J Raptor Res. 39(3):222–228

PRODUCTIVITY AND MORTALITY OF NORTHERN GOSHAWKS IN MINNESOTA

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ABSTRACT.—Compared to other regions of North America, little information exists regarding Northern Goshawk (*Accipiter gentilis*) ecology and population dynamics in the western Great Lakes Region. We examined productivity and nesting habitat characteristics of goshawks in Minnesota from 1998–2001. Apparent nesting success varied annually from as low as 38% to as high as 83%. The Mayfield estimate of daily survival for nests was 0.992 ± 0.002 (SE). The mean fledgling number across years was 1.85 ± 0.14 for successful nests and 1.14 ± 0.17 for all nesting attempts. Twenty-one percent of all nesting attempts failed, primarily due to predation or suspected predation (52%) and inclement weather (35%). Overall, productivity of goshawks in Minnesota was at the lower end of the range reported in other studies across western North America, which is not atypical for peripheral populations. During the 3-yr study, we recorded mortalities of nine (four males and five females; eight radio-marked and one unmarked) adult goshawks—causes of mortality were avian (33%) and mammalian (22%) predation, human persecution (22%), and unknown causes (22%). Fifty-six percent of mortalities occurred during the breeding season, and 44% occurred during the winter. Based on radiotelemetry data, we estimated adult annual survival to be 74 ± 7.8%, which is similar to survival estimated using mark-recapture analysis in three western North America studies.

KEY WORDS: *Northern Goshawk;* Accipiter gentilis; *breeding; Minnesota; mortality; productivity.*

PRODUCTIVIDAD Y MORTALIDAD DE *ACCIPITER GENTILIS* EN MINNESOTA

RESUMEN.—Existe poca información sobre la ecología y la dinámica poblacional de *Accipiter gentilis* en el oeste de la región de Grandes Lagos comparado con otras regiones de América del Norte. Examinamos la productividad y las características del ambiente de nidificación de *A. gentilis* en Minnesota desde 1998 hasta 2001. El éxito de nidificación aparente varió anualmente de modo drástico, desde 38% a 83%. El estimado de Mayfield de la supervivencia diaria de los nidos fue 0.992 ± 0.002 (EE). El número medio de volantones a lo largo de los años fue 1.85 ± 0.14 para los nidos exitosos y 1.14 ± 0.17 para todos los intentos de nidificación. El 21% de todos los intentos de nidificación fracasó, debido principalmente a la depredación o a la supuesta depredación (52%) y a las inclemencias del clima (35%). En total, la productividad de *A. gentilis* en Minnesota estuvo en el extremo inferior del rango reportado en otros estudios para el oeste de América del Norte, lo cual no es atípico para poblaciones periféricas. Durante los tres años de estudio, registramos la muerte de nueve adultos de *A. gentilis* (4 machos y 5 hembras; 8 marcados con transmisores y 1 sin marcar). Las causas de la mortalidad fueron depredación por aves (33%) y mamíferos (22%), persecución humana (22%) y causas desconocidas (22%). El 56% de las muertes ocurrieron durante la estación reproductiva y el 44% durante el invierno. Basados en datos de radio telemetría, estimamos que la supervivencia anual de los adultos fue del 74 ± 7.8%, lo cual es similar a la supervivencia estimada usando análisis de captura-recaptura en tres estudios del oeste de América del Norte.

[Traducción del equipo editorial]

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The Northern Goshawk (*Accipiter gentilis*) is a large, forest-dwelling raptor generally associated with mature deciduous, coniferous, or mixed forests. Possible conflicts between timber harvest practices and goshawk habitat requirements have led to concern for the species' status (Kennedy 1997, United States Fish and Wildlife Service 1998). The goshawk has been proposed for listing several times under the U.S. Endangered Species Act and its status has been (and still is) the object of considerable litigation. In the western Great Lakes Region (WGLR) of North America, the goshawk is currently listed as a migratory non-game 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). Few studies have examined goshawk productivity (Erdman et al. 1998) and mortality in the WGLR. Region-specific information on productivity and mortality factors is essential for development of sound management guidelines, but active management of the species in the WGLR has been hampered by the lack of data. In 1998, we initiated a broad-based ecological study of goshawks in Minnesota (Boal et al. 2001, Boal et al. 2003). Herein, we present the productivity and mortality data we collected on breeding goshawks in Minnesota, 1998–2000.

STUDY AREA

The study area encompassed most of northern Minnesota within the Laurentian Mixed-Forest Province (Minnesota Department of Natural Resources 2004; Fig. 1).Goshawks were distributed across the study area (Fig. 1), but a majority of goshawk nests were located on or near the Chippewa National Forest (47°23′N, 94°35′W). Study area elevation was ca. 200–400 m. Historical mean summer and winter temperatures were 18°C and −11°C, respectively, with maximum and minimum temperature records of 40°C and −46°C, respectively. Vegetation communities are described in Boal et al. (2003).

METHODS

Study Population. We did not systematically survey for breeding goshawks, so known breeding pairs in a single year were likely a relatively small proportion of all goshawks breeding in the study area (Daw et al. 1998). However, the goshawks monitored in this study were all known nesting goshawks in Minnesota during the study period of 1998–2000 (Boal et al. 2001, 2003). Nests in this study were from across the Laurentian Mixed-Forest Province of northern Minnesota and were likely representative of the Minnesota landscapes that goshawks use for nesting (Boal et al. 2001), but because our sample was not randomly selected, our inferences are limited to our sample.

Before this study, few goshawk nesting areas were known in Minnesota. We searched known goshawk nest stands and areas where goshawks had been seen during previous breeding seasons. If a previous year's nest was not occupied, we conducted tree-by-tree searches of the stand, up to 500 m from the old nest (if the stand was sufficiently large for this search pattern). We also located new goshawk nest stands by searching likely areas or following up on reports of probable goshawk nests located serendipitously by personnel from cooperating agencies and the timber industry. We considered an area to be occupied if one goshawk was observed in or near a known nest stand, radio-tagged hawks were located in the area, or other evidence of activity was observed (e.g., recent construction of a nest). If an area was occupied by goshawks, we attempted to locate an occupied nest. An occupied nest was defined as a nest with eggs or young or the presence of an incubating goshawk.

Productivity. Once an occupied nest was located, we made periodic visits to monitor reproductive success. We considered goshawks to be nesting if a female was observed in an incubation position on the nest or during later stages of the nesting period when young were observed in the nest. We considered nestlings to have survived to fledge if they attained at least 80% of their first flight age (32 d old for goshawks; Boal 1994). We considered a nesting attempt as successful if at least one young fledged. We estimated both apparent nest success (e.g., the proportion of monitored nests known to have fledged young) and nest success using the Mayfield estimate based on exposure days (Bart and Robson 1982). Because confidence intervals can be more informative than tests of statistical significance (Johnson 1999), we assessed differences in productivity by examining overlap of 95% confidence intervals.

Nesting Failure. We attempted to determine cause of all nesting failures. In instances where dead adults or their remains were found at nests, we conducted in-field examinations of each carcass and location of death to attempt to identify the cause of death and, if depredated, the predator species. For example, claw marks ascending the nest tree and teeth marks on the carcass, feathers, and radio harness material of radio-tagged birds were indicative of mammalian predation (Einarsen 1956). In contrast, crimping plucks of feathers, stripped bones without tooth marks or evidence of mastication, single bill bite nips, and scrapes in bones indicated avian predators (Einarsen 1956).

Adult Mortality. There is little information on causes of adult mortality for raptors in general and goshawks in particular (Squires and Reynolds 1997). In addition to assessing causes of mortality of adult goshawks at nest sites, our sample of 32 radio-tagged goshawks (Boal et al. 2003) provided us with an opportunity to examine causes and timing of mortality among goshawks in Minnesota. We used telemetry to relocate all radio-tagged goshawks that died during the course of this study (Boal et al. 2001). We estimated the annual survival rate with the Kaplan-Meier survival model (Kaplan and Meier 1958) as modified by Pollock et al. (1989).

RESULTS

We located 13, 19, and 21 areas occupied by goshawks in 1998, 1999, and 2000, respectively. Two

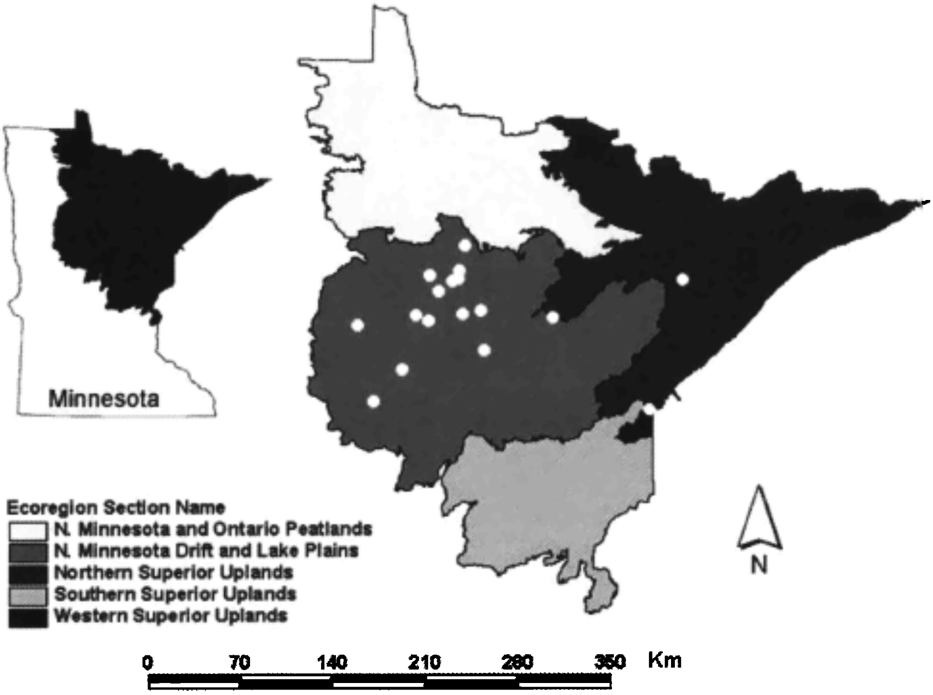

Figure 1. Study area and distribution of Northern Goshawk nests sites (open circles) included in this study, Minnesota 1998–2000. Ecoregions are based on Minnesota Department of Natural Resources (2004).

additional areas were located by cooperators in 1998, but were not reported to us until 1999. Although one of these nesting attempts was verified as successful, the two nests were not monitored to assess productivity. Thus, we only include the original 13 of 15 areas from 1998 for productivity assessment. Of the 15 breeding areas occupied in 1998, 11 (73%) were occupied in 1999. Of 23 known breeding areas occupied in 1998 and/or 1999, 13 (57%) were occupied in 2000. Although breeding did not occur in all occupied areas, 15 occupied areas were located in 1998, seven additional areas in 1999, and nine additional areas in 2000, for a total of 31 areas occupied by goshawks at least 1 yr during the 3-yr study period. We did not monitor productivity at one nest, and two others failed in 1998. Sixteen (84%) pairs of goshawks from 19 occupied areas nested in 1999, and 15 (71%) pairs from 21 occupied areas nested in 2000. We observed that some areas were occupied by non-breeding goshawks. For example, a widowed female, radio-tagged in 1998, was tracked in her breeding area, but did not breed in 1999. Likewise, in 2000 a widowed, non-breeding female roamed more widely than she had while breeding in 1999, but still occupied her 1999 breeding area. A pair that had been radio-tagged and successfully nested in 1999 occupied their breeding area, but did not nest in 2000. In contrast, after her mate died during the winter, one widowed female moved 15 km to pair with a male in a previously unknown breeding area the following spring.

Productivity. We assessed success at 43 and productivity at 42 goshawk nests. Nesting success varied considerably among years, with a high of 83% in 1998 and a low of 37% in 1999. We observed that 67% of nesting attempts fledged young successfully in 2000 and the 3-yr mean for fledging success was 62 ± 23.4% (SE). Mayfield estimates for daily survival were 0.9998 ± 0.0006 (SE) in 1998, 0.985 ± 0.005 in 1999, and 0.993 ± 0.005 in 2000, with an overall daily survival rate of 0.992 ± 0.002. Based on a 32-d incubation period (Squires and Reynolds 1997) and a 32-d period to 80% of first flight age (Boal 1994), Mayfield estimates of nest success were 99% in 1998, 39% in 1999, 65% in 2000, and 59% over the 3-yr study period.

Goshawk nests fledged a mean of 1.75 ± 1.05

young in 1998 ($N = 12$), 0.81 ± 1.17 young in 1999 ($N = 16$), and 0.93 ± 0.80 ($N = 15$) young in 2000. Fledglings per nesting attempt were not statistically different between 1998 and 1999 ($\bar{x}$ difference = 0.938; 95% CI = 0.057–1.820), between 1998 and 2000 ($\bar{x}$ difference = 0.817; 95% CI = 0.082–1.550), or between 1999 and 2000 ($\bar{x}$ difference = −0.121; 95% CI = −0.861–0.619). In contrast, when examining only those nests that were successful, goshawks fledged a mean of 2.10 ± 0.74 young in 1998 ($N = 10$), 2.17 ± 0.75 young in 1999 ($N = 6$), and 1.40 ± 0.52 young in 2000 ($N = 10$). Fledgling numbers at successful nests were not statistically different between 1998 and 1999 ($\bar{x}$ difference = −0.067; 95% CI = −0.890–0.757), but were higher in 1998 ($\bar{x}$ difference = 0.700; 95% CI = 0.102–1.300) and 1999 ($\bar{x}$ difference = 0.767; 95% CI = 0.895–1.440) than in 2000. Mean number of fledglings per nest for all years combined was 1.14 ± 1.07 for all nesting attempts and 1.85 ± 0.73 for successful nests only.

Nesting Failure. Of the 43 goshawk nests monitored, two failed in 1998, 10 failed in 1999, and five failed in 2000. Of these 17 failures, 23% were due to mammalian predation, 18% were due to avian predation, and we suspected another 12% were due to predation, but we were unable to determine whether the predator was avian or mammalian. Two of the mammalian predations resulted in mortalities of adult female goshawks (detailed below). Weather contributed to 35% of nesting failures, the majority of which occurred during the incubation stage of the nesting period in 1999 when the region experienced a 10–11 d period of almost constant rain. The cause of 12% of nesting failures was undetermined.

Adult Mortality. Nine goshawks, eight of which were radio-tagged, died during this study. Five (56%; four females and one male) of these nine mortalities occurred during the breeding seasons. One female and one male were preyed upon by Great Horned Owls (*Bubo virginianus*), two females were killed by mammals, and one female was consumed by a Red-tailed Hawk (*Buteo jamaicensis*). The remaining four (44%) mortalities (one female and three males) occurred during the winter months. The female that died during the winter had been shot. The mortality of one male appeared to also be due to human actions; only the radio that had been attached to the male was recovered and it had been obviously cut from the body of the goshawk. Furthermore, the radio lacked any mastication or pecking marks typical of those on goshawks that were depredated. The causes of death could not be verified for the other two male goshawks.

We excluded the single, non-radio-marked female that was killed in 1999 from estimates of survival. The Kaplan-Meier estimate for annual survival based on 32 radio-tagged goshawks was 74 ± 7.8%. Because our study was not originally designed to estimate adult survival, our survival estimate should be interpreted in the context of our sample of 32 radio-marked goshawks captured at breeding areas over the 3-yr study period. However, these data do provide some insight in the annual survival of goshawks in the study area.

DISCUSSION

Productivity. We observed annual variability in fledglings produced per nest attempt (range = 0.87–1.85) and per successful nest (range = 1.40–2.17) during the 3 yr of this study. Such variability is typical of temporal patterns in reproductive success in goshawks (e.g., DeStefano et al. 1994, Kennedy 1997, McClaren et al. 2002). McClaren et al. (2002) found high temporal variability in productivity among goshawk nests monitored 4–10 yr in three different populations in western North America. Within the WGLR, Erdman et al. (1998) reported fledgling numbers from Wisconsin goshawk nests over a 24-yr period, and found a mean of 1.7 fledglings per nesting attempt ($N = 184$) and 2.2 per successful nest ($N = 138$). However, Erdman et al. (1998) also indicated that fledging rates among nesting attempts decreased from the earlier years (1971–81) to later years (1982–92) of their study. We do not have historical data for this study area to evaluate temporal trends in productivity, but the fledging success over the 3-yr period of monitoring did not vary statistically. Productivity in the Upper Peninsula of Michigan was similar to ours, with a reported 1.1 and 1.7 fledglings per occupied ($N = 36$) and successful ($N = 24$) nests, respectively (Lapinski 2000). Fledgling rate among successful nests in our study and others conducted in the WGLR appear to be slightly lower than average, but well within the range reported in studies from the western United States (e.g., Kennedy 1997, Boal and Mannan 1994, Bull and Hohmann 1994, Reynolds et al. 1994).

Nesting Failure. The most common nest predator of goshawk nests in North America appears to be Great Horned Owls (Kennedy 2003), but wolverines (*Gulo gulo*; Doyle 1995) and fishers (*Martes pennanti*; Erdman et al. 1998) are known to prey upon goshawk nestlings, and raccoons (*Procyon lotor*) are also likely nest predators. Erdman et al. (1998) attributed predation by fishers as the primary cause of nesting failure among goshawks in Wisconsin, but did not provide details for the basis of their conclusion, nor did they report the actual number of nesting failures due to fishers. Mammal depredation (suspected to be fishers) of nests in our study was comparatively low (9%), but collective depredation (mammalian, avian, unknown) caused the failure of 21% of goshawk nests in Minnesota.

Weather can also influence productivity of goshawks. Cold weather and rain can reduce the number of goshawk pairs attempting to nest (Kostrzewa and Kostrzewa 1990) and can lead to egg and chick (Zachel 1985) mortality. In our study, inclement weather accounted for failure of 12% of all nesting attempts. These failures occurred primarily during the incubation stage in 1999 when our study area experienced a 10–11 d period of almost constant rainfall. We suspect that some male goshawks may have been unable to provision their mates adequately during this period, eventually leading females to either abandon their nests or temporarily leave their nests to forage, allowing the eggs to chill and die.

Adult Mortality. Mortality data for goshawks in the WGLR are based almost solely on females found killed at or near their nests (Erdman et al. 1998). Thus, there are no data available prior to our study on causes of goshawk mortality away from their nests or during the non-breeding season. Our estimate of annual survival (74 ± 7.8%) based on telemetry was quite similar to mark-recapture estimates in California (61–69%; DeStefano et al. 1994), New Mexico (60–96%; Kennedy 1997), and northern Arizona (69–87%; Reynolds and Joy 1998). All of these authors indicate imprecision in their studies due to a variety of reasons, and DeStefano et al. (1994) concluded accurate estimates of survival based on mark-resightings would require large numbers of marked birds, high resighting rates, and a minimum of 5 yr of data. This robust a data set has not been and is unlikely to be collected in the WGLR. In contrast, White and Garrott (1990) indicated survival estimates based on radiotelemetry requires smaller samples in general than mark-resighting estimates. Furthermore, backpack radio attachments appear to have no significant effect on survival of goshawks (Reynolds et al. 2004). Our data supported White and Garrott's (1990) assertion; we were able to estimate survival rates with reasonable precision through marking considerably fewer birds than banding and resighting would require. However, we did not have a sufficient sample of radio-tagged birds to estimate temporal and gender differences in adult survival.

One male that died during the winter of 1999–2000 had been banded as a juvenile at Hawk Ridge, MN, during the fall migration of 1988 (D. Evans pers. comm.). This male and his mate had fledged two young successfully in 1999. To our knowledge this 11-yr male is the oldest known recorded breeding male goshawk reported for North America. Interestingly, the oldest reported female goshawk (12 yr old) in North America was also reported from Minnesota (Evans 1981).

The majority of information on causes of mortality among adult goshawks is anecdotal (Squires and Reynolds 1997). Goshawks succumb to several different diseases and parasites (Redig et al. 1980, Ward and Kennedy 1996, C. Boal unpubl. data). Accidents and injuries, such as flying into windows (C. Boal unpubl. data) or choking on prey (Bloxton et al. 2002), also result in mortality. The primary documented cause of mortality among free-ranging goshawks, however, appears to be predation (Squires and Kennedy in press).

Known predators of adult goshawks include Great Horned Owls (Rohner and Doyle 1992, Boal and Mannan 1994, Erdman et al. 1998), Golden Eagles (*Aquila chrysaetos*; Squires and Ruggiero 1996), Pine Martens (*Martes americana*; Paragi and Wholecheese 1994), and fishers (Erdman et al. 1998). Of five adult goshawks taken by predators in our study, two were killed by Great Horned Owls. In the WGLR, fishers may also be an important predator of goshawks; predation by fishers was identified as the cause of mortality for four adult female goshawks in Wisconsin (Erdman et al. 1998) and two of five goshawk deaths in our study. We believe the goshawk killed in our study by a Red-tailed Hawk may be an exceptional incident, but the two species have been observed engaged in physical agonistic encounters (Crannell and DeStefano 1992, C. Boal unpubl. data). In areas of sympatry (La Sorte et al. 2004), Red-tailed Hawk predation may be more common.

Most mortality data for goshawks is for the nesting season. We found that mortality occurred with equal frequency in the breeding and winter seasons, suggesting that survival outside of the breeding season is an important aspect of goshawk population dynamics. Our data also suggested that, despite legal protection, persecution was still a factor affecting goshawk survival.

Results from Wisconsin (Erdman et al. 1998) and our study suggested predators were a major cause of goshawk mortality in the WGLR. However, the influence of predators on goshawk population demography and whether current predation rates are similar to historic rates or have increased as a consequence of human activities (e.g., timber harvest, reintroduction of fishers) in the WGLR, as suggested by Erdman et al. (1998), has yet to be assessed rigorously. The development and use of standardized field methods for evaluating causes of mortality of goshawks and publication of existing mortality data would be helpful in this regard. Without reliable survival data, rates of population growth or decline cannot be estimated accurately for the WGLR goshawk population.

ACKNOWLEDGMENTS

We appreciate our dedicated field assistants that endured long hours of work: L. Belmonte, W. Estes, J. Sammler, R. Sandstrom, and A. Wester. A. Roberson and B. Smithers assisted with practically all aspects of this study, and M. Solensky assisted with trapping. D. Harrington and A. Weaver provided nest sites, and members of the Minnesota Falconers' Association assisted with surveys. Personnel from the many cooperating agencies and organizations provided an array of assistance and logistical support during the projects. They include R. Baker, J. Blanchard, J. Casson, M. Cole, J. Gallagher, L. Grover, M. Hamady, J. Hines, M. Houser, G. Kirk, B. Marty, R. Vora, and A. Williamson. Funding for this project was provided by the Chippewa National Forest, The National Council for Air and Stream Improvement, Minnesota Department of Natural Resources, Potlatch Corporation, Leech Lake Band of Ojibway, Superior National Forest, U.S. Fish and Wildlife Service, The Raptor Center at the University of Minnesota, The Minnesota Falconers' Association, Voyageurs National Park, the Minnesota Cooperative Fish and Wildlife Research Unit, and grants from the National Forest Foundation and the National Fish and Wildlife Foundation.

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Received 8 February 2004; accepted 27 September 2004
Guest Editor: Stephen DeStefano