HOME RANGE AND HABITAT USE OF NORTHERN GOSHAWKS (*Accipiter gentilis*) IN MINNESOTA

FINAL REPORT
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Clint W. Boal[1] and **David E. Andersen**
Minnesota Cooperative Fish & Wildlife Research Unit, University of Minnesota, St. Paul, MN 55108

Patricia L. Kennedy
Department of Fishery & Wildlife Biology, Colorado State University, Fort Collins, CO 80523-1474

[1] Present address: Texas Cooperative Fish & Wildlife Research Unit, Texas Tech University, Lubbock, TX 79409-2120

SUMMARY

The northern goshawk (*Accipiter gentilis atricapillus*) is a large, forest-dwelling raptor generally associated with mature deciduous, coniferous, or mixed forests (Siders and Kennedy 1996, Bright-Smith and Mannan 1994, Beier and Drennan 1997, Squires and Reynolds 1997). In the western Great Lakes Region (WGLR), the species is currently listed as a migratory nongame bird of management concern by the U.S. Fish and Wildlife Service (Region 3), and as a sensitive species by the U.S. Forest Service (Region 9). Although region-specific information on habitat use and productivity is essential for the development of sound management guidelines, active management of the species in the WGLR has been hampered by a lack of information specific to the region (Estabrook 1999, Kennedy and Andersen 1999). We assessed productivity of breeding goshawks in Minnesota, and used radio telemetry to estimate breeding season home range sizes and characterize foraging habitat of 19 male goshawks. Project cooperators located 15 occupied breeding areas in 1998, seven additional areas in 1999, and nine additional areas in 2000, for a total of 31 breeding areas occupied at least one year during the three-year period of the study. Mean fledging success was 1.14 ± 0.17 fledglings per all nesting attempts (n = 42) and 1.85 ± 0.14 per successful nesting attempt (n = 26). We radio-tagged 33 (18 male, 15 female) of 36 goshawks that were captured. The mean range estimate for male goshawks was 2,676 ha using the minimum convex polygon estimator and 3,953 ha using the 95% fixed kernel contour estimator. Male goshawks demonstrated a clear preference to forage in old (>50 yrs) early successional upland hardwood (e.g., aspen, birch) stands, mature (> 50 yrs) late successional upland conifers (e.g., red pine, white pine), and mature (> 25 yrs) early successional upland conifer (e.g., balsam fir, jack pine). Young (< 25 yrs) early successional upland hardwood and young (< 50 yrs) late successional lowland conifer (e.g., black spruce, tamarack) stands were clearly avoided. Foraging stands, regardless of stand type, were consistent in having high stem densities (570 – 1030 stems/ha) of tall, large canopy trees, with horizontal open spaces of 1.1 to 3.5 m between the bottom of the overstory and top of the understory trees, and up to 1 m between the bottom of the understory canopy and top of the shrub layer. These relatively unobstructed spaces between vegetation layers may serve as important flight paths through forest stands, and the heights in which they occurred were consistent among stand types. Mean canopy closure was high among all stand types (53-70%). Goshawks foraged in stands

that, regardless of tree species, were remarkably similar in terms of diameter and heights of the canopy trees, canopy closure, and high stem density.

INTRODUCTION

There has been a great deal of research conducted on northern goshawks (*Accipiter gentilis atricapillus*; hereafter referred to as goshawk) during the last decade. The majority of this work has been conducted in the western United States, western Canada, and Alaska. This research has provided information on many aspects of the ecology of goshawks. Habitat information from these studies, however, may not be directly applicable to the forests conditions and harvest practices of the western Great Lakes region (WGLR). The lack of rigorous, quantifiable habitat data for goshawks in this region has impeded the development of conservation and management plans.

The goshawk is a large, forest-dwelling raptor generally associated with mature deciduous, coniferous, or mixed forests (Siders and Kennedy 1996, Bright-Smith and Mannan 1994, Beier and Drennan 1997, Squires and Reynolds 1997). The species has previously been reviewed by the USFWS for possible listing as threatened under the Endangered Species Act (Clark 1997, 1998). More recently, the Canadian government has listed the Queen Charlotte Goshawk (*Accipiter gentilis langii*), a subspecies found in the coastal regions of west Canada, Washington and Alaska, as threatened. In the WGLR, the species is listed as a migratory nongame bird of management concern by the U.S. Fish and Wildlife Service (Region 3), and as a sensitive species by the U.S. Forest Service (Region 9). Although region-specific information on habitat use and productivity is essential for the development of sound management guidelines, active management of the species in the WGLR has been hampered by a lack of information

(Estabrook 1999, Kennedy and Andersen 1999). For example, there was no information available from the WGLR for inclusion in reviews of goshawk demography (Kennedy 1997) or habitat use (Siders and Kennedy 1994). Although Rosenfield et al. (1998) recently attempted to quantitatively describe nest sites and assess breeding population status beyond single study sites, existing information for the region has generally been limited to long-term monitoring of known nest sites (Erdman et al. 1998) and scattered information on food habits and movements (see Dick and Plumpton 1998). In early 1998, representatives of regional management and conservation organizations in the WGLR were surveyed to identify goshawk research priorities (Kennedy and Andersen 1999). The most pressing information needs for goshawk management were identified as 1) the identification of goshawk breeding habitat and 2) the influence of forest management on goshawk habitat.

In 1998, we initiated a radio-telemetry study to assess the home range size and breeding season habitat use of goshawks in Minnesota. The goal of our study was to radio-track the movements of foraging goshawks and to characterize their foraging habitat during the breeding season. We targeted male goshawks because they do all of the foraging from courtship through at least the early nestling stage (Squires and Reynolds 1997) and often through the fledgling dependency period (Younk and Bechard 1994). However, for comparative purposes, we also radio tracked some female goshawks because they will sometimes forage during the nestling stage (Schnell 1958, Boal and Mannan 1996).

A systematic survey for goshawks was not a component of our study. Rather, the emphasis in this study was to obtain a well distributed sample of nesting goshawks in Minnesota. We do not suggest our information is derived from all, or even a majority of, goshawk pairs in

Minnesota, and our sample was restricted to known goshawk breeding areas, or those located during the course of this study. Further, the data included in this report are limited to breeding season information only. Thus, the information presented may not apply to the nonbreeding season. The goshawks included in this report, however, do include all nesting goshawks known by us or our cooperators during the breeding seasons of 1998-2000.

STUDY AREA

The study area was in the Laurentian Mixed-Forest Province of north-central Minnesota (Figure 1). Goshawks in the study were distributed from as far as Itasca State Park in the west, Jay Cooke State Park and private lands in the east, and the cities of International Falls to the north and Sebeka to the south. A majority of the research was conducted on and near the Chippewa National Forest.

OBJECTIVES

1. Determine productivity of northern goshawks at known nest sites in Minnesota
2. Estimate home range size of goshawks on known breeding areas in Minnesota
3. Assess breeding season habitat use of male goshawks from known breeding areas in Minnesota

METHODS

OCCUPIED AREAS & REPRODUCTION

We considered an area to be occupied if a goshawk(s) was observed in or near a known nest stand, radio-tagged hawks were active in the area, or other evidence of activity was observed (e.g., recent construction on a nest). If an area was occupied by goshawks, we attempted to locate an active nest. Once a nest was located, we made regular visits to monitor reproductive success. We considered the goshawks to be nesting if a female was observed on a nest in an incubation position, which suggested eggs were present, or during later stages of the nesting cycle when young were observed in the nest. We did not climb nest trees to count or band nestlings, but we counted nestlings by visually observing them with binoculars and spotting scopes once they were large enough to see when engaged in normal activities (e.g., feeding, preening, branching). We considered nestlings to have survived to fledge if they attained at least 80% of their first flight age (Steenhof and Kochert 1982), which equates to 30 - 32 days old for goshawks (Boal 1994). We considered a nesting attempt as successful if at least one young fledged and compared productivity among years with an analysis of variance on ranks test. We also attempted to determine the cause of all nesting failures.

For comparison with other studies, we identified nest trees to species, measured tree height and diameter at breast height, and canopy closure. We also identified the nest stand as being in one of the stand type categories as described below.

ADULT MORTALITY

Radio-tagging a substantial number of goshawks provided us with the opportunity to examine causes of mortality, a topic for which there is little information for raptors in general and goshawks in particular (Ward and Kennedy 1996). We used telemetry to relocate all radio-tagged goshawks that died during the course of this study. We conducted in-field examinations of each carcass and death scene to attempt to identify the cause of death and, if depredated, the predator species. For example, claw marks ascending the nest tree, crushed egg shells and chewing and gnawing patterns on the carcass, feathers, and radio harness, are all indicative of mammalian predation. In contrast, crimping plucks of feathers, stripped bones without chewing/mashing bite marks, single beak bite nips and scrapes in bones indicate avian predators. Further, nocturnal (Strigidae) and diurnal (Accipitridae) avian predators can be distinguished by excrement patterns, and, to a lesser extent, location and situation of the kill.

HOME RANGE ESTIMATION

Capture and telemetry

We used dho-gaza traps with live or plastic replicas of great horned owls (*Bubo virginianus*) as a lure to capture adult goshawks (Bloom 1987). Once captured, all goshawks were hooded to reduce stress during handling. All goshawks were banded with a standard USFWS leg band and outfitted with a Biotrack, Inc., TW-3 backpack radio transmitter that weighed 25 grams and had an approximate battery life of 18-20 months.

In 1998, we attempted to radio track goshawks by triangulating their positions between 2 or among 3 trackers. Trackers would approach the goshawks location on foot to minimize error in the estimated bearing between the tracker and the goshawks. These efforts, however, were hampered by physical and vegetative characteristics of the study area that made approaches on foot and determination of the trackers final location very difficult. Ultimately, this resulted in large error polygons around relocation point triangulations and rendered some point estimates suspect. In contrast, location estimates derived from aerial radio-tracking can be more accurate than those derived from ground-based triangulation (Marzluff et al. 1994). We experimented with aerial telemetry as an alternative to ground based tracking during 1998, and fully adopted it as the tracking technique in 1999 and 2000. We followed the homing technique for aerial tracking as described by Samuel and Fuller (1994). Tracking during the breeding season was conducted primarily from a Cessna 172 RG with two wing-mounted Telonics, Inc., RA-2A twoelement antennaes and an Advanced Telemetry Systems, Inc., R4000 receiver. Because of the substantial distances we had to cover, we would fly a circuit of the radio-tagged goshawks, relocating each goshawk in sequence.

Data analysis

Relocations of goshawks were plotted on aerial photographs carried in the aircraft. Following each flight, we used ArcView 3.1 to plot the relocation points onto Digital Orthogonal Quadrate coverages of each goshawk breeding area. From these coverages, UTM coordinates could be calculated for each relocation point. We used the Movement 1.1 ArcView Spatial Analyst Extension (Hooge and Eichenlaub 1997) to estimate home range sizes with the minimum convex polygon (MCP) method, and the Fixed Kernel (FK) method using 50, 65, 75, 85, and 95% contours. The MCP is one of the easiest methods for calculating home range, but there are substantial biological and statistical disadvantages (Samuel and Fuller 1994). However, because MCPs are one of the most frequently reported estimates of home range and habitat analysis, we provide MCP estimates for comparison with other studies and the FK estimator. The FK estimator of utilization distributions is one of the most robust nonparametric estimators for home range, providing probabilistic models that describe the relative amount of time that an animal spends in a given place (Seaman and Powell 1996). To calculate FK estimates, we brought all relocation points into the display, then set the output grid cell size to 801.5, with 250 rows and 355 columns. We compared the area of each FK contour to the area of the MCP for each male goshawk with paired *t*-tests.

Seasonal movement patterns may correspond to the natural biological cycles of a species. Therefore, home range size comparisons among individuals of a species should be conducted during the same periods (Samuel and Fuller 1994). For example, adult raptors may begin roaming farther from the nest during the post-fledging period, which expands their home range (Mannan and Boal 2000). Although some researchers consider all locations collected during the breeding season to be reflective of "breeding season" home range (e.g., Keane 1999), such movements by adult goshawks may not accurately represent the area required for brood rearing. Therefore, we used the MCP Sample Size Bootstrap procedure in the Animal Movement extension for ArcView 3.1 (Hooge and Eichenlaub 1997) to examine the effect of sample size on MCP area for each male goshawk. If we observed a >10% increase in the area of the MCP after a period of stability we considered this as an expansion beyond the area required for brood rearing and truncated the data to those locations prior to the increase. To further assess the adequacy of our relocation sample for each male goshawk, we conducted a correlation analysis between home range size and number of locations.

HABITAT USE

Terminology

Habitat terminology is often used vaguely and can lead to points of contention (Hall et al. 1997). Clearly stated definitions of terms can avoid misunderstandings of data and interpretations. For this report we primarily use habitat terminology as defined by Hall et al. (1997) and review several key terms here. First, "habitat" was defined as the resources and conditions in an area that promotes occupancy by a given species (Hall et al. 1997). Because our examination of forest conditions that goshawks use was limited to structural characteristics, we employed the terms "stand type" or "forest stand type" when examining use versus availability. The term "habitat use" is defined as the way an animal uses the components in a habitat (Hall et al. 1997). "Habitat selection" is generally defined as a hierarchical process in which an individual chooses which habitat components to use (Johnson 1980, Hutto 1985, Hall et al. 1997). "Preference" is the consequence of habitat selection, resulting in disproportionate use of some resources over others (Hall et al. 1997). Therefore, "avoidance" is the counterpart of selection: a disproportionate lack of use of some resources compared to others. "Availability" is the accessibility of habitat components by an animal whereas "abundance" refers only to the quantity of those resources in the habitat (Hall et al. 1997). Because our examination in this paper focuses on forest stand types within the home range of individual goshawks, we assume all stand types within the home range are available for use. Therefore, assessment of stand type "use" versus "availability" is operational.

Home range scale

We used GIS coverages of forest stand types and age classes to identify those stand types used compared to their relative availability within the home range of each goshawk. We used the minimum convex polygon estimates of home range because they included only areas the goshawk was known to occupy and not probabilistic extensions beyond the known relocation points. The digital coverages were provided by the USFS, MNDNR, and county land offices. Stand type polygons had a minimum resolution of approximately 0.5 ha. The different coverages were merged into a single coverage for each goshawk with the Geoprocessing Extension of ArcView 3.1. Cover types were pooled into a common inventory classification system of stand types. Stand types were then placed into a hierarchical categorization system (Table 1). The first hierarchical level was either early or late successional stage. The second hierarchical level was community type. These were early successional lowland hardwoods, early successional lowland conifer, early successional upland hardwood, early successional upland conifer, late successional lowland conifer, late successional lowland hardwood, late successional upland conifer, and late successional upland hardwood (Table 1). Species characteristic of each stand type are provided in Table 2. The third hierarchical level was age, either young or mature. Early successional upland conifer stands of 0-25 years and > 25 years were considered young and mature, respectively. Late successional communities of 0-50 years were considered young, and >50 years were considered mature. There was one exception to this third level categorization. Early successional upland hardwoods (e.g., aspen, birch) are a primary forest product in the study area, and are often harvested under a short rotation program, with harvesting often occurring when trees are about 40-50 years old. A great deal of the concern over goshawks in Minnesota has focused on harvesting of early successional upland hardwood communities and the influence it may have on goshawks. Therefore, to better investigate age-related uses of this community type by goshawks we separated early successional upland hardwoods into three age categories: 0-25 = young, 26-50 = mature, and >50 = old.

Once we dissolved the original stand types into the hierarchical categories, we queried the database for proportions of each stand type within each home range. From this, we conducted stand level habitat analysis within home ranges at two scales. First, we overlaid goshawk relocation points onto the coverage and queried the database for the stand type at each relocation point. A potential criticism of our data is the level of precision of the point relocations. Based on a previous aerial telemetry study of goshawks (Pendleton et al. 1998), our own recoveries of dead birds, and relocation accuracy of test transmitters (Boal et al. 1999, 2000), our relocation estimates are accurate to within approximately 100 m. Therefore, we also identified the proportions of different stand types within a 50 m-radius buffer around each point estimate. We then identified the proportions of each stand type within each buffered relocation point. Then we tested proportional use on the basis of 1) stand type at relocation point and 2) proportions of stand types within each buffered relocation point to the proportional availability of the stand types within the corresponding home range for each goshawk.

The veracity and accuracy of GIS information is often not assessed for habitat assessment at large scales. We attempted to assess the veracity of GIS data from which we conducted our stand use assessment by comparing the stand type according to the GIS database to what was observed during stand visits.

There are an array of procedures for estimating and testing inferences about habitat selection and, although different methods may be appropriate for a given data set, they may produce different results (McClean et al. 1998). Consistency of results among methods, however, may facilitate interpretation of the data. Therefore, we used two methods to examine use versus availability for goshawks. First, we used Compositional Analysis, a method of analysis that is resilient to sample size by using each individual animal as the sampling unit (Aebischer et al. 1993). Compositional Analysis uses ANOVAs to compare the log-ratios of use and availability of each habitat type for each goshawk, and thereby determining if use differed from availability of habitat types within home ranges. The compositional analysis provides a ranking of habitat types according to use.

The second method was the χ^2 method described by Neu et al. (1974). We applied this method to our sample population by summing statistics as described by White and Garrot (1990). In contrast to the ranking of habitat types resulting from compositional analysis, this method allows for determination of what habitat types are preferred or avoided by constructing Bonferroni simultaneous confidence intervals and relevant statistics. Both analytical methods were conducted with the RSW Resource Selection Analysis Software for Windows (Leban 1999).

Stand scale

Use versus availability information derived from digital covers of the study area provides insight as to what stand types goshawks use as foraging habitat. Understanding the structural characteristics of stands used by goshawks for foraging, however, requires quantitative characterization of those features. We randomly selected eight (≈ 25%) of the relocation points for each of 16 male goshawks tracked during this study. Selected stands were visited and an array of variables (Table 3) were measured along a 100 m long, two meter wide transect centered on the location point estimate and running in a random orientation. Each stand was placed into one of the successional communities stand types as described above. Data were entered into Excel spreadsheets, pooled as to stand type and summarized with the JMP IN statistical package.

RESULTS

OCCUPIED AREAS & REPRODUCTION

Occupied Areas

We located 13, 19, and 21 areas occupied by goshawks in 1998, 1999, and 2000, respectively (Table 4). Two additional areas were located by cooperators in 1998 (Pine Ridge, Pipeline), but not reported to us until 1999 (Table 4). Although one of the nesting attempts was verified as successful (Pine Ridge), the two nests were not monitored for fledgling numbers. Thus, we only include the original 13 of the 15 areas from 1998 for productivity assessment. Of

15 breeding areas occupied in 1998, 11 (73%) were occupied in 1999 (Table 5). Of 23 known breeding areas occupied in 1998 and/or 1999, 13 (57%) were occupied in 2000 (Table 5). Although breeding did not occur in all occupied areas, project cooperators located 15 occupied areas in 1998, seven additional areas in 1999, and nine additional areas in 2000, for a total of 31 areas occupied by goshawks at least one year during the three year period of the study (Figure 2).

The majority of breeding areas were located in Itasca (29%), Cass (19%), Beltrami (13%) and St. Louis (13%) counties (Table 4, Figure 2). Most of the breeding areas were in areas managed by the U.S. Forest Service (48.3%), but a substantial proportion were also on private lands (25.8%), with fewer nests on state (12.9%) and county (12.9%) lands (Table 4). Eighty-one percent of 46 nests were built in aspen (*Populus tremuloides*), 11% in paper birch (*Betula papyrifera*), 4% in white pine (*Pinus strobus*) and 2% each in red oak (*Quercus velutina*) and red pine (*Pinus resinosa*). Stand measurements were conducted at one nest stand each for 19 breeding pairs of goshawks. Two nest stands were in early successional upland conifer (10.5%), 12 were in early successional upland hardwood (63.2%), three in late successional upland conifer (15.8%), and two in late successional upland hardwood (10.5%).

Goshawks nested at all 13 of the occupied areas located and monitored in 1998. Productivity was not monitored at one of the nests (Jay Cooke SP) and two others failed. Sixteen pairs of goshawks from 19 occupied areas (84%) nested in 1999, and 15 pairs from 21 occupied areas (71%) nesting in 2000 (Table 4). Nesting success was 83% in 1998, 38% in 1999, and 67% in 2000 (Table 5). Some areas were known to be occupied by non-breeding goshawks. For example, the widowed Pimushe female, tagged in 1998, was tracked in her breeding area, but did not breed in 1999. Likewise, in 2000 the widowed and non-breeding Lost Girl female roamed more widely than she had while breeding in 1999, but still occupied her 1999 breeding area. The Dixon pair, radio-tagged and successful in 1999, occupied their breeding area but did not nest in 2000. In contrast, the widowed Pipeline female moved 15 km to pair with a new mate in a new breeding area (Drumbeater).

Productivity

Goshawks fledged 2.10 ± 0.23 young per successful nest and 1.75 ± 0.31 young per all nesting attempts in 1998, 2.17± 0.31 young per successful nest and 0.87 ± 0.31 young per all nesting attempts in 1999, and 1.40 ± 0.16 young per successful nest and 0.93 ±0.21 young per all nesting attempts in 2000 (Table 6). Fledgling numbers among successful nests differed among years (H_2 = 6.04, P = 0.049) but fledgling numbers among all nesting attempts was not statistically different among years (H_2 = 5.37, P = 0.068). Mean fledgling numbers for all years was 1.85 ± 0.14 for successful nests, and 1.14 ± 0.17 for all nesting attempts (Table 6).

Nesting failures

Of the 42 goshawk nests monitored, two (4.8%) failed in 1998, 10 (23.8%) failed in 1999, and five (11.9%) failed in 2000. Of these 17 failures (40.5%), four were due to mammalian predation, three were due to avian predation, two are suspected to be due to predation, and six are suspected to be weather related (Table 7). Six (35%) nesting failures occurred during incubation and 11 (65%) nesting failures occurred during the nestling stage of the nesting cycle. Two nest predation events included mortalities of the adult female goshawk.

ADULT MORTALITY

Eight goshawks, seven of which were radio-tagged, died during this study. Four females and one male were killed during the breeding season. Breeding season causes of death were identified as predation by a mammal (2), predation by a great horned owl (2), and predation by a diurnal raptor (1). Two of the adult females killed by avian predators in 1998 were killed late enough in the season that the male goshawks were able to care for and fledge nestlings. Three male goshawks died during the winters of 1998-99 and 1999-00. The causes of death could not be determined for any of these individuals. One particular male (Pipeline), radio-tagged in 1999, had been banded as a juvenile at Hawk Ridge, Minnesota, during the fall migration of 1988. The Pipeline nest successfully fledged two young in 1999. To our knowledge, this makes the 11-year old male the oldest known breeding male goshawk to have been reported.

HOME RANGE ESTIMATION

Capture and telemetry

We attached radio transmitters to 33 of 36 adult goshawks (18 males, 15 females) captured during this study (Table 8). The radio on one of the males failed and two females were killed before meaningful data could be collected. Also, due to our concern for the nestlings during periods of inclement weather, two females were released without radios. We did not radio-tag one male goshawk because it had a pre-existing wound to the left breast muscle. The transmitter attachment straps would have crossed the wound and, possibly, abraded or further aggravated the injury. Ultimately, we collected home range information for 17 individual male goshawks and 11 individual female goshawks. In addition, two breeding seasons of data were collected for one female and two male goshawks. These data are considered temporally independent, bringing the total male sample to 19 goshawks. We also collected a second breeding season of data from a female that was widowed in 1999 and mated with a different male on a different area in 2000, bringing the total female sample to 13 goshawks.

Home range size

We obtained an average of 29 relocations per goshawk. There was no correlation between the number of locations and the home range size of male goshawks ($r = 0.027$, $P = 0.91$). Average MCP home range size for male goshawks was 2674 ha, but ranged from 860 ha to 8573 ha (Table 8). Average FK estimates increased as a function of percent contour (Table 8). The MCP home range size estimates statistically differed from the 50% ($\bar{x} = 538 \pm 99$ ha; $t_{18} = 6.12$, $P < 0.0001$), 65% ($\bar{x} = 1079 \pm 203$ ha; $t_{18} = 5.67$, $P < 0.0001$), 75% ($\bar{x} = 1641 \pm 312$ ha; $t_{18} = 4.77$, $P = 0.0002$), and 95% ($\bar{x} = 3953 \pm 573$ ha; $t_{18} = -6.24$, $P < 0.0001$) FK estimates, but did not differ from the 85% FK ($\bar{x} = 2454 \pm 418$ ha; $t_{18} = 1.21$, $P = 0.2416$) (Table 8). Further, 94.2% of goshawk relocations occurred within the 85% FK contour.

We used the MCP estimator to compare home range sizes between male and female members of goshawk pairs (Table 9, Figures 3, 4). There was not a statistical difference in mean size of home range for male ($\bar{x} = 3006 \pm 689$ ha) or female ($\bar{x} = 2649 \pm 596$ ha) members of pairs ($t_{10} = 0.437$, $P = 0.672$). However, the average home range sizes of male and female members of tracked goshawk pairs ($n = 22$; $\bar{x} = 2827 \pm 446$ ha) was significantly smaller than the combined home range size of those pairs ($n = 11$; $\bar{x} = 6454 \pm 1417$ ha; $t_{31} = 3.09$, $P = 0.004$) (Table 9). Thus, home range sizes were comparable between the sexes, but there was not necessarily a great deal of overlap of male and female home range within a breeding area. The combined home range size was on average 56% greater than the home range size for individual members of a pair (Table 9).

HABITAT ANALYSIS

Home range scale

Digital stand information was not available for all breeding areas, and we were limited to assessing home range level habitat use for 12 male goshawk home ranges. Data are still being developed for two areas (Itasca SP, Jay Cooke SP) and may eventually become available for analysis. Other areas are dominated by private land, which results in too few locations in areas with GIS information for the development of meaningful data. Such situations may warrant efforts at aerial photography interpretation, but this is likely to be expensive, and was beyond the scope of this study.

We attempted to assess the veracity of GIS data from which we conducted our stand use assessment by comparing the stand type according to the GIS database to what was observed during 76 stand visits. We found 56 (74%) of the stands were accurately classified by the GIS coverage. The 26% error may be due to 1) small pockets of a stand type, such as upland islands in extensive lowland tracts, not being mapped, 2) more extensive mapping or data entry errors, 3) errors made in our merging of different data sets and converting them to categories for analysis, or 4) on site decisions concerning successional stage. Stands were misidentified as late successional upland hardwoods (n = 6, 30%), early successional upland hardwoods (n = 4, 20%), late successional lowland conifers (n = 4, 20%), other (n = 3, 15%), early successional upland conifer (n = 2, 10%), and late successional lowland hardwood (n = 1, 5%)(Table 10). The misidentified stands were in actuality early successional upland hardwoods (n = 8, 40%), late successional upland conifers (n = 5, 25%), late successional upland hardwoods (n = 4, 20%), late successional lowland conifer (*n* = 2, 10%), and late successional lowland hardwoods (*n* = 1, 5%)(Table 10).

The results of the home range level analysis were remarkably consistent independent of the analytical method used, or whether examining relocation points or buffered relocation points (Tables 11, 12, 13). Early successional lowland communities made up a very small component of stand types in the study area, so we pooled them into the "Other" category (Table 1). Old (>50 years) early successional upland hardwoods (EUH-O) were the highest ranked habitat type based on compositional analysis, independent of whether using points locations or point buffers (Table 11). Likewise, the χ^2 method indicated EUH-O were a preferred habitat whether looking at point locations ($P < 0.0001$) or point buffers ($P < 0.0001$; Table 12). Mature early successional upland hardwoods (EUH-M) ranked eighth and third using points and buffers, respectively, and were identified as a preferred habitat when using points but no level of preference was discernable when using buffers (Table 11, 12). Both analytical methods indicated young early successional upland hardwoods were clearly avoided (Table 11, 12).

Mature early and mature late successional upland conifers were highly ranked and were preferred independent of analytical method and scale (Table 11, 12). Mature late successional lowland hardwoods ranked in the middle of the range of habitat types (Table 11) and, as such a ranking would suggest, the χ^2 method could not discern a preference or avoidance of the habitat type (Table 12). Late successional lowland conifers, independent of age, and the "Other" category all ranked low to midway through the range for habitat types, and all were significantly avoided.

There were two habitat types that the analytical methods diverged on in terms of ranking and preference or avoidance. It is perplexing that mature late successional upland hardwoods ranked low by compositional analysis, but were preferred habitat types based on the χ^2 method (Table 11, 12). Likewise, young late successional upland conifers were the lowest ranked of all habitat types, yet the χ^2 method indicated that, although not significant, it was a preferred habitat when examining buffered areas (Table 11, 12). The three stand types that accounted for the greatest mean availability (mature late successional upland hardwood, young early successional upland hardwood, and other) were all significantly avoided by foraging goshawks (Table 12).

<u>Stand scale</u>

We inventoried 128 foraging stands that represented six stand types (Table 14). Rather than any real differences among the stand types, the most notable factor was the similarity in stand structure regardless of stand type (Table 14). Canopy tree crown height averages were 14.7 to 16.8 m and the bottoms of canopies averaged 6.1 to 9.2 m. Understory tree crowns averaged 5.4 to 6.1 m. This resulted in a 1.1 to 3.5 m space between the bottom of the overstory and top of the understory trees. An exception to this occurred among late successional lowland hardwood, where the flight space averaged only 0.3 m. There was also a 0-1 m open space between the bottom of the understory canopy and top of the shrub layer. These relatively unobstructed spaces between vegetation layers may serve as important flight paths through forest stands, and the heights in which they occurred were very consistent among stand types.

Mean diameter at breast height was also similar among canopy trees, ranging from 19.6 to 24.6 cm. Canopy tree stem density ranged from 570 to 1,030 stems per ha, with densities lowest among early successional upland conifer stands, and highest among the late successional lowland conifer stands (Table 14). Mean canopy closure among all stand types ranged from 53-70% (Table 14). Foraging stands contained from 16 to almost 24 km of down woody debris per ha, averaging 17 to 19 cm in diameter. Debris was typically between 5 and 20 cm above the ground, and mid-way through the decay process.

DISCUSSION

Trees used by goshawks for nesting in our study were similar to, though slightly taller and larger than, those reported for the same region by Martell and Dick (1996). We observed annual variability in reproductive success for all nesting attempts ($\bar{x}$ = 1.14 ± 0.17; range = 0.87-1.85) and for successful nests ($\bar{x}$ = 1.85 ± 0.14; range = 1.40-2.17) during the three years of this study. Such variability is typical of temporal patterns in reproductive success (e.g., Kennedy 1997). For example, Doyle and Smith (1994) reported 0.0 to 2.8 goshawk fledglings per nesting attempt over four breeding seasons in the Yukon. An average of 2.13 fledglings (range = 1.4-2.7) were produced per successful nest among five studies in the western United States (McGowan 1975, Kennedy 1989, Boal and Mannan 1994, Bull and Hohmann 1994, Reynolds et al. 1994). There are few data from the WGLR or eastern United States, but Speiser (1992) found goshawks in New York and New Jersey to fledge 1.4 young per active nest. More pertinent to our study, Erdman et al. (1998) reported 1.6 and 2.1 young fledged from active (n = 184) and successful (n = 135) nests, respectively, from 1968 to 1992 in Wisconsin.

From 1996 to 1999, mammalian predation was cited as occurring at none of 31 goshawk nests in the Lower Peninsula of Michigan, at 9 of 36 nests in the Upper Peninsula of Michigan, at 20 of 70 nests in northeast Wisconsin, and at 4 of 22 nests in northwest Wisconsin (Bowerman et al. 2000). Four of 42 goshawk nests in Minnesota were depredated by mammals from 1998 to

2000. Several mammals are known to prey upon raptors nests (Newton 1979). Raccoons (*Procyon lotor*) are especially notorious as nest predators (Newton 1979), and martens (*Martes americana*) and wolverines (*Gulo gulo*) have both been reported to prey upon goshawks (Paragi and Wholecheese 1994, Doyle 1995). Erdman et al. (1998) attributed predation by fishers (*Martes pennanti*) as the primary cause of nesting failure, but did not provide details as to how this conclusion was arrived at or the actual number of nesting failures due to fishers. Fishers were also identified as the cause of mortality for four female goshawks in Wisconsin (Erdman et al. 1998), but the authors provide no information as to other mortality factors contributing to their reported annual 40% adult female goshawk turnover. In contrast, only two of four adult females were depredated by mammals in our study. Results from Wisconsin and our study suggest predators may have an influence on goshawk populations in the WGLR. The influence of predators on goshawk demographics, however, and whether predation occurs at normal levels or is exacerbated by human activities in the WGLR (e.g., Erdman et al. 1998), has yet to be rigorously assessed. The development and use of standardized field methods of evaluating causes of mortality of goshawks would improve the comparability of mortality results among study areas. Further, goshawk survival and recruitment rates in the region have not been estimated with current modeling approaches (Kennedy and Andersen 1999).

Home range sizes of goshawks in North America range from approximately 500 to 4,000 ha depending on sex, habitat, and estimation method (Squires and Reynolds 1997). The mean home range of three breeding female goshawks in Michigan (513 ha; Lapinsiki and Bowerman 2000) was substantially smaller than breeding female goshawks in Minnesota. However, we caution against using female home range data to assess breeding season habitat use because male goshawks do most of the foraging during the courtship, incubation and nestling periods. Thus, relying solely on female data may prove erroneous when examining habitat needs for foraging by breeding goshawks. Unfortunately, the single male goshawk tracked by Lapinski and Bowerman (2000) was a nonbreeding individual, so comparisons with our data are not appropriate. Although there are no published home range estimates for breeding male goshawks in the WGLR for data comparison, home range sizes of breeding male goshawks in our study appear to fall within the range of those reported in western states (see Squires and Reynolds 1997, Keane 1999).

Kenward and Widen (1989) reported goshawk home ranges were smallest where prey densities were greatest. In some years, goshawks are food-limited and demonstrate demographic responses to food abundance (Ward and Kennedy 1996, Dewey and Kennedy in press). Forestland in our study area is highly fragmented into different age classes and stand types, and by open areas. Increasing edge may correlate to smaller stand sizes, which may relate to prey abundance and availability. The current approach for goshawk management in western states is to manage landscapes to maintain habitat for prey species used by goshawks (Reynolds et al. 1992). The abundance and availability of goshawk prey is likely influenced by forest management practices. For example, scuirids are more abundant and stable in old growth stands compared to managed second growth (Carey 1995), avian populations are more abundant and diverse in mature forests than younger forests (Schwab and Sinclair 1994), and forest floor vertebrates are more abundant in forests with increasing amounts of down woody debris (Butts and McComb 2000).

Our analysis of stand type within home ranges suggests goshawks preferentially use older age classes of forest type for foraging. Old (>50 yr) early successional upland hardwoods (i.e., aspen, birch) appeared to be the most preferred stand type by foraging goshawks. Aspen and birch stands >50 years old accounted for only, on average, 11.7% of stand types within goshawk home ranges, but were preferred for foraging over any other stand type. Likewise, mature early and late successional upland conifers, and mature early successional upland hardwoods were also preferred foraging habitat types.

There are caveats with our assessment of habitat use. First, home range size may be more greatly influenced by the spatial distribution and size of stand type patches. However, our habitat use versus availability assessment was based on minimum convex polygon estimates of home range. The different spatial dimensions derived from different home range estimators may influence the results and interpretations of a use versus availability analysis. Further, just because an area is used disproportionately less than other areas (our definition of avoidance) does not necessarily mean the area is unimportant for the species. For example, an area that is "avoided" by definition may actually be important in terms of prey production. A goshawk may not typically venture into the area, but the area could still be an important component of overall habitat. Finally, as previously stated, our data and assessment are limited to the breeding season only. The relative use of different stand types by goshawks may vary temporally due to seasonal differences in prey availability or requirements for thermal or escape cover.

Goshawks may select habitat on the basis of components such as prey availability and stand structural characteristics, but they are at the mercy of unpredictable factors such as drought, severe storms, or predation. Thus, it is difficult to relate reproductive success to habitat quality. McClaren et al. (2001) found no spatial variation in productivity among three geographically distinct study areas with long-term datasets, but temporal variation was significant in each study area. Their study drew on a much larger data set than we have accumulated in our study. Given the significant lack of variability in reproductive parameters in their substantially more extensive data set, we believe attempting to relate habitat quality to productivity in our study would be both premature and potentially erroneous.

Within stand measurements indicate foraging stands are typified by a relatively high stem density of large, mature deciduous and coniferous trees, depending on the stand type, with a high canopy closure. There tends to be a horizontal space of 1 to 3.5 m at about 6 m above the ground between the bottom of the overstory foliage and the top of the understory foliage. This generally unobstructed layer may be important as a flight corridor for goshawks. There also was a 0-1 m open space between the bottom of the understory canopy and top of the shrub layer, which may serve a similar function. Regardless, these relatively unobstructed spaces between vegetation layers were consistent among stand types.

Foraging stands had large amounts of down woody debris, which may relate to presence and abundance of forest floor vertebrates. For example, Butts and McComb (2000) found some small forest floor vertebrate species increased with the presence of woody debris in forests of Oregon. Woody debris position and distribution within a stand may also be an important factor in the ability of goshawks to hunt and capture prey (Reynolds et al. 1992). The similarity among stands in terms of diameter and heights of the canopy trees, canopy closure, and high stem densities, and flight layers, suggest goshawks are selecting foraging stands that have relatively dense stands of mature, large canopy trees regardless of stand type. However, we did not evaluate prey abundance or availability in specific foraging stands or the study area. Further, our limited information on prey delivered to nests suggests goshawks in the study use prey that are associated with a variety of stand structures (Boal and Andersen, unpubl. data).

Our results support the general belief that goshawks have evolved a morphology for pursuing prey in moderately dense forests (e.g., Squires and Reynolds 1997). Goshawks in Minnesota preferred old and mature forest types, but avoided young forest types, mature lowland conifer, and open areas during the breeding season. Our results are consistent with other studies indicating goshawks prefer mature to old forests, either conifer or hardwood, as foraging habitat. Beier and Drennen (1997) found goshawk foraging sites were in areas with greater canopy closure and density of large trees than was found at contrast sites. Austin (1993) found mature and old-growth habitats with high canopy closure were used whereas seedling and sapling age stands were avoided. Likewise, Brightsmith and Mannan (1994) found goshawk use of foraging habitat increased with increasing canopy closure. The structural factors related to goshawk use in all these studies indicate use of older forest types.

Two primary questions remain to be addressed to develop a more complete understanding of the factors influencing goshawk home range size and habitat use in the WGLR. First, an examination of the habitat fragmentation within home ranges needs to be conducted. Second, prey use and delivery rates need to be quantified and correlated to habitat conditions within the home range of goshawks. Understanding what prey species are used by goshawks and how those species are influenced by forest structure and management practices are important pieces of information needed to develop sound goshawk conservation plans.

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Table 1. Hierarchical levels of stand type categories within goshawk home ranges, Minnesota, 1998-2000. Terms "young", "mature", and "old" are used only for convenience in separating out chronological age groupings.

Level 1	Level 2	Level 3
Early Successional	Upland Conifer	Young (0-25)
	Upland Conifer	Mature (>25)
	Lowland Conifer	Young (0-25)
	Lowland Conifer	Mature (> 25)
	Upland Hardwood	Young (0-25)
	Upland Hardwood	Mature (26-50)
	Upland Hardwood	Old (> 50)
	Lowland Hardwood	Young (0-25)
	Lowland Hardwood	Mature (> 26)
Late Successional	Upland Conifer	Young (0-50)
	Upland Conifer	Mature (> 51)
	Lowland Conifer	Young (0-50)
	Lowland Conifer	Mature (> 51)
	Upland Hardwood	Young (0-50)
	Upland Hardwood	Mature (> 51)
	Lowland Hardwood	Young (0-50)
	Lowland Hardwood	Mature (> 51)
Other	Brush, open areas	

Table 2. Tree species in early successional (ES) and late successional (LS) stand type categories used for goshawk habitat analysis in Minnesota, 1998-2000.

Stand Type	Species	
ES Upland Conifer	jack pine	*Pinus banksiana*
	upland black spruce	*Picea mariana*
	white spruce	*Picea glauca*
	balsam fir	*Abies balsamea*
ES Upland Hardwood	quaking aspen	*Populus tremuloides*
	bigtooth aspen	*Populus gradidentata*
	balsam poplar	*Populus balsamifera*
	paper birch	*Betula papyrifera*
LS Upland Conifer	white pine	*Pinus strobus*
	red pine	*Pinus resinosa*
LS Upland Hardwood	red maple	*Acer rubrum*
	sugar maple	*Acer saccharum*
	basswood	*Tilia americana*
	red oak	*Quercus rubra*
	bur oak	*Quercus macrocarpa*
LS Lowland Conifer	tamarack	*Larix laricina*
	lowland black spruce	*Picea mariana*
	white cedar	*Thuja occidentalis*
LS Lowland Hardwood	black ash	*Fraxinus nigra*
	green ash	*Fraxinus pennsylvanica*
	willow	*Salix* spp.

Table 3. Stand level measurements conducted within a 100 m long, 2 m wide transect at randomly selected goshawk relocation points, Minnesota, 1998-2000.

Variable	Description
Canopy Closure	% of foliage closure at nine points within the stand.
Basal area	Basal area as determined with a 10 factor prism at 5 points.
Canopy tree crown height	Height at top of tree canopy.
Canopy tree foliage bottom	Height at the bottom of a canopy tree foliage.
Canopy tree diameter at breast height	Tree diameter at breast height.
Canopy stem density	Calculation of the number of canopy trees per hectare.
Understory tree crown height	Height at top of understory tree canopy.
Understory tree foliage bottom	Height at the bottom of the understory tree foliage.
Understory tree diameter at breast height	Tree diameter at breast height.
Understory stem density	Calculation of the number of understory trees per hectare.
Shrub height	Mean shrub height calculated in 0.5 m increments.
Proportional shrub coverage	Ocular estimate of the proportion of shrub cover at site.
Down woody debris diameter	Diameter of largest end of woody debris in transect.
Down woody debris height above ground	Height of woody debris above ground surface.
Woody debris decay class	Decay class of woody debris (1 least to 5 most).
Snag height	Height of snags (standing dead wood > 2 m).
Snag diameter at breast height	Diameter of snag at breast height.
Snag decay class	Decay class of snag (1 least to 5 most).
Stump height	Height of stump (standing dead wood < 2 m).
Stump diameter	Diameter of stump.
Stump decay class	Decay class of snag (1 least to 5 most).

Table 4. County of occurrence and property ownership or management of goshawk nest sites in Minnesota, 1998-2000

Breeding area name	County	Ownership
Akeley	Hubbard	County
Barnum	Carlton	Private
Cass	Beltrami	USFS
Chub Lake	Cass	State
Crooked	Cass	USFS
Deer Lake	Itasca	USFS
Dixon	Itasca	USFS
Drumbeater	Cass	USFS
Floodwood	St. Louis	County
Hay Creek	Itasca	County
Hundred Mile	St. Louis	USFS
International Falls	Koochiching	Private
Itasca State Park	Clearwater	State
Jay Cooke State Park	Carlton	State
Little Sand	Itasca	Private
Lost Girl	Cass	USFS
Menahga	Wadena	Private
Minisogama	Itasca	USFS
Necktie	Hubbard	State
Pimushe	Beltrami	USFS
Pine Ridge	Beltrami	County
Pipeline	Cass	USFS
Potlatch	St. Louis	County
Round Lake	Itasca	Private
Skimmerhorn	Beltrami	USFS
Squaw Lake	Itasca	Private
Steamboat Lake	Hubbard	Private
Tasher Island	Cass	USFS
Third River	Itasca	USFS
Wagner	Itasca	USFS
Whiteface	St. Louis	USFS

Table 5. Areas that were occupied by goshawks, where nesting by goshawks occurred, and the number of fledglings among successful goshawk nests in Minnesota, 1998-2000.

		Breeding Area Occupied			Nesting Documented			Fledgling No.		
Breeding area	Code	1998	1999	2000	1998	1999	2000	1998	1999	2000
Akeley	AKE	X			X			2		
Barnum	BAR	X	X	X	X	X		2	0	
Cass	CAS	X	X	X	X	X	X	2	0	0
Chub Lake	CHU	X	X	X	X	X		3	0	
Crooked	CRO		X	X		X	X		0	0
Deer Lake	DEE	X			X			0		
Dixon	DIX		X	X		X			1	
Drumbeater	DRU			X			X			2
Floodwood	FLO		X			X			2	
Hay Creek	HAY			X			X			1
Hundred Mile	HUN			X			X			1
International Falls	INT	X			X			2		
Itasca State Park	ITA			X			X			1
Jay Cooke State Park	JAY	X	X	X	X	X	X	*	2	0
Little Sand	LIT		X	X		X	X		0	2
Lost Girl	LOS		X	X		X			3	
Menahga	MEN	X	X	X	X	X		3	3	
Minisogama	MIN	X	X		X			1		
Necktie	NEC		X	X			X			1
Pimushe	PIM	X	X		X			1		
Pine Ridge	PIN	X	X		X	X		*	0	
Pipeline	PIP	X	X		X	X		*	2	
Potlatch	POT			X			X			0
Round Lake	ROU	X	X	X	X	X		2	0	
Skimmerhorn	SKI		X			X				
Squaw Lake**	SQU	X			X			0		
Steamboat Lake	STE		X	X		X	X		0	2
Tasher Island	TAS			X			X			2
Third River	THI			X			X			0
Wagner	WAG	X	X	X	X	X	X	3	0	1
Whiteface	WHI			X			X			1
Total		15	19	21	15	16	15	21	13	14

*Fledgling numbers not available
**Nest stand harvested in winter 1998-99.

Table 6. Fledgling numbers for successful nests and for all nesting attempts by northern goshawks in Minnesota, 1998-2000.

Year	Successful *n*	Successful $\bar{x}$	Successful SE	All attempts *n*	All attempts $\bar{x}$	All attempts SE
1998	10	2.10	0.23	12	1.75	0.31
1999	6	2.17	0.31	15	0.87	0.31
2000	10	1.40	0.16	15	0.93	0.21
Total	26	1.85	0.14	42	1.14	0.17

Table 7. Causes of nesting failure at northern goshawk nests in Minnesota, 1998-2000.

Cause	98	99	00	Total	%
Mammalian predation		3[1]	1[1]	4	23.5
Avian predation		2	1	3	17.6
Suspected predation			2	2	11.8
Blowout	1			1	5.9
Suspected weather		5		5	29.4
Unknown	1		1	2	11.8
Total	2	10	5	17	100.0

[1] One adult female killed at nest

Table 8. MCP and 50, 65,75,85, and 95% Fixed Kernel estimates of home range size in hectares for northern goshawks, Minnesota, 1998-2000.

			Number of		Fixed Kernel Contours				
Goshawk	Sex	Year	relocations	MCP	50%	65%	75%	85%	95%
AKEM	M	1998	32	1199	258	630	1002	1373	2067
CASM	M	1998	36	2246	437	676	884	1508	3017
MINM	M	1998	37	937	188	393	552	883	1595
PIMM	M	1998	21	1345	896	1555	1972	2487	3306
CASM	M	1999	25	1578	457	867	1257	1820	2852
CROM	M	1999	26	965	76	167	271	426	851
DIXM	M	1999	30	2446	144	286	530	1234	2903
JAYM	M	1999	27	860	194	411	649	905	1615
LOSM	M	1999	29	2336	585	1325	2049	2951	4176
MENM	M	1999	29	3600	487	924	1340	2331	4793
MINM	M	1999	27	3559	588	985	1725	2940	5051
PIPM	M	1999	28	4735	1035	2361	3916	5711	7975
WAGM	M	1999	24	4864	796	1692	2748	4459	7063
DRUM	M	2000	30	3155	375	624	875	1542	3140
HUNM	M	2000	22	2818	1052	2160	2783	3850	5361
ITAM	M	2000	29	1961	304	746	1153	1703	3099
LITM	M	2000	33	1824	127	272	596	1261	2473
NECM	M	2000	NA						
STEM	M	2000	31	8573	1836	3683	5735	7575	11003
THIM	M	2000	32	1813	386	751	1156	1667	2761
WHIM	M	2000	NA						
WAGF	F	1999	24	3240	655	980	1434	2600	4870
WAGF	F	1998	25	2759	586	1056	1452	2197	3682
STEF	F	2000	19	3963	2756	5316	7485	10263	14593
LITF	F	2000	20	1109	142	229	316	559	1379
PIPF	F	1999	24	191	49	84	120	206	519
DRUF	F	2000	17	6616	1624	3475	5364	7999	12433
PIMF	F	1998	12	1909	718	1550	2243	3560	5060
NECF	F	2000	21	581	244	429	610	896	1443
LOSF	F	1999	25	1183	157	294	443	795	1723
JAYF	F	1999	22	732	130	314	512	910	1393
DIXF	F	1999	22	1670	391	714	1063	1681	2868
CROF	F	1999	26	3864	1041	2072	3423	5183	8021
CASF	F	1998	NA						
CASF	F	1999	NA						
ITAF	F	2000	19	4657	1954	3197	4638	6282	9909
HAYF	F	2000	NA						
Ave. Male				2674	538	1079	1641	2554	3953
Ave. Female				2498	804	1516	2239	3318	5223

Table 9. Minimum Convex Polygon home range estimates (ha) for individual male and female members of goshawk breeding pairs, and for the pair, Minnesota, 1998-2000.

Nesting Pair	Male	Female	Pair
Crooked	965	3864	4784
Dixon	2446	1670	3175
Drumbeater	3155	6616	9946
Itasca SP	1961	4657	9549
Jay Cooke SP	860	732	1552
Little Sand	1824	1109	2433
Lost Girl	2336	1183	4230
Pimushe	1345	1909	5374
Pipeline	4735	191	4734
Steamboat	8573	3963	18112
Wagner	4864	3240	7101
Average	3006	2649	6454

Table 10. Distribution of actual stand types misidentified by GIS based categorizations.

GIS	True Stand Type				
	ESUH	LSUC	LSLC	LSUH	LSLH
ESUC			2		
ESUH				1	3
LSLC	2	1			1
LSUH	3	2	1		
LSLH				1	
OTHER	3				

ESUC = early successional upland conifer, ESUH = early successional upland hardwood, LSUC = late successional upland conifer, LSLC = late successional lowland conifer, LSUH = late successional upland hardwood, LSLH = late successional lowland hardwood, OTHER = stand types other than those listed or early successional lowland conifers and hardwoods.

Table 11. Ranking of stand types used by male goshawks, Minnesota, 1998-2000. Assessment based on compositional analysis (Aebischer et al. 1993), using stand types at relocation points and within 50 m radius (0.79 ha) buffers around relocation points, compared to proportional availability of stand types within home ranges. Ranks: 0 = least preferred, 10 = most preferred.

Stand Type	Points	Buffered points	Mean[1] rank	Mean proportion availability
ES Upland conifer-mature	7	9	8.0	3.9
ES Upland hardwood-young	3	6	4.5	18.0
ES Upland hardwood-mature	8	4	6.0	5.6
ES Upland hardwood-old	10	10	10.0	11.6
LS Upland conifer-young	0	0	0.0	5.0
LS Upland conifer-mature	9	8	8.5	2.5
LS Lowland conifer-young	1	1	1.0	6.6
LS Lowland conifer-mature	6	5	5.5	19.4
LS Upland hardwood-mature	5	3	4.0	4.9
LS Lowland hardwood-mature	4	7	5.5	1.9
Other	2	2	2.0	20.6

[1] Mean of point and buffered point ranks.

Table 12. Forest stand types used by male goshawks, Minnesota, 1998-2000. Assessment based on the χ^2 method (Neu et al. 1974), using stand types at relocation points and within 50 m radius (0.79 ha) buffers around relocation points, compared to proportional availability of stand types within home ranges (* = $P < 0.05$; ** = $P < 0.001$; *** = $P < 0.0001$).

Stand Type	Points	Buffered Points	Mean proportion availability
ES Upland conifer-mature	Preferred***	Preferred***	3.9
ES Upland hardwood-young	Avoided***	Avoided**	18.0
ES Upland hardwood-mature	Preferred*	--	5.6
ES Upland hardwood-old	Preferred***	Preferred***	11.6
LS Upland conifer-young	--	Preferred	5.0
LS Upland conifer-mature	Preferred***	Preferred***	2.5
LS Lowland conifer-young	Avoided	Avoided*	6.6
LS Lowland conifer-mature	Avoided*	Avoided*	19.4
LS Upland hardwood-mature	Preferred*	Preferred***	4.9
LS Lowland hardwood-mature	--	--	1.9
Other	Avoided***	Avoided***	20.6

Table 13. Proportions of forest stand types within Minimum Convex Polygon home ranges of male goshawks in Minnesota, 1998-2000.

	Home Range Size[1]	Forest Stand Type[2]										
AREA	MCP	EUC-M	EUH-Y	EUH-M	EUH-O	LUC-Y	LUC-M	LLC-Y	LLC-M	LUH-M	LLH-M	OTHER
CASS 98	2246	9.53	25.27	7.96	11.58	14.06	1.59	0.86	12.56	3.63	0.4	12.48
CASS 99	1578	7.33	16.65	11.64	12.78	21.69	0.14	0.55	9.68	2.63	0	16.09
CROOKED	965	4.85	9.69	11.86	11.55	4.14	10.29	7.56	32.01	2.14	1.88	3.55
DIXON	2446	1.62	21.75	3.77	13.47	5.7	1.47	6.35	24.74	2.22	3.1	15.79
DRUMBEATER	3155	2.16	11.27	2.45	4.25	0.83	0.31	17.07	33.1	8.56	0.18	19.82
HUNDRED MILE	2818	8.87	8.77	1.38	10.42	0	0	1.11	19.57	0.03	0	49.87
LOST GIRL	2336	4.68	19.28	9.92	9.24	0.2	0	4.55	18.33	15.9	3.83	14.04
MINISOGAMA 98	937	0	18.67	0.8	13.67	2.03	5.91	18.89	12.79	6.85	0	20.38
MINISOGAMA 99	3559	0.93	13.27	0.79	10.42	1.19	1.69	7.87	7.98	8.37	0.62	46.86
PIPELINE	4735	2.52	6.98	3.65	8.93	4.75	8.18	6.97	33.47	1.38	1.5	21.65
THIRD RIVER	1813	0.17	34.51	1.71	17.81	2.57	0	2.86	17.06	2.53	9.72	11.03
WAGNER	4864	4.51	30.29	10.76	14.64	2.75	0.9	4.21	11.71	4.01	0.99	15.22

[1] MCP = 100% minimum convex polygon; 95% FK = 95% fixed kernel estimate.

[2] EUC-M = early successional upland conifer 0-25 years; EUH-M = early successional upland hardwood 0-25 years; EUC-M = early successional upland hardwood 25-50 years; EUC-O = early successional upland hardwood >50 years; LUC-Y = late successional upland conifer 0-50 years; LUC-M = late Successional upland conifer >50 years; LLC-Y = late Successional lowland conifer 0-50 years; LLC-M = late Successional lowland conifer >50 years; LUH-M = late Successional upland hardwood >50 years; LLH-M = late Successional lowland hardwood >50 years; OTHER = all other stand types and open areas.

Table 14. Mean values for stand level measurements at 128 northern goshawk relocation points, northern Minnesota, 1998-2000. Stand types are: ESUC = early successional upland conifer (*n* = 15), ESUH = early successional upland hardwood (*n* = 50), LSUC = late successional upland conifer (*n* = 15), LSUH = late successional upland hardwood (*n* = 36), LSLC = late successional lowland conifer (*n* = 8), and LSLH = late successional lowland hardwood (*n* = 4).

Variable	ESUC	ESUH	LSUC	LSUH	LSLC	LSLH
Canopy crown (m)	14.7	16.4	16.8	15.1	15.6	14.9
Canopy bottom (m)	6.5	8.2	9.2	7.3	7.6	6.1
Canopy dbh (cm)	21	20.3	24.6	22.5	22.6	19.6
Canopy stems/ha	570	660	805	685	1030	665
% conifer	64	18	80	6	79	21
% deciduous	36	82	20	94	21	79
Understory height (m)	5.4	5.7	5.7	6.1	6	5.8
Understory bottom (m)	2.5	3	2.6	3	2.7	3
Understory dbh (cm)	5.6	6	5.3	6.3	5.9	5
Understory stems/ha	545	965	635	780	525	1715
% conifer	37	14	59	3	52	7
% deciduous	63	86	41	97	48	93
Shrub height (m)	2.5	2.5	2	2	2	2
Canopy closure (%)	53	73	79	85	70	86
Basal area (acres)	92	101	124	102	137	93
Debris (km/ha)	18	18.5	19.1	16.2	23.9	14.9
Debris dbh (cm)	16.8	17.6	17	19.1	18.8	17.2
Debris decay[1]	2.6	3	2.6	3	3	3.6
Debris height (cm)	19	11	10	12	15	5
Snags/ha	245	103	153	74	213	125
Snag dbh (cm)	18.6	21.6	27.4	28.9	21.1	31.9
Snag height (m)	7	6.8	8.2	7.3	8.7	7.7
Snag decay[1]	1.4	4.7	1.4	1.7	1.2	2

[1] Decay class 1-5; 1 = least, 5 = most.

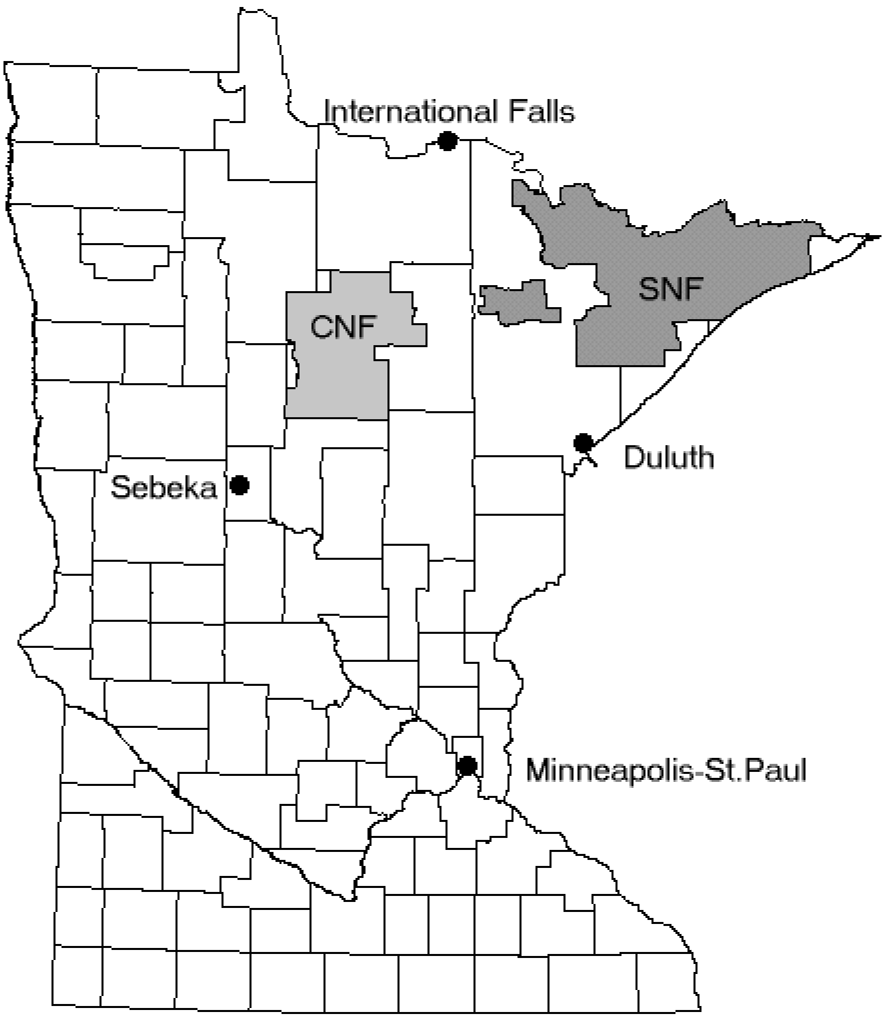

Figure 1. Northern goshawk study area in Minnesota, from Sebeka in the southwest, north to International Falls, and southeast to Duluth.

<Image removed to protect goshawk nest locations>

Figure 2. Distribution of northern goshawk breeding areas in Minnesota, 1998-2000.

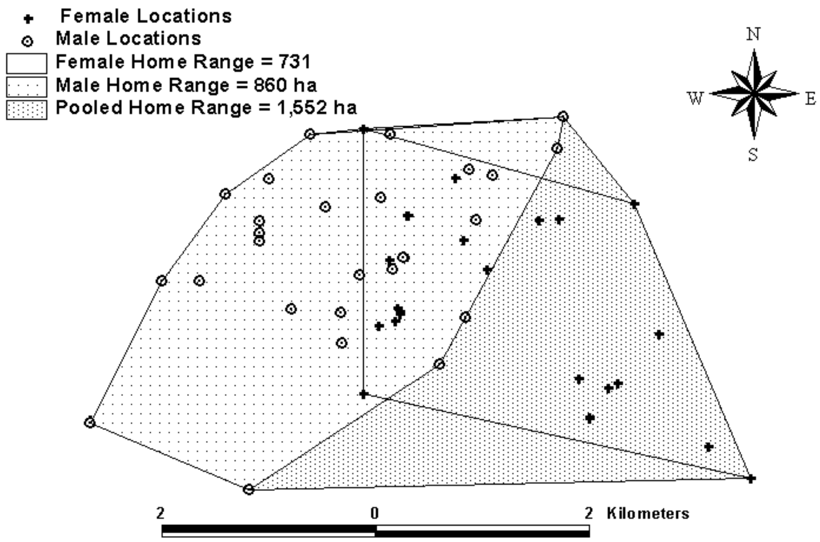

Figure 3. Example Minimum Convex Polygon home range estimates for female, male, and breeding pair of northern goshawks, XXXXXXX, Minnesota, 1999.

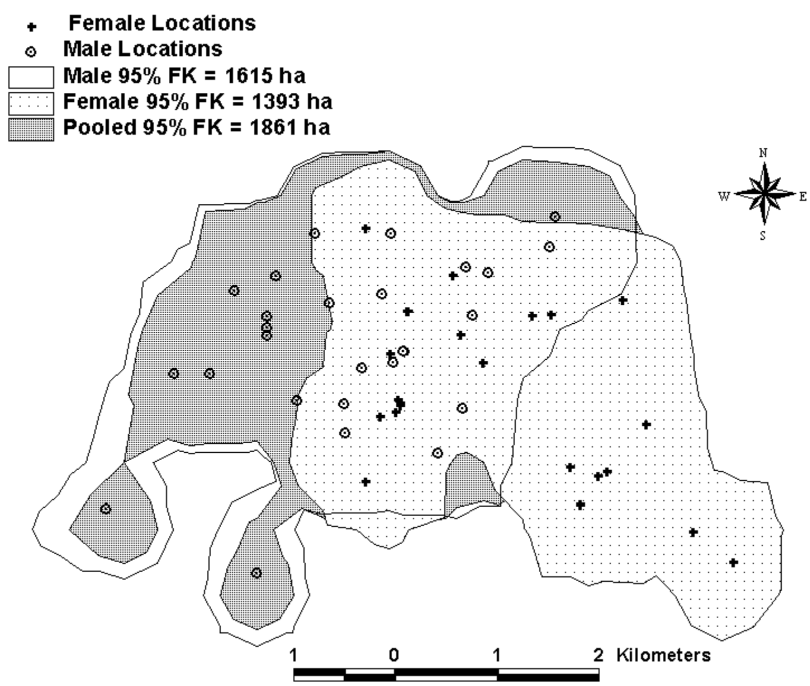

Figure 4. Example 95% Fixed Kernel home range estimates for female, male, and breeding pair of northern goshawks, XXXXXXX, Minnesota, 1999.