing latitude is coincident with increased cycle amplitude in small mammal populations and a decrease in diet diversity for the harrier. Conversely, further south, harrier diet diversity increases and prey population cycles decrease in amplitude. Thus, in northern latitudes Montagu's Harrier is a specialist predator (Newton 1979) under certain conditions and an opportunistic-specialist under others (Salamolard et al. 2000). The goshawk in the WGLR, if the correlation holds, would respond like the southern populations of harriers in Fennoscandia. A predator that depends too heavily on prey species that exhibits fluctuations in density is prone to local extinction (Gause 1934). Three things are necessary to prevent this: 1) alternate prey for predator; 2) immigration and emigration for both predator and prey; and, 3) presence of refugia for prey. Alternate prey and the presence of refugia are products of habitat heterogeneity (Gause 1934, Boutin et al. 1995).

Figure 32. Last of the loggers in western Wisconsin ca. 1895. The extensive pine forests had been totally removed by the time this picture was taken. Photo: Wisconsin Historical Society.

A stark example of the effect of habitat heterogeneity loss on a prey species can be inferred from Errington's (1933) report of the goshawk invasion of Wisconsin in 1907 – 1908. He reports that goshawk had "just about wiped out" a population of ruffed grouse north of Prairie du Sac, Wisconsin. The forests that had formerly blanketed this area had been removed by then, leaving only open fields and prairie (Fig. 15).

Habitat heterogeneity, then, emerges as a key factor in long-term maintenance of goshawk populations. In addition to providing a variety of prey within and across breeding seasons, it is inherently "edge rich". Edges provide for hunting opportunities and are used by diverse prey species for travel, foraging and nesting.

Summary of Goshawk Habitat

If we assume that the goshawk population in the WGLR was viable before European settlement (an unfounded assumption, but one that we implicitly accept), then a description of that ecosystem would help us better understand the species' life history. Working on data for the state of Wisconsin, Canham and Loucks (1984) offer the following reconstruction. Much of the WGLR was covered with mesic hemlock-northern hardwood forest. Within this vast forest, disturbance events, especially catastrophic windthrows, created large openings (e. g., the June 7, 2007 tornado on the Chequamegon-Nicolet NF, Fig. 16). In northern Wisconsin, there was an average of 51.8 separate patches of complete canopy windthrow each year. These patches, each at least 1 ha in size, covered a total of 4828 ha annually. Upland sites may have reached the characteristics of old-growth forest, but these were transient as each stand would have been subject to catastrophic disturbance on average of every four or five generations (Canham and Loucks 1984).

Figure 33. Track of a tornado through mixed upland hardwoods and conifers on the Chequamegon-Nicolet NF.

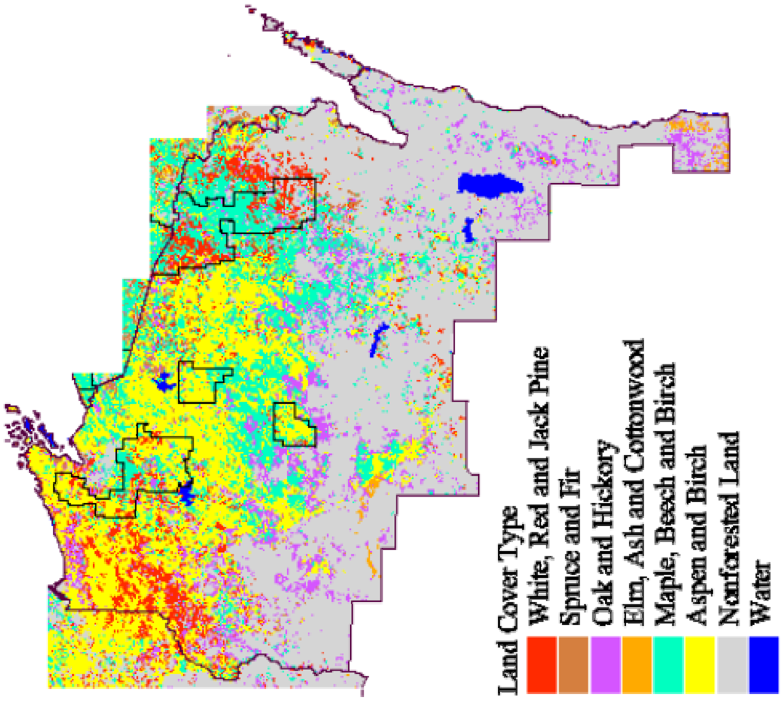
There exist data on how goshawks respond to these habitat "catastrophes". Penteriani et al. (2002) had six years of data on goshawk populations in the oak-beech forests of northern France when, in December 1999, an exceptionally strong storm swept across the area. Winds with speeds as high as 173 kmh^{-1} caused variable damage to nearly every forest stand and 10% of all forested areas were severely affected. Stand damage correlated positively with stand age and height – the same two elements that the goshawk prefer for nesting (Penteriani et al. 2001). Nineteen nest stands were damaged by windthrow. The following year, 13 of these pairs used the same nest as the previous year for nesting. Nest sites that were more than 30% damaged within 50 m of the nest (n = 6) were abandoned (damage within 500 m did not seem to be a factor). If any of these stands had alternate nests the pair moved there (providing the damage was not > 30%). At the end of the season the authors found no differences in breeding density, nesting stand choice, or productivity before and after the storm.

The preceding paragraphs help us better visualize what "ideal" goshawk habitat would be in the WGLR. Combined with what we know about breeding season and winter habitat we can make some generalizations about the nature of goshawk habitat in the WGLR.

In effect, habitat for a pair of goshawks would cover something on the order of 2000 ha (male home range) of forest with stands of different ages and structures and clearings of various sizes interspersed throughout (prey habitat). Within or nearby this area there would be at least one stand of lowland conifer (winter thermal cover). There would also be at least one integrated stand of older trees (relative to the surrounding area) with canopy cover sufficient to prohibit understory growth from reaching the bottom of the canopy (nest area). This stand should be about 40 ha. Within the stand there would be trees of size and structure capable of supporting a goshawk nest.

Status and Distribution of Goshawk Habitat in the WGLR

The 'big picture' of the status of goshawk habitat in the WGLR is reflected in the loss of forested land from presettlement days (Figs. 17 - 19). More specifically, the somewhat vague characterization of WGLR goshawk habitat in the preceding section must serve as our standard in exploring status and trend in the region. As one decreases spatial extent from states to the ecosystem and beyond the data become less available and trends become more difficult to detect. Our discussion will begin at the ecosystem scale.



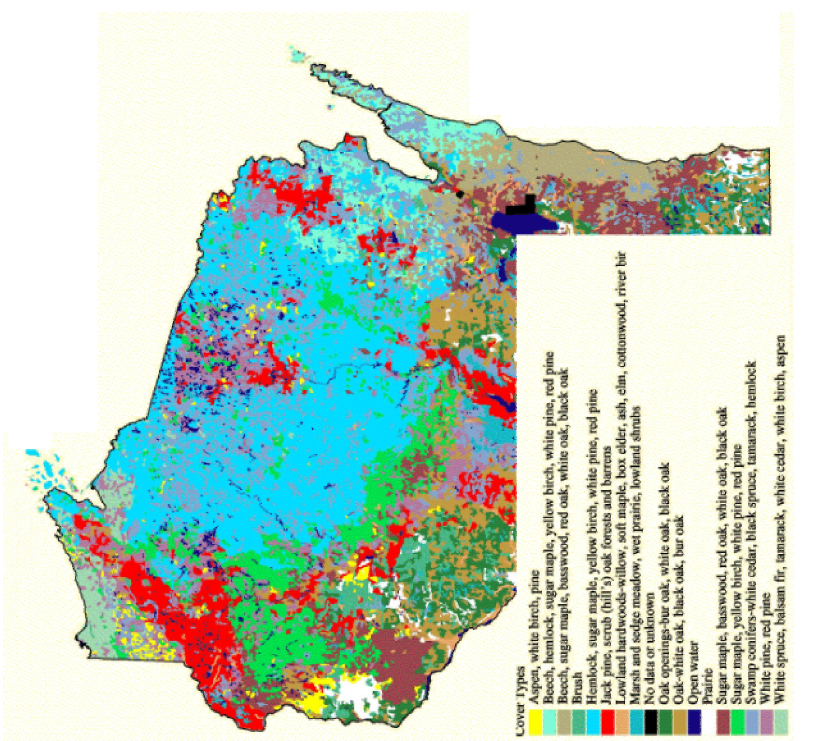
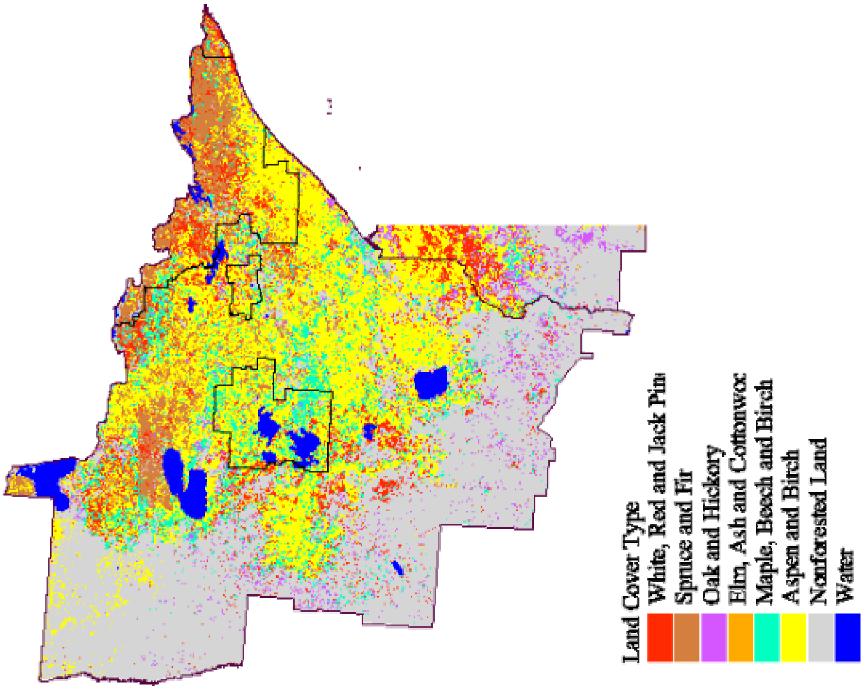


Figure 34. Wisconsin vegetation presettlement and current (from Great Lakes Assessment)



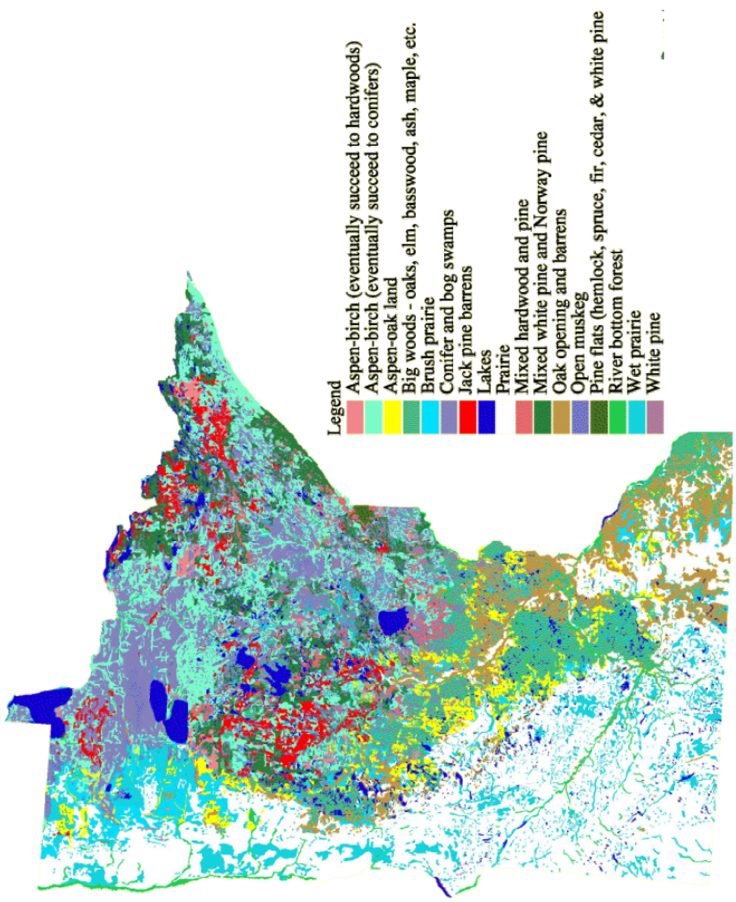
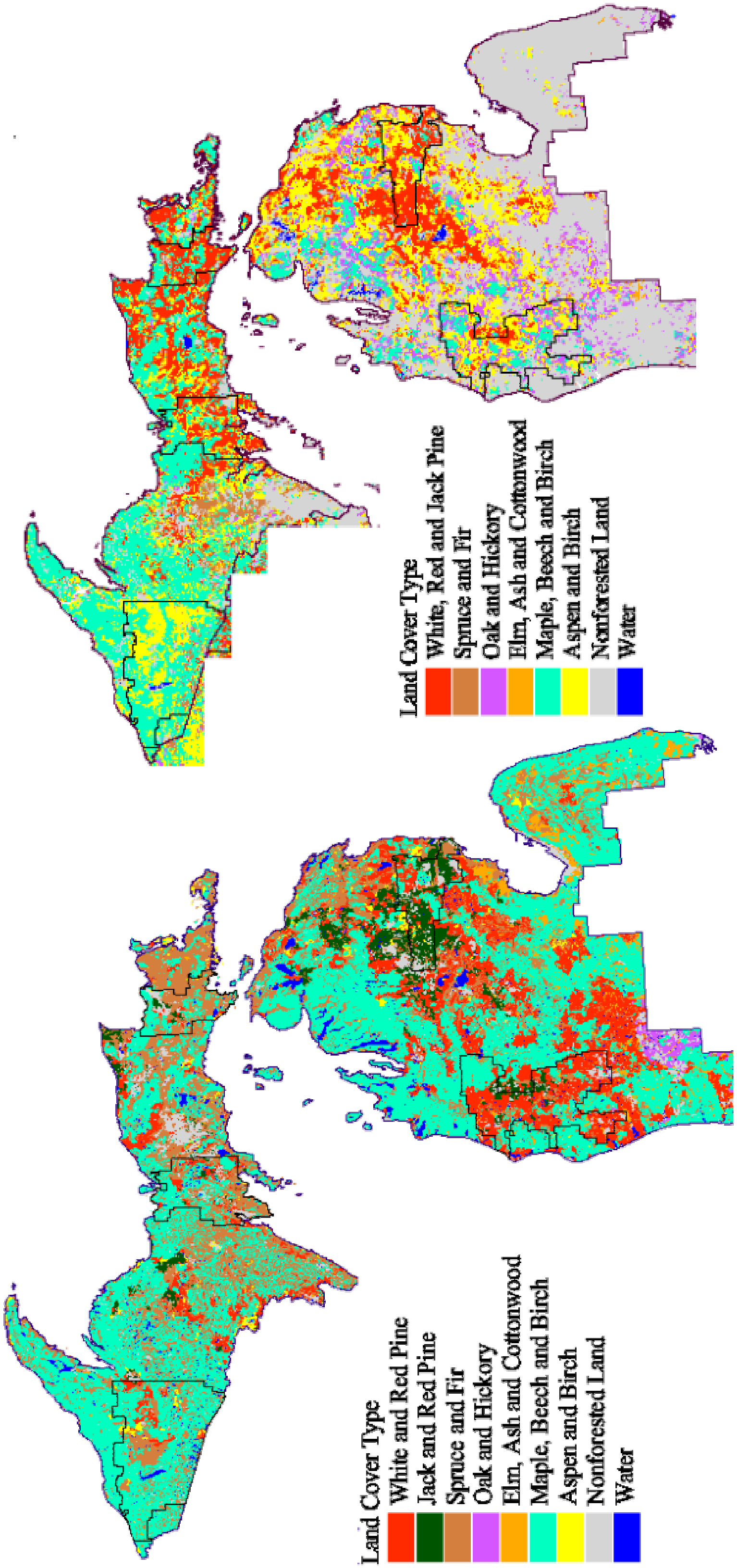


Figure 35. Minnesota vegetation presettlement and current (from Great Lakes Assessment)



Ecosystem Pattern
In 1992 the Upper

Figure 36. Michigan vegetation presettlement and current (from Great Lakes Assessment).

Great Lakes Region consisted of 42% forest land. Over 90% of forest land is used for commercial forestry (Brown et al. 2000). Increased development and declining rates of agricultural abandonment are likely to lead to declines in forest area over the long term (Brown et al. 2000).

At the level of an ecosystem, species' habitats are derived rather than measured. Properties of ecosystems include such things as self-organization, emergence and commensurate response – important but not applicable to our effort. Ecosystems also exhibit spatial patterns like connectivity and patch size. These help determine movement and population dynamics of species which, in turn, structures biodiversity.

There are no studies, to my knowledge, that address specifically the ecosystem of the WGLR with respect to goshawks. However, Mladenoff et al. (1993) produced useful information that can be applied to goshawk conservation. They compared spatial patterns in unaltered old-growth and disturbed forests of the western Upper Peninsula of Michigan and bordering Wisconsin. They found that the altered landscape had significantly more small forest patches and fewer large patches than what would naturally occur as matrices. The shapes of patches differed as well, with the altered landscape consisting of simpler, less fractal shapes compared to the complex patches that occurred naturally. Although the authors didn't test the ecological significance of this simplification it is at the root of the loss of complexity that occurs with an artificial disturbance regime. As Mladenoff et al. (1993) point out, significant habitat heterogeneity is produced by the complex landforms of this region, whereas human-caused disturbance is generally more regularly distributed. In unmanaged forests in northeast Minnesota, natural disturbance (e. g., windthrows, fire, flooding) produced slight increases in evenness (0.6%) and decrease in patch size (-1.39%) compared to those caused by management activities (primarily logging) where evenness increased 4.37% and patch size decreased -10.99% (Wolter and White 2002).

Although these studies cannot be used to determine goshawk habitat status in the WGLR, they do hint toward a trend. Whereas it is possible to manage forests holistically and provide most ecological services(Everett and Lehmkuhl 1996), small-scale forest management can lead to decreasing complexity, patch size and connectivity. If unmanaged areas become managed one would expect the consequences to be similar. Thus, trends in ownership and parceling of properties is a surrogate for trends in availability of healthy forest habitat.

In Wisconsin about 30% of forested land is under public ownership and 10% more under public management (Wisconsin Department of Natural Resources [WDNR] unpubl. data). The largest public tracts that are managed by single entities are the Chequamegon-Nicolet NF (615,300 ha), and two state forests: Northern Highland American Legion (89,900 ha) and Flambeau River (36,500 ha). Each of these tracts contain many small, privately owned parcels located within their boundaries, making large scale land management activities difficult to implement (Woodford et al. 2003). In Michigan, 53% of the land is covered by forest – about 19 million acres of forests, 65% in private ownership. Only 7% of the private owners hold more than 100 acres. The largest forest type is northern hardwoods (5 million acres), followed by aspen/birch (3.2 million acres), mixed oak/hickory (2.6 million acres), aggregate pine communities (2.4 million acres), cedar and mixed conifer swamps (2.1 million acres), and southern (or central) hardwoods (1.5 million acres). Since 1800, aspen/birch, black ash, red pine, jack pine, mixed oak/hickory and cedar forest types have increased in extent. The aspen/birch forest type has increased in extent by almost 1,000%. The forest types that have decreased in extent since 1800 are hemlock, southern hardwoods, mixed conifer swamp, mixed white pine, northern hardwoods and spruce/fir (Michigan DNR 2006). From 1970 through 1990 parcel size in three northern Lower Peninsula counties decreased each decade from as much as 12 ha/parcel to about 4 ha/parcel (Drzyzga and Brown 1998). Data for the rest of the state's forests are lacking.

Minnesota has the best available data on forest status and trends. The extent of forests declined significantly in the late 1800s and now covers about 33% of the state (Minnesota DNR 2007). Figure 20 shows that the overall composition of Minnesota's forests hasn't changed considerably since the late 1970s. There have been considerable changes in structure and management of forests in the state. In a thorough study of landscape-scale changes in northeast Minnesota from 1990 to 1995 Wolter and White (2002) found trends of both smaller patches and a more even distribution of cover types. Patch size of upland conifers, lowland conifers and lowland hardwoods decreased (Fig. 21). For the goshawk a glimmer of a silver lining is that the patch size of mature upland hardwoods increased in most size classes except the > 500 ha class which showed a substantial decrease in area. The area of early successional types increased in most patch size classes. All of these trends are more pronounced on state, county and private lands than on federal or tribal lands. Wolter and White (2002) also report that over a 5 year period (1990 – 1995) a little more than 4% of mature forest in northeast Minnesota was converted to early successional stages. Over all of northeast Minnesota there was a 10.5% decrease in interior forest area between 1990 and 1995. Non-industrial private forestland increased and represented the lowest proportion of interior forest of any category (Wolter and White 2002).

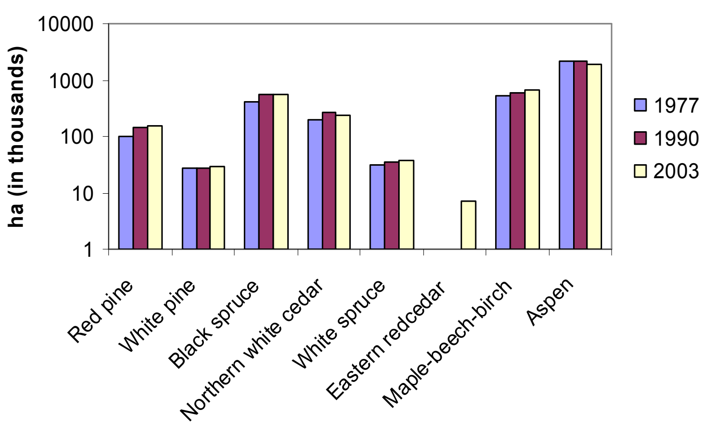


Figure 37. Log scale of area of forest types in Minnesota at three times since 1977. based on data from Univ. of Minnesota (http://mfric.cfans.umn.edu/contact.html)

In fact, Minnesota forest land has been converted to non-timber uses (primarily residential) at a rate of 3,600 acres per year in the last few years (Minnesota DNR 2007). The economic catalyst for this recent change is the disposal of land assets from timber and mining companies to Timber Investment Management Organizations. These investment firms sell the land as real estate at a higher profit than would be realized under a resource management scenario. The result is division of large forested tracts into smaller and smaller parcels. This same phenomenon is occurring across the northern portions of the WGLR states. In Wisconsin, the number of non-industrial private forest owners increased by over 20% between 1985 and 1997 (Rickenbach and Jahnke 2006).

The ecosystem is not habitat, but it provides habitat through complex temporal and spatial patterns with a great deal of stochastisity thrown in. The greater the spatial extent of the functioning ecosystem, the greater the probability of formation of habitat for a species. Loss of ecosystem extent can be the underlying cause of range contraction for any species that occurs there (Curnutt 1997). We can expect the trend of increased parceling of forests to continue in the WGLR. This will decrease interior forests, increase susceptibility to non-native invasive species infestation, and make management for species habitat more difficult.

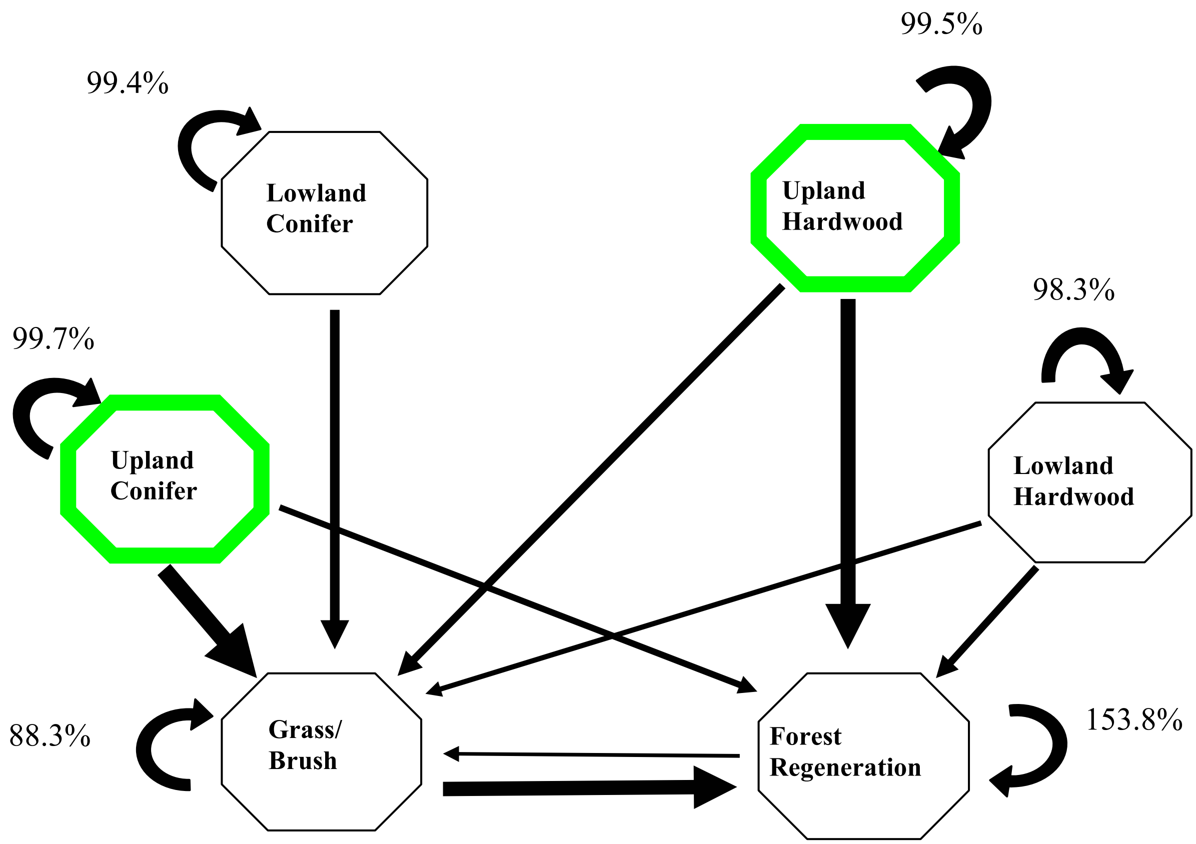


Figure 38. Ten year transition rates for forests in NE MN from Wolter & White 2002. Thickness of lines represents relative magnitude. % indicates amount of area that remained in category.

Status and trends at the 40 ha scale

The large-scale analyses mentioned above tell us one part of the story, but for goshawk breeding we need data at the 40 ha scale and structural data that cannot easily be had from remote sensing. A quick analysis of the status of forest stands across the region is not possible, but the Chippewa NF has GIS data that can be used to determine the number of forest patches that could potentially hold a goshawk breeding pair (Fig. 23). This same type of map could be generated for other parts of the WGLR once data become available. At present there is no way to determine the absolute trend in smaller patches in the WGLR, nor is it possible to address the status and trends of individual potential nest trees. (THIS SECTION UNDER RE-WRITE WITH ADDITIONAL DATA PROVIDED BY WGLR NATIONAL FORESTS)

An indirect way to approach the status and trend of goshawk preferred nest trees in Minnesota is possible. In that state, goshawk often seem to prefer large old aspen for nest trees. As figure 22 shows, the availability of the 35 to 55 year age class of aspen is declining. Older age classes are not declining, but they are close to senescence for this species. Furthermore, there is an increasing transition from aspen to maple-beech-birch is evident from west to east. Of course, there also are transitions into aspen—the major source of new aspen acreage is from various softwood forest types. But overall, more land is converting from aspen to more tolerant species than to aspen.

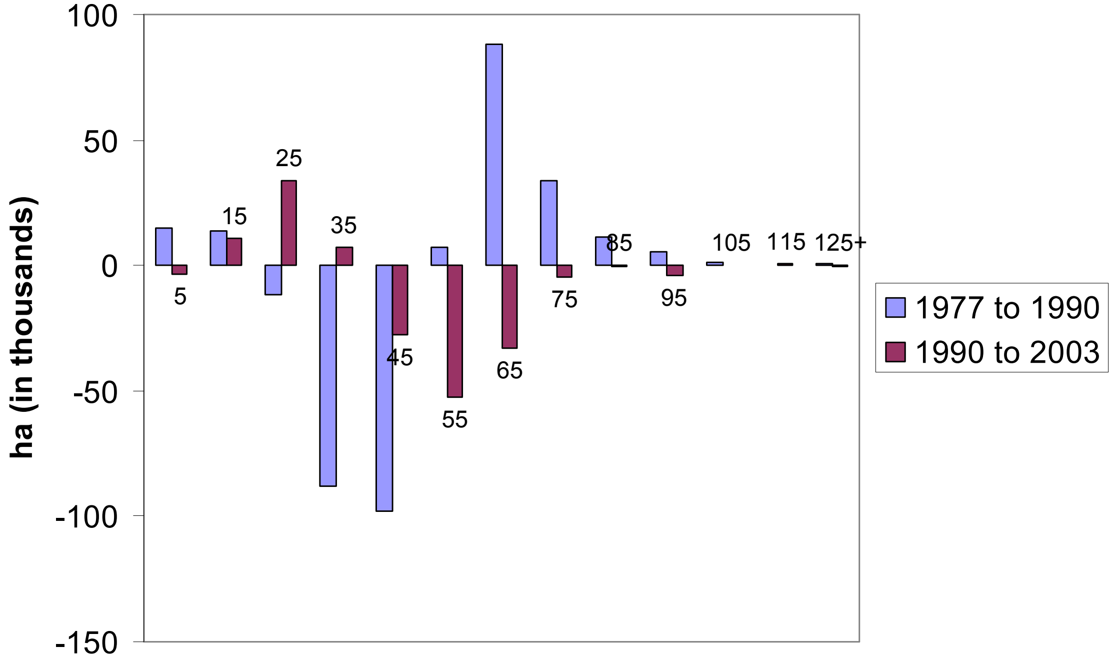
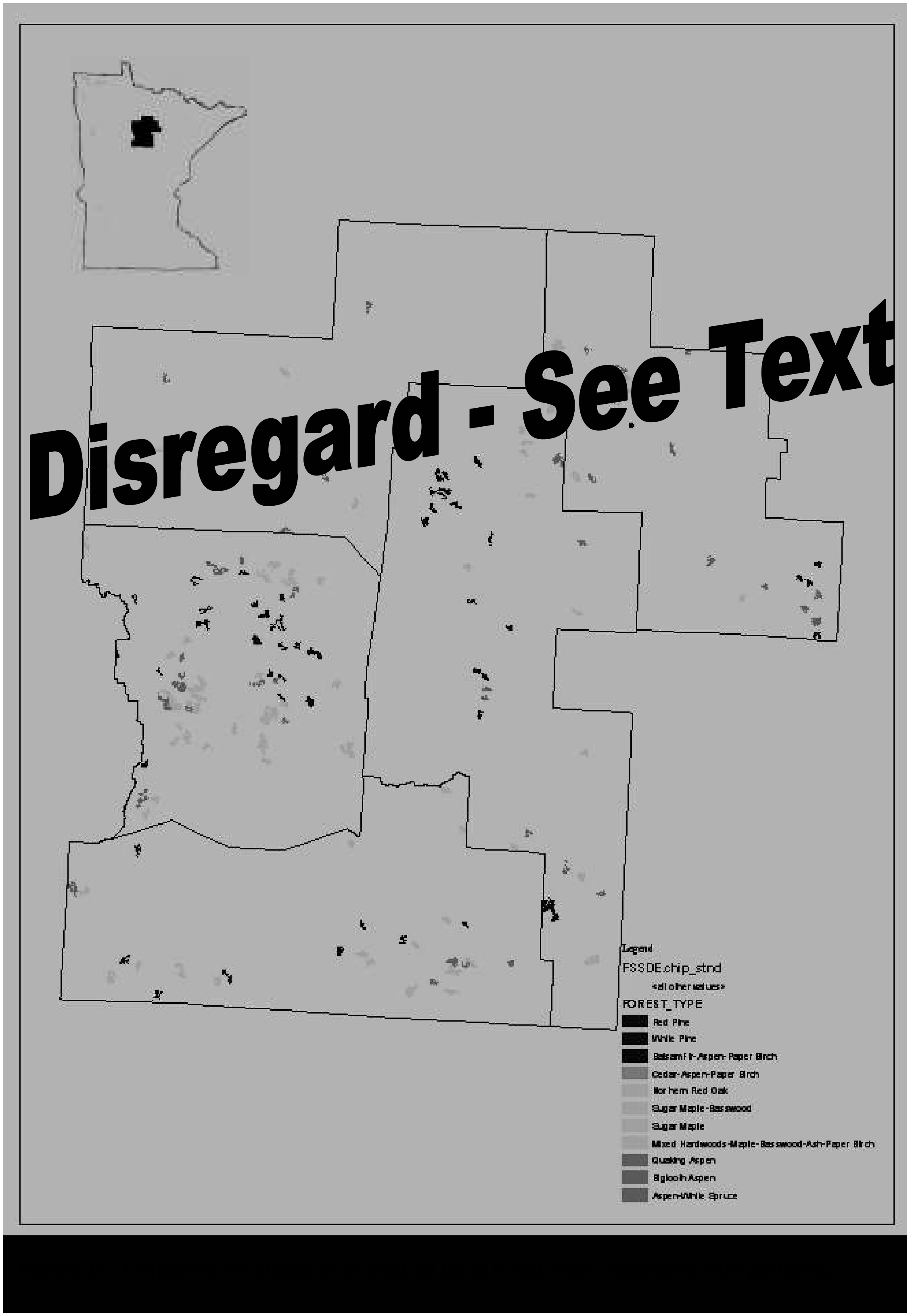


Figure 39. Change in area (ha) of aspen forest type age classes between 1977 to 1990 and 1990 to 2003 for Minnesota. Data labels indicate age class in years (Minnesota DNR data).


Disregard - See Text
Legend
FSSDE.chip_stnd
<all other values>
FOREST_TYPE
Red Pine
White Pine
Balsam Fir-Aspen-Paper Birch
Cedar-Aspen-Paper Birch
Northern Red Oak
Sugar Maple-Basswood
Sugar Maple
Mixed Hardwoods-Maple-Basswood-Ash-Paper Birch
Quaking Aspen
Bigtooth Aspen
Aspen-White Spruce

Summary of goshawk habitat status and trends

We are sorely in need of more spatial data on goshawk habitat in the WGLR. With more data we will be better able to determine the extent of potential goshawk habitat across the region and develop better models that incorporate parameters other than just stand size. Woodford et al. (2003) did this for Wisconsin, although the model has yet to be entirely validated.

For the present, it is safe to assume that private forestland will continue to be fragmented into smaller and smaller patches barring any temporary setback to this process due to economics. The way goshawk respond to this parceling of habitat has yet to be determined.

GOSHAWK POPULATION ECOLOGY

What is a Goshawk Population?

When an ecologist thinks of a population an almost instantaneous cascade of definitions is likely to occur – from the total number of individuals (N), to the breeding population (N_b), perhaps even to the effective population size (N_e) which describes the genetic component of a population. In studying goshawks even the first of these steps may lead to a complete misunderstanding of the species' population dynamics. With most first year birds not breeding there is always a proportion of the population that can not be counted as a breeding adult (Krüger [2007] estimated 30% of a stable goshawk population would be 1st-year birds). Furthermore, the dynamic presence of adults that are capable of breeding but do not complicates the estimation of the population even more. The low detectability overall, especially of non-breeders combined with variation in the proportion of goshawks actually laying can lead to serious sampling error (Reynolds et al. 2005).

Floaters

'Floaters' are adult birds that are physiologically capable of breeding but fail to do so because of lack of opportunity (no available mates or unoccupied territories) (Newton 1979). Evidence of floaters has been provided for at least 26 species of raptors (Newton 1979). The impact of floaters on population response to changes in the environment (e. g., declining/increasing prey availability) is difficult to ascertain but can play a major role in population dynamics (Rohner 1996). In a rare study that included marked non-breeding adults, Rohner (1996) showed that 40-50% of the adult population of great horned owls in his study area were floaters. Floaters were more affected by decreasing habitat quality than territorial birds. Floater survival declined faster than that of breeders as snowshoe hare populations declined in the study area. This differential survival can mask important changes in a population of raptors. For example, if habitat remains suitable the loss of individual adult breeders could go unobserved as that role is filled by a floater. Conversely, if habitat declines the overall adult population could decline for some time as floaters disappear, but this population decline would go unnoticed if estimates are based solely on censuses of territorial birds.

Breeding Adults

Once a goshawk begins breeding it normally continues to do so each year. However, there are a number of factors that determine when and where an adult will nest. In a 26 year study of goshawks in the Netherlands, Rutz (2006) demonstrated that the population showed a “numerical response” (Holling 1959) to diminishing food supplies (i. e., as prey became less available the predator population decreased). Over the study period (1974 – 2000) bird populations declined as a result of changes in farming practices and forest acidification and rabbits declined because of harsh winters coupled with an outbreak of viral hemorrhagic disease, all against a background of unfavorable habitat succession (Rutz 2006). Brood size remained unchanged over the population decline. Breeders and non-breeders declined in concert, so empty territories went unfilled,. This indicates that the local food situation was below a threshold for initiating breeding.

To breed or not

Temporal and spatial variation in the frequency of egg laying was pronounced in a long-term study by Reynolds et al. (2005). Following 37 well-documented territories in Arizona over 12 years 36% had eggs laid during 6 or fewer breeding seasons, 64% had eggs 7 or more years and one territory was never used for egg laying. Combining additional data, the authors report that of those territories that had skipped egg-laying at least one breeding season 87% were occupied and/or used for egg-laying in subsequent years, often by the same banded goshawks that previously laid in the same territory.

Annually, 50 – 75% of egg-laying goshawks moved from a previously used nest to an alternate nest in their territories and the existence of nearly half of these nests was unknown to the researchers until an extensive search of the territory revealed them (Reynolds et al. 2005)

In a highly successful pilot study of the use of genotyping for mark-recapture studies of goshawks on the Kaibab Plateau, Bayard de Volo et al. (2005) found no evidence of inbreeding or inbreeding avoidance, suggesting that goshawks in this population mate randomly. Further results showed that the genetically-derived effective population size was apparently an underestimate, suggesting strongly that distant populations of goshawks contribute to the gene flow by migration into the study area (Bayard de Volo et al. 2005)

Weather may influence occupancy and/or activity at goshawk territories. This has been studied in Nevada by Fairhurst and Bechard (2005), but the results were inconclusive. Goshawk reproduction (young/breeding pair) correlated inversely with temperatures in April and May and territory occupancy correlated directly with April precipitation. Unfortunately, there are a number of potential confounding variables that weren’t studied – prey cycles, adult population trends, differences in detectability among territories, to name a few. Given that there is a relationship between Spring temperatures and goshawk nesting, this may be a result of temperature effects on prey species instead of goshawk survival/energetics (Tornberg 1997). If the study of weather effects on goshawk breeding is to be fruitful well-designed, long-term studies will be necessary.

To move or not

Although breeding goshawks generally have a strong fidelity to their nest sites (Squires and Reynolds 1997), some do move to new sites and therefore effect the local population dynamics. In the Kaibab Plateau both male and female goshawks had strong lifetime fidelity to their breeding territories – 94 – 96% stayed on their original territories (Reynolds et al. 2004). In southeast Alaska, 9 of 26 female goshawks radio tagged between 1992 and 1998 moved to new breeding territories and nested with different mates than in previous years (Titus et al. 1999). In Arizona, a 12 year study of scores of thoroughly surveyed goshawk territories showed high breeding territory fidelity but movement within territories to alternate nests was high (Reynolds et al. 2005)

Immigrating Goshawks

Goshawks exhibit a range of migratory behavior. Some populations are completely or partially migratory under low prey population conditions (i. e., parts of a population migrate while others remain) or migration is dependent on age, sex, or other unknown factors (Doyle and Smith 1994, Squires and Reynolds 1997). Adult breeding goshawks radio-tagged at their breeding sites in Sweden showed that nearly half of the tagged birds left the breeding area early in the winter and that there was no correlation between body condition and tendency to depart (Widen 1985). In the southern parts of the species' range, including the WGLR, the goshawk appears to be primarily a year-round resident (Meng 1959, Boal et al. 2003). There are no records of obligatory migrant populations of northern goshawks in North America.

The effect of goshawk immigration into the WGLR has yet to be fully appreciated. The historical record is replete with observations of the timing and magnitude of these 'invasions':

1896 – (Toronto) "Mature birds in full plumage were practically unknown till the great migration of 1896 when they became abundant, the young being almost entirely absent. The migration reached Toronto on October 26, and from then till December 20, many birds were taken. A few adults were noted the three following years, but none have been reported since December, 1899; the number of young birds since then has been normal" (Fleming 1907).

1905-06 - Largest numbers of goshawks in New England and south as far as Virginia in memory was in 1905-06 (Deane 1907)

1916 - Kansas irruption in 1916 (Bunker 1917); same year an "invasion" of eastern goshawks (as differentiated from western" in California (Grinnell 1917); invasions also occurred across the Midwest – Illinois, Michigan, Iowa (Eifrig 1917).

1927 – first goshawk collected in central Ohio (Blendon Township) (Hicks 1935).

At a bird banding station at the shoreline of Lake Michigan in Cedar Grove, Wisconsin goshawk invasions were recorded for 1962-63, 1972-73, 1982-83 (highest number recorded in one year), and 1992-93 (Mueller et al. 1997).

The cyclic nature of goshawk invasions is obvious from the items listed above. Mueller et al. (1977) used 25 years of data from the Cedar Grove banding station and developed the following hypothesis: Large-scale goshawk invasions of the WGLR from the north occur when the two key prey species for northern populations (snowshoe hare and ruffed grouse) decline simultaneously; the more drastic the decline, the greater the invasion. There is always a southward movement of goshawks in the WGLR, but in normal years this is predominantly composed of young birds; as prey availability decreases in the north more adults and older adults begin to be food stressed and, consequently, move south in search of prey (Mueller et al. 1977). (See **PREY CYCLES** Box)

This untested hypothesis is strengthened by Speirs (1939) who showed a 9 to 11 year cycle in the numbers of goshawk wintering in the Toronto (Canada) area. The author compared peak goshawk years to population cycles of ruffed grouse in Ontario (from (Clarke 1936) and snowshoe hare in the Hudson Bay watershed (from MacLulich 1937). The goshawk v. grouse/hare cycles were approximately the same length but were out of phase by one year. Speirs (1939) remarked that goshawk peaks occurred in the years immediately following maximum abundance of prey to the north.

The cyclic migration of adult goshawks into the WGLR may be an important component of the region's breeding population. Irruptions may lead to residence for some time. Temple and Temple (1986) show how goshawk numbers in Wisconsin peaked with a 1982 invasion and tapered off over the next 3 years.

The elusive λ

If we wished to know precisely the population dynamics of the goshawk in the WGLR then we would have to know the value of something called *λ*– the population growth rate, which is simply births minus deaths (May 1976) and is formulated as:

$$N_t = N_0\lambda^t \quad \text{where } N_t = \text{population size at time t}, \; N_0 = \text{population size at time 0}$$

Unfortunately, the data required to calculate *λ* are difficult to obtain. For the goshawk, which, like most birds, reproduces at discrete intervals, one needs at least the following information (Begon and Mortimer 1986): number of females surviving from one year to the next (S_x), age specific survival (l_x), and age-specific reproduction of females (m_x); where x is age in years. Additionally, not all goshawks breed each year (see below), so breeding probability should be added into any population model. There has been only study published wherein all of these parameters were determined (Krüger 2007). In that study, the author used a 30-year data set on a goshawk population in Eastern Westphalia, Germany. Many other studies provide some of the needed data. I will discuss the available information for the vital rates individually, then return to attempts at modeling goshawk populations.

Vital Rates

Longevity

In the wild, the record is 19 years (del Hoyo et al. 1992). In the WGLR, an oldest known goshawks include 11-yr-old male in Minnesota (Boal et al. 2001), and a 12-yr-old female in Wisconsin (Evans 1981 *in* [Squires and Kennedy 2006]). Mean breeding life span of goshawks in Germany of 3.8 years. (Zang et al. 1989 *in* [Krüger 2002]).

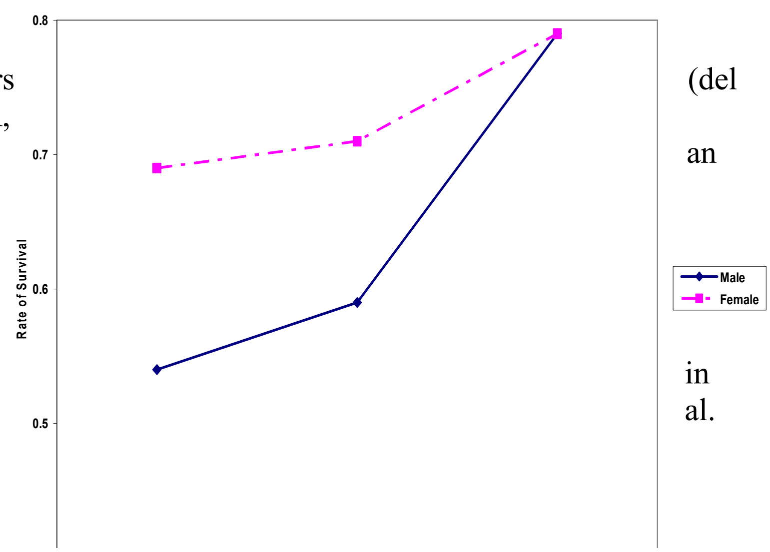


Figure 41. Survival rates of male and female goshawks on Gotland Island, Sweden. Based on data presented in (Kenward, Marcstrom et al. 1999)

Age at first reproduction

In Germany, Krüger (2002) found that 41.9% of females began breeding at age 1, 35.1% at age 2, 13.5% at age 3, and 9.5% at age 4. In Arizona, mean age of first breeding was 3.2 yr ± 1.1 (range = 2–5 yr) for males and 4.3 ± 1.9 (range = 2–8 yr) for females (Squires and Kennedy 2006). No data from the WGLR

Age-specific survival

In Germany, survival fluctuated between 62% and 92% for goshawk aged 1 to 8 years (Krüger 2007). In a powerful study of goshawk survival and reproduction, Kenward et al. (1999) collected data from 318 radio-tagged birds on the Baltic island of Gotland. The radio-tags were tail-mounted, staying attached to each bird until its next molt. Survival results are displayed in figure 24. During the seven-year study, 63 dead goshawks were found. The major cause of death was shooting (35%) which, in Sweden, is legal under certain circumstances. The remaining birds died of natural causes - primarily starvation. Even though adequate food may be available during the fledgling-dependency period, young raptors may starve because they are inexperienced and ineffective foragers (Newton 1979) Adult mortality is much more varied. Two adult female goshawks in Washington and Arizona died presumably of choking on a Douglas' squirrel (*Tamiasciurus douglasii*)and cottontail rabbit, respectively (Bloxton et al. 2002). Data from the Raptor Center at University of Minnesota, reported in Dick and Plumpton (1999) showed that from 1974 - 1996, 115 goshawks were admitted. Sources of trauma for the birds were: collision 31%, miscellaneous trauma 18%, injury by projectile 15%. Collisions were 28 windows, 5 power lines, and 3 vehicles The age was listed for 95 goshawks. Of these, 58% were immature or hatch-year. Of course, these data are not representative of a random sample because of biased detection frequencies.

Kenward et al. (1999) reported a skewed sex ratio determined from data collected on over 300 radio-tagged goshawks. Differences in survival – especially in the first two years of life – favor females in low prey-availability years, possibly because their larger body size makes them less susceptible to starvation than males. A model population, based on the data collected in the field, shows a male:female ratio of 1.0:1.78; furthermore, 71% of males breed annually but only 40% of females.

In a study that encompassed all of Finland yet analyzed the data at local scales, (Byholm et al. 2002) found that offspring sex ratio is directly effected by prey availability. In particular, 'good" grouse years, i. e., when prey is plentiful and available, offspring sex-ratio is skewed toward males and, *vice versa*. A plausible hypothesis for this is presented by the authors. Males, being smaller than females, are more dependent on the availability of grouse than larger prey, for example hare. In years when grouse are scarce female survival would be higher than that of males because their larger size would allow a higher capture rate of larger prey. A final novel discovery by (BYHOLM et al. 2002) was that local offspring sex ratios were corrected towards equity with a time lag of one year. In other words, years where the sex ratio favored female offspring are followed by years that favored male offspring. consequently derived patterns that are applicable across spatial and temporal scales.

Ingraldi (2005) reported a skewed sex ratio for fledglings in east-central Arizona: 1.77:1 male to female for all fledglings combined over 6 years. The author explored two hypotheses to explain the sex ratios – nutritional stress and weather. The author found that as territory occupancy increased (an assumed measure of increased prey availability) the sex ratio tended toward 1:1 and, conversely, if occupancy was low more males were fledged than females. He also found weak but significant relationship between sex ratio and combined May-June (brood rearing period). As noted above, “good” prey years favor male fledglings (Kenward et al. 1999). The relationship between weather and sex-ratio may be real, however with only 6 data points and with the possibility of other effects that weren’t considered (e. g., prey cycles) robust conclusions aren’t possible.

Age-specific reproduction
Krüger (2007) again has the best data. In his 30-year study he could account for differences between years and individual females in determining the relationship between reproduction and age. He found mean juvenile production increased three-fold from 0.7 per breeding attempt for 1-year old females to 2.0 per attempt at age 8 years. No females in the study survived past 10 years, however, there was no sign of senescence with age. Ten-year olds produced as much as 8-year olds. All females followed this same trajectory over their lives, suggesting that female goshawks have to ‘learn’ how to be good producers.

λ revisited
Krüger’s (2007) analysis resulted in a value for λ of 1.0072 over the entire 30 years of data. A value of 1 indicates an stable population, less than 1 is decreasing and greater than 1 is an increasing population. This result translates to a 0.7% annual growth rate which, after considering confidence intervals, can be interpreted as a stable population. In this example, the number of birds observed in the population over the 30 years is reflected in the calculated population growth rate, but this need not be the case. Since the method involves reproduction and survival of reproducing birds it may show more or less birds being produced than the local population can account for. In the case of overproduction the population would serve as a source of emigrants to colonize new breeding areas or augment those already populated (e. g., bald eagle production in the Everglades of Florida far surpassed the number necessary to maintain the breeding population which remained stable for 40 years [Curnutt 1991]). Conversely, underproduction may be masked by immigration from other populations (Pulliam and Danielson 1991).

A further use of this type of matrix analysis for understanding the population dynamics of a species is measuring the elasticity of parameters (Heppell et al. 2000). Elasticity analysis examines the effects of proportional changes in demographic transitions (survival, growth, and reproduction parameters) on the population. In Westphalia, goshawk population growth was much more sensitive to variation in survival than variation in reproduction (Krüger 2007).

I have focused on Krüger’s (2007) study because data and analyses like his are not available for the WGLR goshawk population. In addition to making plain the case for conducting such research in our region, we can also apply his results to the discussion of what limits our goshawk population.

Limiting Factors
Even a modest growth rate of 1% per year would lead to a doubling of the population in 70 years. With the exception of ourselves, species do not exhibit this type of population growth, which begs the question of what limits growth. The answer is basically density-dependence (Begon and Mortimer 1986). Generally, one thinks of density-dependent

effects as stemming from intraspecific completion – that is, there is a limited supply of food, nest sites, etc. and as the goshawk population increases competition for these resources will act to dampen population growth. There is another class of density-dependent effects. These also change with the density of goshawk populations but are not the result of increased numbers of goshawks – these include predation, parasitism and interspecific competition. There is some overlap in the topics of limiting factors and potential threats. In the former I include things that the goshawk would contend with even in the absence of humans; realizing that human influence may mitigate or exacerbate the effects. I discuss factors caused directly by humans in the section on potential threats.

Food

Prey availability has a profound effect on raptor populations from before nesting (female body condition) to after fledging and throughout the non-breeding season. As noted above, the WGLR goshawk has a broad diet compared to more northern populations. Solid informative studies of the effects of prey availability on the population dynamics of goshawk are difficult to conduct under any circumstances, but with the multitude of potential prey in the WGLR it is even more so. The primary source of information on diet and population come from the boreal region of the goshawk's distribution where the effects of cyclic populations of key prey species are pronounced.

In a beautiful long-term 13 year study in Finland, a 500 km^2 study site was searched at least annually for goshawk nests and annual prey densities were calculated (Linden and Wikman 1983). The authors found that when the numbers of a key prey species (hazel grouse [*Bonasa bonasia*]) are very low the species diversity of the goshawk prey was high, and vice versa. The goshawk breeding population declined when the grouse population declined. Surprisingly, however, the goshawk population then increased without a coincident increase in grouse. Linden and Wikman (1983) concluded that there is *not* a numerical relationship between goshawk and the population cycle of its major prey (*contra* [Rutz 2006]). In Sweden, goshawk predation on female grouse increased with drops in the vole population (Widén et al. 1987).

Boutin et al. (1995) used nest surveys on a 100 km^2 study site in Canada's boreal forest to study the population response of goshawks (and other vertebrate species) to cyclical changes in the snowshoe hare population. They found that the goshawk breeding population correlated quite strongly ($r = 0.08$, $P = 0.04$) with the hare population of one year previous. However, recruitment changed (i. e., declined) immediately after hares began to decline (Boutin et al. 1995). Keith et al. 1977 (*in* Boutin et al. 1995) reported that hare predators (including goshawk) reached peak densities at the same time as hares but declined more slowly.

Data from the WGLR is sparse primarily because there are so few long-term studies that would encompass multiple prey cycles. In Wisconsin, Erdman et al. (1998) reported cyclical trends in goshawk productivity (fledged/active nest) from 1970 to 1992 which correlated positively with combined snowshoe hare and ruffed grouse population cycles. In Michigan, Postupalsky (1998) also noted a positive relationship with a measure of goshawk productivity and the prey cycle. There, nest area occupancy changed with prey abundance, but mean brood size changed little throughout the cycles. These two studies hint at the relationship of prey availability and goshawk population dynamics in the WGLR, but they fall short of fully explanations.

Space

How area limits goshawk populations is more complicated than simple territoriality, although that is a major factor. For example, habitat pattern can affect habitat quality by determining the distribution of resources within the potential home range or territory of an organism. In an extreme case, a highly fragmented habitat may not contain adequate resources within the search radius of an individual. Habitat pattern can also affect population dynamics by limiting dispersal and hence the colonization of isolated habitats (Lawler and Schumaker 2004).

Goshawks interact with conspecifics and their habitat in a spatially dependent manner (Reich et al. 2004). Intraspecific interference competition occurs when an individual of a species interferes with another member of the same species in obtaining a limited resource (Begon et al. 1996). A classic example with birds is aggressive territorial exclusion within a breeding area. For goshawk the area used for nesting and fledging of young is considered a territory (Woodbridge and Hargis 2005). I was unable to discover records of observed antagonistic behavior among territorial goshawks. On the Kaibab Plateau in Arizona, where Reynolds et al. (2005) have shown that goshawk territory centroids were regularly spaced (indeed, “packed”, with each territory abutted another except for the outermost) and appeared to be spatially fixed over years, one would expect antagonistic behavior between neighbors, but I found no mention of it. It may be that neighbors exercise mutual avoidance instead (Newton 1979).

The effectiveness of territoriality on limiting population, then, would be directly related to the number of breeding goshawks and territory size. Leaving the number of goshawks fore the moment, what determines the size of a territory? Kenward (1982) found that high prey availability allows for small territories and, consequently high densities, of breeding goshawks. Kenward’s (1982) study of radio-tagged goshawk showed a preference for foraging in woodlands within 200 m of open country. Range size was related to the proportion of the range that was made up of this “edge” and with prey availability. “The importance of woodland edge can explain how the highest goshawk densities known, of less than 100 ha per pair, can occur in Westphalia with only 12-15% woodland…; the woods are well-scattered and the land very fertile, which implies a high availability of both woodland edge and prey” (Kenward 1982). Of course, there must be a lower limit to the size of a goshawk territory. Squires and Kennedy (2006) describe territoriality in the form of non-compressible goshawk territories that limit the local nest density. In the Kaibab, Reich et al. (2004) showed that potential nest sites were abundant and randomly distributed on the landscape, however, availability of sites was limited by territories.

Siblicide/Cannibalism

A not uncommon occurrence in raptor nests is the death of chicks either directly or indirectly caused by its siblings. Goshawks hatch asynchronously – this is believed to be an adaptation to an uncertain prey supply during the nesting season (Newton 1979). If prey is scarce the youngest chick will die of starvation, leaving the larger siblings a better chance at survival. This hypothesis is supported by Estes et al. (1999) through observations during one food supplement study. Siblicide has been directly observed in goshawks Estes et al. (1999) as has cannibalism following siblicide (Boal and Bacorn 1994). In Germany, one adult goshawk was observed killing and eating an older male goshawk and one goshawk was observed killing its nestmate in a fight over a jay (Brüll 1964). As far as a limiting factor to population growth, siblicide and cannibalism seem to be minor contributors.

Predation

Based on their intensive study of the goshawk population in Arizona, Reynolds et al. (2006) concluded that "it seems unlikely that predation was a significant mortality factor of adult goshawks on the Kaibab Plateau." Indeed, there are accounts of adult goshawks falling prey to golden eagles (*Aquila chrysaetos*), bald eagles and, most commonly, great horned owls (see Squires and Kennedy [2006] for a full review), but the impact of these events at the population level must be minimal. Predation on goshawks has been observed most frequently during nesting, fledging, and juvenile stages of the species' life history. Squires and Kennedy (2006) have the most up to date catalogue of predation observations so I wont repeat it all here. They report that most predation events are incidental in the literature and that there has been no study of the effects on overall population dynamics.

For the purpose of this assessment we can look more closely at what we know about predation on goshawks in the WGLR. For Table 4 I combed through the data presented in the sources I had at hand to determine the actual impact of predation recorded for various WGLR studies. None of these studies were designed to investigate predation on goshawks. Just as Squires and Kennedy (2006) say, all of these predation events were incidental to the purpose. The table includes nesting studies and studies of radio-tagged adults, single season and multiple season, and is not meant to compare across studies– rather, it sets the predation issue in context.

Unfortunately, of all of the species accounts and assessments (Squires and Reynolds 1997, Dick and Plumpton 1999, Kennedy 2003, Roberson et al. 2003, Andersen et al. 2005, Boal et al. 2006, BOYCE et al. 2006, Squires and Kennedy 2006), none report actual data on predation. Therefore, a comparison of the magnitude of predation on the WGLR goshawk population with others is not possible. These reports all mention that the great horned owl is the predominant predator on goshawks, and the effects of even this predator on goshawk population ecology are as yet unknown (Squires and Kennedy 2006).

Erdman et al. (1998) claimed the fisher (*Martes pennanti*) was the most harmful predator to goshawks in northeastern Wisconsin and that increasing density of fisher is causing declines in the goshawk population (see FISHER Box). Most WGLR goshawk studies have observed or suspected predation by great horned owls , raccoon (*Procyon lotor*), and other species of raptors (Dick and Plumpton 1999). Krüger (2007) showed that goshawk populations are most effected by adult female mortality. Making the values in table 4 more troubling.

Table 5. Goshawk studies in the WGLR and the occurence of predation events.

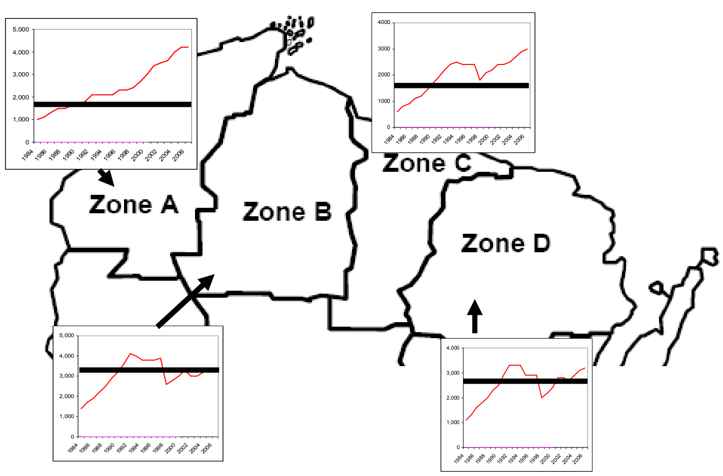
Source	Result Units	Predation events	%
(Erdman et al. 1998)	181 Nest attempts 288 young	4 adults unknown young	1.1% of adults
(Erdman 1998)	16 Nest attempts	3 adults 8 nestlings	9.4% of adults 30.7% young
(Rosenfield et al. 1998)	14 Nest attempts	None recorded	0
(Doolittle 1998)	32 Nest attempts	None recorded	0
(Christiansen 1998)	7 Nest attempts	1 failure	14.3% of nests
(Richardson and Bach 2002)	31 Nest attempts	1 failure	3% of nests
(Richardson and Bach 2002)	54 nestlings	3 nestlings	5.5% of nestlings
(Lapinski et al. 2002)	36 Nest attempts	7 failed nests	19.4% of nests
(Gibson 2003)	11 Nest attempts	1 failure	9% of nests
(Boal et al. 2003)	33 radio tagged adults	2 adults	6.2% of adults
(Boal and Andersen 2005)	17 radio tagged adult males	None recorded	0
(Boal et al. 2005)	43 Nest attempts	9 failed nests	20.9% of nests
(Boal et al. 2005)	32 radio tagged adults	5 adults	15.6% of adults

THE RISE OF THE FISHER

Photo by Mark Higley, Hoopa Tribal Forest

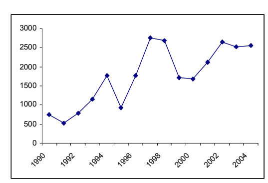
Fisher populations in the Great Lakes region declined steeply as a result of the period of extensive logging and extreme wildfires of the late 19th century, followed by near unregulated trapping for subsistence during the economic depressions of the early 20th century (Berg and Kuehn 1994). Populations began recovering in the 1950s (Gibilisco 1994). Fisher were trapped from remnant populations in Minnesota and translocated to Wisconsin and Michigan from 1958 to 1967 (Berg and Kuehn 1994). During the 1980s the fisher population grew rapidly in the northern third of Wisconsin (WDNR 2006). The rise in population was checked in the 1990s through allowing higher harvest rates resulting in a relatively stable population of about 10,700. In 2000 – 2002 harvest was below recommended quotas and the population quickly responded reaching about 13,000 by fall of 2005.

Home range size for male fisher vary across the species range, but typically are on the order of 35 km^2. Male and female fisher exhibit intrasexual exclusion territoriality (Powell 1994), but overlap occurs (Koen et al. 2007). Fisher diet has the lowest prey diversity in the Midwest compared to the species' entire range (Martin 1994). Midwestern fisher do share the common trait of having one or two "large" food items that make up the bulk of their diet. Here, the two primary prey species are the snowshoe hare and porcupines (Martin 1994). Fisher respond to the ca. 10 year snowshoe hare cycle with a 3 year lag time (Powell 1994).



Fisher populations are exceeding population goals (black lines) in every management zone in Wisconsin. The effects of these population densities may mean increased predation on some

Population regulation of fishers can be instituted by liberal trapping regulations. In Minnesota, the statewide fisher population declined by an estimated 33% after two consecutive years of liberal trapping regulations (Berg and Kuehn 1994).



Parasites

The role that parasites play in regulating wildlife populations is just recently being addressed (Ebert et al. 2000). Among viruses, the West Nile virus is a recently invading non-native "species" that has been shown to negatively impact some North American passerine populations (LaDeau et al. 2007). There are very few published reports of parasite studies concerning goshawks and, since the topic is beyond my area of expertise, I catalogue the findings of my literature search in Appendix II and provide no other comment.

Interspecific Competition

Interspecific competition in birds usually takes the form of nest sites and/or food (Lack 1946). Two other accipiters – Cooper's hawk and sharp-shinned hawk – are sympatric predators with goshawk throughout much of the latter's North American range (Siders and Kennedy 1996). Predicted niche partitioning for nesting sites based on body size were only partially substantiated by Siders and Kennedy (1996). They tested for differences among the three species for 10 nest tree and nest site variables in New Mexico. Of these, only nest tree height and diameter supported the body size predictions (goshawk largest, sharp-shinned smallest).

Gibson (2003) reported species turnover at raptor nests in the Upper Peninsula of Michigan. Using data from her study and Lapinski (2000) a total of four species turnover events occurred at originally goshawk nests; two nests were taken over by red-tailed hawks and two were taken by broad-winged hawks. The red-tailed hawks occupied the nests after a nearby timber harvest operation and no timber activity occurred at the sites where broad-winged hawks occupied nests.

The effect of interspecific competition for food on goshawks has not been directly addressed with experimental design. Squires and Kennedy (2006) review the lack of information on the subject.. In Norway, Selas (1998) compared goshawk population response to the decline due to an epidemic of sarcoptic mange, and return of red foxes (*Vulpes vulpes*), which prey heavily on grouse. The author found that the goshawk population did show a positive numerical response to the greater abundance of grouse in the absence of most foxes.

Timber management may exacerbate interspecific competition among forest raptors. Work on the distribution of red-tailed hawks in Michigan's Upper Peninsula (reviewed by Gibson (2003) suggest that creation of small forest openings reduces habitat suitability for more forest-obligate raptors and increases suitability for generalist raptors. The effect specifically on the goshawk population there was not shown.

WGLR Goshawk Population Status and Viability

Given what we know about the goshawk population in the WGLR, what can we say about its current status and viability? For any kind of certainty we would need to know the parameters of this most simple population model:

$$N_{t+1} = N_t \lambda$$

Where N_t is the population at time t, N_{t+1} is the population at the next time interval and λ is the population growth rate (as discussed above). The problem is that we have no idea what N is. To estimate the goshawk population of the WGLR we need to conduct a region-wide survey. A protocol for this type of survey exists (Woodbridge and Hargis 2005) and I will address the issue more thoroughly below. For now, though, all we have are a few site-specific analyses. As good as these may be, they cannot be used to estimate the population of a flying, long-lived and secretive bird that inhabits forests that cross ownership boundaries.

Erdman et al. (1998) analyzed 26 years of breeding season data on goshawks in northeastern Wisconsin. The authors state that from 1971 to 1981 nest success was high (94%), but from 1982 to 1992 "overall nest success" declined to 62% (Erdman et al. 1998). This is the only long-term data set for goshawks in the WGLR, so it warrants a closer look. Figure 25 shows number of young fledged per active territory and per successful nest by year. Young per active territory declined over time; a simple linear regression yields a slope of -0.05, significantly different from 0 ($p_F = 0.02$). The number of young fledged per successful nest was stable over time ($b = 0.001$, $p_F = 0.93$). In fact, what happened over the course of the study was production of young stayed relatively stable, but the number of active territories rose, especially after 1982. Territory occupancy rate may be a biased estimator of breeders in a population because territories can continue to be occupied during non-breeding years (Reynolds et al. 2005). There was minimal among year variation in nesting success "Thus both the annual proportion of used territories and total number of young produced per year provide a more sensitive measure of the variable reproductive output of goshawks than the annual mean number of young produced per used nest. The work of Erdman et al. (1998) would be more informative if we understood the underlying dynamics of territory occupancy in the region.

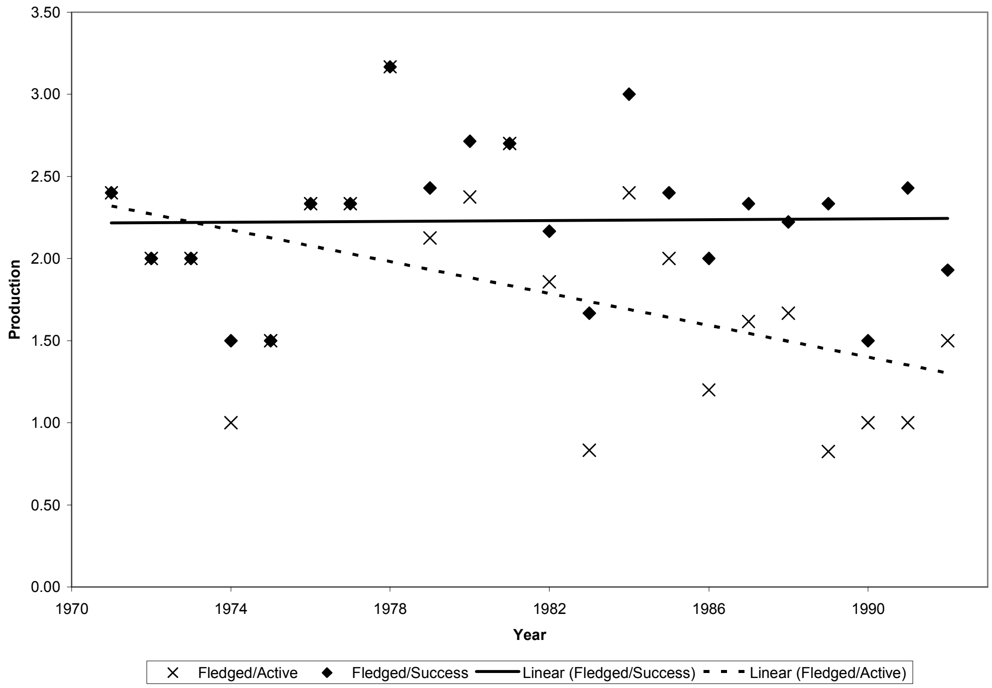


Figure 42. Productivity of goshawks in northeastern Wisconsin over 21 years. Data from Erdman et al. 1998.

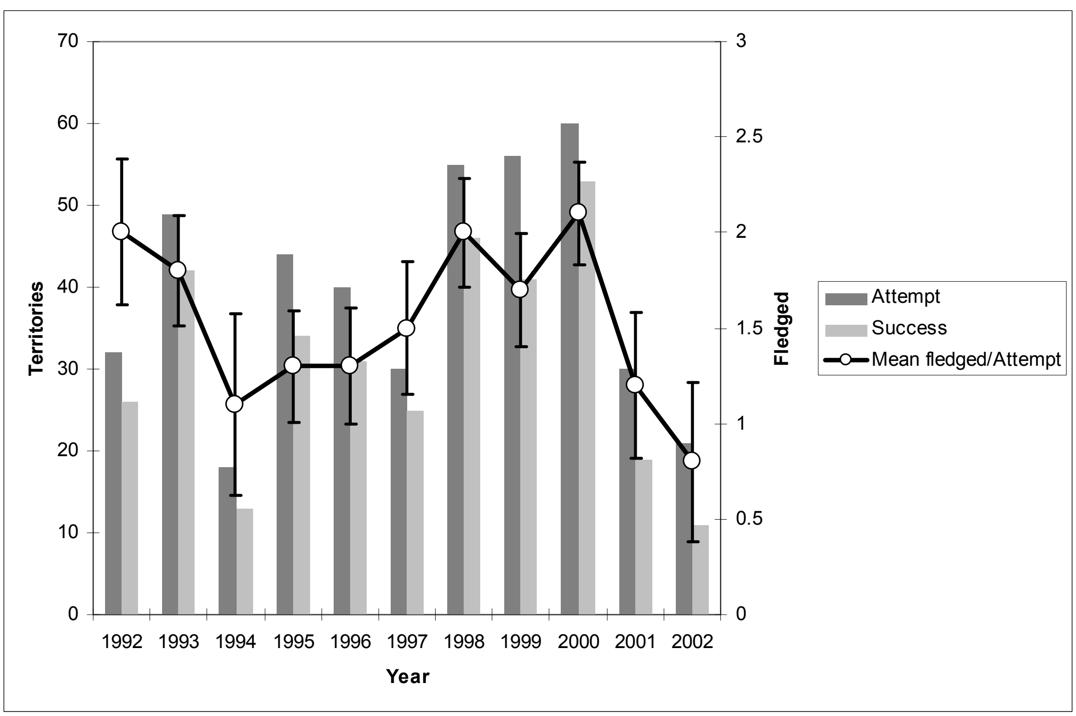


Figure 43. Goshawk productivity from Reynolds et al. 2005.

Erdman et al. (1998) determined the longevity of breeding territories (apparently the number of consecutive years that a territory was active, though not necessarily by the same breeding pair) ranged from 1 to 26 years (the span of years with data), with an average of 3.9 years for all 69 territories combined. They analyzed the data by forest ownership and found significantly greater longevity on state-owned forests ($\bar{x}$ = 10.2 yrs) than on county, private or USFS forests (2.4 yrs, 4.0 yrs, 3.7 yrs, respectively). The authors suggest that the differences in territory longevity may be a result of differing land use practices, especially negative impacts of timber removal, however, this hypothesis wasn’t tested directly.

Gibson (2003), in her study of goshawks in the west unit of the Hiawatha NF, found more nests than in a previous study (Christiansen *in* Gibson 2003), but the number of active nests was not significantly higher. Lapinski et al. (2002) found reproductive success in the Upper Peninsula of Michigan measured from 1996 through 1999 was well below that of other regions in North America, leading the authors to contend that goshawks in the Upper Peninsula appear to have impaired reproduction.

Summary of Goshawk population Ecology

Of the three sections so far covered in this assessment – goshawk life history, goshawk habitat, and goshawk population ecology – it is this last one of which we are most ignorant. Taken together, production of young, survival to breeding age, available habitat, the prey cycle, and the once per decade influx of birds from the north, form a complex web of interactions that results in the goshawk population in the WGLR. The various small-scale reproduction studies prove more titillating than explanatory when we cannot place the results within a region-wide framework.

Goshawk productivity in the WGLR may be on the low side of the average for North America. The significance of this estimate is questionable. It could be that the WGLR is a source for other regions or a population sink *a la* Pulliam (1988). Without overall population numbers we cannot know. Predation of nestling goshawks seems to be higher in our region than in others, but a direct comparison isn’t possible. No one has conducted a unified study on the subject. The use of habitat as a surrogate for goshawk population viability was tested by Lawler and Schumaker (2004) by incorporating demographic and habitat data in a spatial model. Due to limitations of the model (e. g., not taking landscape pattern into account) and, possibly, limitations of input parameters (variables are not described) the model was unable to successfully predict population source and sink territories.

Sæther et al. (1996) offer the following informative synopsis of goshawk population strategy. Goshawk life history strategy can be categorized as ‘bet-hedging’. This category falls between the two extreme strategies of: ‘high-reproduction’ – characterized by small body size, high reproductive rates and high mortality rates (especially outside the breeding season); and, ‘survivorship’ – characterized by high adult survival, delayed maturation and low reproductive capacity. High-reproduction species include small songbirds, survivorship species are exemplified by long-lived seabirds. Bet-hedging species are similar to survivorship species except whereas survivorship species depend on a relatively stable resource base between years, bet-hedgers are able to exploit high resource years with an increase in breeding attempts and larger clutch sizes. This strategy allows population stability even when resource availability is temporally stochastic or cyclical (Sæther et al. 1996). The value of this esoteric discussion in northern goshawk conservation is in the prediction that population fluctuations in bet-hedging species are driven primarily by adult survival – not reproductive rate or survival of nestlings/fledglings.

HUMANS AND THE GOSHAWK

Only recently have Americans come to appreciate raptors in general and goshawks in particular as something other than “bold robbers of our game and looters of the poultry yard”(Deane 1907). In 1918, noted ornithologist E. H. Eaton was against the goshawk, claiming that they upset the “development of the forest” by removing beneficial species (Eaton 1918). In Pennsylvania, a bounty $2.00 for each adult and half that for each fledgling was available in 1938 and 1939 (McDowell 1941). The author argued against the bounty as legislated, calling it ineffective. Instead he called for the bounty to be offered only during the winter months when migrating goshawks would be targeted, thereby exerting “appreciable effort toward control” over their numbers. As late as 1959, conservationists were arguing against the assumptions that all raptors (especially large accipiters) feed largely on poultry and game, and calling for changes in state laws to protect *all* birds of prey (Meng 1959) because “as long as even one species of hawk or owl remains unprotected all will continue to be shot”.

Now, of course, we spend time and money trying to understand the goshawk and it’s place in the forest ecosystem. As is evident from the preceding sections of this assessment, our understanding is far from coherent. In this section I present current conservation guidelines and potential threats to the goshawk population in the WGLR.

Legal and Conservation Status

The following governmental entities have some legal or policy standing for the goshawk in the WGLR:

U. S. Fish and Wildlife Service, Region 3

"Species of **c**oncern" is an informal term that refers to those species which Region 3 believes may be in need of concentrated conservation actions. Such conservation actions vary depending on the health of the populations and degree and types of threats. At one extreme, there may only need to be periodic monitoring of populations and threats to the species and its habitat. At the other extreme, a species may need to be listed as a Federal threatened or endangered species. "Species of concern" receive no legal protection and the use of the term does not necessarily mean that the species will eventually be proposed for listing as a threatened or endangered species. The goshawk is also covered under the Migratory Bird Treaty Act.

U. S. Forest Service, Region 9

The goshawk is a Regional Forester Sensitive Species on the Allegheny, Chequamegon-Nicolet, Chippewa, Finger Lakes, Hiawatha, Huron-Manistee, Monongahela, Ottawa, and Superior NFs (see **Introduction** above).

Wisconsin

Species of Special Concern, i. e., “species about which some problem of abundance or distribution is suspected but not yet proved. The main purpose of this category is to focus attention on certain species before they become threatened or endangered." (http://www.dnr.state.wi.us)

Michigan

Species of Special Concern – listed because of declining or relict populations in the state. (http://www.michigan.gov/dnr)

Minnesota

None (http://www.dnr.mn.gov)

Ontario

None (Dick and Plumpton 1999)

Existing Protective/Management Measures on WGLR State, Federal, and Tribal Lands

U. S. Forest Service

Superior and Chippewa NFs

Provide habitat to provide for population goal minimum: 20-30 breeding pairs.

At northern goshawk nest sites with an existing nest structure, prohibit or minimize, to the extent practical, activities that may disturb nesting pairs in an area of 50 acres minimum (860 ft. radius) during critical nesting season (March 1 – August 30). At northern goshawk nest sites in an area of 50 acres minimum (860 ft. radius), to the extent practical, allow only those activities that protect, maintain, or enhance high quality habitat conditions: 100% mature forest (>50 yrs old) with continuous forest canopy (>90% canopy closure) and large trees with large branches capable of supporting nests.

Within northern goshawk post-fledging areas, minimize activities, to the extent practical, that may disturb nesting pairs during critical nesting season (March 1 – August 30) and, to the extent practical, within a 500 acre area encompassing all known nest areas within the territory: Maintain suitable habitat conditions on a minimum of 60% of the upland forested acres in post-fledging areas. Suitable habitat: jack pine and spruce/fir forest types >25 years and all other forest types >50 years with semi-closed to closed canopy (>70%). Aspen and birch forest types 25-50 years may be considered suitable if field review verifies that foraging habitat trees average 50 feet tall and canopy closure is 50-70% or greater. (2004 FINAL Forest Plan)

Chequamegon-Nicolet NF

Protect active and historic nest sites. Within an area of at least 30 acres surrounding nest site(s), land use activities will be limited to those that do not reduce canopy closure or are necessary to protect the nest site for as long as the territory or stand is suitable habitat. No timber harvest will occur within the buffer area. Human disturbance will be minimized within the buffer from February 15 to August 1.

Within a minimum of 330 feet of the designated 30-acre buffer area:

1. Do not use even-aged management.
2. Emphasize at least 80% crown closure with not more than 4 canopy gaps per acre up to 40 feet in diameter.

Close roads and trails under Forest Service jurisdiction to vehicular traffic within 330 feet of a nest site from February 15 to August 1 unless no feasible alternatives exist and use can be justified.

Conduct surveys for these species prior to projects being implemented within potential habitat areas.

Goshawk take will be by permit only. (2004 Forest Plan)

Ottawa NF
Protect active goshawk and red-shouldered hawk nesting territories. Protection from disturbance (noise, human intrusion) as well as habitat protection measures should be considered. Specific measures may vary on a case-by-case basis. (2006 Forest Plan)

Hiawatha NF
Best available science recognized by Forest biologists, should be used to protect active and historic breeding territories, nesting areas and post-fledging habitat. (2006 Forest Plan)

Huron-Manistee NF
Implement the Management Recommendations for the Northern Goshawk on the Huron-Manistee National Forests (USDA-Forest Service 1993, or current version).(2006 Forest Plan – Proposed). The document cited above is (Ennis et al. 1993), wherein:

Recommendations

- Provide long-term nesting habitat for goshawks in forested landscapes
- Provide hiding cover (from predators, siblings and weather) for goshawk fledglings
- Provide habitat for prey and foraging opportunities for the adults and fledgling goshawks during the fledgling-dependency period
- Monitoring known nest sites use the nationally established protocol and locate additional nest areas on the Huron-Manistee NF. Minimum effort is survey all planned timber treatments the previous year
- Identify potential habitat and survey this if possible
- Existing timber sale contracts with goshawk nest sites will utilize the following recommendations (Ennis et al. 1993):
    - Seek deletion of the nest area (30 acres) from the sale as a minor modification of the total sale. Usually this is when it is less than 10% of the total sales volume. This will only occur with the concurrence of the contractor.
    - Evaluate the "sale area" for opportunities to do possible volume adjustments. This must be negotiated with and agreed to by the contractor.
    - Seek restrictions of sale activity to the time period outside the nesting season for the area ½ mile from the nest site. The nesting season is considered to be March through August.

- All future timber sale contracts should include the timber sale clause 17.1, Sensitive Species. This clause will be implemented after all other options have been attempted or evaluated

Standards and Guidelines

Nest Area

Designate 30 acre area around all active nests and two alternative nests per territory. Adverse management activity will not occur within these areas at any time.

Within 300 feet of 30 acre area, timber harvest may not reduce canopy closure below 60%

Minimal human presence during nesting season (March 1 through August 31), this includes seasonal closure of FS roads

PFA

Approximately ½ mile radius from nest

No more than 20% of the area will be in upland openings and/or in the 0-9 age class

Retain 60% of area in 30 year old plus age classes

Dead and Down Woody Debris

Snags – at least 2 large (> 10 in. DBH, > 10 ft tall)snags per acre

Downed logs – at least 3 large (> 10 to 12 in. diameter at midpoint, > 10 ft long) downed logs per acre

Bad River Reservation

Specific Nest Site Guidelines:

1) The nesting area – defined as an area including all known nests for a single territory; minimum size 40 acres. An additional 40 acres from the nest area boundary may only be selectively cut (30% tree removal). This size may be increased for a particular goshawk territory depending on the spacing of all alternate nests. Or the size can be increased if the quality/sensitivity of the habitat requires a larger special protection zone.
2) Nest tree site – within 300 yards of the nest tree. No activities permitted in this area between February and August 1.

General Nest Site Guidelines:

1) No logging in riparian areas; or areas with slope gradient > 15°.
2) Maintain existing, encourage new, extensive, native, mature forests of mixed hardwood and conifer species.
3) No new roads or reconstruction in nesting areas.

Minnesota DNR

Considerations for Goshawk Breeding Territory Management

I. Goshawk breeding territory encompasses the foraging habitat of a breeding pair; area around a nest that has been active within the past 2 years. Encourage management that would enhance suitability:

A. Consider effects on area of 12,000 to 19,000 acres
B. Consider effort to move area toward following structural conditions:
   1. Mature forest conditions (mean DBH ≥ 8 – 10 inches)in large patches.
   2. 60 – 100% closed canopy with at least 40% upland forest.
   3. Manage for 4 – 12 foot flight paths between top of subcanopy and bottom of canopy.
   4. Manage for <3 foot flight paths between top shrub layer and bottom of subcanopy.
   5. Retain and manage for abundant woody debris.
C. Avoid destruction of alternate nests.

II. Within a goshawk breeding territory, a goshawk nest area is that area in the immediate vicinity of the active nest. For this area the flowing accommodations are suggested:
   A. Identify 30 – 40 acre zone surrounding any known nest site.
   B. Avoid harvesting activities between February 1 and August 1.
   C. Maintain minimum average canopy closure of ≥ 70%.
   D. Protect actual nest tree for 2 years following last known nesting.
   E. Monitor all known active nests for reproduction, continue for 2 years past last nesting.
   F. Favor selective tree harvest as individual tree selection and/or small group selection at 1/3 to 1 acre scale.
   G. Report all large stick nests to Regional Nongame Specialist.

III. Also within a goshawk breeding territory, a post-fledging area is the portion used to support alternative nest sites, and to provision and protect young until they are independent:
   A. Identify zone of 400 – 600 acres surrounding post-fledging area.
   B. Maintain at least half of the area in regeneration > 1/3 its potential height.
   C. Maintain 2/3 in a 60-100% closed canopy condition.

Wisconsin DNR

Proposed Guidelines (James Woodford, Wisconsin DNR, unpubl. report)

No-cut Area. In all forest types, create a no-cut buffer around the active and any alternative nest trees; the area of no-cut depends on stand type, conifer density, topology, and distance to sale boundary. The recommended minimum no-cut radius is 660 feet around all nest trees. This distance provides a no-cut area of 31 acres for a territory with one nest. The no-cut buffer is designed to eliminate disturbance within the nest area and reduce the impact of weather on nesting birds. This reserve area also will reduce the likelihood of predation and interspecific competition from red-tailed hawks and great horned owls. All these factors have been shown to negatively affect or eliminate nesting goshawks in established territories.

Residual Basal Area. In addition to the no-cut buffer, when uneven-age harvests or thinnings are prescribed, maintain residual basal areas higher than is typical for these types of harvests within the nest stand area or possibly throughout the nest area (i.e., 1000 foot radius of the nest tree or center of nest area). At this time the best available information is to retain 70% of the nest area's pre-harvest basal area. For example, a stand with pre-harvest basal area of 140 ft^2/ac could be thinned to 98 ft^2/ac basal area. The nest area size (i.e., a 1000 foot radius circle) is the mean nest area size (approximately 72 acres) of known goshawk territories in Wisconsin and is similar to the nest area size reported in other goshawk studies (see Finn et al. 2002.)

Breeding Season Disturbances. Limit harvesting, loading, hauling, and road/trail building activities within the nest area (i.e., 1,000 ft radius) to periods that minimize disturbance to adults and nestlings. Restrict these activities from February 1 to August 1. (February1 to June 1 is most critical). This guideline is proposed because goshawks are most susceptible to human-caused disturbance during the breeding season. Significant disturbance over a prolonged period will likely cause failure of a breeding attempt and may result in complete territory abandonment.

Confine Nearby Disturbances to One Year. Limit timber harvesting, loading, hauling, and road/trail building within the nest area (i.e., 1000 foot radius of the nest tree) to one-year during a timber sale period. This guideline is intended to limit the duration of human disturbance near goshawk nests. Multiple years of disturbance in succession is likely to cause goshawks to abandon the nest area.

Michigan DNR

No specific guidance for goshawk. However, general within-stand retention guidance considers goshawk (and other species) (Bielecki et al. 2006)

POTENTIAL THREATS TO THE GOSHAWK POPULATION OF THE WGLR

Directly, it is injury – either accidental or intentionally perpetrated by humans – that is the commonest cause of death in birds of prey (Cooper 1969). The days of "hawk shoots" are over, fortunately, and most current threats are more ecological in nature. This section addresses the human-caused potential threats to goshawk viability, natural causes are addressed above in "Limiting Factors".

Human-caused Disturbance

It would be difficult to get permission from the proper authorities to carry out an experiment on disturbing raptors to discover the effects. Perhaps that is why there are so few scientific data available on human-caused disturbance effects on goshawks. A pair of nesting goshawks in early 1930s Rusk County, Wisconsin was intentionally disturbed in an effort to rid the landowner's property of such an unsavory animal. The pair was repeatedly harassed, even to the point of destroying two partially completed nests. The birds persevered, built a third nest and successfully fledged young (Zirrer 1947). A more modern and opportunistic study measured the effects of logging-truck noise on nesting goshawks in northern Arizona (Grubb et al. 1998). Four trucks passed within 500 m of two active nests – one with a brooding female and chicks, the other with a lone 7-week-old juvenile. Direct observations revealed that none of the birds displayed any discernable behavioral response to the noise.

The absence of data has not prevented the development of guidelines to protect nesting goshawks from disturbance. Richardson and Miller (1997) reviewed protection recommendations for all raptors. For goshawks, they cite Jones' (1979) recommendation of a 400-500 m buffer-zone with unspecified temporal restraints. Guidelines for state, federal and tribal agencies are listed above.

Altered Habitat

Habitat alteration can occur at various scales. The smallest scale is probably represented by structures. Goshawk have been observed colliding with residential windows (Dawson and Dalby 1973) and electric-utility structures (Harness and Wilson 2001).

We have discussed above the parcelization of forest habitat in the WGLR and it's potential; effect on goshawk habitat management. For example, on the Huron-Manistee, 35% of compartments with goshawk nests are in private ownership (as of 1993), private forests tend to be younger and contain less pine (Ennis et al. 1993)

Some management practices could increase the probability of non-native invasive species infestation, which can directly or indirectly effect native species by altering the structure and function of habitat (Allen et al. 2006). Not all habitat loss is the same for all species. Loss of native forest to exurban and plantation areas was studied in the Cumberland Plateau; an analysis of the resulting habitat showed that pine plantations had the lowest diversity and conservation priorities compared to agricultural and exurban areas (Haskell et al. 2006). In Europe, goshawk populations seem to be sustained by anthropocentric prey communities – e. g., rock doves and other agriculturally related species constitute the main bulk of diet in winter, and to a lesser degree, in the breeding season (Opdam et al. 1977)

Timber Harvest

Much of the impetus for this and previous conservation assessments for goshawk stems from a paper published late in the last century -(Crocker-Bedford 1990). In what the author described as an 'experimental test', Crocker-Bedford (1990) compared occupancy rates and productivity of goshawk nest site areas designated as either: 1) 'treatment' - subject to timber harvesting around a nest-centric buffer that was either 'small' (1.2 to 2.4 ha) or 'large' (16 – 200 ha) at some time between "the 1950's and 1960's" and 1985; or, 2) 'control' - areas of forest of at least 4700 ha that had not been harvested since the '1950's and 1960's'. The sites were selected *a priori*, so the study doesn't represent a true test of hypotheses. The results reported by Crocker-Bedford (1990) were unbelievably staggering. Compared to the control sites, nest site occupancy rates were 75 – 80% lower where timber harvesting occurred and nestling production was 94% lower, and buffers had virtually no effect on maintaining goshawk reproduction. The author conceded that "there are indications that some goshawks persist 1 to 5 years in their territories following logging, though with little successful reproduction"(Crocker-Bedford 1990).

Kennedy (1997) reviewed the available data and determined that there was no evidence of goshawk populations declining. Yet, the point that I have seen most often cited from that paper is that there is a potential conflict between habitat needs and timber harvest (Boal et al. 2005, Reynolds et al. 2006, Wiens et al. 2006). After publication of (Kennedy 1997) a volley of papers were sent between Kennedy and Crocker-Bedford (Crocker-

Bedford 1998, Kennedy 1998) discussing the value of demographics in determining goshawk population status. The most significant outcome of this *tête-à-tête* was Kennedy's call for experimental design and model development of goshawk response to silvicultural practices (Kennedy 1998). In the decade since then some papers have been published that answer that call.

McGrath et al. (2003) developed a spatial model using logistic regression and classification and regression trees to describe goshawk nesting habitat in the Interior Northwest (Oregon) and to assess the effects of forest management activities on habitat suitability. Overall, the model had a 63% accuracy rate. Their model showed timber harvest can be managed to maintain or enhance goshawk nest site suitability over time and that a non-harvest strategy can be just as detrimental as an aggressive, maximum-yield forest practices.

Recent papers investigate the effects of actual timber harvest on goshawk nesting (Penteriani and Faivre 2001, Lõhmus 2005, Mahon and Doyle 2005). Lõhmus' (2005) study was in Estonia and was similar to that of Crocker-Bedford (1990) in that it was an opportunistic comparison of nest areas within and outside of areas of timber harvest. In Estonia, four of five raptor species (goshawk, honey buzzard [*Pernis apivorus*], common buzzard [*Buteo buteo*], and lesser spotted eagle [*Aquila pomarina*]) preferred natural forest, but the preference was not significantly related to the incidence of timber harvest. Instead, the presence of nests was dependent on availability of some structures found in old growth stands. Lõhmus (2005) concluded that timber harvest and other uses when incorporating buffers around nests could be consistent with maintenance of forest raptor populations. A similar finding was reported by Penteriani and Faivre (2001) for goshawks in Italy and France.

Mahon and Doyle's (2005) study on the effects of timber harvest on goshawk reproductive success in British Columbia is precisely the kind of research Kennedy (1998) called for. Mahon and Doyle (2005) had two study areas, 79 nest areas, 27 nest areas subject to harvesting trials, a range of treatments (5% to 95% of the 24 ha areas), all set within an experimental design. Monitoring of nests was conducted pre-treatment *and* post-treatment. The two response variables they quantified were nest area reoccupation rate and nest productivity. Their results showed no difference in reoccupation rates of nest areas between treatment and control areas ($\chi^2 = 0.021$, $p = 0.89$). The mean number of chicks fledged per nesting attempt did not differ between treatment and control ($t = 0.306$, $p = 0.77$). Seven nest areas had > 50% of the nest stand removed and goshawks returned and bred successfully in all seven the next year.

Timber harvest can be a threat to goshawk viability only if it is performed without proper planning and the establishment of buffer areas around nests. Studies published since Crocker-Bedford (1990) have repeatedly weakened the premise that timber harvest, even with buffer areas, is incompatible with the maintenance of goshawk populations. Proper planning calls for identification of limits beyond which goshawks will abandon nest areas (e. g., Desimone and DeStefano [2005] concluded that the loss of large (>53 cm DBH) trees and a reduction of canopy cover to <50% negatively influences goshawk territory occupancy).

NNIS – "exotic species"

The rate of non-native invasive species (NNIS) introductions has increased globally with international trade (Curnutt 2000). Most introduced species do not become established, let alone invasive. The accepted (but untested) paradigm is that about 10% of species move from introduced to established, and 10% of those would move on to invasive status (Williamson 1996). A deceptively small proportion given that the U. S. imports about 20 billion transport containers each year (U. S. Bureau of Transportation Statistics [http://www.bts.gov], many carrying material that allows organisms to survive transit.

In forests, NNIS have been shown to affect everything from nutrient cycling (Ehrenfeld 2003) to forest community composition and structure (Waldron et al. In Press) to the ability to recover from natural disturbance (Horvitz et al. 1998). Gordon (1998) examined the effects of 31 NNIS species in Florida and found that 12-20 (39-64%) have the potential to alter the ecosystem properties of geomorphology, hydrology, biogeochemistry, and disturbance. Also, the majority of species are capable of modifying natural systems at both ecosystem and community/population scales.

In the WGLR, two extant NNIS have the potential to severely reduce available goshawk habitat: buckthorn (*Rhamnus spp.*) and honeysuckle (*Lonicera spp.*). In addition to reducing the growth rate of overstory trees (Hartman, 2007), both species can invade northern hardwoods and form subcanopies. In an earlier section, I wrote that goshawk habitat in the WGLR would include "…at least one integrated stand of older trees (relative to the surrounding area) with canopy cover sufficient to prohibit understory growth from reaching the bottom of the canopy (nest area)." Buckthorn and honeysuckle are two species that could effect directly the availability of this component of goshawk habitat.

NNIS in the WGLR can alter the structure of goshawk habitat, especially as pertains to understory prey habitat.. For example, garlic mustard (*Alliaria petiolata*) invasion severely decreases understory species richness and has an especially deleterious effect on tree seedling populations (Stinson et al. 2007). structure and diversity, reducing habitat quality for all prey species. Earthworm (*Lumbricus* spp.) invasion into the previously earthworm-free northern hardwood forests of the WGLR has been shown to affect forest species composition (Holdsworth et al. 2007). Those authors showed decreases in sugar maple seedlings and several forb species in both the Chequamegon-Nicolet and Chippewa NFs. Holdsworth et al. (2007) suggest that earthworm invasion could influence the successional trajectory of these forests via differential effects on seedlings. Their work showed that earthworm invasion favors survival of ash (*Fraxinus* spp.) over maple (*Acer* spp.), ironwood (*Ostrya virginiana*), oak (*Quercus* spp.) and basswood (*Tilia Americana*). Of course, the very tree species favored by the earthworm invasion is seriously threatened by the invasion of the emerald ash borer (*Agrilus planipennis*).

Management actions, whether to control NNIS or to improve goshawk habitat quality, must be approached cautiously. Buckthorn and honeysuckle re-sprout when cut and can dominate a cut-over area before native species can become established. Some management activities promote invasion (e. g., powerline corridors, trails) (Rubino et al. 2002) because NNIS plant establishment in forests has been tied to fragmentation and consequent increased edge for some species (Yates et al. 2004).

Pesticides and other contaminants

Rampant use of DDT is no longer occurring in the U. S., but the history of the event is worth remembering. Mercury is a more persistent problem than DDT and mercury emissions into the atmosphere have not halted as yet.

DDT/DDE toxicity causes eggshell thinning, embryonic death and abnormal parental behavior in birds (Snyder et al. 1973). In a comparison of goshawk, Cooper's and sharp-shinned hawks, the goshawk had the lowest DDE levels, no eggshell breakage has been reported and the goshawk population in the northeast US did not rapidly decline in the latter half of the 20th century as did the other two species. This can be attributed to the goshawks prey being lower in the food chain than that of the other two accipiters and, thus, less bioaccumulation (Snyder et al. 1973).

In 1974, an emergency exception for the use of DDT to fight an infestation of the Douglas-fir tussock moth was granted by the U. S. Environmental Protection Agency in Oregon (Henny 1977). This provided a unique opportunity to monitor the effects of one aerial application on birds of prey in the area. Goshawks in the area registered 2.03 ppm DDT after the single spraying. This is 2. 6 times higher than kestrels tested in the same area (Henny 1977). Goshawk prey (birds and mammals) is from a higher trophic level than that of kestrels (insects, lizards) and, therefore, subject to greater bioaccumulation.

Based on measurements of mercury content in feathers, the mean value for goshawks in Sweden from 1863 to 1946 2.2 mg/g and for 1947 to 1965 was 29 mg/g (Berg *cited in* Peakall and Lovett 1972).

Sublethal effects of mercury include adverse effects on growth and development, reproduction, blood and tissue chemistry, metabolism, and behavior. Behavior includes lack of responsiveness to taped calls and hyper-responsiveness to a fright stimulus (Eisler 1987). Interactions of contaminants may be worse, high correlation between mercury and DDT and its metabolites have been found in birds of prey (Eisler 1987). There are no recent data on contaminant levels in WGLR goshawks.

Falconry

Falconry regulations are set by states. In Michigan, up to two northern goshawk can be taken from the wild by winners of permits issued through a lottery. Removal of eyas's can only occur at nests with at least 3 nestlings. One can be taken if at least 2 healthy nestlings remain.

In Minnesota, three raptors (including goshawk) can be taken by an individual each year, only one eyas has to be left in a nest. In Minnesota, between 1992 and 1996, 25 goshawk were removed by permitted falconers (Baker 1998).

In Wisconsin, two raptors per year can be taken by an individual, one eyas must remain in a nest. The state requires permission from the Forest Service for take on Forest Service lands. The Chequamegon-Nicolet NF has recently ceased take of goshawks.

Data on illegal take of goshawks are not available. A comprehensive, region-wide estimate of the effect of goshawk take on the population is not available. Millsap and Allen (2006) used available data and models to recommend maximum sustained yield of raptors by species in the United States. They recommended that take not exceed one half of the maximum sustained yield up to 56% of annual production. For goshawk the 5% limit would apply. Compared to other forms of mortality (e. g., 50% of fledglings die in their first year through accident and/or starvation) legal falconry take has minimal impact on the WGLR goshawk population. Falconry served as a source for repopulation of Britain after the goshawk was virtually extirpated by the 1950s. Kenward (1981) estimates that about 25 goshawks were successfully introduced into the British countryside by loss from falconers. These birds went on to successfully reproduce to a level that explains the re-establishment of the species in Britain.

Global Climate Change

Predictions of the structure and composition of landscapes as the global climate changes are, by default, untested hypotheses. Natural resource managers conduct a risk-benefit analysis to determine the amount of action or inaction appropriate for their pieces of land. All this assessment can do is present the current state of knowledge.

The Upper Great Lakes Region is characterized by two climate-related gradients – the southwest to northeast prairie to forest and the north to south boreal to hardwood forest (Brown et al. 2000). Predicted changes to vegetation of the WGLR are summarized in (Brown et al. 2000). Using the STASH model (Sykes et al. 1996), Brown et al. (2000) predicted that certain tree species in the Upper Great Lakes – among them species used for nesting by goshawks – will retreat northward over the next century. For example, quaking aspen (*Populus tremuloides*) will be restricted to far northern Minnesota and Wisconsin. The trajectory of beech, a species often reported as a goshawk nest tree in the WGLR, is more difficulty to predict. Overall, Brown et al. (2000) model predicts a substantial reduction in area covered by temperate coniferous and cool temperate mixed forest types. The area currently covered by these forest types will be dominated eventually by temperate deciduous forests and savannas. There is a risk of a "dieback phenomenon" wherein current land cover recedes north and, due to land management, lack of time, or invasive species, the advance of more southerly land cover types is delayed (Brown et al. 2000). Under this circumstance the land cover type would not represent a known association.

The most recent report on climate change in the Great Lakes is Kling et al. (2003). The report includes the following predicted changes to forests in the region:

- The extent of boreal forests will shrink and many forest species will move northward.
- New forest composition will depend on the ability of individual species to colonize new sites and the presence of both geographic and human barriers to migration
- Increasing atmospheric CO2 concentration is likely to spur forest growth in the short term, but the long-term response is not clear at present.
- Long-distance migratory birds who time their migration by day length rather than by weather, may find food sources severely reduced when they arrive in the Great Lakes region
- Resident birds such as northern cardinals, chickadees, and titmice might be able to begin breeding earlier and raise more broods each season. However, increasing populations of resident species could further reduce the food available for migratory songbirds that breed in the Great Lakes, ultimately reducing forest bird diversity in the region.

- The geographic range of forest pest species such as the gypsy moth is likely to expand as temperatures warm and the distribution of food plants changes.

One would expect tree migration to lag behind other climate-driven changes, e. g., bird migration. The breeding distribution of some North American bird species has already shifted significantly to the north from the late 1960s to the early 21st century (Hitch and Leberg 2007). It is unclear if this would effect the goshawk in North America as the authors examined the distribution of only 56 species – none of which are preyed upon extensively by goshawks. Price and Root (2000) used the equilibrium Canadian Climate General Circulation model to predict a loss of around 50% of perching bird species in Michigan, Minnesota and Wisconsin (no time scale provided). Incorporating species that will move into the area as a result of climate change the loss of perching bird species is predicted to be around 20%.

How these changes may effect goshawk ecology in the WGLR is, at best, an educated guess. As noted above, the WGLR already forms the southern limit to the goshawk's eastern North American range, a migration of tree species and perhaps whole forest communities to the north will mean the loss of the goshawk from much of the area. Assessment of effects of climate change on any species requires models that incorporate interactions between climate, landscape trends, environmental stochastisity and species life history (Carroll 2007). For example, Carroll (2007) developed a spatially-explicit model that incorporated these parameters and projected a northern Appalachians marten population to 2055 with simulated climate change, trapping and timber activities. His model predicted stronger declines due to climate change (40% of decline) than to trapping (30%) or logging (16%).

GOSHAWK MONITORING

A monitoring program should provide three types of data: an estimate of the population size and trends; an estimate of the demographic parameters; and, habitat data to link the density and demographic parameters of target species populations to habitat characteristics (Ralph et al. 1993). Of course, there are limits – both natural and human-imposed – on what can be attained in monitoring goshawks in the WGLR. Cost and land-ownership are two of many. Table 5 reviews the uses and costs associated with the most common bird monitoring methods. Monitoring of habitat as a surrogate for goshawks has proven to be ineffective (Squires and Kennedy 2006).

Demographic monitoring is discussed above in the section on population ecology. It is the most labor intensive, expensive and, if applied across a population, useful type of monitoring available. In the rare instances when researchers have sufficient funding and interest (e. g., Reynolds in Arizona [Reynolds et al. 1992], Kenward on Gotland Island [Kenward et al. 1999], and Krüger in Germany [Krüger 2007]) the results are magnificent. In the WGLR, we are far from being able to apply this type of effort even if funding were available. For results to be meaningful we first need an idea of the size of the regional population and the magnitude of immigration and emigration.

Doerr and Enderson (1965) and Allen (1978) both state that goshawks are probably more common than they seem and what hides this fact is the lack of a comprehensive census. Census monitoring is used more commonly in bird studies because of the relatively low cost and the larger area of inference. As to the above two needs – census information can give us an idea of the magnitude of the goshawk population in the WGLR and, if repeated sufficiently, the population trend (if any). Census methods do not provide data on immigration/emigration.
Squires and Kennedy (2006) suggest that a viable alternative for monitoring goshawk population performance is estimating trends in site occupancy (presence or absence of breeding goshawks at a site). Dawn vocalization surveys conducted in a sampling framework that allows for estimation of detection probabilities would provide trends in site occupancy which could be used as an index of goshawk population performance. This approach has been developed for regional goshawk populations and field tested in at least two Forest Service regions (Hargis and Woodbridge 2006).

The Bioregional Monitoring Protocol

The northern goshawk bioregional monitoring protocol (Hargis and Woodbridge 2006) has three objectives: 1) to estimate the relative abundance of territorial adult goshawks within a bioregion; 2) to assess changes in goshawk relative abundance over time; and 3) to determine whether changes in relative abundance, if any, are associated with changes in habitat.

A complete description of the protocol is in Hargis and Woodbridge (2006). An abbreviated excerpt from that publication follows:

> The sample population is a grid of square, ~600 ha primary sampling units (PSUs) across all potential goshawk habitat owned or managed by the collaborating parties. The sampling frame is stratified to obtain a reasonable estimate of goshawk relative abundance with an efficient use of funds. The monitoring indicator is the proportion of sampled PSUs with goshawk presence, based on the broadcast acoustical survey method. After the sampled PSUs are surveyed two times (nestling and fledgling periods), the frequency of goshawk presence within the bioregion is estimated using a maximum likelihood estimator. Changes in frequency of goshawk presence will be assessed after a minimum of five years, using a logistic model with habitat parameters entered as covariates. Information from bioregional monitoring will help determine the status of goshawk populations and their habitats over a spatial extent that is meaningful for goshawk conservation.
>
> Each survey results in one of two possible outcomes: presence (1) or absence (0). After both surveys, each PSU has four possible combinations of presence or absence outcomes: 00, 01, 10, or 11. The frequencies of these combinations over all sampled PSUs are used in an equation called the "likelihood function", along with the detection rate coefficients and the probability of presence. The values of the detection rate coefficients and the probability of presence that maximize the likelihood function are used as estimates for those parameters, hence the name "maximum likelihood estimates." The estimated probability of presence is the estimate of how many of the total number of PSUs in the sampling frame are likely to have goshawks present.

The protocol also includes data collection on habitat. The sample sites are analyzed at the landscape-level using both remotely-sensed data and Forest Inventory and Analysis (USDA, Forest Service) data. Thus, the protocol meets two of the three objectives of a monitoring program as defined by characteristics Ralph et al. (1993) – there are no demographic data collected. This is not, however, a panacea. The protocol produces a population estimate for the region – not at any lower spatial scale (e. g., National Forest) and the cost is not insignificant; ~$300,000 to completely survey the WGLR for one year. Even so, to date, this is the most promising tool at our disposal for determining the magnitude of the WGLR goshawk population, and that is a *sine qua non* to the rest of our management efforts.

Table 6. Various bird monitoring methods and associated attributes. Compiled by the author.

Type	Method	Examples	Area Covered	Population/Trend?	Demographics?	Habitat?	Cost
Census	Point Count	Breeding Bird Survey Raptor Migration Count	Broad	High	None	High	Low
Census	Spot Map	Breeding Bird Census	Local	Low	High	High	High
Census	Area Search	Christmas Bird Count Breeding Bird Atlas	Broad	High	Low	High	Low
Demographic	Mist Nets	MAPS Bird Banding Lab	Broad	Low	High	Very Low	High
Demographic	Nest Searches	Waterfowl production (e. g. Gloutney et al. 1993)	Local	Low	Very High	Very High	Very High
Demographic	Genetic	Schwartz et al. 2007					

RESEARCH NEEDS

As mentioned above, interest in WGLR goshawks has recently increased, but the preponderance of goshawk research is still performed in the western U. S. and Europe. Even within the WGLR there are still aspects of goshawk ecology that are not well addressed (e. g., foraging outside of the breeding season). We are sorely in need of more spatial data on goshawk habitat in the WGLR. With more data we will be better able to determine the extent of potential goshawk habitat across the region and develop better models that incorporate parameters other than just stand size. Woodford et al. (2003) did this for Wisconsin, although the model has yet to be entirely validated. I gleaned the following research needs from the body of this document. The list is not comprehensive and any additions to the list will be welcomed.

Habitat

- To date, the use of GIS technology to the study of WGLR goshawk habitat has not met its full potential. This application is useful for raptors because of large tracts of lands and extensive foraging areas needed for viable populations (Austin et al. 1996). The ultimate promise of being able to predict likely effects of management actions on goshawk populations is especially useful to the Forest Service.

- Habitat variables included in a model must be biologically significance. After subjecting the variables to logistic regression analyses with backward elimination, the final model may include a predominance of derived statistical measurements (Austin et al. 1996). A good example of proper habitat mapping using GIS is Beazley et al. (2005) work in Nova Scotia, Canada.
- In developing habitat models one must consider interspecific competition and/or congeneric predation rates in addition to forest structural characteristics (Siders and Kennedy 1996). Simply addressing habitat characteristics would fail to discern goshawk habitat potential from that of Cooper's hawk, for example. A good example of a spatially explicit model of goshawk nest distribution in a landscape that incorporates both habitat and conspecific interactions is Reich et al. (2004) work on the Kaibab Plateau. A similar effort should be made for the WGLR.
- Ecosystem-scale spatial analyses of the WGLR with respect to goshawks must be performed if we wish to understand, predict and monitor goshawk population viability in the region. Studies that incorporate the measurement of ecosystem processes as the land-type association scale and larger with respect to goshawk life history are especially needed. Although not designed to address specifically goshawks, examples of what is needed are Mladenoff et al. (1993) examining old-growth in the western Upper Peninsula of Michigan and Wolter & White (2002) determining forest transition rates in northeast Minnesota.

- We need better data on the foraging habits of goshawks across space and time, and how this habitat best relates to preferred nesting habitat. This juxtaposition of habitat types is doubtless region-specific and other work would serve as a poor substitute for understanding WGLR goshawk ecology.
- The southern edge of goshawk distribution occurs in the WGLR. The nature of the edge is important in understanding how populations change and respond to the environment over time. Caughley et al. (1988) suggest the following: determine the nature of the edge by measuring some attribute of the population (e. g., density, reproductive success, physiological condition) from the edge toward the center. If the attribute is low at the periphery of the range and increases gradually toward the center the spatial trends is described as a 'ramp'; if the attribute is similar from the edge to the center of the range the trend forms a 'step'. The task then is to discover what causes the species' range to end where it does; ramps implicate factors such as climate, a facultative predator, parasite or pathogen, or some unmodifiable resource; steps indicate a physiographic border, e. g., substrate. A concerted research effort on understanding why goshawks are where they are *and* why they aren't where they aren't would take us a long way in understanding goshawk ecology in the WGLR.

Population

- With most of the goshawk's North American range well north of the WGLR we are not able to determine the range-wide structure of the population. This is unfortunate because eruptive migrations from Canada may play an essential role in maintaining the WGLR goshawk population. Research is needed that answers how and why these immigrations occur and what proportion of immigrants remain to reproduce in the WGLR.
- As mentioned above, there is no substitute for solid long-term demographic data (a la Krüger [2007]) when the goal is to understand the population dynamics of a species.
- Some territories seem to be productive regardless of prey cycle. Research is needed to find out what it is about these habitats or birds that allows them to serve as a source of recruitment. Aldridge and Boyce (2007) developed a method to combine greater sage grouse (*Centrocercus urophasianus*) occurrence and survival models and identify source and sink habitats; the same should be investigated for the WGLR goshawk.
- We need to untangle the apparent contradiction in comparing Mueller et al. (1977), who show that prey abundance correlates positively with clutch size, and Postupalsky (1998), who reported that brood size was unaffected by the prey population cycles.
- Lapinski et al. (2002) show that goshawk home range sizes in the Upper Peninsula of Michigan were small compared to those measured in western states.

They suggest that this small home range size is due to increased prey availability in conjunction with the snowshoe hare/ruffed grouse population cycles. We need to determine if this conjecture can be supported with data. In order to do this, however, we need a solid understanding of the prey cycles in the WGLR. In a related note, why has the snowshoe hare cycle collapsed? I can find no tested hypotheses.

- If territories limit local goshawk nest density as in the Kaibab Plateau (Reich et al. [2004] showed that potential nest sites were abundant and randomly distributed on the landscape, however, availability of sites was limited by territories), then shouldn't the relatively small home ranges of the WGLR allow higher densities of nesting goshawks than occurs in other regions? If not, why not?
- Research is needed on goshawk productivity in the WGLR. Productivity in the WGLR appears to be below the average for North America. The significance of this estimate is questionable because we have no so few data on post-fledging movement and survival to reproducing age.
- Predation of nestling goshawks may or may not be a significant factor determining overall goshawk population in the WGLR. We need studies designed specifically to investigate predation on goshawks. This should include ancillary research into fisher population , habitat and foraging habits in the WGLR.
- Interspecific competition for food on goshawk population and reproduction has not been investigated in the WGLR. Consequently, the magnitude of the effect cannot even be estimated.
- An intensive search for historical records that can be used to reconstruct North American goshawk demography. Beissinger and Peery (2007) used this method successfully to identify the demographic cause of the decline of the marbled murrelet (*Brachyramphus marmoratus*) and to set demographic benchmarks for the species' recovery.

MANAGEMENT CONSIDERATIONS/QUALIFIED INSIGHTS

Tbd

GOSHAWK CONSERVATION STRATEGIES

Tbd

SUMMARY AND CONCLUSIONS

Tbd

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Appendix I. Species of prey reported in literature for the WGLR goshawk and associated habitats.

Birds	Habitat*
American robin [3, 4] *(Turdus migratorius)*	Forest, woodland, scrub, parks, thickets, gardens, cultivated lands, savanna, swamps, suburbs.
blue jay [2, 3, 4] *(Cyanocitta cristata)*	Primarily deciduous or mixed forest, open woodland, parks, residential areas with trees; less frequently in open situations with scattered trees.
blue-winged teal [2, 4] *(Anas discors)*	Marshes, ponds, sloughs, lakes, and sluggish streams. Commonly colonizes newly available habitats.
bobwhite [1] *(Colinus virginianus)*	In the Midwest, associated principally with heterogeneous, patchy landscapes comprised of moderate amounts of row crops and grasslands and abundant woody edge.
common nighthawk [4] *(Chordeiles minor)*	open and semi-open habitat; in open coniferous forests, savanna, grasslands, fields, around cities and towns
brown thrasher [3] *(Toxostoma rufum)*	Thickets and bushy areas in deciduous forest clearings and forest edge, shrubby areas and gardens; in migration and winter also in scrub.
common crow [2] *(Corvus brachyrhynchus)*	Open and partly open country: agricultural lands, suburban areas, orchards. Generally avoids dense coniferous forest and desert.
common grackle [3] *(Quiscalus quiscula)*	Partly open situations with scattered trees, open woodland, forest edge, marsh edges, islands, swamp thickets, coniferous groves, cities, suburbs, farms.
Cooper's hawk [3] *(Accipiter cooperii)*	Generally deep woods, utilizing thick cover both for nesting and hunting. Openings, especially where hedgerows or windbreaks offer shelter for prey species, may also be used when foraging.
eastern meadowlark [3, 4] *(Sturnella magna)*	Grasslands, savanna, open fields, pastures, cultivated lands, sometimes marshes.
eastern screech owl [3] *(Megascops asio)*	Open woodland, deciduous forest, orchards, woodland/forest edge, swamps, parklands, residential areas in towns, scrub, and riparian woodland in drier regions.
European starling [3] *(Sturnus vulgaris)*	Found in a wide variety of habitats including open wood- lands, agricultural and urban areas.
green heron [2, 3] *(Butorides virescens)*	Swamps, mangroves, marshes, and margins of ponds, rivers, lakes, and lagoons.
hooded merganser [3] *(Lophodytes cucullatus)*	Nests in deciduous or coniferous trees up to 18 m above ground, also shrubs, roadside plantings, swamp vegetation, natural cavities, marshes.
mallard [3] *(Anas*	Primarily shallow waters such as ponds, lakes, marshes, and flooded fields.

platyrhynchos)	
mourning dove [3] *(Zenaida macroura)*	Open woodland, forest edge, cultivated lands with scattered trees and bushes, parks and suburban areas, and second growth
northern cardinal [3] *(Cardinalis cardinalis)*	Thickets, brushy areas, fields, shrubbery, forest edge, clearings, around human habitation, typically avoids dense forest
northern flicker [3, 4] *(Colaptes auratus)*	Open forest, both deciduous and coniferous, open woodland, open situations with scattered trees and snags.
piliated woodpecker [3, 4] *(Dryocopus pileatus)*	Dense deciduous, coniferous, or mixed forest, open woodland, second growth. Prefers woods with a tall closed canopy and a high basal area. Most often in areas of extensive forest or minimal isolation from extensive forest.
rock dove [3] *(Columba livia)*	Feral birds occasionally in natural habitats, more abundantly near human settlement.
ruffed grouse [1 2, 3] *(Bonasa umbellus)*	Dense forest with some deciduous trees, in both wet and relatively dry situations from boreal forest (especially early seral stages dominated by aspen) and northern hardwood ecotone to eastern deciduous forest and oak-savanna woodland Young forest provides optimum conditions.
scarlet tanager [3] *(Piranga olivacea)*	Deciduous forest and mature deciduous woodland, including deciduous and mixed swamp and floodplain forests and rich moist upland forests; prefers oak trees.
blue-headed vireo [3] *(Vireo solitarius)*	Mixed coniferous-deciduous woodland, humid montane forest.
Mammals	
eastern chipmunk [3] *(Tamius striatus)*	Prefers deciduous woodlands with ample cover, such as brush piles/logs, rocky forested slopes, ravines.
eastern cottontail [1, 3, 4] (*Sylvilagus floridanus*)	Early mid-successional habitats. May be found in brushy areas, open woodlands, swampy areas, stream valleys, grasslands, and suburbs.
eastern fox squirrel [3] (*Sciurus niger*)	Often in open mixed hardwood forest or mixed pine-hardwood associations, but has adapted well to disturbed areas, hedgerows, and city parks. Prefer savannas or open woodlands to dense forests
eastern mole [3] *(Scalopus aquaticus)*	Most commonly occurs in open areas with moist soils, such as lawns, meadows, and golf courses. Bottomland wooded areas also are utilized.
gray squirrel [3] *(Sciurus carolinensis)*	Prefers mature deciduous and mixed forests with abundant supplies of mast (e.g., acorns, hickory nuts). A diversity of nut trees is needed to support high densities.
red squirrel [3, 4] *(Tamiasciurus hudsonicus)*	Prefers coniferous and mixed forests, but also occurs in deciduous woodlots, hedgerows, second-growth areas.
flying squirrel [4] *(Glaucomys sabrinus)*	Prefers coniferous and mixed or deciduous forest. Optimal cool, moist, mature forest with abundant standing and down snags.
snowshoe hare [3, 4]	Prefers the dense cover of coniferous and mixed forests; abundant understory cover is important. Coniferous swamps and second-growth areas that are

(Lepus americanus)	adjacent to mature forests, and alder fens and conifer bogs, are also utilized.

[1] (Errington 1933), [2] (Haug 1981), [3] (Richardson and Bach 2002), [4] (ENG and Gullion 1962). * habitat data from Natureserve (www.natureserve.org)

Appendix III. Parasites reported in literature for the goshawk.

Kingdom	Phylum	Class	Order	Family	Genus species	Source
Animalia						
	Nematoda					
		Secernentea				
			Spirurida			
				Tetrameridae		
					Microtetrameres accipiter	(Schell 1953)
			Ascaridida			
				Toxocaridae		
					Porrocaecum angusticolle	(Morgan & Schiller 1950)
		Adenophorea				
			Dorylaimida			
					Microfilaria spp	(Stabler and Holt 1965)
Protozoa						
	Apicomplexa					
		Conoidasida				
			Eucoccidiorida			
				Eimeriidae		
					Isospora buteonis	(Holling and Fowle 1955)
					Haemoproteus spp	(Stabler and Holt 1965)
					Plasmodium spp	(Peirce and Cooper 1977)
					Hepatozoon spp	(Peirce and Cooper 1977)
		Aconoidasida				
			Haemosporida			
				Plasmodiidae		
					Leucocytozoon	(Stabler and Holt 1965)
	Euglenozoa					
		Trypanosomatidae				
				Trypanosomataceae		
					Trypanosoma spp	(Stabler et al. 1966)
Bacteria						
	Proteobacteria					
		Gammaproteobacteria				
			Pasteurellales			
				Pasteurellaceae		
					Pasteurella multocida	(Morishita et al. 1996)
	Firmicutes					
		Clostridia				
			Clostridiales			
				Clostridiaceae		
					Clostridium botulinum	(Keymer 1972)
Viruses						
	RNA					

dsRNA			
	Totiviridae		
		Trichomonas gallinae	(Cooper 1969)