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## PREFACE RAPTOR RESPONSES TO FOREST MANAGEMENT: A HOLARCTIC PERSPECTIVE

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Forest raptors are one of the most sensitive groups of vertebrates to forest management and forest habitat change due to their position at the top of the forest food chain, their relatively large territories and home ranges, and their historical persecution by man (Fuller 1996). The highly visible case of the Spotted Owl (*Strix occidentalis*) controversy in the northwestern U.S. exemplifies many issues and conflicts between forest use and the need for appropriate ecological management for forest-dependent organisms (Yaffee 1994). Conflicts between forest resource use and the management or preservation of forest areas can be minimized with appropriate knowledge and understanding of how species respond to forest change (e.g., through logging, natural disturbance or succession). With this increased understanding, we can modify forest management to provide a sustainable harvest, yet ensure that we protect biological diversity and the fundamental processes of forest systems.

With this philosophical perspective, we embarked on organizing a symposium focused on selected raptor species of northern temperate and boreal forest habitats. The focus of the symposium was to summarize our current understanding of forest raptors with holarctic distributions—those with distributions in the temperate and boreal regions of North America and northern Europe. The symposium focused on six species with holarctic distributions: Osprey (*Pandion haliaetus*), Northern Goshawk (*Accipiter gentilis*), Long-eared Owl (*Asio otus*), Boreal/Tengmalm's Owl (*Aegolius funereus*), Northern Hawk Owl (*Surnia ulula*) and

Great Gray Owl (*Strix nebulosa*). For each of these species, two individuals (one from North America and one from northern Europe) were selected based on recommendations from a variety of raptor experts. Each of the individuals selected made a presentation at the symposium and those papers completing the peer-review process are included here.

### SYMPOSIUM ORGANIZATION AND QUESTIONS POSED TO AUTHORS

The focus of each paper was on forests, forest management and how the ecology of each species relates to these issues. Each author was asked to address or consider the questions below. Because solid quantitative information was lacking for many questions, the presenters were invited to use educated guesses and common sense. Hence, if statements in the papers are not supported with data or references, then it is likely that the author did not use such empirical information. This is highly appropriate because in many cases a scientist has worked a lifetime with a species and has accumulated considerable knowledge on how a species may respond to forest management.

#### Questions:

- (1) Using the best available knowledge, what is the present population trend of the species over the past 10 yr, 25 yr, 50 yr and 100+ yr?
- (2) What are the primary factors associated with these trends? Factors such as food supply, habitat availability, chemical effects, human persecution, interspecific interactions and modern forestry practices should be discussed in the context of these trends.



(3) If modern forestry is associated with these trends, then how has the species been affected by either past or current management practices? Among additional factors to be considered were riparian zone management and secondary effects of logging on water quality (e.g., nonpoint source pollution).

(4) There are many ways that logging and forest management can affect forest raptors. Among these the following should be considered. (a) How would the species be affected by cuts of different sizes such as 1–3 ha cuts, 10–20 ha cuts, 20–100 ha cuts or cuts greater than 100 ha? (b) How would the species be affected by cuts of different shape? Assume that shapes vary from the simplest shapes, such as circular or square cuts, to those that are infinitely complex with convoluted edges. (c) What are the effects and what is the importance of leaving live trees, dead trees, shrubs or patches of these vegetational forms or different species of trees (e.g., future snags) within cut areas? The responses of forest raptors to these alternative ways to log forests would be especially useful if considered in the context of mitigation strategies that would improve habitats and populations for the specific raptor species.

(5) What is an ideal mix and spatial distribution of forest cut sizes and shapes that would be both: (a) highly beneficial to the species and (b) highly detrimental to the species? For example, would small cuts of 1–3 ha of circular or square shapes with many dead trees remaining within the cuts be beneficial or detrimental to the species in comparison with large cuts of complex shapes with few residuals? Alternatively, how should cuts be grouped spatially within respective management areas such as distributed randomly or connected by corridors between uncut areas?

(6) Integrate the information available to the ex-

tent possible with specific management recommendations. In addition, speculate on similarities and differences in the species response to forest-management practices on the two continents. For instance, forestry has occurred in northern Europe for more than 100–300 yr, whereas forestry in North America is generally less than 100-yr old. Have there been any short-term evolutionary responses by the species to forest regeneration today versus how forests have regenerated in the past (e.g., forest regenerating following forest fire versus logged forests).

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## THE NORTHERN GOSHAWK (*ACCIPITER GENTILIS ATRICAPILLUS*): IS THERE EVIDENCE OF A POPULATION DECLINE?

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**ABSTRACT.**—I evaluate the claim that Northern Goshawk (*Accipiter gentilis atricapillus*; hereafter referred to as goshawk) populations are declining in North America based on a review of the published literature and analyses of demographic data collected on two goshawk populations in New Mexico and Utah. Evidence of a decline would include range contractions, temporal decreases in density, fecundity and/or survival, and/or a negative rate of population change. The goshawk is a former *Category 2* species as determined by the U.S. Fish and Wildlife Service and two petitions have been submitted to list the goshawk as threatened or endangered under the U.S. Endangered Species Act. The petitions claimed that goshawks suffered significant declines in the U.S. because of logging practices and were threatened with extinction as a result of overharvest. There is no evidence of range contractions in western North America and the goshawk's range appears to be expanding (perhaps due to reoccupancy of former range) in the eastern U.S. The majority of data on abundance of breeding pairs indicate that goshawk densities are highly variable spatially and temporally. There is some evidence to suggest that abundance is correlated with food availability. One study claims that goshawk abundance has declined in the past several decades in northern Arizona but the conclusions are based on an inadequate sampling design. Fecundity fluctuates widely but there is no evidence of a negative trend. Fecundity is apparently influenced by a combination of food availability and predation rates. Survival estimates are too limited to analyze for temporal trends and, as a result of insufficient survival data, ( $\lambda$ ) have not been estimated for any North American goshawk populations. I conclude there is no strong evidence to support the contention that the goshawk is declining in the U.S. This result can be interpreted either that goshawk populations are not declining or goshawk populations are declining but the declines have not been detected with current sampling techniques (Type 2 error). These two hypotheses cannot be rigorously evaluated with existing published information and will probably not be evaluated in the future with datasets from a single study area because of sampling limitations. To rigorously and objectively evaluate the population trends of the North American goshawk in a timely and cost-effective manner, I recommend a meta-analysis be conducted of all existing published and unpublished datasets.

**KEY WORDS:** *Accipiter gentilis atricapillus*; *Northern Goshawk*; *population status*; *forest management*; *endangered species listing*.

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El halcón norteno (*Accipiter gentilis atricapillus*): ¿hay pruebas de una reducción de población?

**RESUMEN.**—Yo he evaluado la demanda que las poblaciones del (*Accipiter gentilis atricapillus*; de aquí en adelante referido como halcón) se están reduciendo en norte américa basado en un examen de literatura publicada y un análisis de datos demográficos colectados de dos poblaciones de halcón en Nuevo México y Utah. Las pruebas en la reducción deberían incluir contracciones del campo, reducción temporal en densidad, fecundo y/o supervivencia, y/o ritmo negativo de cambio en la población. El halcón fue marcado una especie de Categoría 2 como determinado por el U.S. Fish and Game Service y dos demandas han estado entregadas para designar el halcón como amenazado o en peligro debajo del U.S. Endangered Species Act. Las demandas susieren que los halcones sufrieron reducciones significantes en los Estados Unidos por las reglas que dirigen la cortada de árboles y amenazado con extinción por el resultado de cosechas muy numerosas. No hay ninguna prueba que de las contracciones de campos en el oeste de norte américa y el campo de halcones parece e star haciendo se mas amplio (Tal vez por la ocupación de nuevo de los campos antiguos) en el este de los Estados Unidos. La mayoría de datos sobre la abundancia de parejas de cría indica que la densidad de halcones varia mucho en su espacial y su temporal. Hay pruebas que sugieren que la abundancia esta correlacionada con la disponibilidad de comida. Un estudio susieren que la abundancia se ha reducido en las pasados décadas en el

norte de Arizona pero las conclusiones están basadas en un proyecto con insuficiente muestreo. Fluctuaciones de fecundo varían mucho pero no hay ninguna prueba de una tendencia negativa. Fecundo esta aparentemente influido por una combinación de disponibilidad de comida y ritmos de cazar. Estimaciones de supervivencia son muy limitadas para analizar tendencias temporal y, el resultado de los datos insuficiente de supervivencia, no han estado estimados para poblaciones de halcones en norte américa. Yo concluido que no hay pruebas fuertes para soportar el argumento que el halcón se esta reduciendo en los Estados Unidos. Este resultado puede estar interpretado por un lado, que las poblaciones de halcón no están reduciéndose o por otro lado, que las poblaciones se están reduciendo pero las reducciones no han sido descubridas con la técnica de muestreo usada hoy en día (error Pipo 2). Estas dos hipótesis no pueden estar evaluadas con rigor con la información publica que existe y probablemente no va estar evaluada en el futuro con los datos de un área singular de estudio por limitaciones de muestreo. Para poder evaluar rigurosa y objetivamente las tendencias de poblaciones del halcón de norte américa en una manera oportuna y con un precio justo, yo recomiendo que una meta-análisis sea conducida con todos los datos publicados y no-publicados que existen.

[Traducción de Raúl De La Garza, Jr.]

Because the Northern Goshawk (*Accipiter gentilis atricapillus*; hereafter referred to as goshawk) often nests (Siders and Kennedy 1996, Squires and Ruggiero 1996) and hunts (Bright-Smith and Mannan 1994) in old-growth or mature forests, potential conflicts between timber harvest and maintenance of viable goshawk populations concerns various publics (Hitt 1992, St. Clair 1992). These concerns have resulted in two petitions to list the goshawk as threatened or endangered in the southwestern (Federal Register 1992a) and western U.S. (Federal Register 1992b, 1996a), and the classification of the goshawk as a Category 2 species (Federal Register 1992a) prior to the elimination of this category by the USDI Fish and Wildlife Service (FWS) in 1996 (Federal Register 1996b). In addition, it is included on the Sensitive Species lists of several USDA, Forest Service (USFS) regions (e.g., Pacific Northwest, Southwest, Intermountain, Rocky Mountain and Alaska) and is a Species of Special Concern in several states (Wisconsin Bureau of Endangered Species 1995, K. Titus pers. comm.). The goshawk has no federal or provincial protection in Canada (World Wildlife Fund Canada Web Site, <http://www.wwfcanada.org/specelist.html>).

The listing petitions claimed that goshawks had suffered significant declines because of logging practices and that it was under threat of extinction as a result of overharvest. In reviewing a listing petition, the FWS must determine if the petition presents substantial information to warrant a status review. Both of the goshawk petitions were denied by the FWS because the petitions could not document that goshawk populations west of the 100th meridian constitute a distinct population (Federal Register 1996a). Only species, subspecies and, for ver-

tebrates, distinct populations are listable entities under the Endangered Species Act (ESA).

My goal in this paper is to evaluate the claim that goshawk populations have suffered significant declines in the western U.S. I address the following question: is there demographic evidence that goshawk populations are declining? The mark of a species in trouble is not its population abundance or geographic range size at one point in time, but the rate of population decline or range contraction (Caughley and Dunn 1995). A rare or uncommon species can have a stable population or range size (Gaston 1994). Conversely a species in decline can seem relatively common until only a short time before it becomes rare (Caughley and Dunn 1995). Evidence of a decline for both rare and common species would include range contractions, temporal decreases in abundance, fecundity and/or survival and/or a negative rate of population change ( $\lambda$ ) (Caughley and Dunn 1995). In this paper I evaluate these lines of evidence by reviewing the available demographic data on goshawks throughout its subspecific range. Although the listing petitions pertain only to the western U.S., I did not restrict my analyses to this region because it is not recognized as a distinct population. Diagnosing causes of decline is irrelevant if there is no evidence that a decline has occurred.

#### METHODS

This paper summarizes and evaluates the published demographic literature on goshawks and presents results of demographic analyses I have conducted on datasets from New Mexico and Utah. The New Mexico population and study area are described in detail in Siders and Kennedy (1996). The Utah population is located in the Ashley National Forest (ANF) in eastern Utah. During 1991–1995, 42 occupied nest sites were located on the ANF using



survey methods recommended by Kennedy and Stahlecker (1993). The ANF is located in the Uinta Mountains and contains approximately 340 000 ha of forested land. The average annual precipitation is 70 cm (range 40–90 cm), with roughly equal precipitation from winter snowfall (November–April) and summer rains (May–October). Lodgepole pine (*Pinus contorta*), spruce-fir (*Picea engelmanni*-*Abies lasiocarpa*), mixed conifer (includes lodgepole pine, Engelmann spruce and subalpine fir) and ponderosa pine (*Pinus ponderosa*) are the most prevalent forest communities present in the study area. Douglas fir (*Pseudotsuga menziesii*), quaking aspen (*Populus tremuloides*), pinyon-juniper (*Pinus edulis*-*Juniper osteosperma*), subalpine meadows, sagebrush grasslands and riparian woodlands are also present.

To evaluate changes in ranges, I compared current distribution maps with historic maps and reviewed published accounts of changes in the status of the goshawk at the state and regional scale.

In this review I did not include the migration literature which contains temporal data on counts of migrating goshawks. These data were not included because the relationship between counts of migrants and population abundance is unknown. I agree with Bednarz et al. (1990) and Titus and Fuller (1990) who suggest that population fluctuations in this species may not be adequately monitored by migration counts because goshawk migrations are characterized by irruptive invasions which can mask trends in abundance.

I also did not include results from non-peer-reviewed literature because these datasets have not been subjected to a rigorous scientific evaluation via peer review. Although there is potentially valuable information in this body of literature, the information hasn't been sorted through selectively to separate questionable from reliable information (Bury and Corn 1995).

## RESULTS

**Range Contractions.** Range contractions may be seen in a species' distribution as a partial erosion of the boundary or as a range fragmentation where populations are removed from within the distribution (Caughley and Dunn 1995). In range contraction, the agent of decline can often be identified by knowing something about those factors that determine the boundary of the range (Caughley et al. 1988).

Goshawks are holarctic in distribution, occupying a wide variety of boreal and montane forest habitats throughout North America and northern Mexico (Johnsgard 1990). I assume its breeding range is discontinuous because there are no records of birds breeding in nonforested areas (e.g., prairie regions of Canada and the U.S.). However, its winter range may not be discontinuous because it is observed in nonforested habitats in the winter (P. Kennedy unpubl. data, J. Squires pers. comm.). The northern limit of its distribution is the bound-

ary of boreal forest and tundra habitats. The eastern and western boundaries are the Atlantic and Pacific Oceans, respectively (Palmer 1988, Johnsgard 1990). Factor(s) that limit the southern extent of the range are unknown.

In the eastern U.S., the goshawk may have been more abundant before the extinction (early 1900s) of the Passenger Pigeon (*Ectopistes migratorius*; Bent 1937, Mengel 1965, Brauning 1992) and before the extensive deforestation of this region which reached a peak at the end of the 19th century (McGregor 1988, Foster 1992, Smith et al. 1993, Pimm and Askins 1995). Since 1920, the amount of forested habitat has been increasing throughout the eastern U.S. resulting from the conversion of primarily agricultural landscapes into landscapes dominated by forest (Pimm and Askins 1995). Since this time, there is evidence that eastern goshawk populations may be expanding. Although few records exist before the 20th century, the goshawk was considered a casual or accidental breeding species in the northeast from the late 1800s into the 1950s (Forbush 1927, Bagg and Eliot 1937, Andrle and Carroll 1988, Zeranski and Baptist 1990, Brauning 1992). However, from the 1950s onward, the species' range appears to have expanded and its numbers have increased in many northeastern states (Bull 1974, 1976, Speiser and Bosakowski 1984, Leck 1984, Andrle and Carroll 1988). For example, the first breeding record for Massachusetts was reported by Farley (1923) and there were no reported nests in Connecticut at this time. By 1964 it was a casual nester in northwestern Connecticut and by 1978 at least 19 occupied nest sites were located in this area (Zeranski and Baptist 1990). The first goshawk nest in New Jersey was recorded in 1964 (Speiser and Bosakowski 1984) and it was considered a rare summer resident in New York until the 1950s. Forty-eight breeding sites were located in New York between 1952 and the early 1970s (Bull 1974) and 20 occupied sites were recorded in the Highlands region of northern New Jersey and southeastern New York by the mid-1980s (Leck 1984, Speiser and Bosakowski 1987). In a recent atlas of the breeding birds of New York, the goshawk was recorded as a breeding bird in all but 11 counties (Andrle and Carroll 1988). Andrle and Carroll (1988) compared Bull's (1974) goshawk distribution for New York with their atlas distribution for the state and concluded that the species has expanded its breeding range in New York since the early 1970s.

Table 1. Density of breeding goshawk populations from North America estimated from nest censuses.

YEAR <sup>a</sup>	No. 100 km <sup>-2</sup>	(N) <sup>b</sup>	FOREST TYPE	LOCATION	SOURCE
1982-85	11	?	Ponderosa pine <sup>c</sup>	Arizona	Crocker-Bedford and Chaney (1988)
1974	3.6	4	Mixed conifer/ Ponderosa pine	Oregon	Reynolds and Wight (1978)
1971-72	7.5	6	Lodgepole pine <sup>d</sup>	Colorado	Shuster (1976)
1984-92	5.7-10.7 <sup>e</sup>	6-11	Mixed conifer	California	Woodbridge and Detrich (1994)
1990	10.0	40	Spruce	Yukon	Doyle and Smith (1994)
1992-93	4.6-6.2	4-8	Lodgepole pine	Oregon	DeStefano et al. (1994a)
1992-93	6.6-8.8	6-8	Ponderosa pine/ Mixed conifer	Oregon	DeStefano et al. (1994a)
1992-93	2.6-7.0	3-8	Mixed conifer	Oregon	DeStefano et al. (1994a)
1993	3.8-8.6 <sup>e</sup>	4-9	Mixed conifer/ Ponderosa pine	Oregon	DeStefano et al. (1994a)

<sup>a</sup> Time period in which study was conducted. If temporal variation in density is available, the range in annual estimates of density and sample sizes are reported.

<sup>b</sup> N = Number of nests.

<sup>c</sup> Range of values for two different study areas in the same forest type.

Although these data suggest a range expansion (or reoccupancy), this needs to be interpreted cautiously. Increasing populations of goshawks reported in the eastern U.S. could reflect an increased search effort rather than a range expansion. An inability to distinguish these two phenomena has been documented for other poorly detectable raptor species (Stahlecker and Duncan 1996).

Johnsgard (1990) suggested that range contractions might be occurring in the Pacific Northwest and other parts of the west as a result of overharvest of mature forests. However, the goshawk's western distribution as described by Bent (1937) has not changed (Palmer 1988, Johnsgard 1990). In addition, there are no current reports of local population extirpation in any portion of the goshawk's geographic range.

**Patterns of Abundance.** Range size and abundance are correlated variables. Within particular taxa and geographical regions, species with large ranges tend to have greater local abundances at sites where they occur than do species that are more restricted geographically (Gaston 1994, Lawton 1995). Based on these zoogeographic patterns, the goshawk, which is widely distributed across North America, is predicted to be more abundant locally than comparably-sized forest-dwelling species with more restricted ranges such as the Red-shouldered Hawk (*Buteo lineatus*). Hejl et al. (1995) recently classified the goshawk as a common breed-

er in the majority (6 of 8 types) of forest types in the Rocky Mountains.

Breeding density has been estimated for several North American populations of goshawks. Two methods based on searches for occupied nests have been used to estimate these densities: counts of breeding pairs and distribution of nearest-neighbor distances. Both methods are based on the unlikely (and untested) assumption that all nests have been located in the survey area (Gould and Fuller 1995). Comparability of these estimates also is complicated by use of different survey techniques among studies (Siders and Kennedy 1996).

Mean nearest-neighbor distances range from 3.0-5.6 km [Oregon, 1974, N = 4, range = 2.4-8.4 (Reynolds and Wight 1978); California, 1984-1992, N = 21, range = 1.3-6.1 (Woodbridge and Detrich 1994); Arizona, 1992, N = 59, range = 2.4-8.4 (Reynolds et al. 1994)]. Nest densities have been estimated to range from 2.6-11 nests per 100 km<sup>-2</sup> (Table 1). High densities of 10-11 nests per 100 km<sup>-2</sup> have been recently reported in three study areas: Arizona, California and the Yukon (Table 1).

In addition to the extensive spatial variation described above, breeding densities can vary annually. Although densities did not vary during two years in one study area in Colorado (Shuster 1976), in three study areas in Oregon, densities varied from 33-270% during 2 yr (DeStefano et al. 1994a; Table 1). The Bly study area censused by DeStefano



et al. (1994a) in 1993 was the same study area censused by Reynolds and Wight (1978) in 1974. The number of occupied nest sites located on this study area ( $N = 4$ ) did not change over the 21-yr period and thus densities were equivalent (3.6 in 1974 and 3.8 in 1993; Table 1; variation due to slightly more acreage censused in 1974).

Two studies have attempted to quantify population trends in goshawk populations using data from breeding populations (Crocker-Bedford 1990, Doyle and Smith 1994). Crocker-Bedford (1990) was the first person to suggest in the scientific literature that goshawk populations were declining due to overharvest of their forested habitat. This idea is important and it needed to be published. However, his study does not do an adequate job of rigorously evaluating this hypothesis. Crocker-Bedford claims that the goshawk population on the North Kaibab Ranger District of the Kaibab National Forest in Arizona declined from an estimated 260 nesting pairs to approximately 60 pairs by 1988. This estimated decline is not based on temporal variation in densities. Rather, it is based on a comparison of densities estimated during the 1985–87 breeding seasons between areas harvested during two different time periods. He compared densities from areas lightly harvested in the 1950s and 1960s (controls) to areas that were more intensively harvested from 1970–85 (treatments). Crocker-Bedford estimated densities by censusing the number of nest structures found per unit area and multiplying the number of structures by the ratio of nests to breeding pairs. He did not identify how he differentiated nest structures of different species such as Cooper's Hawks (*Accipiter cooperii*) and Red-tailed Hawks (*Buteo jamaicensis*) that nest in similar habitats and build similar structures (Preston and Beane 1993, Siders and Kennedy 1996). Although his data suggest more nest structures can be found in lightly harvested areas as compared to heavily harvested areas, his inference from this dataset to estimating rate of population change is unwarranted. The relationship between number of nest structures and number of goshawk breeding territories is unknown and the assumption that spatial variation in nest structure density reflects temporal variation in nest structure density is not supported by any data and is probably unjustified biologically.

Doyle and Smith (1994) examined variations in an index of goshawk abundance (intensive surveys of breeding pairs combined with year-round sight-

ings) from 1987–93 in the boreal forest in southwest Yukon, Canada. Although these data were not analyzed statistically, the abundance index changed by more than a factor of four over a 2-yr period. They also monitored hare abundance from 1987–93 and concluded that changes in goshawk abundance probably resulted from cyclic changes in hare densities. During periods of high hare density, goshawks were abundant on the study area all years and hares accounted for over 55% of the total prey biomass. As hare populations declined, goshawks became more nomadic and virtually disappeared in the winter. They located 40 pr in a 400 km<sup>2</sup> area during 1990, a peak prey year. No successful breeding was recorded in this same area during 1992 when hare numbers were lowest.

Indirect evidence of a decline in abundance might also be indicated by a loss of territories (defined below) over time. However, evidence suggests that more territories are being located annually as search effort increases. For example, in the southwestern U.S., few locations of nesting goshawks were known prior to 1990 and no systematic effort was made to monitor known nest sites. After the development of a standardized survey technique by Kennedy and Stahlecker (1993), efforts by the USFS to inventory proposed timber sale areas began on many of the national forests in this region. Since 1991, the annual number of nesting locations discovered has risen steadily (Fletcher and Sheppard 1992). In northcentral New Mexico, 39 goshawk territories were located during 1984–95 (Siders and Kennedy 1996). An average of 3.3 new territories (SD = 4.9) have been located every year since 1984 and only one territory has been abandoned since it was located. An average of eight new territories (SD = 5.1,  $N = 42$ ) has been located every year from 1991–95 in the Uinta Mountains, Utah. Territory abandonments have not been documented in this study area. Rates of territory discovery and abandonment are not available for other study areas with long-term (>5 yr) datasets.

**Reproductive Patterns.** Typically the reproductive patterns of raptors are subdivided into three components, each of which is estimated separately: occupancy rates, nest success and productivity. Terminology defined by Postupalsky (1974), Steenhof and Kochert (1982) and Woodbridge and Detrich (1994) was used to define these components.

*Occupancy rates.* An occupied territory is defined as a cluster of nest stands exhibiting regular use by a minimum of one adult goshawk during the

breeding season. Occupancy rate is defined as the proportion of known territories that are occupied. Similar to many long-lived species (Newton 1979, 1991, Marti 1994), not all goshawks produce offspring annually. In three studies with a minimum of four yr of data, average occupancy rates/territory were remarkably similar: New Mexico = 74.4% (SD = 30.5%,  $N = 22$ ); Utah = 74.7% (SD = 28.7%,  $N = 26$ ) and California = 74% (SD = 5.5%,  $N = 26$ , Woodbridge and Detrich 1994). The sample sizes in each study were comparable and the number of monitored territories increased over time in each study. Territories with <4 yr of data were not included in these statistics. The New Mexico dataset included a maximum of 22 territories with 4–11 yr of occupancy data per nest. The Utah dataset included a maximum of 26 territories with 4–7 yr of occupancy data per nest and the California dataset included a maximum of 26 territories with 5–9 yr of data per nest (Woodbridge and Detrich 1994).

Interstudy comparisons of occupancy rates need to be done cautiously because occupancy rate is probably positively correlated with the amount of effort expended to determine territory status. Level of effort was comparable among the three studies where all territories were checked a minimum of 2–3 times each year and most territories were visited numerous times each season (B. Woodbridge pers. comm.). In New Mexico and Utah, an area with a radius 0.7–1.0 km (the postfledging area as defined by Kennedy et al. 1994) surrounding the previously occupied nest was intensively surveyed using broadcast vocalizations (Kennedy and Stahlecker 1993) and visual searches of all individual trees. Woodbridge and Detrich (1994) used the same searching methods but their search area was larger, a 1.6 km radius surrounding the previously occupied nests.

Doyle and Smith (1994) found that the number of territorial pairs (range 0–8) of goshawks detected changed with hare densities. When hare densities were low, no goshawks were detected as breeding birds. At maximum hare densities, eight territorial pairs were recorded. The variation in occupancy rates in other studies could be a function of prey availability during the winter and courtship.

*Nest success.* I define nest success as the proportion of occupied territories that produce at least one young of bandable age. Average nest success varies from 0.47–0.94 (Table 2). Annual variation in nest success is high; in New Mexico over a 12-yr

period it varied from complete nesting failure to 100% success in two successive years (Fig. 1). In Utah, over a 7-yr period it varied from 0.33–0.91 (Fig. 1). To explore the possibility of a decline in nesting success over time, I evaluated the temporal variation in these nest-success estimates using linear regression (Regression Data Analysis Procedure—Microsoft EXCEL Ver. 7.0 for Microsoft Windows 95). There was no evidence of a negative correlation between time and nest success in New Mexico ( $R^2 = 0.20$ ,  $P = 0.14$ ,  $N = 12$  yr) or Utah ( $R^2 = 0.03$ ,  $P = 0.694$ ,  $N = 7$  yr) (Fig. 1). It is interesting to note that the temporal patterns in nest success between 1990–95 are qualitatively similar for both study areas.

In Arizona during 1991–92, Reynolds et al. (1994) found that 3% ( $N = 3$ ) of 98 nest attempts did not lay eggs or failed in early incubation, 6% ( $N = 6$ ) of the clutches were lost later in incubation and 6% ( $N = 6$ ) of the nests failed during the nestling period. Possible causes of nest failure were not discussed. In New Mexico, over a 12-yr period, out of 122 nest attempts, 8% ( $N = 10$ ) failed during incubation from predation and unknown causes and 8% ( $N = 10$ ) failed during the nestling period from predation, disease, harvest by falcons or inclement weather.

*Productivity.* I define productivity as the mean number of bandable young produced per occupied territory. Productivity of North American goshawks ranges from 0.0–2.8. The lowest estimate of average productivity (0.0) are from the Yukon and the highest average estimates (2.8) are from Nevada and the Yukon (Table 2). In the Yukon, productivity appeared to increase with hare abundance (Doyle and Smith 1994). Pairs breeding at the hare peak fledged 2.8 young per pair. In two low-hare years they reported zero productivity.

To explore the possibility of a decline in productivity over time, I evaluated the temporal variation in this variable for New Mexico and Utah using linear regression (Regression Data Analysis Procedure—Microsoft EXCEL Ver. 7.0 for Microsoft Windows 95). There was no evidence of a negative correlation between time and productivity in New Mexico ( $R^2 = 0.05$ ,  $P = 0.49$ ,  $N = 12$  yr) and Utah ( $R^2 = 0.07$ ,  $P = 0.56$ ,  $N = 7$  yr) (Fig. 2). Similar to nest success, the pattern in productivity between the two study areas is qualitatively similar during 1990–95.

**Survival Patterns.** *Nestling survival.* Nestling survival rates have been estimated in two studies in

Table 2. Average nest success and productivity of goshawks in North America.

LOCATION	YEARS (NO. NESTS)	NEST SUCCESS <sup>a</sup> (SD)	MEAN PRODUCTIVITY <sup>b</sup> (SD)	SOURCE
Arizona	1985–87 (19) <sup>c</sup>	NA <sup>d</sup>	2.1 (NA)	Crocker-Bedford (1990)
	1985–87 (12)		0.5 (NA)	
Arizona <sup>e</sup>	1991 (37)	0.94	2.0 (0.83)	Reynolds et al. (1994)
	1992 (61)	0.83	1.7 (1.08)	
California	1984–92 (28)	0.87 (NA)	1.93 (0–4) <sup>f</sup>	Woodbridge and Detrich (1994)
Nevada	1991 (14)	NA	1.2 (NA)	Younk and Bechard (1994)
	1992 (22)		2.8 (NA)	
New Mexico	1984–95 (4–31) <sup>g</sup>	0.47 (0.34)	0.94 (0.64)	This study
E. Oregon	1969–74 (48)	0.94	1.7 (0.76)	Reynolds and Wight (1978)
E. Oregon	1992 (6–10) <sup>h</sup>	NA	1.0–2.2 (0.57–0.75)	DeStefano et al. (1994a)
	1993 (3–7) <sup>i</sup>		0.3–2.2 (0.72–1.08)	
E. Oregon	1992 (12)	0.83	1.2 (NA)	Bull and Hohmann (1994)
Utah	1989–95 (3–42) <sup>g</sup>	0.59 (0.21)	1.22 (0.3)	This study
Yukon	1989 (3)	NA	1.3 (0.88)	Doyle and Smith (1994)
	1990 (8)		2.8 (0.57)	
	1991 (7)		1.3 (0.47)	
	1992 (1)		0.0	

<sup>a</sup> Nest success is defined as the proportion of occupied territories that produce at least one young of bandable age. See text for definition of territory.

<sup>b</sup> Productivity is the mean number of young of bandable age per occupied territory.

<sup>c</sup> Study included 19 control territories and 12 treatment territories. See text for more details.

<sup>d</sup> NA = not available.

<sup>e</sup> Same study area as Crocker-Bedford (1990).

<sup>f</sup> Range in one study area.

<sup>g</sup> Number of territories increased over time.

<sup>h</sup> Range from three study areas.

<sup>i</sup> Range from five study areas.

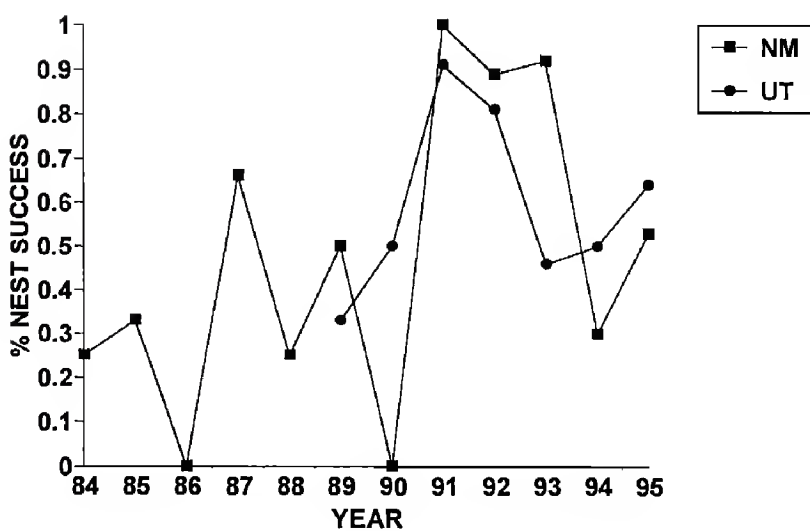


Figure 1. Temporal patterns in nest success of two goshawk populations: northcentral New Mexico and eastern Utah. Yearly sample sizes for New Mexico are 4, 3, 3, 3, 4, 2, 3, 18, 19, 24, 20 and 19 occupied territories, respectively. Yearly sample sizes for Utah are 3, 2, 11, 27, 26, 22 and 25 occupied territories, respectively.

North America. Reynolds and Wight (1972) reported a fledgling success rate (number of young fledged/number of young hatched) of 72% (28% mortality rate) for 11 successful nests monitored from 1969–74 in Oregon. This estimate is probably underestimated because unsuccessful nests are not included. In addition, this estimate was based on data pooled over 1969–74 so temporal variation in nestling mortality was not estimated. Ward and Kennedy (1996) investigated the effect of food supplementation on juvenile survival during 1992–93. In 1992, survival of birds provided with supplemental food (treatment) averaged 80% ( $N = 15$  nestlings) and was not significantly different from the 100% survival rate of unfed (control) birds ( $N = 16$  nestlings). In 1993, treatment survival was significantly higher ( $\bar{x} = 90\%$ ,  $N = 10$  nestlings) than the survival of unfed birds ( $\bar{x} = 37\%$ ,  $N = 8$  nestlings). These data suggest that nestling mortality can vary annually from 0–63%. No data are available to determine long-term temporal trends in nestling mortality.



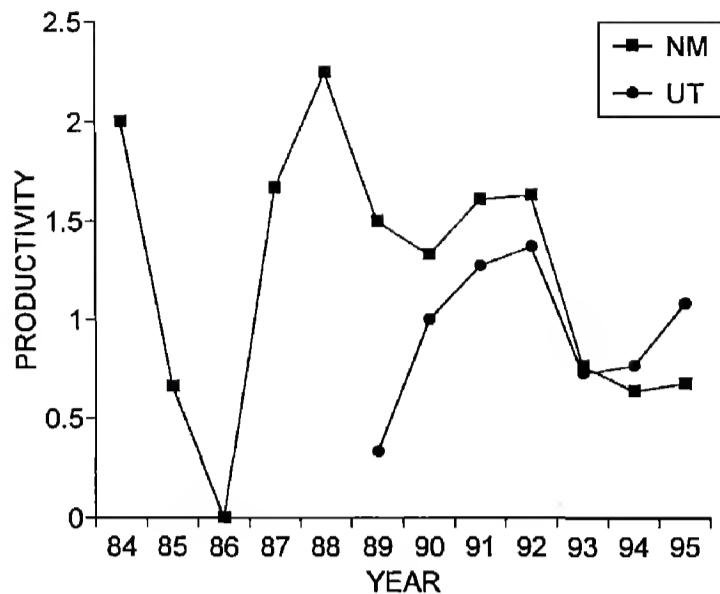


Figure 2. Temporal patterns in productivity of two goshawk populations: northcentral New Mexico and eastern Utah. Yearly sample sizes for New Mexico are 4, 3, 3, 3, 4, 2, 3, 18, 19, 24, 20 and 19 occupied territories, respectively. Yearly sample sizes for Utah are 3, 2, 11, 27, 26, 22 and 25 occupied territories, respectively.

Ward and Kennedy's (1996) study suggest that nestling survival rates are influenced by both food availability and predation rates. They found that no juveniles died of starvation and the majority died of predation or disease. Based on behavioral observations of the adults they suggest that food limitation can result in higher predation rates on nestlings because females must allocate more time to foraging and less time to nest defense.

*Juvenile survival.* Using radiotelemetry, Ward and Kennedy (1996) estimated juvenile survival rates from fledging until the juveniles were approximately 5.5 mo of age in 1992 (telemetry monitoring ceased in mid-October) and from fledging until the juveniles were approximately 7-mo old in 1993 (telemetry monitoring ceased at the end of November). These survival rates include the fledging-dependency period (approximately 50 d) and 2.5–4 mo after independence (Ward 1994). During 1992–93, treatment survival was not significantly higher than control survival; overall survival varied from 67–100%. No estimates of annual juvenile mortality are available for North America and temporal trends in this parameter are unknown.

*Adult survival.* Adult survival estimates are available from two studies in North America: northern California (DeStefano et al. 1994b) and northern New Mexico (this study). Both studies estimated survival using mark-recapture/resight methodology (Lebreton et al. 1992, Gould and Fuller 1995). Both studies used program RELEASE for data sum-

marization and goodness-of-fit tests (Burnham et al. 1987). Goodness-of-fit tests examine the data with a series of  $\chi^2$  tests to determine if the data fit the general capture-recapture model (Burnham et al. 1987, DeStefano et al. 1994b). DeStefano et al. (1994b) used program SURGE (Lebreton et al. 1992) to derive point estimates and variances of survival. I used program MARK (G. White unpubl. software) to develop the same estimates for the New Mexico population. Both programs use Cormack-Jolly-Seber models to estimate parameters. In these models  $\phi$  = survival and  $p$  = probability of resighting. MARK provides the same capabilities as SURGE but it has an improved user-interface and allows the user to test additional models not available in SURGE (G. White pers. comm.).

DeStefano et al. (1994b) examined eight models and I examined 12 models, where  $\phi$  and  $p$  are assumed to vary among years ( $\phi_t$ ,  $p_t$ ) and between sexes ( $\phi_s$ ,  $p_s$ ) and all possible interactions of sex and time were evaluated. Both studies used Akaike's Information Criteria (AIC) to select the model that best fit the data with the fewest number of parameters and was still biologically reasonable (Lebreton et al. 1992). AIC is a quantitative method of selecting the "best" data-driven model among a set of competing models. AIC selects a model that balances bias and variance tradeoffs (Lebreton et al. 1992).

The New Mexico estimates were based on capture-recapture/resighting histories on 45 adult breeding goshawks that were trapped and banded from 1984–95 (Kennedy et al. 1994). This dataset fit the general capture-recapture model ( $\chi^2 = 3.69$ ,  $P = 0.72$ ). The two models [ $\phi$ ,  $p_{s+t}$ ]( $\phi$ ,  $p_{s*t}$ ) with the lowest AIC values (Table 3) indicated there was no evidence that survival varied by sex or time and recapture probabilities varied by sex (higher for females because they were sighted more frequently at the nest) and year (increased efficiency of resighting with time). It is likely that survival does vary by sex and year and my inability to detect this variation is a result of small sample sizes and low resighting probabilities. Annual adult survival in this study area during this time period is estimated to be  $0.86 \pm 0.09$ . Because recapture probabilities varied by sex and year and sample sizes were small, the precision in this estimate is low: 95% CI = 0.60–0.96. In addition, these estimates may be low because some marked birds may have emigrated from the study area.

DeStefano et al. (1994b) estimated survival with

Table 3. Capture-recapture models used to estimate survival of adult, breeding northern goshawks in north-central New Mexico, 1984–95.

MODEL	NO. PARAMETERS	DEVIANCE	AIC <sup>a</sup>
General model			
$(\phi, p)$ <sup>b</sup>	2	55.346	137.001
Time-specific models			
$(\phi, p_t)$	5	48.748	136.403
Sex-specific models			
$(\phi_s, p_s)$	4	48.707	134.362
$(\phi, p_s)$	3	50.709	134.364
Time- and sex-specific models			
$(\phi, p_{s+t})$	6	40.283	129.937
$(\phi, p_{s^*t})$	9	35.669	131.324
$(\phi_s, p_{s+t})$	7	40.278	131.932
$(\phi_t, p_{s+t})$	8	38.359	132.014
$(\phi_s, p_t)$	6	43.152	132.807
$(\phi_t, p_{s^*t})$	11	33.854	133.509
$(\phi_{s+t}, p_{s+t})$	9	37.861	133.516
$(\phi_{s^*t}, p_t)$	11	37.593	137.247
$(\phi_{s^*t}, p_{s^*t})$	12	32.084	133.739

<sup>a</sup> AIC = Akaike's Information Criteria (AIC =  $[2 \times \text{No. Parameters}] + \text{Deviance}$ ).

<sup>b</sup>  $\phi$  = survival rate and  $p$  = recapture probability.

a larger dataset ( $N = 95$ ) over a comparable time period (1983–92). In their analysis, the model  $(\phi_{st}, p)$  had the lowest AIC value indicating that survival varied among years and by sex. Female survival was estimated to vary annually from 0.35–0.93. Male survival was estimated to vary from 0.20–0.94. However, the overall fit of the California data to the model was inadequate so their survival estimates must be interpreted cautiously. As the authors indicated, this lack of fit is probably a function of three factors: sample size, high rates of breeding dispersal resulting in an underestimation of survival and methodological constraints (only resighted birds at successful nests).

Although the results of these two studies provide imprecise point estimates of goshawk survival in North America, they are not adequate to evaluate temporal trends in survival. As noted by DeStefano et al. (1994b), temporal trends in goshawk survival can only be estimated with capture-recapture techniques if the estimates are based on large numbers of marked birds (>100), high resighting rates and at least five yr of data. This will require large study areas and large field crews. In addition, this tech-

nique is not appropriate if breeding dispersal outside of the study area is common.

**Rate of Population Change.** Because of the aforementioned insufficient survival information, rates of population change ( $\lambda$ ) are not available for any North American goshawk population.

#### CONCLUSIONS

Based on an analysis of nesting records, there is no evidence of range contractions in western North America and the goshawk's range appears to be expanding (or reoccupied) in the eastern U.S. Populations may have been lost in the west as a result of deforestation but these losses have not been recorded in the published literature. A detailed analysis of 20th century deforestation and reforestation rates throughout North America would provide additional indirect information on potential temporal changes in the goshawk's range.

The majority of data on abundance of breeding pairs indicate that goshawk densities are highly variable spatially and temporally. There is some evidence to suggest that abundance is correlated with food availability. Breeding densities in one study area in Oregon were estimated during 1971 and 1993, and these two estimates were identical. Crocker-Bedford (1990) has claimed that goshawk abundance has declined in the past several decades in northern Arizona but his conclusions are suspect for reasons detailed earlier in this paper.

No declines in fecundity have been recorded and fecundity fluctuates widely. Results from several studies indicate that fecundity is influenced by a combination of food availability and predation rates. Survival data are too limited to analyze for temporal trends and as a result of insufficient survival data,  $\lambda$  has not been estimated for any North American goshawk population.

I conclude there is no evidence to support the hypothesis that goshawk populations are declining. This result can be interpreted in two ways: (1) goshawk populations are not declining; or (2) goshawk populations are declining but the declines have not been detected with current sampling techniques (Type 2 error). If the first interpretation is correct then goshawk populations are not declining and thus, it should not be listed as threatened under the ESA. The lack of demographic evidence to support a decline corroborates the results of the FWS analyses of both listing petitions (insufficient evidence to support a status review).



These results also suggest that the national concern for goshawk populations may not be driven by concerns for goshawk viability but is motivated by concerns of overharvest of old-growth forests. Although the concerns about overharvest of forested communities is certainly justifiable, listing a species for which there is no evidence of a population decline would be a misuse of that legislation and could greatly erode the credibility of the ESA. In addition, it would impact the recovery process of truly threatened and endangered (T&E) species by diverting the limited resources available for T&E species conservation to goshawk recovery.

Alternatively, it is possible the goshawk is declining and the decline is going undetected because of the paucity of data on temporal trends in mortality and abundance. Typical of many raptor studies, goshawk research has focused on quantifying trends in reproduction, not mortality or abundance. This is because reproductive data are easier and less expensive to collect than abundance or mortality data. Obtaining estimates of abundance and mortality with reasonable levels of precision requires large sample sizes of goshawks and long-term sampling (>5 yr). Unbiased estimates of goshawk abundance also require use of randomized or stratified study designs where all forested communities (not just old-growth forests) are surveyed for goshawk presence (Siders and Kennedy 1996, Squires and Ruggiero 1996).

Because of the low detectability of the goshawk and the resulting analysis problems associated with limited sample sizes, it is unlikely that data collected by any single investigator will be sufficient to determine whether or not goshawk populations are declining. It is clear that the information currently available to the agencies concerning goshawk population trends and demographic parameters is insufficient to diagnose population declines. However, I think goshawk population trends could be diagnosed with a meta-analysis of all existing datasets.

Meta-analysis is a method of integrating statistical results from independent studies. It provides both a rigorous, quantitative analysis of cumulative evidence and a practical method of systematically and objectively developing and examining a large dataset based on pooled observations (VanderWerf 1992). Meta-analysis is frequently used in the biomedical field (Mann 1990) but rarely has it been applied in ecology and conservation biology (Jär-

vinen 1991, VanderWerf 1992, Burnham et al. 1996, Forsman et al. 1996).

If goshawk researchers are willing to collaborate, a meta-analysis could be conducted to evaluate the existing demographic datasets on the goshawk. The main objective of this meta-analysis would be to conduct a rigorous and objective analysis of the empirical data available on the North American populations of this species to determine the population trends of the North American goshawk. The results of this analysis would provide an objective analysis of existing information for federal and state agencies involved with goshawk management and listing decisions and identify future goshawk research needs, if the aforementioned questions cannot be answered definitively with existing datasets.

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## HOW, AND WHY, IS THE GOSHAWK (*ACCIPITER GENTILIS*) AFFECTED BY MODERN FOREST MANAGEMENT IN FENNOSCANDIA?

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**ABSTRACT.**—The Northern Goshawk (*Accipiter gentilis*) is a common raptor in the boreal forest of Fennoscandia (Norway, Sweden and Finland), with a present breeding density of about 3 pr/100 km<sup>2</sup> of forest area. Several independent studies show that goshawk populations in Fennoscandia have declined by 50–60% from the 1950s to the 1980s. This decline coincides in time with an intensification of forest management, which has changed the forest landscape. Among other effects, forests are more fragmented and the proportion of old forest is decreasing. Neither pesticide use nor persecution can explain the goshawk decline. However, changes in habitat and prey populations are both important factors that are affected by forestry. Goshawks need only a small patch of suitable habitat for nesting, but for their foraging home ranges cover 2000–6000 ha, and in boreal forest areas they prefer large patches of mature forest. I suggest that changes in the boreal forest landscape have resulted in a deterioration of goshawk hunting ranges, making it more difficult for them to secure adequate food for breeding. This factor is more important than a shortage of suitable nest sites. Declining prey densities (e.g., grouse) may be associated with forestry and is also an important factor that may affect goshawk numbers.

**KEY WORDS:** *Accipiter gentilis*; *Northern Goshawk*; *forest management*; *home range*; *breeding*; *habitat selection*; *Fennoscandia*; *Sweden*; *Norway*; *Finland*.

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¿Como, y Porque, esta el *Accipiter gentilis* afectado por la administración forestal moderna en Fennoscandia?

**RESUMEN.**—El *Accipiter gentilis* norteno es un rapaz común en el bosque boreal de Fennoscandia (Noruega, Suecia y Finlandia) con una densidad de cría presente como 3 pr/100 km<sup>2</sup> de área bosque, varios estudios independientes enseñan poblaciones de *Accipiter gentilis* en Fennoscandia aun reducido por uno 50–60% de los 1950s a los 1980s. Está reducción coincide con el tiempo de intensificación de administración de bosque, que ha cambiado el paisaje del bosque. Entre otros efectos, bosques están mas fragmentados y la proporción de bosques viejos se esta reduciendo. Ni uso de pesticida ni persecución puede explicar reducción del *Accipiter gentilis*. Sin embargo, cambios en el hábitat y poblaciones de cazar son las dos importantes factores que son afectados por forestales. *Accipiter gentilis* necesitan no mas una parcela chiquita de hábitat conveniente para hacer nidos, pero sus forrajes naturales cubren 2000–6000 ha, y en áreas de bosque boreal ellos prefieren parcela grandes de bosque maduro. Yo, propongo que cambios en el paisaje de bosques boreal han resultado en un empeoramiento en campos de cazar del *Accipiter gentilis*, haciendo mas dificil para ellos a proveer suficiente comida para cría. Este factor es mas importante que una falta de nidos conveniente. La reducción de densidad de cazados, (por ejemplo, urogallo) puede ser asociada con forestales y es también un factor importante que puede afectar la cantidad de *Accipiter gentilis*.

[Traducción de Raúl De La Garza, Jr.]

The forests of Fennoscandia (Norway, Sweden, and Finland) have been used by man for a very long period of time. However, in the 1950s, a major change occurred in forest-management practices, including intensified methods based on clear-cutting, replanting and thinning. This practice gradually replaced the traditional way of harvesting forest by selective cutting. In Sweden, 58% of the land

area is productive forest which is very intensively managed. About 40% of this area has been clear-cut since 1950 and is now covered by forest established according to modern methods (Anonymous 1989).

As a result of this intensive management, the boreal forest landscape of Fennoscandia is now a highly fragmented patchwork of clear-cuts and for-



Table 1. Population studies showing goshawk density changes in boreal forests of Fennoscandia.

STUDY AREA	PERIOD	CHANGE IN BREEDING PAIRS	DENSITY CHANGE (pr/100 km <sup>2</sup> )
Central Norway <sup>a</sup>	1964–93	8 → 0	5.7 → 0
Southern Norway <sup>b</sup>	1950–84	13 → 5	7.2 → 2.7
Southern Norway <sup>c</sup>	1950–85	35 → 20	9 → 3
Southern Norway <sup>c</sup>	1985–88	20 → 26	3 → 4
North-central Sweden <sup>d</sup>	1950–76	12 → 5	2.4 → 1
Central Sweden <sup>e</sup>	1950–70	10 → 5	2 → 1
Central Sweden <sup>f</sup>	1960–80	35 → 15	35 → 15
Southern Finland <sup>g</sup>	1974–81	25 → 10	5 → 2
Southern Finland <sup>h</sup>	1977–84	16 → 10	5.3 → 3.3

<sup>a</sup> Tømmeraas 1993.

<sup>b</sup> Hansen 1985, Frydenlund Steen 1989.

<sup>c</sup> Selås unpubl. data.

<sup>d</sup> Carelius (1978).

<sup>e</sup> Bylin (1975).

<sup>f</sup> Lind (in Nilsson, 1981).

<sup>g</sup> Wikman and Lindén (1981).

<sup>h</sup> Forsman and Ehrnsten (1985).

est stands in different successional stages. Less than 5% of the Swedish forests are primeval, as compared to 22% and 60% of the forests in the U.S. and Canada, respectively (Olsson 1992).

The Northern Goshawk (*Accipiter gentilis*) occurs in forested areas throughout the Holarctic region (Brown and Amadon 1968), and is one of the more numerous birds of prey in Fennoscandia. The object of this paper is to review available information about goshawk population status and trends in the Fennoscandian countries and to discuss possible effects of modern forest management on those trends.

#### POPULATION STATUS

In Norway, the goshawk population was estimated to be 2700 breeding pairs (Bergo 1992). This is equivalent to 0.8 breeding pr/100 km<sup>2</sup> of land area and 3.1 pr/100 km<sup>2</sup> of forest area.

The Swedish goshawk population was estimated at 10 000 breeding pairs by Svensson (1979), based on a nationwide bird censusing program. However, Nilsson (1981) suggested that there were only 6000 breeding pairs after analyzing a number of different local studies. Marcström and Kenward (1981), based on capture-recapture estimate of ringed (banded) birds, calculated that the number of goshawk pairs older than two yr was between 3500 and

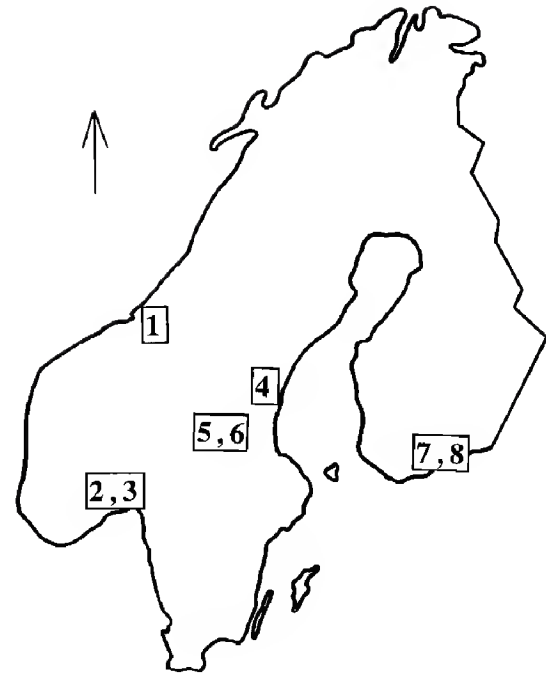


Figure 1. Map showing the location of goshawk population studies cited in the text. 1. Tømmeraas (1993), 2. Hansen (1985), Frydenlund Steen (1989), 3. Selås (pers. comm.), 4. Carelius (1978), 5. Bylin (1975), 6. Lind (in Nilsson 1981), 7. Wikman and Lindén (1981) and 8. Forsman and Ehrnsten (1985).

13 600. I judge the two latter estimates to be the most reliable and conclude that the Swedish goshawk population is about 7000 breeding pairs, which is equivalent to a breeding density of 1.9 pr/100 km<sup>2</sup> of land area and 2.9 pr/100 km<sup>2</sup> of forest area.

The goshawk population in Finland was estimated at about 6000 breeding pairs by Saurola (1985a), implying a breeding density of 2.0 pr/100 km<sup>2</sup> of land area and 3.0 pr/100 km<sup>2</sup> of forest area.

Thus, although the density per land area differs between the Fennoscandian countries, the density per forest area is virtually the same, about 3 breeding pr/100 km<sup>2</sup> of forest.

#### POPULATION TRENDS

The best way to study long-term population changes in raptors is to monitor a breeding population of a given area for a long period of time. By examining trends in individual populations, we should be able to make conclusions regarding trends over larger areas. In Fennoscandia, a number of such local, long-term goshawk population studies have been reported, and they are summarized in Table 1. The locations of the studies are shown in Fig. 1. A paired *t*-test between early and late years show a statistically significant decline ( $t = 3.474$ ,  $df = 8$ ,  $P = 0.0084$ ).

Thus, it is well documented from a number of

different, independent studies in all three Fennoscandian countries that goshawk populations have decreased from around 1950 to around 1980. In most studies, the decrease has been 50–60%. After that period, the pattern is less clear since most studies have not continued. However, the nationwide raptor monitoring scheme in Finland indicates stable populations after 1982, when the program started (Haapala et al. 1994), and Selås (pers. comm.) reports a temporary, slight increase in one area of Norway.

#### WHY HAS THE GOSHAWK DECLINED?

To determine the reasons for such a dramatic decline, we must look at all possible environmental factors, not only forest management. The factors most often associated with declining raptor populations are pesticides, persecution, declining prey populations and habitat degradation or loss (Newton 1979).

**Pesticides.** Most adult goshawks in the boreal forests of Fennoscandia are not migratory and remain in or close to the boreal forest throughout the year. Further, their most important prey species are also sedentary. Thus, they do not directly pick up contaminants from other regions, probably making them less vulnerable than other raptor species to pesticide contamination. However, juveniles and some adult females move south and winter in farmland areas (Widén 1985), where there is more prey, but also generally more pesticide use than in forested habitats.

**Mercury.** In Sweden, alkyl-mercury was used for seed dressing in agriculture from the 1940s until 1966, when it was prohibited. This use caused widespread contamination of the terrestrial fauna, and as a result many terrestrial bird species were seriously affected (Berg et al. 1966, Borg et al. 1969, Jensen et al. 1972, Westermarck et al. 1975, Johnels et al. 1979). Increased levels of mercury were found in breeding female goshawks' feathers in the period 1940–65, but decreased to background levels rapidly after alkyl-mercury was banned in 1966 (Johnels et al. 1979).

**Organochlorines.** A common way of assessing the impact of organochlorines on raptor populations is by measuring the eggshell thickness. Newton (1979) concluded that whenever a population showed more than 16–18% shell-thinning over several years, it declined. Nygård (1991) reported a 6.6% decrease in eggshell thickness in eggs from goshawks in Norway after 1947, a result that sug-

gests organochlorines have not been an important factor in their population decline.

Thus, although pesticide use has been reported as the cause of declines in goshawk populations in other parts of Europe (Bijlsma 1991), I conclude that there is no evidence that this has been the case in the boreal forest region. When the use of persistent pesticides stopped in the early 1970s, positive goshawk population trends were reported throughout Europe (Bijlsma 1991). In the boreal forest region, this has not occurred and goshawks did not recover when the pesticide situation improved. In fact, several population studies show that goshawks declined even after mercury levels dropped. This can be compared to the Sparrowhawk (*Accipiter nisus*), which decreased drastically in Sweden from the 1950s, but recovered markedly when organochlorines were prohibited in the 1970s (Wallin 1984).

**Persecution.** Goshawks have always been persecuted in Europe, especially in farmland areas by hunters wanting to protect small game species from predation. In Fennoscandia, this has mainly affected wintering juvenile goshawks. Locally, persecution also affected adult breeding birds since some hunters specialized in finding and destroying breeding goshawks. However, during the period of goshawk decline between 1950–80, legal protection has improved and there has been a gradual changing opinion favoring raptors, leading to reduced pressure of persecution. Accordingly, Saurola (1985b) reports a 50% decrease in goshawk persecution between 1960–80. Thus, persecution is not likely to be the major reason for goshawk decline in Fennoscandia.

**Prey Populations.** The goshawk feeds on a wide variety of prey species, but in the boreal forests of Fennoscandia different grouse species are the most important prey (Höglund 1964, Sulkava 1964, Tornberg and Sulkava 1990), although in winter squirrels (*Sciurus vulgaris*) may also be a major prey item (Widén 1987). It is well documented that goshawks respond numerically and functionally to short-term fluctuations in grouse populations (Lindén and Wikman 1980, 1983) and they are likely to respond also to long-term population changes.

Selås (pers. comm.) suggested that the goshawk decline was caused by a decline in forest grouse, due to a long-term increase in the number of generalist predators such as red foxes *Vulpes vulpes* (Storaas and Wegge 1985, Storaas 1993). The increase in goshawk numbers from 1985 in his area

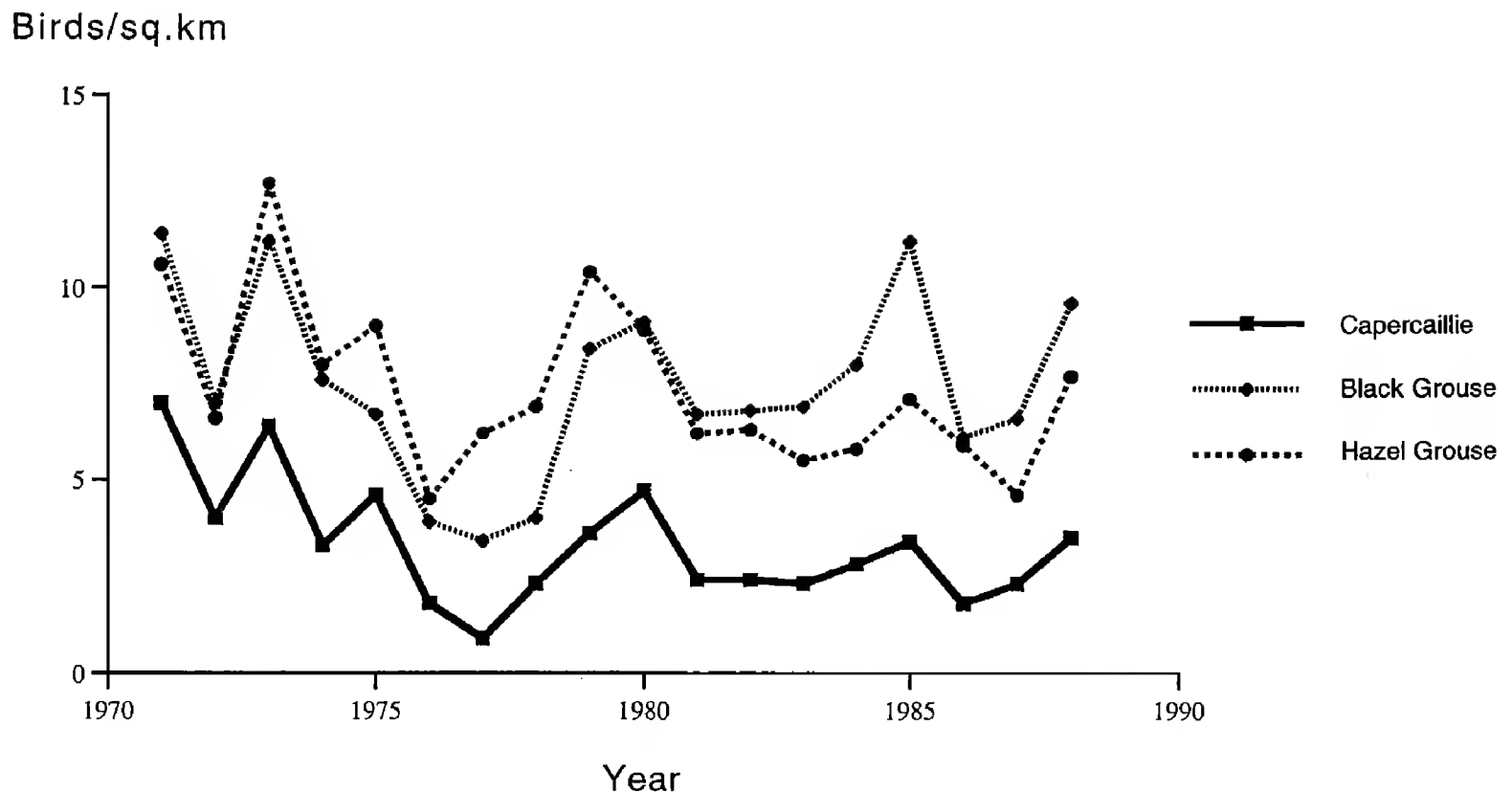


Figure 2. Population trends in forest grouse: Capercaillie (*Tetrao urogallus*), Black Grouse (*Tetrao tetrix*) and Hazel Grouse (*Bonasa bonasia*) in southern Finland (Finnish Game and Fisheries Res. Inst. unpubl. data).

was explained as a temporary reversal of this process, when the red fox drastically decreased due to sarcoptic mange, resulting in an increase in grouse numbers. However, the red fox is now recovering and there will probably not be any long-term effect on prey numbers. Thus, Selås explains the goshawk population changes as long-term numerical responses to changing prey populations.

Wikman and Lindén (1981) found that the goshawk decline coincided with a general decline in grouse numbers in the same area, but concluded that the rather moderate grouse fluctuations could not explain the 60% decline in the goshawk population. Grouse populations were very low in 1976–77 when the goshawk decline started. Although grouse numbers increased for a number of years after 1977, goshawks failed to respond numerically and still remain at a low population level. More recent grouse data (Finnish Game and Fisheries Research Institute unpubl. data) show a continuing downward trend in numbers of Capercaillie (*Tetrao urogallus*), Black Grouse (*Tetrao tetrix*) and Willow Grouse (*Bonasa bonasia*) in Finland (Fig. 2).

Thus, there is some indication that decline in prey populations, mainly grouse, is a factor involved in the long-term decline of Fennoscandian goshawk populations. Unfortunately, for most of the studies reporting goshawk decline, there are no good corresponding data on grouse populations, so it is un-

clear how general this explanation is. Further, the fact that the goshawks in southern Finland failed to respond to increasing grouse populations in the late 1970s and the early 1980s, indicates that the relationship between grouse and goshawks is not always a simple numerical response.

**Habitat Degradation or Loss.** Goshawk habitat can mean different things. Quite often it refers to nesting habitat (e.g., the site where the bird builds its nest and breeds). Less often it refers to the rest of the bird's living space (e.g., the home range that is used to find the food necessary for survival and raising of young). Here, I will cover both aspects, since both of them are important for goshawk survival.

*Nesting habitat.* Several reports (Carelius 1978, Forsman and Ehrnsten 1985, Hansen 1985, Frydenlund Steen 1989, Tømmeraas 1993) have indicated that goshawk population declines were mainly or partially due to the loss of nest sites during modern forest management.

The breeding habitat of Northern Goshawks has been described by several authors (Dietzen 1978, Reynolds 1983, Reynolds and Meslow 1984, Link 1986), and generally it is found that goshawks do not select nest sites randomly. Since nest sites are relatively easy to find and describe, there is a tendency to emphasize the importance of that part of the bird's environment, as compared to the much



larger home range. Goshawks need only a small patch of suitable habitat for nesting and successful goshawk breedings have been reported in forest patches as small as 0.4 ha (Lindell 1984). One goshawk nest was recorded in an isolated willow tree (*Salix alaxensis*) in Alaska, 145 km north of the tree line on the tundra (Swem 1992).

The reported habitat requirements may not be specific, observed relationships may not be causal and, if they are, they may not represent major restraints (Kenward and Widén 1989). Although lack of nest sites may become a problem on a local scale, it seems unlikely that it should become limiting on a larger scale for goshawk populations in boreal forests, even in strongly impacted systems. For example, the study area in central Sweden where Widén (1989) studied goshawk hunting habitats was an area with very intensive forest management, yet the proportion of mature forest suitable for nesting goshawks was about 24%.

I conclude that nesting habitat availability is not likely to be a major factor behind the recorded decline in goshawk numbers.

*Hunting habitat.* Goshawks move over large areas when hunting, and in Sweden home range sizes are between 2000–6000 ha (Kenward 1982, Widén 1989). Important clues regarding hunting habitat requirements might be found by taking a closer look at how the goshawk uses this landscape, especially where and how it hunts.

Widén (1989) studied goshawk hunting habitat with radiotelemetry in continuous coniferous forest in the boreal forest region of Sweden (Sjörs 1965), at Grimsö Wildlife Research Station. Of the area, 74% was conifer-dominated forests. Bogs and fens comprised 18% of the area and only 3% was farmland. Of the six different habitat classes, goshawks strongly preferred mature forest. Some hawks were monitored more intensively in order to record their predation, and results showed that most kills were made in mature forest, strongly indicating that this was the most important hunting habitat. It was also clear that goshawks preferred large patches of mature forest, although the preference for large patches was evident in the mature forest only. It was also in the large patches that most kills were made.

The goshawk hunts by making short flights between perches, where it stays for longer periods and from which nearly all attacks are made (Kenward 1982, Widén 1984). With such a hunting technique, it is obvious that hunting success de-

pends not only on prey density, but also on different habitat features that determine its ability to hunt. This may be a major factor behind their preference for hunting in mature forest. It is important for the hawk to reach perches undetected by prey and to remain undetected. At the same time, habitat must be open enough for the goshawk to maneuver and attack. The mature forest is the best compromise; prey in more open or denser habitat is less accessible. For example, goshawks avoided young forest, despite the fact that this habitat was preferred by one important prey species, the Black Grouse (Kolstad et al. 1985).

Due to forestry, the proportion of old, mature forest in Sweden has decreased (Svensson 1980) and the forest is being fragmented into smaller patches. Obviously, both trends may negatively affect goshawks in boreal Fennoscandia.

Kenward (1982) studied goshawk habitat utilization in three areas with mixed farmland/woodland in central Sweden, containing 41–61% woodland. In all areas, he found preference for forest as compared to farmland, although he did not separate successional forest stages. He also found a preference for forest edge. The forest patches he studied were surrounded by farmland where prey occurred, predominantly Ring-necked Pheasants (*Phasianus colchicus*) and European hares (*Lepus europaeus*). Goshawks used the forest edge as cover where they perched and from where attacks were launched.

In the Widén (1989) study area, the forest patches were mainly surrounded by forests in other successional stages (e.g., younger than the preferred mature forest). These younger stages offered no good hunting habitats for the hawks and thus the edges were not preferred.

#### DISCUSSION

**Effects of Forest Management.** Available data show that Fennoscandian goshawk populations have declined by 50–60% from the 1950s to the 1980s, and I have concluded that neither pesticides nor persecution can explain this decline, but that changes in prey populations and habitats are important factors. Further, it is striking that the decline coincided in time with forest-management intensification. Thus, we are left with the conclusion that forest management, acting in different ways, is a prime factor behind the goshawk decline. I suggest that large-scale changes in the boreal forest landscape, caused by modern forest management, has resulted in a deterioration of goshawk hunting

range quality, and that this, although difficult to measure, is more important than nest-site availability. When discussing habitat suitability, it is important to include prey accessibility and density in addition to nest-site availability. The goshawk requires prey that it is able to catch. To discover important hunting habitat requirements, one needs to know where raptors hunt and their hunting success in each place (Kenward and Widén 1989).

In Denmark, which is south of the boreal forest, the population trend seems to have been different. Here, the goshawk has increased from the 1960s until the beginning of the 1980s (Jørgensen 1989). This was explained as a result of decreased pressure from persecution and pesticides.

My conclusion that hunting habitats are more crucial than nesting habitats for goshawks in the modern forest landscape does not indicate that availability of good nesting habitat can be completely rejected as a possible limiting factor for goshawk populations. Since goshawks are territorial, with a regular spacing of nests (Widén 1985), they cannot breed close together, and therefore it is important how the patches of good nesting habitat are spaced.

Further, there must be more suitable habitat patches than are currently needed. New individuals recruited into the population must be able to find unoccupied sites. In order for the whole population to survive, sites that are temporarily unoccupied must be available for colonization by new breeders. A site that has become temporarily unoccupied is a potential resource for new breeders, which are recruited into the population. If unoccupied sites are destroyed because there are no longer any hawks there, we lose that possibility. A raptor population may go extinct because of a lack of nest sites, even if we never destroy a single occupied nest site, but destroy those that are temporarily unoccupied.

Declining prey populations can be an important factor, but the relationship between prey decline and forestry needs to be explained. Selås (pers. comm.) explains grouse number declines as an effect of increasing numbers of red fox, but does not explain why foxes have become more common. Forsman and Ehrnsten (1985) argue that the goshawk decline is due to modern forestry, affecting the goshawk in two different ways. Birds of optimal prey size (e.g., grouse) are becoming rarer and are being replaced with smaller birds. Second, good nesting habitat (e.g., mature forests) is becoming rarer. Wikman and Lindén (1981) argue that lack

of nesting habitat is not a problem, but that habitat destruction may act indirectly by depleting habitat for prey animals.

A general discussion about grouse populations in Fennoscandia is beyond the scope of this paper, but considering the effects that forestry has had on the forest landscape, it would be surprising if grouse have not been affected.

The goshawk problem in boreal forests cannot be solved by creating protected areas; they need areas too large to be effectively protected that way. We must concentrate on determining what is important for goshawks and use that knowledge to direct forestry practices that establish adequate protection.

**Recommendations.** First, when mature forest is fragmented by clear-cutting, the fragments should be as large as possible. It is generally better to make one large clear-cut than several small ones. Second, nest sites must be protected, even if they are unoccupied. A surplus of well-spaced patches of good nesting habitat is needed. Third, there must be enough forest with old-forest qualities in the landscape. Research is needed to determine how much is enough. Fourth, we need more research on the goshawk's hunting technique and hunting success in different habitats.

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## FOREST MANAGEMENT AND CONSERVATION OF BOREAL OWLS IN NORTH AMERICA

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**ABSTRACT.**—Boreal Owls (*Aegolius funereus*) in North America occur throughout the boreal forests of Canada and Alaska and in subalpine forests of the Rocky Mountains north of central New Mexico. A recent assessment of Boreal Owl conservation status in the western mountains of North America suggested that Boreal Owls were not in immediate peril. However, in the long-term and in selected local areas, Boreal Owls likely face conservation problems. This conclusion reflects the hypothesized response of Boreal Owls to the type and pattern of forest harvest that occurred in the past and may occur in the future. Over the last 40 yr, a majority of timber harvest occurred as clear-cutting that removed the older, more diverse forest stands. Forest structure influences the availability of suitable cavities, the quality of roost sites, the foraging movements of individual owls and prey availability. Components of mature and older forests are especially important to Boreal Owl habitat quality; the owls nest in large tree cavities and prey populations are most abundant in older forest stands. Clear-cut sites will remain unsuitable for roosting or foraging for a century or more and new nest trees will not develop in some situations for two centuries or longer. Timber harvest which maintains components of mature forest well dispersed across the landscape may be compatible with conservation of Boreal Owls. In particular, forest management must consider the consequences of management decisions across broad spatial scales and over a long-term horizon. Metapopulation modeling and experimentation through adaptive management will be necessary to develop timber harvest practices compatible with conservation of Boreal Owls.

**KEY WORDS:** *forest management; Boreal Owl; Aegolius funereus; woodpeckers; small mammals; adaptive management.*

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### Administración Forestales y Conservación de Búhos Boreal en Norte América

**RESUMEN.**—El Búho Boreal *Aegolius funereus* en norte américa ocurre en todas partes de bosques boreal en Canadá y Alaska y en bosques sub-alpino en las montañas Rocosas norte de centro Nuevo México. Una evaluación reciente del estado de conservación del Búho Boreal en las montañas del oeste en norte américa sugiera que el Búho Boreal no está en peligro inmediato. Sin embargo, en la larga duración, y en áreas seleccionadas en el local, Búho Boreal pueden encontrarse con problemas de conservación. Esta conclusión refleja la respuesta hipotesizada del búho boreal para el tipo y ejemplo de cosechas de bosque que ocurrió en el pasado y puede ocurrir en el futuro. En los últimos 40 años una mayoría de cosechas de madera ocurrió en el corte-completo que quito áreas de bosque maduros y de mas diversidad. La estructura de bosque influencia la disponibilidad de parcelas suficiente, la calidad de perchas, los movimientos de forraje de búhos solitarios, y la disponibilidad de cazar. Componente de bosques maduros y viejos son especialmente importante al hábitat del Búho Boreal: Los búhos hacen nidos en cavidades grandes de los árboles y poblaciones de cazar son mas abundante en parcelas de bosque viejas. Sitios cortados-completo se quedaran inconveniente para perchas o forraje para un siglo o más y árboles con nidos nuevos no se desarrollan en unos situaciones por dos siglos o mas. Cosecha de maderas que mantienen componente de bosques maduros bien dispersos a través el paisaje puede estar compatible con la conservación de Búhos Boreal. En particular la administración de bosques necesita considerar las consecuencias de las decisiones que hace a través de la escala de espacio amplio y sobre suficiente tiempo con perspectiva. Modelos de meta-población y experimentación a través de administración adoptivo va ser necesario para desarrollar costumbres compatible de cosechas de madera con conservación de Búhos Boreal.

[Traducción de Raúl De La Garza, Jr.]

The North American distribution for Boreal Owls (*Aegolius funereus*) forms a relatively continuous band extending from the Pacific to Atlantic coasts in the boreal forests of Alaska and Canada (Godfrey 1986). South of the continuous transcontinental band, disjunct populations occur in the

Rocky Mountains extending from Canada to northern New Mexico (Palmer and Ryder 1984, Hayward et al. 1987, Whelton 1989, Stahlecker and Rawinski 1990). Throughout this broad distribution the owl occurs in a variety of boreal and subalpine forests: conifer and mixed forests in Canada (Bondrup-Nielsen 1978), transition forests in Minnesota (Lane 1988) and subalpine forests in the Rockies (Hayward et al. 1993). Boreal Owl populations are intimately linked to the composition, structure and dynamics of these forests (Hayward and Hayward 1993, Hayward and Verner 1994). Therefore, the distribution and abundance of Boreal Owls may be strongly influenced by forest management practices.

How do populations of Boreal Owls respond to alternative approaches in forest management? In this paper I provide a perspective on the potential impacts of forest management on the owl. Forest management represents the human activity most likely to influence the long-term distribution and abundance of Boreal Owls. Among Holarctic raptors, Boreal Owls, at least in the North American Rockies, may represent the species whose ecology is most universally tied to the forest system. An understanding of the potential response of Boreal Owls to various changes in forest structure and dynamics is a critical step in designing management.

In the U.S., management of Boreal Owls has become an important task on public lands. Four National Forest Regions and the Superior National Forest which represent most of the species' range south of Canada have designated the Boreal Owl as a "sensitive species." Within the National Forest System, sensitive species are plants and animals whose population viability is identified as a concern by a Regional Forester. Sensitive species require special management and programs are underway to develop management plans for Boreal Owls (J. Friedlander pers. comm.).

Unfortunately, the knowledge needed to develop a sound management strategy may be lacking (Hayward 1994a). To date, only four major published investigations from North America provide the ecological basis for management planning (Bondrup-Nielsen 1978, Palmer 1986, Hayward et al. 1992, Hayward et al. 1993). None of these investigations represent experimental approaches to ecological questions, none of these was designed to directly address forest management issues and all extended for 4 yr or less—a temporal scale insufficient to address important issues in forest management or the ecology of a long-lived verte-

brate. The Boreal Owl in North America represents a classic example of uncertainty in wildlife management.

Over 14 yr ago, Romesburg (1981) admonished wildlife managers for the development of management plans built upon unreliable knowledge. Management built on poor science leads to a loss of credibility and poor resource management. Current understanding of Boreal Owl ecology and biology is poor. Management built on this foundation alone will invite criticism and loss of credibility. Recently though, Murphy and Noon (1991) discussed an approach to deal with the inherent uncertainty associated with management of a forest raptor, the Spotted Owl (*Strix occidentalis*). They advocate applying the hypothetico-deductive approach to management. Through a rigorous assessment of the assumptions that form the basis of management, they reduce the uncertainty clouding an evaluation of the efficacy of various management options. Walters' (1986) adaptive management concepts are another attempt to deal with the uncertainty that accompanies wildlife management.

My perspectives on forest management for Boreal Owls is guided by a philosophy that combines the concepts of the hypothetico-deductive method and Walters' adaptive management to develop management in the face of poor knowledge. Therefore the statements I make regarding the potential response of Boreal Owls to forest management, must be regarded as hypotheses. I would advocate the testing of these hypotheses through multi-scale experiments in the spirit of adaptive management.

To provide a perspective on forest management and Boreal Owls, I will review the conservation status of Boreal Owls in North America including a discussion of trends in forest management, examine our understanding of the ecology of Boreal Owls as it relates to the owl's potential response to forest management, present some hypotheses concerning how different forest management approaches may influence Boreal Owls on different geographic and temporal scales and provide some ideas concerning strategies to approach forest management for Boreal Owls.

The perspective I present is biased by the geographic limits of my field experience with Boreal Owls—I have worked in the Rocky Mountains. More important, the literature on Boreal Owl ecology in North America is limited. Literature from



Europe significantly broadens our understanding of the species. However, the ecology of Boreal Owls differs geographically within Europe (Korpimäki 1986) and within North America (Hayward et al. 1993). I suspect that the response of Boreal Owls to forest management differs between the Old and New Worlds and geographically within both.

Although our understanding of Boreal Owl ecology in North America is limited to three forest systems (one in each of northcentral Canada, central Idaho and northern Colorado), the Boreal Owl appears to occupy a variety of forest types. These forests range from deciduous and mixed forests to subalpine conifer forests (Meehan and Ritchie 1982, Palmer 1986, Lane 1988). The dynamics of these forests differ substantially due to differing patterns of forest growth and different disturbance regimes (Knight 1994). Likewise, Boreal Owl population dynamics, relationships with primary cavity nesters and relationships with prey populations differ among these forest types (Hayward 1994b). Therefore, the response of the owl to alternative forest management patterns almost certainly differs geographically. Any forest management scheme must be cognizant of the differences among the forest systems.

#### STATUS OF BOREAL OWLS IN NORTH AMERICA

Trends in population abundance or trends in habitat conditions are often used to assess status (Anderson 1991). In 1994, the U.S. Forest Service published an assessment of Boreal Owl status (Hayward and Verner 1994). That document concluded that Boreal Owls were not in immediate peril throughout their range but that over the long-term and in local areas over the short-term, Boreal Owls likely face significant conservation problems in the absence of conservation planning. To reach this conclusion the assessment examined evidence concerning trends in the distribution and abundance of the owl and the habitat relationships of the owl.

**Distribution and Abundance of Boreal Owls.** Little evidence exists to assess changes in the distribution of Boreal Owls in North America. Prior to 1979 the owl was not recognized as a breeding bird south of Canada (Eckert and Savaloja 1979). Since then numerous published reports have extended the recognized range of Boreal Owls in North America (Palmer and Ryder 1984, Hayward et al. 1987, Whelton 1989). Today, evidence exists for breeding populations throughout the Rocky Mountains south to southwestern Colorado and

northern New Mexico (Stahlecker and Rawinski 1990, Stahlecker and Duncan 1996). Do these records indicate an extension of the species range?

I suggest that the actual distribution of Boreal Owls has not changed recently, but our knowledge of distribution has increased because of an increase in survey effort. Historical records indicate that Boreal Owls were recorded in the western United States but not recognized as breeding. A closer look at the literature indicates that Boreal Owls were documented in Colorado for nearly 100 yr (Ryder et al. 1987). Despite the occurrence of Boreal Owls in the western U.S., checklists and field guides did not list the species even after breeding populations were documented in 1983. Biologists in Europe also located new populations of Boreal Owls during the past three decades and attributed these to increased interest in the species (Cramp 1977).

Direct evidence concerning trends in Boreal Owl abundance is completely lacking for North America. Breeding populations of Boreal Owls were only recently documented throughout most of the species' range in the U.S. Studies in North America generally have not focused on demography, precluding any assessments of trend in the near future. I am aware of only two populations (one in Idaho and one in Montana) that have been sampled using methods that will facilitate rigorous assessment of trends within the next 5 yr (Hayward et al. 1992). The prospects for assessing trends in the near future appear bleak.

**Abundance and Distribution of Important Habitats.** Information on trends in condition of forest habitats used by Boreal Owls offers an indirect method to infer population trends. Gathering and summarizing the necessary information at a broad geographic scale is not feasible for this paper. Furthermore, most statistics on timber harvest do not include the information necessary to evaluate the pattern in distribution and abundance of important forest types. For instance, stand-replacement harvests (clear-cuts) create stands without habitat value for Boreal Owls for a century or more, while partial cutting may leave stands with high habitat value if dominant trees are not removed. An objective evaluation of habitat trends relies not only on knowledge concerning recent timber harvest but knowledge on succession of lands that experienced large disturbance events 100–150 yr ago.

Maybe more important than the problems with describing impacts from past harvest are the diffi-



culties in predicting future harvest. As the availability of timber has declined on lower elevation forest lands in western North America, focus is shifting to high elevation spruce-fir forests used by Boreal Owls. Furthermore, the rules regulating timber harvest in the U.S. have changed recently regarding salvage after fire (U.S. Public Law 104-19). The consequences of these changes are difficult to predict. As they might say in a prospectus, the extent of future harvest and therefore impact on Boreal Owl habitat may not be related to past trends.

**Summary.** There is little direct evidence concerning trends in North American Boreal Owl populations. In a Boreal Owl conservation assessment (Hayward 1994c), evaluation of habitat use patterns, life history and trends in habitat condition were used to infer owl trends.

#### HABITAT RELATIONSHIPS OF BOREAL OWLS

I review the habitat relationships of Boreal Owls. My goal is to establish the relationship between the owl and the forest to form hypotheses concerning the potential response of Boreal Owls to forest management.

Habitat relationships of Boreal Owls and habitat relationships of principal prey species will, in large part, dictate the potential response of Boreal Owls to timber management. The realized impact of forest management in a particular situation will be determined by the interaction of habitat relationships of the owl and prey populations mediated by those factors currently limiting population growth. Nesting habitat conditions (especially cavity availability), prey availability (winter and summer) and microclimatic conditions related to owl thermoregulation likely limit the distribution and abundance of Boreal Owls in different populations (Hayward 1994b). Management that focuses on these limiting factors, after examining evidence suggesting which factor may be most critical in a particular setting, will most effectively target management actions.

As I have emphasized, the ecology of Boreal Owls varies geographically. For instance, daily and annual movement patterns, relationship with principal prey populations, population stability and limiting factors vary from the boreal forests of Canada to southern New Mexico (Hayward et al. 1993). Despite this variation, Boreal Owls are forest owls throughout their range and their ecology is linked to forest habitats with particular structural

characteristics. I also consider nesting, roosting and foraging habitat separately because each of these may be limiting in different management settings. I will review the evidence describing the link between forest conditions and Boreal Owl populations. In my review I move from fine scale habitat characteristics to more broad scale relationships.

**Fine Scale Habitat Relationships.** *Nesting habitat.* The requirement for a large tree cavity constrains the range of sites used by Boreal Owl for nesting habitat. As secondary cavity nesters, boreals are intimately linked with the organisms and processes associated with formation of large tree cavities. An envirogram (Andrewartha and Birch 1984) emphasizes the linkage between forest structural conditions, primary cavity nester populations (woodpeckers), forest insects and pathogens (Fig. 1). The elements of the centrum relate directly to the owl while the web depicts components of the system important to maintaining the centrum. Elements of this envirogram are forest characteristics associated mainly with the presence/absence of suitable nesting cavities.

Beyond cavity availability, observations in the Rocky Mountains suggest that forest structural characteristics are important in nest-site selection. In Idaho, comparisons of forest structure at nest sites and random sites indicated use of stands with mature and older forest structure. Forest structure at nest sites differed from the random sample (101 sites) of available forest. Used sites occurred in more complex forest, with higher basal area, more large trees and less understory development than available sites (Hayward et al. 1993). Also in Idaho, a small nest-box experiment evaluated whether choice of nest sites is driven solely by cavity availability or if forest structure per se is important when a range of alternatives are available (Hayward et al. 1993). In this experiment nest boxes were hung in three forest types that differed significantly in structural characteristics. Owls used boxes in two forest types with complex structure (e.g., multiple canopy layers, many tree size classes) but did not use boxes in the forest type with a more simple structure (e.g., single canopy layer, more uniform tree diameters). Based on our observations I hypothesize that forest structure is important in an indirect way. Owls first search for nest sites in forests of a particular structure because the probability of finding cavities is highest in those types. So selection of old forest for nesting may be

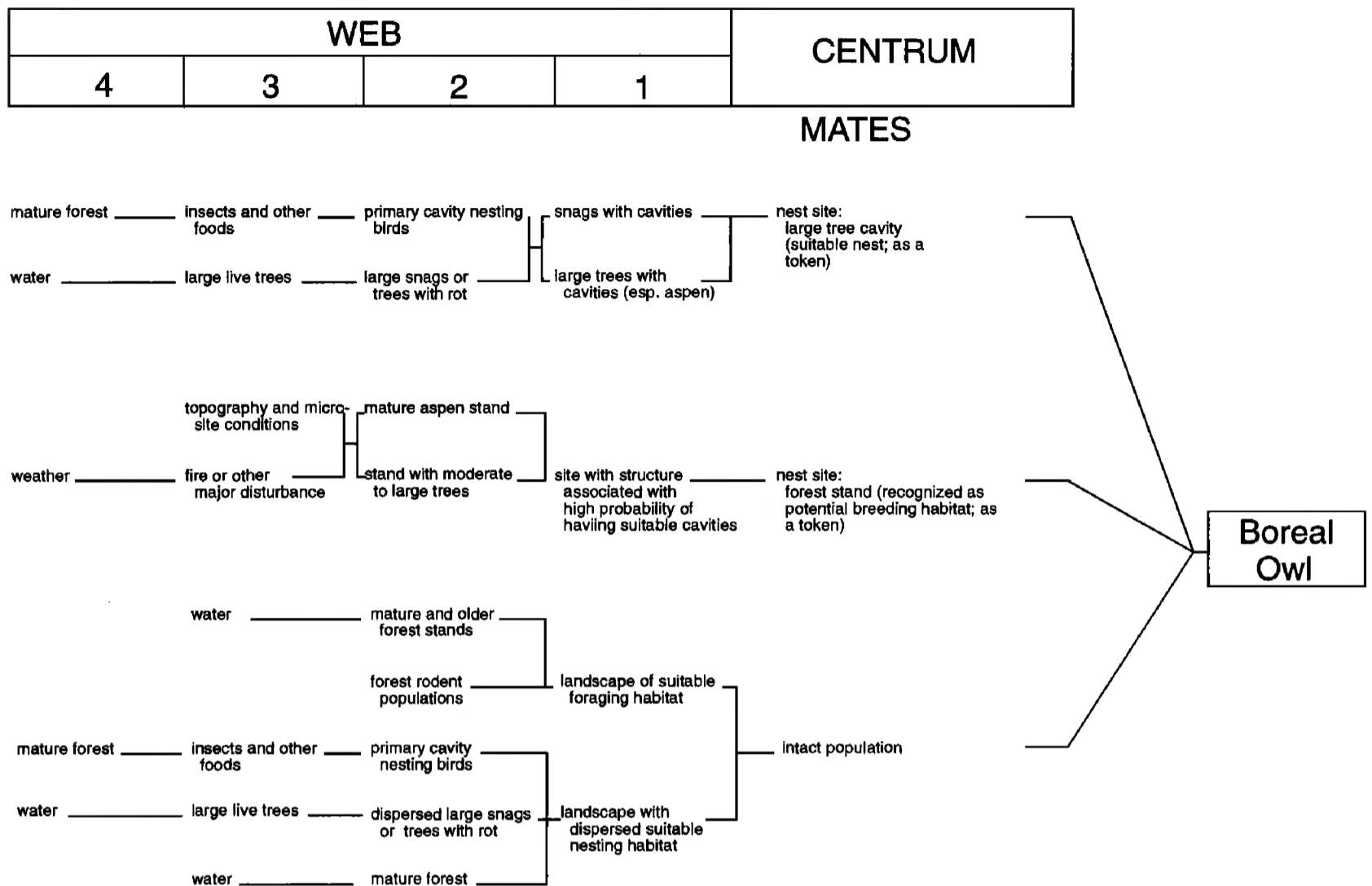


Figure 1. Envirogram (Andrewartha and Birch 1984) illustrating the relationship between Boreal Owls and specific components of the forest system. This portion of a larger envirogram (Hayward 1994b) focuses on Boreal Owl nesting ecology.

based more on efficiency in finding a cavity than increased survival after locating a nest.

The same studies in Idaho suggest that patch size may not be an important characteristic of nest stands. Nest stands ranged in size from 0.8 to 14.6 ha and averaged 7.6 ha.

*Roosting habitat.* Patterns of roosting habitat use also suggest these owls choose forests with particular structural features during certain times of the year. In Idaho, forest structure at summer roost sites differed substantially from paired random sites. Roost sites had higher canopy cover, basal area, and maybe most important, were significantly cooler microsites (Hotelling's  $T^2$ ,  $P < 0.001$ ) (Hayward et al. 1993). In summer, and particularly in the southern portion of their range, Boreal Owls find roost sites to minimize heat stress. We witnessed owls gular fluttering and other behaviors associated with heat stress when the temperature was as mild as 18°C. I hypothesize that the elevational distribution of Boreal Owls in the Rockies may be determined, in part, by summer tempera-

tures and the availability of cool microsites for roosting. Forest structure, then, may influence the distribution of Boreal Owls through an interaction with limitation by heat stress.

*Foraging habitat.* A variety of evidence suggests that Boreal Owls in the Rockies forage principally in mature and older forest, especially spruce-fir forests (Hayward 1987). These observations are corroborated by evidence that red-backed voles (*Clethrionomys gapperi*) represent a dominant prey for Boreal Owls throughout their range in North America (Bondrup-Nielsen 1978, Palmer 1986, Hayward and Garton 1988, Hayward et al. 1993). Red-backed voles are principally forest voles (Hayward and Hayward 1995). Our studies of small mammals in Idaho found redbacks were up to nine times more abundant in mature spruce-fir forest than other forest habitats (Hayward et al. 1993). The argument for the importance of mature forest for foraging stems also from observations of snow characteristics in openings, young forest and mature forests. Snow crusting is significantly reduced

in mature forests facilitating access to small mammals during critical winter periods (Sonerud 1986, Sonerud et al. 1986). In Idaho, mortality and significant movement events most often occurred during warm winter periods when snow crusting became severe.

An envirogram further emphasizes the link between Boreal Owl foraging habitat and particular features of the forest, especially features linked with mature forests (see Hayward 1994b). The envirogram illustrates the indirect tie between Boreal Owl fitness and abundance of lichen, fungi and *Vaccinium* ground cover—all of which can be influenced by various forest management practices.

The evidence regarding habitat use for nesting, roosting and foraging in the Rockies suggests that at a fine scale, Boreal Owls rely on particular characteristics of mature and older forests. This relationship suggests that forest management at the level of stands will likely influence abundance of Boreal Owls.

**Landscape Scale Habitat Relationships.** Analysis of patterns of Boreal Owl abundance in relation to landscape patterns is not available for North America. Indirect evidence from Europe and North America suggests that Boreal Owls differentiate among forest habitats at the landscape scale. Our observations of owls in Idaho suggest that landscapes dominated by mature spruce-fir forest or those with mature spruce-fir juxtaposed with mature larch (*Larix sp.*), ponderosa pine (*Pinus ponderosa*) or aspen (*Populus tremuloides*) sites will have the greatest abundance of boreals (Hayward et al. 1992, 1993). In other words, an interspersed of forests that generally support high density of cavities in mature spruce-fir forest will provide quality habitat.

More direct evidence from Europe supports the notion that landscape scale forest cover influences Boreal Owl density and productivity. As the proportion of Scotch pine (*Pinus sylvestris*) forest decreased and the proportion of Norway spruce forest (*Picea abies*) and agricultural land increased, quality of territories (those with more frequent nesting) increased (Korpimäki 1988). The conclusion that territories with spruce forest and agricultural land (in small patches) were the highest quality habitat was corroborated by evidence on breeding frequency and clutch sizes.

**Regional Scale Habitat Relationships.** At very broad geographic scales, distribution patterns of Boreal Owls may also have important implications

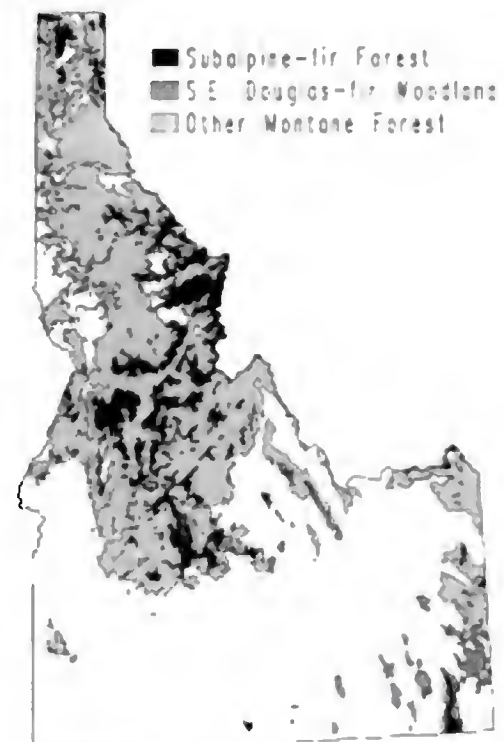


Figure 2. Pattern of potential Boreal Owl habitat in Idaho suggesting the distribution of a portion of the metapopulation extending along the Rocky Mountains. Potential habitat is defined as forested sites in the subalpine-fir zone throughout the state and Douglas-fir woodland in southeastern Idaho. Other montane forests are not considered potential habitat (adapted with permission of *Wildl. Monogr.* from Hayward et al. 1993).

for management. In portions of the boreal forest, distributions of Boreal Owls may be quite continuous. Along the southern and northern borders of the boreal forest and in the Rockies, the owl may occur in an interesting geographic pattern which likely results in a strong metapopulation structure (Hayward et al. 1993). In Idaho, patches of suitable habitat occur throughout the mountainous landscapes in a wide range of patch sizes (Fig. 2). Assuming that subpopulations of owls occupy habitat as hypothesized in Figure 2, the metapopulation structure of the owl in the region is a complex mix of subpopulations. Because of this structure, management of forest at the scale of individual national forests may have important implications for neighboring national forests over a broad geographic region.

#### HYPOTHESES: BOREAL OWL RESPONSE TO FOREST MANAGEMENT

**Stand-Replacement Harvest.** The importance of mature forest to Boreal Owls for nesting, roosting and foraging suggests that the short-term impact of stand-replacement harvest (clear-cut) will be negative. Open habitats as well as young, even-age forests provide few resources for Boreal Owls. Fur-



thermore, these habitats generally do not enhance habitat for woodpeckers or small mammals. Large clear-cuts appear to provide no resource values for Boreal Owls except along edges where owls may capture prey (Hayward 1994b). However, impacts will depend upon the size and spacing of cuts and the forest type being harvested. Furthermore, long-term impacts may not parallel short term response.

I hypothesize that small, patch clear-cuts implemented with long rotations may not negatively impact Boreal Owl habitat over the short- or long-term. Boreal Owls generally attack prey within 30 m of a perch (Hayward et al. 1993), so most of a 1–3 ha patch cut will be accessible for foraging. Furthermore, in small patch cuts, ground cover, which could reduce prey availability, often does not change significantly from that found under the forest, snow crusting affects only a small proportion of a small forest opening and small patch cuts emulate, to some extent, the landscape structure of mature spruce-fir forests (Knight 1994). In cases where small patch cutting is employed, I hypothesize that potential negative impacts will be reduced if the patch cutting is concentrated in a portion of each watershed rather than dispersed throughout entire watersheds and mature forest remains in the matrix between cuts.

Larger clear-cuts in conifer forest most often will reduce habitat quality for 100 to 200 yr. However, clear-cutting of aspen may be important in maintaining the long-term availability of cavities in some systems. In many forest systems aspen is a pioneer species that is lost through succession (DeByle and Winokur 1985). Restoration of aspen forests through silviculture may be an important management tool to maintain Boreal Owl habitat in forest systems where aspen provides a majority of the nesting habitat. Through coordinated timber harvest, large aspen which provide cavities for nesting may be maintained over the long-term, at the landscape scale, despite loss from individual stands. Focus on aspen management may even be more important in systems where aspen occupies a small proportion (<1%) of the landscape and occurs in small patches associated with particular microsites.

The shape of clear-cuts will likely influence both the short- and long-term impact on Boreal Owls. Although no direct evidence is available, I hypothesize that more complex shaped cutting units, especially those with stringers of forest extending into cutting units in upland areas, riparian buffers

and patches of forest remaining within the cut unit, will have fewer negative impacts than large rectangular or circular cuts. This hypothesis stems from the pattern of habitat use by Boreal Owl prey species (Williams 1955, Merritt 1981, Wells-Gosling and Heaney 1984) and observations that Boreal Owls will nest in small patches of forest (G. Hayward unpubl. data).

Based on the same arguments, sloppy clear-cuts (clear-cuts with residual standing dead and live trees, especially aspen and patchy slash), and cuts that retain standing and downed wood on the site, will have fewer negative impacts, especially over the long-term. The mitigating qualities of retaining patches of live trees and shrubs, snags and woody debris arise from several factors. These elements will accelerate the rate at which the future stand attains mature and older forest characteristics (Knight 1994). In particular, recovery of fungi and lichen populations may be accelerated by maintenance of residuals (Ure and Maser 1982, Hansen et al. 1991).

**Partial Cutting and Uneven-Age Management.** Discussion of sloppy clear-cuts or irregular shelter-wood prescriptions leads logically to discussion of partial cutting and uneven-age regeneration prescriptions. I hypothesize that group selection (harvest of small groups of trees in an uneven-age stand, maintaining the uneven-age properties) may not significantly reduce Boreal Owl habitat quality in many situations if, over the long-term, mature and old forest qualities are maintained and tree species composition does not exclude important cavity trees. Timber harvest prescriptions such as group selection and single tree selection (harvest of individual trees from an uneven-age stand in a pattern that maintains the size structure of the original stand) that retain forest structure, are compatible with developing owl nesting habitat. Thinning from below (harvest which removes individuals smaller than the dominant size class) and single tree selection that reduces competition among dominant trees and increases tree growth, could accelerate the process of developing suitable nest structures. While clear-cutting eliminates red-backed voles in Rocky Mountain forests (Campbell and Clark 1980, Scrivner and Smith 1984, Ramirez and Hornocker 1981), preliminary results of an experiment examining clear-cuts and group selection harvests indicate that red-backed voles remain abundant in partial cut stands when many large

trees are retained and ground disturbance is minimal (G. Hayward unpubl. data).

**Broad Scale Predictions.** Predicting the response of Boreal Owls to differing landscape scale patterns is more difficult. The lack of information on patterns of Boreal Owl abundance at the landscape and broader scales precludes extensive predictions at broad scales. I would argue that a primary focus of adaptive management approaches should be at this scale.

The issue of fragmentation seems to dominate much of the discussion of landscape scale impacts, so preliminary predictions regarding fragmentation may be useful in stimulating inquiry. In referring to potential response to fragmentation, I explicitly separate the influence of habitat loss from the influence of increased landscape heterogeneity. Fragmentation effects result from the process of changing the characteristics of the landscape mosaic and must be considered after eliminating the direct influence of reducing habitat area.

The high mobility and the extensive areas used on a daily basis by Boreal Owls suggests they may react to fragmentation differently from passerines. For instance, timber harvest of 30% of a basin through clear-cutting mature lodgepole pine (*Pinus contorta*) in 1–5 ha patches dispersed throughout the area may not significantly reduce habitat quality if the remaining forest is dominated by mature and older spruce-fir forest. The forests used by Boreal Owls exhibit a patchy mosaic under natural disturbance (Knight 1994). In a natural forest mosaic, owls move between distant patches on a daily basis (Hayward et al. 1993). This hypothesis assumes that timber harvest would not significantly reduce small mammal populations in the unharvested stands.

Aside from fragmentation, it is important to consider the impact of harvest schemes that target different forest types: aspen, lodgepole pine or old spruce-fir forests. I hypothesize that the negative impacts of any stand replacement harvest scheme will be decreased if stands of mature and older spruce-fir or aspen forest remain dispersed throughout the landscape.

Predicting the consequences of management at the broadest spatial scales is challenging. Conservation strategies at the regional scale should focus on maintaining the continuity of Boreal Owl metapopulations. This involves identifying subpopulations and landscapes that likely play key roles in the persistence of owls within the region and

neighboring regions. These subpopulations would receive special attention to assure that management actions either favored the owl or did not negatively impact the subpopulation. Spatial modeling and good information on dispersal will be necessary to make sound management predictions at this scale.

#### STRATEGIES TO APPROACH FOREST MANAGEMENT FOR BOREAL OWLS

I began this discussion by emphasizing the extent of uncertainty in our understanding of Boreal Owls and noted the substantial geographic variation in Boreal Owl ecology across North America. In combination, these factors produce a discouraging management environment where predictions must be made tentatively. Therefore, the response of Boreal Owls to forest management was framed as a series of hypotheses to be tested and likely only testable through adaptive management. Despite the degree of uncertainty and the extent of geographic variation, I believe some general points can be made concerning approaches to forest management and planning for Boreal Owls.

**Limiting Factors.** Site-specific forest management for Boreal Owls must consider the factors most likely limiting the population in a particular setting. Thermal stress likely limits the elevation distribution of Boreal Owls in the central and southern Rocky Mountains. Therefore, availability of cool microsites, which often occur in mature and older forests, may be important in many regions.

The availability of nest cavities and prey likely limit populations of Boreal Owls in different situations. In regions with few or no Pileated Woodpecker (*Dryocopus pileatus*) or Northern Flicker (*Colaptes auratus*) cavities, nest-site availability will limit Boreal Owl abundance. Even within the geographic range of Pileated Woodpeckers, the absence of these woodpeckers at higher elevations may limit Boreal Owl abundance (Hayward et al. 1993). If cavity availability limits Boreal Owl populations, management of primary cavity excavators as well as the forest processes that support large snags will influence Boreal Owls.

In some forests, cavities are abundant and prey availability may play a strong role in Boreal Owl population dynamics. It is unclear whether absolute abundance or variation in prey populations is more important in owl population regulation. However, small mammal populations appear to be



linked to forest conditions (Hayward and Hayward 1995) and forest management will influence the abundance of potential prey, and in turn, affect owl population persistence. Forest structure will also influence the availability of prey by changing owl access to prey. For instance, forests with dense ground cover or a high density of small trees will reduce the efficiency of foraging Boreal Owls. Furthermore, forest structure affects snow conditions which influence prey availability (Sonerud 1986).

Cavity availability and prey availability likely interact to influence Boreal Owl population growth. Tree cavities occur nonrandomly across the landscape as do small mammal populations. The spatial arrangement of cavities and prey (relative to one another) are important in determining Boreal Owl abundance. The conservation status of Boreal Owls will be intimately tied to the interaction of these resources.

While cavities and prey likely limit Boreal Owl populations in most landscapes, predation and competition may influence populations in certain circumstances. In local situations, mustelids destroy a high proportion of owl nests in some years (Sonerud 1985). The influence of these losses on population abundance is unknown. Evidence also indicates that interactions with other owls may influence the distribution of Boreal Owls suggesting that competition may be an important limiting factor in some situations (Hakkarainen and Korpi-mäki 1996).

**Boreal Owl Management Within Ecosystem Management.** In western North America the ecology of Boreal Owls is linked with many characteristics of mature and older spruce-fir forests (Hayward 1994b). Management which facilitates the long-term maintenance of a landscape with significant representation of mature and older forest habitat will provide quality Boreal Owl habitat. Therefore, management schemes which promote the processes that maintain productive spruce-fir forests, and management which facilitates the stand dynamics necessary to produce old spruce-fir forest, will provide the habitat characteristics necessary for Boreal Owls. As indicated earlier, this is not incompatible with timber harvest.

Most applications of ecosystem management strive to manage systems to emulate natural disturbance patterns and processes. As reviewed by Knight (1994), spruce-fir forests experience a variety of disturbance agents that act at scales ranging from single trees to hundreds of hectares. De-

velopment of old forest conditions following stand replacement disturbance proceeds slowly; succession to mature forest conditions takes >150 yr. However, old forest stands represent a mosaic resulting from the frequent action of small scale disturbance. Partial cutting emulates (to some extent) insect mortality and windthrow, two common disturbances integral to the formation of old spruce-fir forest structure. Alexander (1987:59) indicated that "uneven-aged cutting methods—individual tree and group selection—have seldom been used in spruce-fir forests, they appear to simulate the natural dynamics of these forests." Therefore, careful harvest of trees from spruce-fir forest may not be incompatible with maintaining important elements of old forest and habitat characteristics linked with Boreal Owls.

The paucity of information available on the response of Boreal Owls to specific forest management actions presents an obstacle to the formulation of management within an ecosystem framework. A strong conservation strategy for Boreal Owls cannot be produced without new knowledge on Boreal Owl ecology. Management based on current knowledge must contend with uncertainty and be devised specifically to deal with this uncertainty. Adaptive management (Walters 1986), then, must be built into any approach to manage the species, particularly an ecosystem management strategy.

#### CONCLUSIONS

Based on my review of the habitat relationships of Boreal Owls and management considerations, I offer the following conclusions: (1) Maintaining Boreal Owls on a local scale is not incompatible with timber harvest but is incompatible with extensive, stand replacement silviculture implemented over entire watersheds, employing large cutting units; (2) Forests with high habitat value for Boreal Owls develop through long successional trajectories. Therefore forest management must consider long-term forest patterns on broad spatial scales; (3) The hypothesized metapopulation structure of Boreal Owls in North America suggests that forest management must be coordinated at a regional scale; (4) Adaptive management which links managers and research ecologists is necessary to produce the knowledge needed to understand the response of Boreal Owls to alternative management approaches at a variety of spatial scales; (5) As a top carnivore that preys upon the dominant small mammal species in subalpine forests and nests in



large tree cavities, the Boreal Owl integrates into its ecology many aspects of forest dynamics. As such, the owl may represent a good model to aid in developing ecosystem management; (6) At all spatial scales, an eye to restoration management must be taken in landscapes that have experienced intensive harvest in the past. Restoration may be particularly appropriate in aspen forests of the Rocky Mountains.

Forest management which sustains mature subalpine and boreal forests likely will conserve Boreal Owls. Such management, however, must consider (among other things) the successional dynamics of spruce-fir forests including the detritus food chain, the consequences of various disturbances and the long-term (post-glacial) trends in these forests. Management must focus as much on the long-term condition of the plant communities used by Boreal Owls as on the population dynamics of the owl.

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## BOREAL OWL RESPONSES TO FOREST MANAGEMENT: A REVIEW

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**ABSTRACT.**—Modern forestry during the last decades has strongly increased fragmentation of forest habitats. This may result in harmful effects on raptor species which are strictly dependent on boreal forests, such as the vole-eating Boreal Owl (*Aegolius funereus*). The long-term data from Finland shows that in extensive forest areas, fledgling production of Boreal Owls is higher on intensively clear-cut territories than on less clear-cut territories. Breeding frequency, clutch size and laying date, however, have not been shown to be related to the proportion of clear-cut areas within a territory. Snap-trapping data suggests that large clear-cut areas sustain more *Microtus* voles than small clear-cut areas. The increased number of saplings and clear-cut areas during the last two or three decades has created new suitable grass habitats for *Microtus* voles, and simultaneously new hunting habitats for Boreal Owls. There is some experimental evidence that the presence of the Ural Owl (*Strix uralensis*) decreases the breeding density of Boreal Owls within 2 km of Ural Owl nests. Therefore, forest fragmentation does not seem to harm Boreal Owls at the present day scale, but a lack of nest holes has to be compensated for by setting nest boxes far (>2 km) from medium-sized and large raptors that can prey upon the Boreal Owl. In the long-term, however, establishment of snags and patches of mature forests with large trees, dense enough to satisfy the ecology of the hole-nesting Black Woodpecker (*Dryocopus martius*), will provide a natural way to establish new nesting cavities for Boreal Owls.

**KEY WORDS:** *Aegolius funereus*; *Strix uralensis*; *clear-cuttings*; *modern forestry*; *vole density*.

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### Respuesta del Búho Boreal a la Administración Forestal: Un Reviso

**RESUMEN.**—El forestal moderno durante los últimos décadas ha aumentado con frecuencia la fragmentación de hábitat de bosque. Esto puede resultar en efectos dañosos en especie de rapaces que están estrictamente dependiente en bosques boreal, como el Búho Boreal (*Aegolius funereus*) que come ratones. La información de Finlandia enseña que larga duración en áreas de bosques enormes, la producción de pajaritos de búhos es más alto en territorios cortados-completo con intensidad que en territorios menos cortados-completo. La frecuencia de cría, tamaño de nidada, y la fecha de poner, no han enseñado estar relacionado a la proporción de áreas cortadas-completo entre el territorio. Información de trampas sugiere que áreas grandes que están cortadas-completo sostienen mas ratones, y simultáneamente hábitat nuevo para cazar para los búhos. Hay un poco de pruebas experimental que la presencia de Búho Ural (*Strix uralensis*) reduce la densidad de cría del Búho Boreal dentro de 2 km del nido del Búho Ural. Por lo tanto, la fragmentación del bosque no parece ha cerle daño al Búho Boreal en la escala presente, pero la falta de nidos de agujero necesita que estar compensado con poniendo nidos de agujero lejos (>2 km) de rapaces medianos y grandes que pueden cazar a los búhos boreal. En la larga duración el establecimiento de tocones y parcelas de bosque maduros con árboles grandes, de suficiente densidad para satisfacer la ecología de los nidos de agujero de el Carpintero Negro (*Dryocopus martius*), va proporcionar una manera natural para establecer cavidades de nidos nuevos para el Búho Boreal.

[Traducción de Raúl De La Garza, Jr.]

During the last decades, modern forestry has had a strong and perceivable impact on boreal forest ecosystems, both in Palearctic and Nearctic regions. At the landscape level, there is a lack of large pristine forests (Ohmann et al. 1988), while remaining mature forest patches have become internally more homogeneous and more isolated

from larger forest complexes (Hansson 1992). Raptors living in forest habitats are generally considered to be one of the most sensitive groups of vertebrates to forest management and habitat change (Newton 1979, Forsman et al. 1984, Carey et al. 1992). This is at least in part because raptors inhabit large territories (Newton 1979) where as top



Table 1. Annual breeding percentage of nest boxes, laying date (1 = 1 April), clutch size and fledgling production in sparsely and widely clear-cut territories of Boreal Owls in the Kauhava region, western Finland (ca 63°N, 23°E). Statistical tests were performed by Student's *t*-test and Mann-Whitney *U*-test (two-tailed). *N* = number of territories.

	PROPORTION OF CLEAR-CUT AREAS WITHIN TERRITORY						TEST VALUE	<i>P</i>
	LOW <sup>a</sup>			HIGH <sup>b</sup>				
	$\bar{x}$	( $\pm$ SD)	<i>N</i>	$\bar{x}$	( $\pm$ SD)	<i>N</i>		
Breeding percentage	15	(9)	17	14	(15)	13	<i>U</i> = 139.0	0.22
Laying date	1.41	(19.44)	14	1.10	(21.98)	10	<i>T</i> = 0.04	0.97
Clutch size	5.43	(0.88)	14	5.20	(1.26)	11	<i>T</i> = 0.54	0.59
No. of fledglings	2.45	(1.26)	14	3.55	(1.39)	11	<i>T</i> = 2.06	0.05

<sup>a</sup> 18% (SD = 7%, range = 10–30%) of total area within 1.5 km of nest was clear-cut.

<sup>b</sup> 49% (SD = 11%, range = 35–70%) of total area within 1.5 km of nest was clear-cut.

carnivores capture prey which is scarce and difficult to catch (Temeles 1985). Therefore, they expend considerable energy in each feeding event, especially if prey is sparsely and patchily distributed within the territory. In addition, due to forest harvesting, there often is a lack of suitable nesting places, such as natural cavities and large nesting trees for many raptor species.

The Boreal Owl (*Aegolius funereus*) is a small nocturnal hole-nesting raptor which commonly breeds in coniferous forests in northern Europe (Mikkola 1983). *Microtus* voles (field vole, *Microtus agrestis*; sibling vole, *M. rossiaemeridionalis*; and bank vole, *Clethrionomys glareolus*) are the main prey of this species (Korpimäki 1988). Field and sibling voles inhabit fields as well as clear-cut areas, whereas the bank vole inhabits mainly forest habitats (Hansson 1978). In poor vole years alternative food sources have to be used, such as shrews (*Sorex* spp.) and small passerine birds (Korpimäki 1988). Males are resident after the first breeding attempt, while females disperse widely (up to 500 km) between successive breeding attempts (Korpimäki et al. 1987).

In this review, we focus on how clear-cut areas in Boreal Owl territories affect reproductive output and breeding frequency of this species. We also discuss how clear-cut areas affect the main prey densities of Boreal Owls. Finally, we identify how interspecific interactions have to be considered when setting new nest boxes for owl species that suffer from the lack of natural cavities. This review is based on recent investigations (Hakkarainen and Korpimäki 1996) and on snap-trapping data which are now examined especially from the perspective of forest management.

#### THE EFFECTS OF CLEAR-CUT AREAS ON BOREAL OWLS

The long-term study (1981–95) conducted in the Kauhava region of western Finland made it possible to evaluate the effects of clear-cut areas on the Boreal Owl. These areas comprise clear-cut areas with 0.2–1.5 m high saplings (<10-yr old) covering about one-third of the forests in our study area. Boreal Owls breeding in areas that are primarily forested with a mean of 18% (SD = 7%, range 10–30%) (herein referred to as sparsely clear-cut) of the total forest area clear-cut within 1.5 km of nests produced about one fledgling less than those in areas with a mean of 49% (SD = 11%, range 35–70%) of the area clear-cut (herein referred to as widely clear-cut) (Table 1). Most of the territories and areas sampled within sparsely clear-cut areas were small cuts of <10 ha with most areas between 1–5 ha. In contrast, in the territories sampled within the widely clear-cut areas, most were relatively large cuts of up to 200 ha. In addition, territories within the widely clear-cut areas exhibited relatively high fledgling production ( $\bar{x}$  = 3.6) for Boreal Owls (Korpimäki and Hakkarainen 1991). Territories in both clear-cut areas were occupied with equal frequency in different vole years (Table 2), indicating that Boreal Owls breed successfully in the neighborhood of large clear-cuts also in low vole years. Clutch size, breeding frequency and laying date, however, were not affected by the proportion of clear-cut areas within a territory (Table 1). Therefore, forest management does not seem to harm Boreal Owls at present day scales, if no more than half of the total forest area is clear-cut at long intervals enough (>60 yr). In contrast, the positive effects of clear-cut areas on fledgling pro-

Table 2. The number of Boreal Owl nests in proportion of landscape with clear-cuts of low and high percentages (see Table 1), in different phases of the vole cycle in the Kauhava region, western Finland (ca. 63°N, 23°E).

PHASE OF VOLE CYCLE	PROPORTION OF CLEAR-CUT AREAS WITHIN TERRITORY	
	LOW	HIGH
Low	1	2
Increase	7	4
Peak	13	12
Total	21	18

duction suggest that this species may achieve beneficial fitness from clear-cut areas because, for Boreal Owls, lifetime reproductive success (LRS) is dependent on the success of males in rearing young to the fledgling state (Korpimäki 1992). Today, LRS is the best known estimate of fitness (Clutton-Brock 1988, Newton 1989).

What would be the reason for the higher fledgling production for Boreal Owls in areas with higher level of clear-cuts within territories? The increased number of saplings and clear-cut areas during the last two or three decades (Järvinen et al. 1977) has created new suitable grass habitats for field voles (Henttonen 1989), which is the preferred prey of Boreal Owls (Korpimäki 1988, Koivunen et al. 1996). Snap-trapping in the peak vole year of 1994 in western Finland also suggested that large clear-cut areas sustain dense field vole populations. Similar results have also been found in Sweden (Hansson 1994). Because of intensive growth of hay species in new clear-cut areas, hay-eating field voles may colonize them successfully for about 10 yr (Hansson 1978). In contrast, small clear-cuts (ca. 1–3 ha) may not achieve such high densities of field voles, especially if small clear-cuts are isolated from source habitats, such as large fields and large clear-cuts. This may explain why fledgling production of Boreal Owls may increase with the increasing amount of clear-cut area within territories, especially if saplings are tall enough (ca. 2 m) for perch hunting by Boreal Owls (Bye et al. 1992). Densities of many bird species are also found to peak at forest edges (Helle 1984, Hansson 1983), especially Chaffinch (*Fringilla coelebs*) densities (Hansson 1994). This species is the most important bird prey of Boreal Owls on our study site (Korpimäki 1981, 1988). Therefore, the edges of

forests and clear-cuts may increase the amount of alternative prey of Boreal Owls in poor vole years.

Prey abundance and fledgling production appear to increase with forest fragmentation. However, clear-cutting also decreases the number of suitable natural cavities for Boreal Owls. Large trees and aspen groves with suitable nesting cavities for the Black Woodpeckers (*Dryocopus martius*) are decreasing due to logging. There is a need to protect these suitable nesting sites in forest landscapes. Alternatively, nest boxes can be provided for Boreal Owls to compensate for the lack of natural cavities.

#### ESTABLISHING NEST-BOX LOCATIONS FOR BOREAL OWLS

Interspecific competition is expected to reduce the fitness of individuals (Roughgarden 1979). Therefore, coexisting large owl species may reduce the breeding success of smaller owl species, including preying upon these owls (Mikkola 1983, Hakkarainen and Korpimäki 1996). At our study site, the Ural Owl (*Strix uralensis*) is a large owl species that is probably most harmful to the Boreal Owl. Nest-box experiments, along with long-term observational data (Hakkarainen and Korpimäki 1996) revealed that Boreal Owls avoid breeding within 2 km of Ural Owl nests. When nesting <2 km from Ural Owls, breeding was delayed substantially when compared with breeding >4.5 km away. Furthermore, when in the neighborhood of Ural Owl nests, male Boreal Owls were younger and paired more often with short-winged females. Most breeding near Ural Owls failed during the courtship period (Hakkarainen and Korpimäki 1996). This suggests that inexperienced male Boreal Owls are forced to establish their territories in the vicinity of Ural Owls where they pair with less experienced females. These findings suggest that nest boxes for Boreal Owls should be set >2 km from the medium-sized and large raptors that may have adverse effects on Boreal Owls.

In conclusion, moderate forestry may not harm Boreal Owls at the present day scale if suitable nest holes are available. A lack of nest holes can be compensated for by erecting nest boxes, but boxes should be set far from threatening allospecifics. In the long-term, however, the establishment of snags and patches of old mature forests with large trees, dense enough for hole-nesting Black Woodpeckers, will provide a natural way to establish new nesting cavities for Boreal Owls.

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## THE OSPREY (*PANDION HALIAETUS*) AND MODERN FORESTRY: A REVIEW OF POPULATION TRENDS AND THEIR CAUSES IN EUROPE

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ABSTRACT.—Nearly all European Osprey (*Pandion haliaetus*) populations have had a similar fate during the 20th century. In the first two decades, if not earlier, dramatic decreases and even extirpations of many local populations occurred due to heavy persecution. There was then a recovery period until the second decrease from the 1950s to the mid-1970s, caused by DDT and other contaminants. Since then, populations have been recovering. The annual rates of population increase have varied from about 1% in Fennoscandia to about 10% in Scotland during the last 20 years. At present, 90% of all European Ospreys breed in Finland, Sweden and Russia. The nesting habitats vary widely from steep cliffs in the Mediterranean to closed climax coniferous forests, open peat bogs and large clear-cut areas in northern Europe. In some areas (e.g., Finland), cutting of old, flat-topped potential new nests by intensive commercial forestry has been the most important national threat for the local Osprey population during the last three decades. As early as the late 1960s dedicated bird banders started to construct artificial nests for Ospreys to compensate for the losses caused by one-track forestry. In 1995, 46% of all occupied Finnish Osprey nests ( $N = 951$ ) were artificial. Also, clear-cuts around nesting trees are harmful because nests become more exposed to storms, predation by Eagle Owls (*Bubo bubo*) and disturbances. In Finland and some other countries, new guidelines for foresters also account for the welfare of the Osprey. However, the principles and practices are still quite far from each other.

KEY WORDS: Osprey, Europe, forestry; *Pandion haliaetus*; artificial nest.

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El *Pandion haliaetus* y forestal moderno: un reviso de las tendencias de población y sus causas en Europa

RESUMEN.—Casi todas las poblaciones de *Pandion haliaetus* europeo han tenido destino similar durante el siglo veinte. En las primeras dos décadas, si no mas temprano, aumentos dramáticos y también el desarrollo de muchas poblaciones local ocurrieron a causa de alta persecución. Luego hubo un tiempo de recuperación hasta la siguiente reducción de 1950s hasta el medio de 1970s, causado por DDT y otros contaminantes. Desde esos tiempos, poblaciones han estado recuperando. Los ritmos anual de aumento población han variado de 1% en Fennoscandia a casi 10% en Escocia durante los último veinte años. Al presente, 90% de todo los *Pandion haliaetus* europeos se crían en Finlandia, Suecia y Rusia. Los hábitats de nidos varia muy diferente de precipicio abrupto en el mediterráneo a bosque de conifero cerrado y clímax, turbera abierto, y áreas grandes cortadas en el norte de Europa, en unas áreas (e.g., Finlandia), de potencia de nuevos nidos por intensidad comercial de forestales ha tenido lo mas importante peligro nacional para la población local de los *Pandion haliaetus* durante las tres décadas pasadas. Tan temprano como los últimos años de los 1960s marcadores de pájaros a empezaron construir nidos artificiales para el *Pandion haliaetus* para compensar la perdición causada por forestales con solo una meta. En 1995, 46% de todos los nidos de *Pandion haliaetus* ocupados en Finlandia ( $N = 951$ ) eran artificial. También, áreas cortadas alrededor de árboles con nido eran peligrosos porque los nidos estaban mas desprotegidos a tormentas, en peligro de búho águila *Bubo bubo*, y disturbios. En Finlandia y otros países, nuevas reglas por guardabosques también cuenta por el bienestar de *Pandion haliaetus*. Sin embargo, los principios y costumbres están todavía muy lejos de cada uno.

[Traducción de Raúl De La Garza, Jr.]

The Osprey (*Pandion haliaetus*), the emblem of the former International Council for Bird Preservation (ICBP), is a suitable species as a flagship for bird protection. It is cosmopolitan and around the

world has suffered heavily from several human impacts: persecution, pesticides, acid rain, disturbances, fishery practices and modern forestry (Saurola & Koivu 1987). However, it is now recov-

Table 1. Present population estimates (breeding pairs) and trends of European Ospreys.

	ESTIMATE	TREND <sup>a</sup>	REFERENCE
Norway	200	+	Fremming 1988, O. Steen pers. comm. 1996
Sweden	3200	+	Risberg 1990
Finland	1200	+	P. Saurola unpubl. data
Denmark	3–5	+	M. Grell pers. comm. 1996
Estonia	30–35	+	E. Tammur pers. comm. 1996
Latvia	120	+	M. Kreilis pers. comm. 1996
Lithuania	25–30	+	B. Sablevicius pers. comm. 1996
Scotland	99–105	+	R. Dennis pers. comm. 1996
Germany	290	+	Schmidt 1996
Poland	50–60	0	T. Mizera pers. comm. 1996
Belarus	120–180	+	A. Tishechkin pers. comm. 1996
European Russia	2500–4000	0(±)	V. Galushin pers. comm. 1996
Ukraine	1–5	–	Tucker and Heath 1994
Moldova	0–3	–	Tucker and Heath 1994
Bulgaria	3–6	–	Tucker and Heath 1994
France			
—mainland	6	+	Y. Tariel pers. comm. 1996
—Corsica	25	+	Y. Tariel pers. comm. 1996
Spain			
—mainland	0		C. Viada pers. comm. 1996
—Balearic Islands	16	+	C. Viada pers. comm. 1996
—Canary Islands <sup>b</sup>	13–15		C. Viada pers. comm. 1996
Portugal	1	–	L. Palma pers. comm. 1996

<sup>a</sup> Symbols: + = increasing, – = decreasing, 0 = stable, ± = in some parts of area increasing and in other parts decreasing.

<sup>b</sup> Canary Islands belong administratively to Spain but not geographically to Europe.

ering almost everywhere in its range, as a result of successful protection efforts. In many areas the Osprey has been classified as a species for which further monitoring and support is still necessary.

Here, I give a short review of the present distribution, population estimates, production and population trends of Ospreys in Europe. In addition, I describe the significance of human factors, especially modern forestry, to the welfare of European Ospreys. The majority of these data come from Finland where a nationwide monitoring program *Project Pandion* was started in 1971 and continues today (Saurola 1995a).

#### EUROPEAN OSPREYS

**Historical Records.** Bijleveld (1974) has collected historical records on all European birds of prey. During the 19th century, Ospreys were breeding throughout Europe. Due to heavy persecution, local populations decreased rapidly and, in many countries, they were extirpated. The last known breeding in former Czechoslovakia was recorded in about the 1850s, in Switzerland in 1911, in Great

Britain and Denmark in 1916, in Austria in the 1930s, in the former West Germany in 1933 and in Italy in 1956 (Bijleveld 1974).

In the beginning of this century, the Osprey was a rare bird everywhere in Fennoscandia (Finland, Sweden and Norway). After legal protection in the 1920s in Finland and Sweden, populations slowly recovered until a new decrease occurred in the late 1950s and 1960s (Saurola 1986). This decrease was mainly due to toxic chemicals.

**Present Distribution and Status.** The present distribution of the European Osprey population extends from northern Norway and Finland to southern Portugal, the Balearic Islands and Corsica and from Scotland to the eastern border of the European part of Russia (Table 1). The total European population is estimated at 7000–9000 breeding pairs; about 50% of the population breeds in Sweden and Finland, 35–40% in Russia, 8% in eastern Germany, Poland, Belarus, Estonia, Latvia and Lithuania, 3% in Norway and Scotland and less than 1% in southern Europe (Table 1).

The accuracy of these population estimates var-

Table 2. Average breeding output in some local Osprey populations in Europe.

COUNTRY	PERIOD	YOUNG/ OCCUPIED NEST <sup>a</sup>	YOUNG/ ACTIVE NEST <sup>a</sup>	YOUNG/ SUCCESSFUL NEST <sup>a</sup>	REFERENCE
Finland	(1971–95)	1.46	1.91	2.17	Saurola this study
Sweden	(1971–93)		1.59		Odsjö pers. comm. 1996
Germany	(1972–93)				Meyburg et al. 1996
—trees		1.32	1.47	2.08	
—pylons		1.65	1.81	2.22	
Scotland	(1954–94)	1.29			Dennis 1995
Poland	(1976–92)	1.34		1.81	Mizera 1995

<sup>a</sup> See Postupalsky (1977) for definitions.

ies greatly from country to country, although most were provided by Osprey specialists from each country. For example, in Scotland (Dennis 1995) and Finland (Saurola 1995a) all known occupied territories have been checked annually for more than 20 yr. In contrast, the estimate for European Russia (V. Galushin pers. comm.) is based on extrapolation of information from a handful of large study areas, but still small if compared with the huge area for which the estimate is given.

**Productivity and Population Trends.** At the moment, all local Osprey populations breeding in northern and central Europe seem to be either stable or increasing (Table 1) and the average breeding output is good (Table 2). Definitions are according to Postupalsky (1977). Also, the remnant populations in Corsica, mainland France (Tariel pers. comm.) and the Balearic Islands (Viada pers. comm.) are now increasing, but in Portugal only one breeding pair remains (Palma pers. comm.) and in mainland Spain there are no breeding Os-

preys (Viada pers. comm.). The real situation in southeastern Europe, in Ukraine, Moldova and Bulgaria is poorly known; however, all population trends from this area are negative (Tucker & Heath 1994).

In Finland, *Project Pandion* was started in 1971 (Saurola 1980) and since then almost all known occupied territories have been checked by bird banders (ringers) every year. These data indicate that breeding success has increased significantly since the start of the project. During the 1970s, Finnish Ospreys raised on average 1.38 young/occupied nest/year, but during the 1980s and 1990s, the corresponding figures have been 1.47 and 1.61. The trend for these three decades is similar in production per occupied (1.81, 1.96 and 2.03) and per successful nests (2.09, 2.21 and 2.23; Fig. 1).

According to all data from *Project Pandion*, the Finnish Osprey population remained stable through the 1970s and then increased during the 1980s and 1990s (Table 3, Fig. 2). A part of this increase, especially in sparsely inhabited northern Finland, may be only a result of increasing survey coverage. In Häme, southern Finland, where my intensive study area is located and where few, if any, nests are not known by *Project Pandion*, the increase rate in 1972–1995 has been 0.7% per year. This is considerably less than the 2% per year calculated from all data for the whole country (Table 3). My estimate for the real growth rate of the total Finnish Osprey population during the last 25 yr is between 1% and 1.5% per yr.

Swedish Ospreys have been monitored at six study areas located in southern and central Sweden. These areas have been carefully checked in 1971–73 and after that every 5th yr in 1978, 1983, 1988 and 1993 (Odsjö pers. comm.). The average

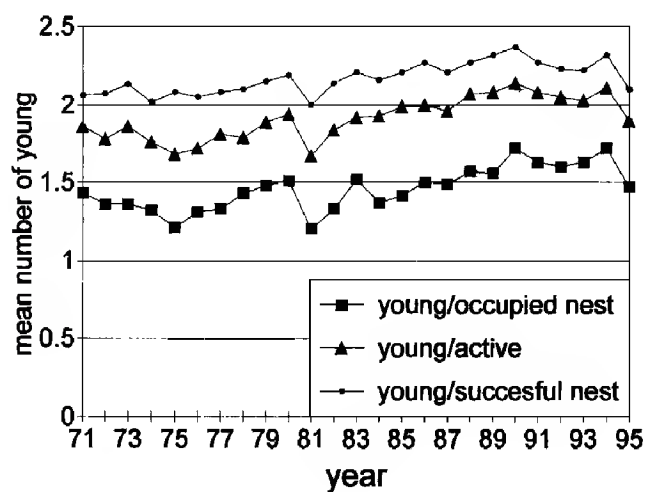


Figure 1. Average annual breeding success of Finnish Ospreys in 1971–95 (see Figure 2 for sample sizes and Postupalsky (1977) for definitions).



Table 3. Mean annual rate of population increase of the Osprey in some European study areas.

	PERIOD	CHANGE		INCREASE PER YEAR <sup>c</sup>	REFERENCE
		$N_1^a$	$N_2^b$		
Finland (active nests)					
—all known	1972–95	465	736	2.0%	Saurola, this study
—Häme	1972–95	94	110	0.7%	Saurola, this study
Sweden (active nests)					
—6 study areas	1972–93	97	113	0.7%	Odsjö 1982 and pers. comm. 1996
Germany (pairs)					
—Mecklenburg	1980–93	62	94	3.3%	Meyburg et al. 1996
—Brandenburg	1980–92	45	120	8.5%	Meyburg et al. 1996
Scotland (pairs)					
—all known	1977–95	20	99	9.3%	Dennis 1987 and pers. comm. 1996

<sup>a</sup>  $N_1$  = number of active nests or pairs in the first year of study period.

<sup>b</sup>  $N_2$  = number of active nests or pairs in the last year of study period.

<sup>c</sup> Mean increase per year ( $p$ ) was calculated from the formula:  $N_2 = N_1(1 + p/100)^t$ , where  $t$  = elapsed time in years.

annual increase during the last 20–25 yr within these study areas has been 0.7%, which is the same as in Häme, but much lower than in Germany and Scotland (Table 3). So far, no clear explanation has been proposed for these geographic differences in rates of population increase (Saurola 1990, 1995a).

**Migration and Wintering Areas.** European Ospreys migrate to the tropics (Österlöf 1977, Dennis 1991, Saurola 1994), except for the Mediterranean populations, which remain in the Mediterranean (Thibault et al. 1987). The main wintering area is the Sahel-zone between latitudes 5–15°N. Band recoveries revealed longitudinal differences in wintering areas of the local populations from different parts of the breeding range: Scottish Ospreys win-

ter along the west coast of Africa (Dennis 1991), Swedish birds mainly in inland waters of west Africa and the Finnish ones still further east, in west and central Africa (Österlöf 1977, Saurola 1994). So far, only four banded European Ospreys have been recovered from South Africa, about 10 000 km from their natal area, all of Finnish origin.

In the late 1970s, a detailed study on the winter ecology of European Ospreys was made in Senegambia (Prevost 1982).

**Nesting Habitats and Nest Sites.** The Osprey eats live fish almost exclusively (e.g., Häkkinen 1977, 1978, Saurola & Koivu 1987) and for this reason its distribution is always restricted by the distribution of favorable fishing waters. In ideal conditions the nest is located just at the shoreline. However, in areas disturbed by human activities, the distance from the nest to the fishing grounds may be several km.

In addition to sufficient food resources, the most important prerequisite of a good nest site is a stable and exposed base to support the nest. Because the Osprey nest has to be exposed to all directions, it is nearly always at the very top of the tree and no branches reach the upper edge of the nest. There are few exceptions from this general rule. The nesting habitat and the base of the nest can be varied if the two main requirements are filled. More than 95% of European Ospreys breed in forested habitats (coniferous forests or on peat bogs). The cliff-nesting birds in Corsica (Terasse and Ter-

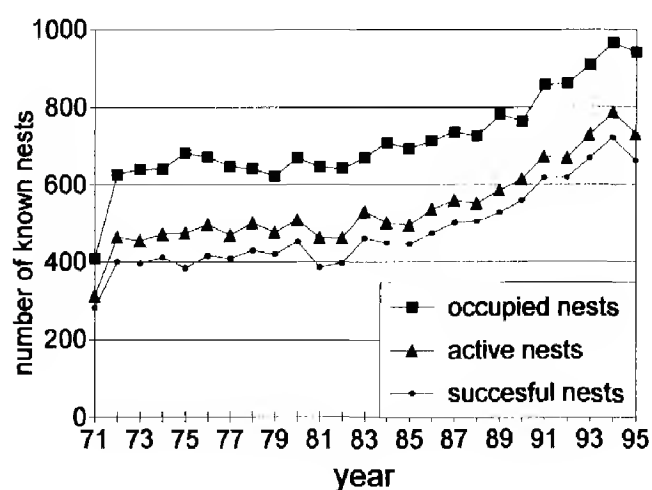


Figure 2. Total number of known occupied (squares), breeding (triangles) and successful (dots) Osprey nests in 1971–1995 in Finland (see Postupalsky (1977) for definitions).

asse 1977), the Balearic Islands (González et al. 1992) and in Portugal (L. Palma pers. comm.), and pairs nesting on power line pylons in the middle of open fields in Germany (Moll 1962) are the only exceptions to this general pattern. The successional stage, structure and openness of the forests around the nest varies from closed climax coniferous or mixed forests to clear-cuts where the nest tree is the only one left. One of the favorite natural sites is a small islet in a lake covered by big trees.

The most common nesting tree species both in European forests and peat bogs is the Scotch pine (*Pinus silvestris*). For example, this tree species hosts 88% of natural nests in Finland. In this species the structure of the flat top of an old tree provides a stable base for the huge stick nest of the Osprey. Norwegian spruce (*Picea abies*) is the next most commonly utilized tree species (3% in Finland), and broad-leaved trees (e.g. *Betula*, *Populus*, *Alnus*, *Quercus*) are rarely used as nesting trees by European Ospreys (only 1% in Finland). A total of 7% of natural Osprey nests are on dead trees in Finland. Norwegian spruce is suitable for the Osprey only if the top has been broken some meters from the tip, so that the branches are thick enough to carry the heavy nest. In Scotland, about one-quarter of the nests are now on an introduced species, Douglas fir (*Pseudotsuga menziesii*) with broken tops (Dennis pers. comm.).

#### HUMAN IMPACT

**Persecution.** Birds of prey were heavily persecuted throughout Europe as early as the 17th century. This persecution intensified during the 18th century and peaked in the 19th and early 20th centuries (Bijleveld 1974). For more than 200 yr, millions of birds of prey were killed because they were considered harmful pests. During World Wars I and II, hunters were allowed to shoot each other, so killing of birds of prey decreased. Immediately after World War II, intensive persecution resumed. For example, in autumn 1953 at least 93 Ospreys were killed at three fishponds in Lower Saxony (Bijleveld 1974).

The Osprey has been legally protected since 1926 in Finland (Saurola & Koivu 1987) and since the late 1920s in Sweden (Österlöf 1973). In many other European countries full legal protection was given to the Osprey less than 40 yr ago, for example, in Denmark in the 1950s, Poland in 1952, United Kingdom in 1954, former East Germany in 1954, Norway in 1962, France in 1964, former

USSR in 1964 (enforced in 1974), Spain in 1966, former West Germany in 1968 and Italy in 1971 (Bijleveld 1974).

Legal protection does not necessarily mean that killing ceases. Saurola (1985a, 1994) attempted to assess changes in persecution of Fennoscandian Ospreys in Europe and Africa by calculating area-specific persecution indices from band recoveries. This analysis, which might be biased by changes in reporting rates, suggested that persecution decreased in Italy, France and in the former USSR in the 1970s after changes in legislation. In contrast, killing of Ospreys in Africa has remained the same during the last 30 yr.

In addition to being killed as a competitive consumer of fish, European Ospreys have suffered from illegal egg and skin collecting. In Scotland, egg robbing still continues, perhaps at least partly as a challenging game against police and conservation authorities. For example, in 1988 and 1989, 11 and 9 out of 49 nests were robbed in Scotland, respectively (Dennis 1991).

**Pesticides.** In the late 1940s and 1950s, when persecution increased again after World War II, DDT and other environmental contaminants appeared as a new threat to the future of the Osprey and other birds of prey all over the world (Poole 1989). Odsjö (1982) found that eggshell thickness of unhatched Swedish Osprey eggs was 11% lower than that of shells collected before DDT was first in use in 1947. In nests where all eggs were broken, eggshell thickness was 20% lower than in pre-DDT eggs, and, as expected, breeding success had decreased from the pre-DDT level.

In Finland, during *Project Pandion*, all addled eggs have been collected and DDT, DDD, DDE and total PCB concentrations have been analyzed but not yet published. Preliminary results show that DDT concentrations in Finnish Osprey eggs have decreased significantly during the last 20 yr. Moreover, even in the early 1970s the concentrations were much lower than in Swedish eggs (Odsjö 1982).

**Acidification of Lakes.** Eriksson et al. (1983) and Eriksson (1986) suggested that reduced breeding success of the Osprey in southwestern Sweden was due to higher nestling mortality caused by reduced foraging success in acidified lakes. They predicted that a population decrease would occur as a consequence of more widespread acidification. So far, no further evidence of the negative effects of acid-

ification on European Osprey populations has been published.

**Fishing and Fish Farms.** Of Finnish band recoveries (returns) of dead Ospreys in 1950–1987, 29% were found dead with no more information; while of the remainder, 53% were shot or otherwise killed intentionally, 25% were entangled in a fishing net and 10% were hit by overhead wires (Saurola & Koivu 1987). Although the distribution of causes of death assessed from ring recoveries is biased, it clearly demonstrates that fishing is an important factor. In Finland, the most dangerous period for Ospreys is early spring when most of the fishing grounds are still covered by ice. At this time Ospreys are caught in nets in small areas of open and shallow water exploited both by Ospreys and by fishermen.

In Finland, at commercial fish farms growing North American rainbow trout (*Oncorhynchus mykiss*), Ospreys have been killed both by illegal shooting or by poorly placed strings or nets set to protect trout. At the moment, most Finnish fish farms are safe for Ospreys because the state pays compensation to the owners from damages caused by Ospreys.

Illegal shooting of Ospreys at fish farms is still a problem at least in Poland (Mizera 1995) and probably in other countries in eastern Europe.

**Land Use and Disturbances.** In Finland, about 15% of the present nest sites of the Osprey are close to the shoreline (*Project Pandion*). The main reason for this unexpectedly low proportion is land use because the dream of every Finn is to have a summerhouse by a lake or in the Baltic archipelago. Hence, there is little shoreline left for Ospreys. In many cases the historic nest sites have been abandoned and Ospreys have moved to the middle of forests, often several kilometers away from their historic nest sites.

After the persecution and pesticide eras in the 1980s, human disturbances (fishing, canoeing, sailing and bathing) became the major threats to the species in Swedish lake areas, where many Ospreys still bred close to the shore (Odsjö & Sondell 1986).

#### OSPREYS AND MODERN FORESTRY

Modern forestry may have four kinds of negative effects on the welfare of the Osprey: cutting of occupied nest trees, cutting of potential alternative nest trees, cutting of trees from the protection zone around the nest and noise disturbance from

forestry activities in the neighborhood of the nest during the breeding season.

**Cutting of Occupied and Potential Alternative Nest Trees.** The Osprey is fully protected by national laws in those European countries which have breeding Ospreys (Bijleveld 1974). Consequently, the occupied nest trees should be protected during the breeding season throughout Europe. In contrast, during the nonbreeding season the nests and nesting trees are not protected in all European countries. Hence, in some countries the nest tree can legally be cut after the breeding season, even though this nest tree would likely be used again the following summer if left intact.

The same Osprey nest may be in use for decades (Saurola & Koivu 1987) and for this reason it is crucial to protect the nest tree all year. However, the protection of an occupied nest tree is not enough because of the evolution of the top of an Osprey nest tree. The Osprey brings new sticks to the nest every year, the nest grows higher and higher, and finally falls down. After this the top of the tree usually is not of sufficient quality to serve as a base for the nest. Thus, within each territory, a sufficient number of old, flat-topped nest trees should be saved as alternative nest trees for the future.

**Cutting of Trees from the Protection Zone Around the Nest.** If all trees around the nest tree are removed, the probability of a breeding failure increases for several reasons. First, a solitary tree is much more exposed to damage caused by storms. Second, a tall tree in a clear-cut is an ideal hunting perch for the Eagle Owl (*Bubo bubo*), which is mainly an open-land hunter (Mikkola 1983). Thus, the probability is high that a hunting Eagle Owl will locate and kill an incubating or brooding Osprey or the entire brood. Moreover, the fledged young are especially vulnerable because they use their nest as a perch for eating for 4 wk after fledging (Saurola & Koivu 1987). The noisy begging of the young at sunset from the middle of a clear-cut is like a dinner bell for an Eagle Owl starting to hunt. In Finland, where the Eagle Owl population has been increasing rapidly during the last decades (Saurola 1985b, 1995b) and where many of the Osprey nest sites have been classified as clear-cuts or other types of open forests (22% in 1995, *Project Pandion*), more and more Osprey nests have been predated by Eagle Owls. Third, it is clear that the disturbance zone of many activities (e.g., forestry, recreation, sports) around the nest is wider in open clear-cuts than in closed forests.



**Forestry Activities Near the Nest During Breeding.** According to the 26-yr data from *Project Pandion*, inappropriate timing of forestry work in the neighborhood of the nest has caused several breeding failures in Finland. These failures have been demonstrated as results of construction of logging roads, digging ditches, harvesting, improving of young stands and planting seedlings.

**A Promising Example for a Better Future: Guidelines by the Finnish Forest and Park Service.** Finnish Forest and Park Service (1994) has recently published the new guidelines for all activities near the Osprey nests for land owned by the government. The main points of these guidelines are that the nest tree is protected all year under the Nature Conservation Act, a protective tree stand (density 200 stems/ha) must be left around the nest for a radius of approximately 50 m, a bog surrounding a clump of trees in which there is an Osprey nest must be left in a natural state, any forestry activities must be avoided close to the nest in the period 15 April–31 July, old Scotch pines and saw timber trees must be left in clumps for future development into ideal nest sites and paths and hiking routes must not be established within about 500 m from the nest. Almost identical advice has been given by the Forestry Center Tapio (1994) for the management of Osprey nest sites on private land.

These guidelines for state-owned and private lands are sufficient for the protection of Finnish Ospreys. In practice, these guidelines, especially on private lands, are only recommendations and therefore not always followed by foresters. For example, clear-cuts still occur around nest trees and seedlings are planted close to active nests during sensitive periods in the breeding season.

In some countries the guidelines are even more strict than in Finland. For example, in Poland no trees are allowed to be cut within 200 m from the nest and during the breeding season (1 February–31 July), all forestry activities are forbidden within 500 m from the nest (Mizera 1995). In many other European countries, guidelines for forestry near nest sites of endangered or rare birds, such as eagles and Ospreys, are under changes or in preparation. For example, in the eastern states of Germany, old, and often very strict, regulations are no longer officially enforced but are still in practice because new ones are not yet available (D. Schmidt pers. comm.). Hence, it is difficult to make an overall European summary of this subject.

**Artificial Nests.** Construction of artificial nests has been the only possible direct measure to compensate for the effects of one-track commercial forestry. In Finland, the first artificial nests for Ospreys were constructed in 1965 (Saurola 1978). In 1995, 45.8% of all occupied nests in Finland were artificial (*Project Pandion*). In my intensive study area in southern Häme, the percentage of artificial nests was as high as 90% of 79 occupied nests. I have estimated that in this area which, without intensive modern forestry, would be an ideal natural area for the Osprey, the population would be less than 50% of the present level without artificial nests (in total 160 artificial nests are available for the Osprey in this area).

Meyburg et al. (1996) have demonstrated that, in Germany, breeding output was clearly higher in artificial nests on power line pylons than in natural tree nests within the same area (Table 2). However, in Finland, no difference in breeding success between artificial and natural nests was detected (Saurola 1990). This perhaps unexpected result was probably because most of the unstable natural nests were replaced by artificial nests. Therefore, artificial nests were not compared with normal natural nests but with high quality natural nests.

In Europe, artificial nests have been constructed during the 1980s and 1990s in almost all countries with breeding Ospreys and in most cases with good success. For example, soon after artificial nests were provided in southern Norway, Ospreys started to expand their range westward back to their historic breeding sites, where the number of suitable nest trees had greatly decreased because of forestry (Steen 1993). In Sweden, artificial nests have been constructed to move Ospreys from disturbed areas to undisturbed areas with good results (Hallberg et al. 1983).

#### CONCLUDING REMARKS

During the last 10 yr, local Osprey populations in northern and central Europe have been stable or are still recovering from the effects of persecution and organochlorine pesticides. These two threats are currently not major problems in Europe but still may be so in Africa.

In contrast, both past and present effects of modern forestry may be an important negative factor for the Osprey. In addition to the lack of suitable nest trees in some areas, many breeding failures are due to modern forestry, either directly (forestry activities near the nest during the breed-

ing season) or indirectly (nests on the open clearcuts are more exposed to storms, Eagle Owls and disturbances).

Official silvicultural guidelines are important for the protection of traditional nest sites of Ospreys in commercially treated forests. Instructions for management of Ospreys have been provided in some countries for foresters. In some others, such as the former socialist countries in eastern Europe, the new guidelines are under preparation.

Construction of artificial nests has been an effective tool to compensate for some of the effects of modern forestry. However, the extensive protection of natural nest trees and their surroundings should always be the primary long-term goal. Construction of artificial nests should be used as the last and temporary measure to save or reintroduce local populations, but never as an excuse to destroy natural breeding sites.

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## OSPREY (*PANDION HALIAETUS*) POPULATIONS IN FORESTED AREAS OF NORTH AMERICA: CHANGES, THEIR CAUSES AND MANAGEMENT RECOMMENDATIONS

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**ABSTRACT.**—Prior to European settlement of North America, Ospreys (*Pandion haliaetus*) bred throughout much of the continent in tall trees near productive shallow-water freshwater bodies. Ospreys need exposed locations to build their large nests, often in dead tops of older trees or snags in beaver swamps. Historical nest sites are poorly documented, but timber extraction and shoreline development have undoubtedly removed many preferred nest trees, likely causing population declines. Widespread use of persistent organochlorine pesticides after 1945 caused dramatic declines of breeding ospreys. Since bans on these toxins were imposed in the 1970s, most populations have increased at average rates up to 15% per year. Ospreys have adapted well to nesting on a wide range of artificial substrates, and in some areas up to 70% of nests are now on such structures. In many areas nowadays, up to 80% of tree nests occur within 500 m of open water. It is difficult to know what this figure was historically since more recent forest management often retains trees in shoreline buffer zones primarily for recreational and landscape reasons. Other important factors currently affecting breeding ospreys are: nest predation from raccoons (*Procyon lotor*) and Great Horned Owls (*Bubo virginianus*), degradation and loss of foraging areas, human disturbance and Bald Eagle (*Haliaeetus leucocephalus*) population increases. Forestry guidelines protecting Osprey habitat vary considerably among regions. Maintaining nonintervention buffer zones around Osprey nest trees results in substantial lost profit for foresters, yet the ecological basis for such zones is often unclear. Systematic studies of breeding Ospreys in relation to different forestry practices, and associated activities, are needed to provide more consistent, realistic and integrated conservation advice to resource managers.

**KEY WORDS:** *forestry; North America; Osprey; nest trees; Pandion haliaetus.*

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Poblaciones de *Pandion haliaetus* en áreas de bosque en Norte América: cambios, sus causas y recomendaciones de administración

**RESUMEN.**—Antes de la colonización de Norte América, *Pandion haliaetus* se criaban por mucho del continente, en árboles de grande altura cerca de aguas de pesca productivas. *Pandion haliaetus* necesitan lugares desabrigados para construir sus nidos grandes. Con frecuencia en la copa de árboles maduros o también tocones en pantanos de castor. Sitios de nido históricamente están documentados de ser pobres, por extracciones de madera y el desarrollo a la orilla del agua, sin duda han quitado muchos árboles de nido preferidos, probablemente causando reducción de la población. Usos amplios de pesticidas de organoclorados (OC) después de 1945 causo reducciones dramáticas en la cría de *Pandion haliaetus*. Prohibición de estos tóxicos fueron imponados en los 1970s, y desde entonces la mayoría de población a subido a ritmo regular hasta 15% por año. *Pandion haliaetus* se han adaptado bien haciendo nidos que abarcan un campo amplio de soportes artificial, y en unos áreas hasta 70% de nidos están en tal estructuras. En muchas áreas hoy hasta 80% de los nidos en árbol ocurren dentro de 500 m al agua libre. Es difícil saber que fue la cantidad históricamente; mas reciente administración de bosque muchas veces retiene árboles dentro la orilla del agua en zonas de espacio primeramente para razones recreacional y aesthetico, a un extenso grande que en bosques mas lejos de la agua. Otros factores importantes actualmente afectando los *Pandion haliaetus* de cría son: depredador de nido, (la mayoría de mapaches, *Procyon lotor*, y búhos, *Bubo virginianus*), degradación y la pérdida de áreas de forraje, molestia humana, y aumento en población de águilas *Haliaeetus leucocephalus*. Reglas del forestal protegiendo los *Pandion haliaetus* varia considerablemente entre regiones. Manteniendo zonas de no-intervencion de espacio alrededor de nidos de *Pandion haliaetus* resulta en suficiente ingresos perdidos para la industria de madera, y la razón ecológica para tal zonas es muchas veces poco claro. Estudios sistemáticos de *Pandion haliaetus* de cría en relación a diferente

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costumbres del forestal, y actividades asociadas, son necesarias para proveer mas consistenes realitarias y consejos de conservación integrada para la administración de recurso.

[Traducción de Raúl De La Garza, Jr.]

Prior to the colonization of North America by Europeans, Ospreys (*Pandion haliaetus*) bred in trees throughout most of North America, though a few pairs nested on cliffs or on the ground on small islands (Poole 1989). The major changes in land-use patterns (notably forest clearance for agriculture and residential and industrial development) which have occurred since European settlement (Lawrie and Rahrer 1973, Caldwell 1978, Sly 1991) have undoubtedly affected the breeding distribution of Ospreys, but many other factors have also impacted these populations. In this paper, I review the documented population changes, highlighting cases for which the causes are reasonably well established. I then focus on Osprey nesting requirements, especially in relation to forestry practices and current timber management guidelines for Ospreys. I also suggest some key studies which should be done to better evaluate the sensitivity of Ospreys to different timber management regimes.

#### BACKGROUND

Ospreys are large (1.5–2 kg) raptors which eat almost exclusively fish, which they catch in water usually up to 2 m deep by diving in feet-first, either from a shoreline perch or from a hover or stoop from up to 40 m above the water (Poole 1989). They are monogamous, breed first when 3–4 yr old, have an 85–90% adult annual survival rate and can live for up to 25 yr. They have relatively long wings for their body mass and so are rather poor at maneuvering among trees. For this reason they require very open sites in which to nest so that birds can readily fly to and from the nest in any wind direction without getting tangled in branches. They build large stick nests which are added to each year. Thus, Ospreys favor nesting at the top of old, large trees, live or dead, with adequate strong support branches at the top and clear air space around the nest. Nest sites surrounded by water are usually preferred, since mammalian predators are thus deterred. Most Ospreys which breed in North America winter in northern South America or the Caribbean basin, but there are resident populations in Florida and California/Baja California (Poole and Agler 1987, Poole 1989, Ewins and Houston 1993).

Despite major reductions in both the extent and

age of forests in North America over the past two centuries (Lawrie and Rahrer 1973, Caldwell 1978, Holla and Knowles 1988, Sly 1991), Ospreys persist as a relatively widespread and highly visible breeding species near to many waterways. Unlike some other raptor species, Ospreys have in many cases adapted remarkably well to living in close proximity to humans, and will nest readily and very successfully on artificial nest structures, especially when there is a tradition of this habit in an area (Postupalsky 1978, Ewins 1994, 1996). It has been estimated for the mid-1980s that North America supported about 18 000–20 000 pairs of breeding Ospreys or about 57–84% of the world population and that about two-thirds of these bred in Canada and Alaska (Poole 1989). Although Ospreys do breed in loose colonies in some areas, particularly near to rich food supplies in marine estuaries (Greene et al. 1983, Hagan 1986), the bulk of these birds breed as scattered, isolated pairs in relatively remote forests close to fishing areas in the numerous rivers and lakes of northern North America.

#### POPULATION CHANGES AND ASSOCIATED FACTORS

Ospreys have been relatively well studied over the past 30 yr in North America (Henny 1977, Poole 1989) and many factors are now known, or are suspected, to have influenced their populations since European settlement of the continent (Table 1).

**Historical Populations (>100 years ago).** Unlike Bald Eagle (*Haliaeetus leucocephalus*) nests, Osprey nests were seldom noted by early naturalists in North America, so it is often difficult to assess current occupancy of nesting areas occupied in the last century. However, given what we now know of the Osprey's nesting requirements, it is likely, given the massive reductions to the extent and mean age of forests, that prime nesting trees are very scarce in many former breeding areas. Impressions noted by Victorian naturalists lead us to suspect very large declines in some areas. For example, Beardslee and Mitchell (1965) cite a visit by the naturalist De Witt Clinton to the Niagara River in 1820: "In various places I have seen bald eagle, grey eagle and osprey *falco haliaetus*. . . the immense quantities of fish which collect below the falls of Niagara. . . draw together these birds, and I have never seen so many

Table 1. Main factors affecting North American Osprey populations.

Nest-site availability	—timber extraction —shoreline development —fur trade (beaver populations) —water level changes/reservoir creation —artificial nest structures
Food availability	—loss of foraging habitat to: —agriculture —shoreline development —nutrient changes —fish removal (chemical, over-fishing) —exotic species effects —lake acidification
Human activities	—egg collecting, taxidermy —persecution —disturbance at nest —environmental legislation and societal attitudes
Toxic chemicals	—persistent organochlorine pollutants —heavy metals (mercury)
Competition	—Bald Eagles ( <i>Haliaeetus leucocephalus</i> ) —intra-specific
Predators	—raccoon ( <i>Procyon lotor</i> ) —Great Horned Owl ( <i>Bubo virginianus</i> )
Weather	—wind storms (nest loss) —cold and wet (chick starvation/hypothermia)
Wintering and Staging areas	—habitat loss —hunting/persecution —mercury (gold mining) —organochlorine pesticides

as appear to occupy this region.” Today, eagles and Ospreys are rare sights along the entire Niagara River, even though there are still huge quantities of fish available below the falls, supporting very large concentrations of foraging gulls and fish-eating ducks in autumn. Very little undisturbed nesting, perching or roosting habitat now exists along the river banks, due to recreational access and residential development.

Along the Oregon-California border, a huge colony of 250–300 pairs of Osprey was recorded at Tule Lake in 1899 (Bailey 1902). The birds bred in two groves of large ponderosa pine (*Pinus ponderosa*) and junipers (*Juniperus occidentalis*) 6–10 km from the shallow, highly productive lake, because these were apparently the nearest stands of suitable nest trees to the lake (Henny 1988). So, even 100 yr ago it appears that the availability of preferred nest trees was influencing Osprey nesting distribution. After 1906, Tule Lake was drained to provide irrigation and new, fertile agricultural land; the area now supports a range of cash crops but only about 12 pairs of Ospreys (Henny 1988).

There are reasonable historical population estimates for Ospreys in six areas and biologists have been able to suggest factors associated strongly with the population change over the period (Table 2). In four of these cases, large declines were associated with combinations of factors such as persecution, egg/skin collection, wetland drainage for agriculture, loss of nesting trees to forestry or shoreline development and toxic effects of organochlorine pesticides. The provision of artificial nesting structures seems to have offset the effects of other factors and maintained reasonably stable populations in parts of Maryland and Ontario (Reese 1969, Ewins 1996).

**Changes Since the 1930s.** The simple chemical process of adding a chlorine atom to a benzene molecule probably had a greater effect on Osprey populations than all other factors combined. From the mid-1940s to the early-1970s, organochlorine pesticides were used widely and effectively in North America and these molecules proved to be extremely persistent environmental contaminants. Ospreys, like other raptors at the top of food webs, bioaccu-



Table 2. Historical records of Osprey population changes, and factors implicated by authors.

AREA	NUMBERS/YEAR	FACTORS IMPLICATED
Gardiner's I., NY	300 prs./1850s 300 prs./1940 100 prs./1960 31 prs./1975	Protection from persecution Organochlorine pesticides
Seven Mile Beach, NJ	100 prs./1884 <25 prs./1890 30 prs./1927	Egg collecting and shooting
Queen Annes Co., MD	32 prs./1892 31 prs./1968	Forestry, artificial nest structures
Georgian Bay, Lake Huron, ONT	"generally distributed"/1890s 0/1940s-72 43 prs./1993	Forestry, shoreline development, organochlorine pesticides, artificial nest structures
Tule Lake/Klamath, OR	250-300 prs./1899 ca. 12 prs./1976	Drainage, agriculture
Eagle Lake, CA	>2 prs./1905 30-35+ prs./1925 23 prs./1975	Water level changes providing snags

mulated substantial concentrations of these lipophilic compounds from their diet. Most notable was DDT and its more stable metabolite DDE, which impaired shell gland function and led to severe thinning of eggshells and resultant reproductive failures as the eggs broke during incubation (Ames 1966, Cooke 1973). The cyclodiene dieldrin was also highly toxic and may well have increased mortality

Table 3. Population trends for North American Ospreys since the 1930s. Means expressed as percentage change per annum.

LOCATION	PERIOD	MEAN % PER ANNUM
Migration look-outs		
Northeast U.S.A.	1972-87	+8.9
Hawk Mt., PA	1934-86	+0.1
Duluth, MN	1974-89	+5.5
Grimsby, ONT	1975-90	+6.8
Western U.S.A.	1983-91	+7.0
Breeding areas		
Wisconsin	1974-90	+8.9
Northeast U.S.A.	1975-87	+10.0
Upper NY	1976-90	+6.8
St. Marys R., MI	1975-93	+15.4
Michigan	1976-89	+6.0
L. Huron, ONT	1975-94	+13.2
Oregon	1976-93	+10.5
California	1981-93	+9.4

rates of Ospreys. By the 1960s, naturalists noticed numerous empty Osprey nests, broken eggs, large population decreases (Ames and Mersereau 1964, Ames 1966, Petersen 1969) and even local extirpations (Ewins et al. 1996). By the early to mid-1970s the use of organochlorine pesticides and polychlorinated biphenyls (PCBs) had been banned throughout North America.

Increases in breeding Osprey populations were noted in most parts of North America from the mid-1970s (Table 3, Fig. 1), associated with declining organochlorine contaminant residue levels in eggs and increases in eggshell thickness towards pre-DDT values (Henny et al. 1977, Spitzer et al. 1978, Wiemeyer et al. 1987, 1988, Ewins et al. 1996). The mean rates of population recovery across the continent (6-15% per annum) have been remarkably similar in different areas (Table 3), suggesting that the organochlorine pesticide effects were widespread and relatively uniform. The long-term monitoring at Hawk Mountain migration station in Pennsylvania started just before the introduction of these pesticides, so the 50-yr population trend includes many of the pesticide-use years. Extensive and intensive state- and province-wide Osprey surveys over the past 20 yr have shown similar recovery trends in reproductive output.

**Some Cause-effect Examples.** The availability of suitable nest sites appears frequently to limit local breeding populations. The creation of reservoirs for

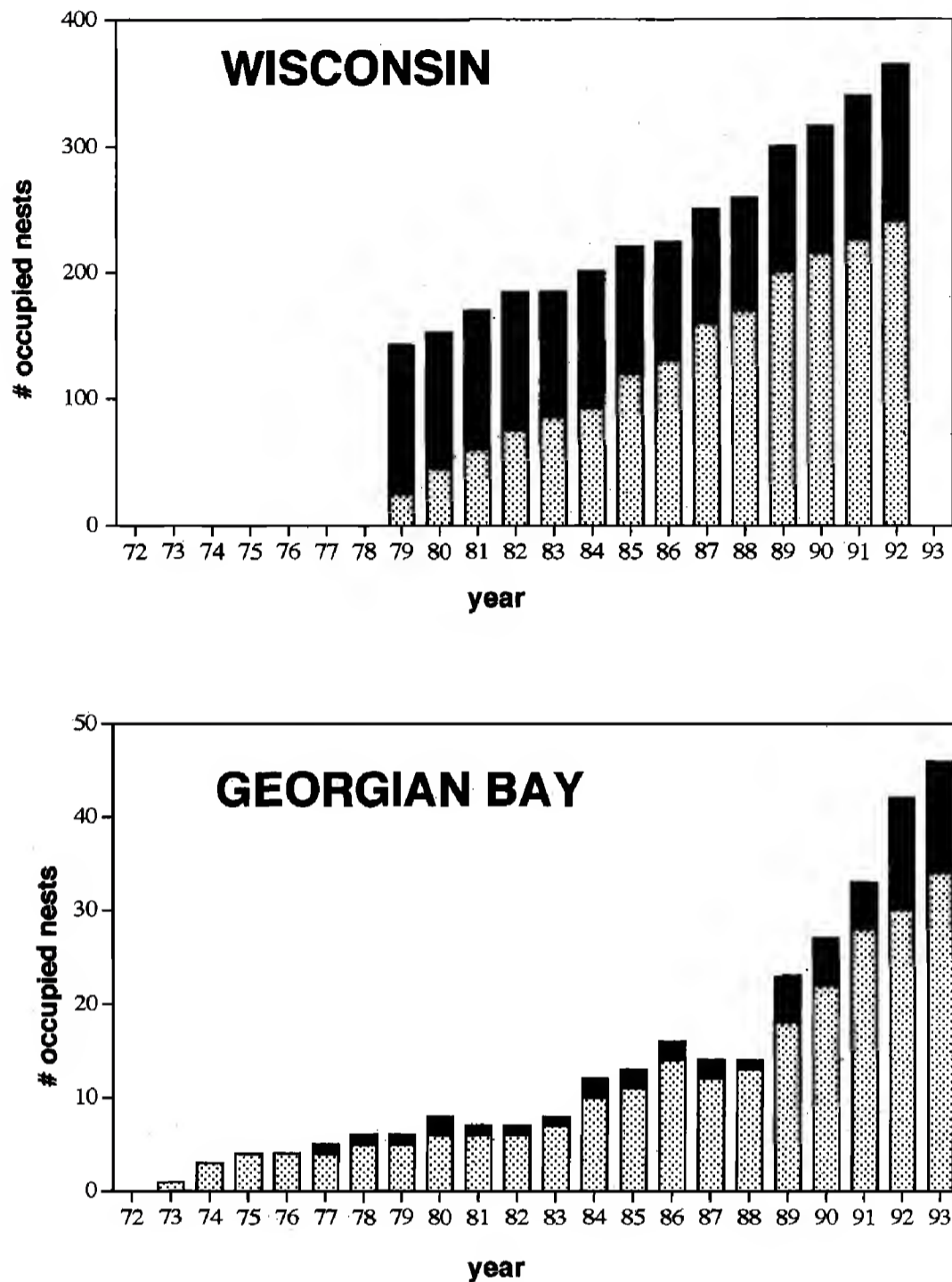


Figure 1. Changes in breeding populations of Ospreys since early 1970s in Wisconsin and Georgian Bay (Lakes Huron and Ontario), at artificial nest-platforms (stippled) and other (solid shading) sites. Most "other" sites were in trees. Wisconsin data are from Gieck et al. (1992).

hydroelectric power generation, irrigation of agricultural land and raising of water levels for navigation or other purposes, has often provided quality nest sites for Ospreys by flooding trees. At Eagle Lake, California, population increases earlier this century were attributed to raised water levels providing prime nest sites, but subsequent steady decay of these flooded trees had reduced the nesting population by the 1970s (Table 2). Similar phenomena have been observed in the Great Lakes basin, at Ogoki Reservoir (Postupalsky 1971) and in the Kawartha Lakes and in Montana (Mace et al. 1987).

Human attitudes towards raptors and general environmental issues have changed markedly in recent

decades. Protective legislation is now available for many habitats and species and people often want to take positive actions to assist with restoration of degraded ecosystems. In many areas, particularly those close to centers of human population, customized artificial nest structures are occupied readily by Ospreys (Poole 1989, Gieck et al. 1992, Ewins 1994, 1996, Ewins et al. 1995), and these initiatives have greatly assisted population recoveries post-DDT. In some areas, up to 70% of occupied Osprey nests now occur on artificial support structures. For example, in Wisconsin and Ontario, much of the recent population increase has been due to increases in the number of artificial sites available and not

the number of tree sites occupied (Fig. 1). Hydro poles, high-voltage transmission towers, navigation aids and a wide range of other structures are also used by Ospreys, enabling them to reoccupy areas in which preferred large trees and snags are in short supply close to good foraging areas (Reese 1970, Westall 1983, Poole 1985, Martin et al. 1986).

Reductions in fish populations and their predators in northern, base-poor lakes and rivers have been associated with acidification from precipitation (Almer et al. 1974, Mason and Seip 1985, Bevanger and Ålbu 1986, Schindler et al. 1989, Gill 1993). Although there are few North American Osprey lake acidification studies, reduced productivity and breeding population density of Swedish Ospreys has been noted in lakes experiencing high degrees of acidification (Eriksson et al. 1983, Eriksson 1986). An increased availability of naturally-occurring metals (such as mercury and aluminum) in highly acidified lakes may also prove to be a significant toxicological factor for Ospreys (Nyholm 1981, Poole 1989, Gill 1993, Scheuhammer and Blancher 1994).

The influence of human disturbance of Ospreys at their nest seems to vary according to whether the birds are already used to human presence or not, whether the disturbance is regular from the onset of the nesting season or if it commences during a sensitive stage such as the incubation or small chick stage (Swenson 1979, Poole 1981, Van Daele and Van Daele 1982, Levenson and Koplín 1984). In many areas nowadays Ospreys nest very successfully within 100 m of cottages, roads, railways, boating channels etc., and it is likely that birds recruiting to such sites have been raised in similar situations. Contrastingly, reduced breeding success is often experienced by birds disturbed after nesting has begun, particularly in remote areas or where little or no human disturbance has occurred earlier in the season (Swenson 1979, Levenson and Koplín 1984, Poole 1989). There is little evidence that propeller or jet fixed-wing or rotor-winged aircraft flying low over Osprey nests, even in remote areas, cause marked reductions in breeding output or site occupation in subsequent years (Carrier and Melquist 1976).

Bald Eagles are generally more sensitive to human disturbance than are Ospreys, particularly in the early spring, but in more remote areas Ospreys are excluded from suitable nest trees and foraging areas by the eagles (Ogden 1975, Gerard et al. 1976). As Bald Eagles continue to slowly recover from the effects of DDT and other organochlorine

contaminants, they are likely to move into former nesting areas which already support Ospreys, which will result in local declines in Osprey numbers or shifts to suboptimal nesting locations, further away from the foraging areas. In various parts of the Great Lakes basin, this phenomenon is already well-established.

#### TREES AND OSPREYS

Ospreys will nest in a wide range of tree species, heights and ages. I agree with Henny (1986) that historically most Ospreys probably nested "... in the tops of snags or trees with dead tops, although live trees were also used." The most important nest-site selection criteria today seem to be: clear aerial access to the nest, at least one strong side branch to support the heavy nest, proximity to water/inaccessibility to mammalian predators, avoidance of Bald Eagle territories and nearby elevated perch. Islands are particularly attractive to Ospreys, largely due to proximity to foraging areas and reduced mammal populations, and at least 50% of the world's ospreys are thought to breed on islands (Poole 1989). Of equal importance as the characteristics of occupied nest trees is the surrounding stand. In forests, Ospreys usually build their nests above the surrounding canopy, whether it is 15 m or 50 m above ground level. As a result, they tend to select older trees and often dead trees or those with dead, flat or blown-out tops. For example, of 85 occupied nest trees I documented in various parts of Ontario between 1990–95, 80% were conifers (mostly white pine, *Pinus strobus*) and 20% were deciduous species (mostly white birch *Betula* spp., with some poplars *Populus* spp.). Live trees supported 47% of the nests, flat-topped or dead-topped conifers supported 12% and the remaining 41% of nests were in totally dead trees, often in swamps created originally by beaver activity.

Some species have more open, irregular crown architecture than others, making them more suited to Osprey nests. For example, in Minnesota's Superior National Forest, 77% of 301 Osprey nests over 31 yr were in super canopy white pine, even though this species represented less than 0.5% of trees with dbh >10 cm (Rogers and Lindquist 1993). In Oregon's Deschutes National Forest, large ponderosa pine are the preferred nest tree (90% of nestings), with mean tree height 35 m, mean dbh 95 cm and 30% of nests are in live trees, 21% of dead-topped trees and 49% on dead snags (Gerdes pers. comm.). Dead-topped tall trees are often more



common in areas infected with insect pests, blister rusts (Eckstein pers. comm.) or in areas with heavy winter icing or wind storms which snap off the growing top.

As timber has been removed from North American forests, so the mean age of forests has declined. The mean height of trees available to nesting Ospreys has decreased, as presumably has the number of trees with sufficiently strong side branches at the top to support Osprey nests over a number of years. The lowest rates of nest collapse from blow-down or branch breakage (% nests lost per year) are in the north, likely reflecting tree age/suitability: northwestern Ontario 5% (Grier et al. 1977), southcentral Ontario 12% (Ewins 1996), Montana 10–15% (Grover 1983), New York 30–40% (Poole 1984), Maryland 10% (Reese 1977), Florida 50–70% (Poole 1984), California 30% and Mexico 18–44% (Airola and Shubert 1981). Various studies have found that reproductive output from tree nests is often lower than at nests on artificial platforms (Reese 1977, Postupalsky 1978, Van Daele and Van Daele 1982, Westall 1983, Poole 1989), but when hydro poles are considered separately from customized nest platforms, these differences are less obvious, especially in areas with large trees (Ewins 1996, Henny and Kaiser 1996). In general, with populations still increasing at rates averaging up to 15% per annum, there is little evidence for population-level impairment of reproduction due to shortage of quality nest support structures.

Surveys of Osprey breeding distribution over the past 25 yr have usually found most tree nests to be close to water. For example, 55% of nests in northern California were within 1 km of water and all were within 10 km (Garber 1972), and in Oregon 83% of 78 nests in 1978 were within 1 km and all were within 2 km of water (Henny et al. 1978). In the Deschutes National Forest in Oregon, successful nests in large ponderosa pines >200 yr old in 1970–71 were not significantly closer to water than unsuccessful nests ( $\bar{x}$  = 1.2, SD = 1.6 km, range = 0.1–4.8 km for successful nests;  $\bar{x}$  = 1.6, SD = 1.4 km, range = 0.1–4.8 for unsuccessful nests; Lind 1976). In Ontario during the 1990s, 93% of 179 tree nests were within 500 m of water; the median distance to water for tree nests was 10 m, but only 4 m for nests on artificial platforms (Fig. 2).

To what extent does this evidence indicate that Ospreys prefer to nest close to water? Clearly, Ospreys will seek to minimize energy expenditure wherever possible and nest close to food resources.

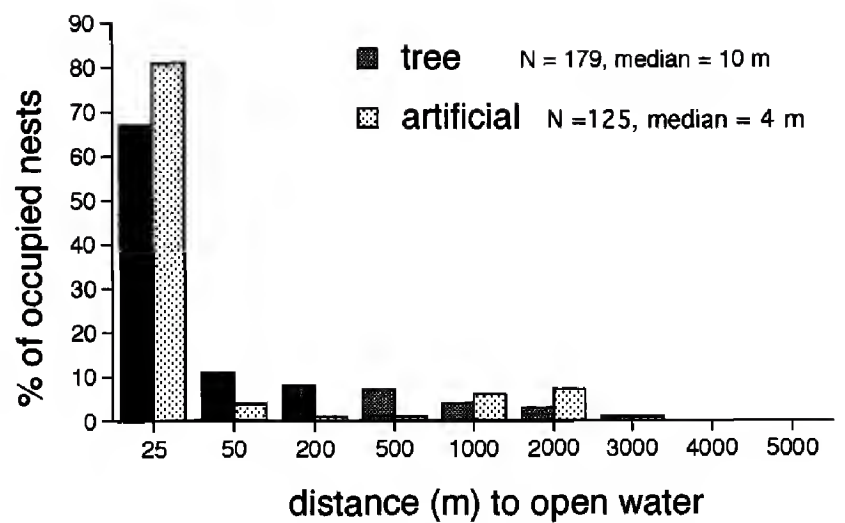


Figure 2. Frequency distribution for 304 occupied Osprey nests in Ontario of distance from open water (river, or lake >2 ha), 1990–95.

But, this must be balanced against nest stability and risk of predation. Selective and clear-cut logging in many areas has usually been more intensive further away from water courses, due in part to landscape considerations and the need to provide visual screens for recreational boaters and canoeists. Thus, the availability of potentially suitable large trees for nesting Ospreys may not be comparable at differing distances from the foraging areas. Perhaps there were, historically, many more suitable large trees for ospreys further away from the water. A clue is provided from studies along the Atlantic coast. There, some Ospreys regularly nest in trees 14 km or more from the main fishing areas due to a shortage of suitable nest sites (Greene et al. 1983, Hagan 1986). In New Brunswick, Ospreys commonly nest on hydro poles, and for 151 nests in 1993, the median distance to water was 1.0 km, but 45% of nests occurred from 1–5 km from water (Stocek pers. comm.). This suggests that provided suitable tall nest support structures are available, a greater proportion of Ospreys will breed further from the foraging areas than is found in areas where suitable tree sites are in short supply. Thus, I suspect that, historically, considerable numbers of Ospreys bred well away from the water in most of North America and especially in areas where Bald Eagles occupied the prime super canopy or large snag nesting trees in water's-edge territories (Ospreys generally avoid nesting near Bald Eagles).

Nesting immediately over water, such as on a stump, flooded tree or navigation aid, presumably reduces the risk of predation at the nest, and so would be expected in preference to tree nesting on land. There is little firm evidence for this, but

on Chesapeake Bay, navigation aids, duck blinds and nesting platforms over water seem to have been occupied even though large trees were apparently still available along the river banks (Reese 1969). However, predation by raccoons (*Procyon lotor*) and Great Horned Owls (*Bubo virginianus*) does occur at over-water nests (Poole 1989) so no generalizations can yet be made about the selective advantage to nesting in these different situations.

There is remarkably little published or unpublished information on Osprey nest trees and reproductive outcomes in areas subjected to timber extraction. Collating data from many individuals across North America, I reached the conclusions that there is an urgent need for a systematic field study and that no firm generalizations can be made. In some cases Ospreys continued to nest successfully in an isolated tall tree or snag left after clear-cutting, in others Ospreys have actually moved to an isolated tree within a clear-cut and in other cases Ospreys have abandoned a nest during logging activities, or road construction, or have abandoned the entire area after a nest tree was removed and no suitable alternatives seemed to be available nearby.

In California, 15 Osprey nests within 500 m of logging roads suffered significantly reduced breeding output if logging traffic use of roads commenced once Ospreys had already initiated breeding (Levenson and Koplín 1984). This study rejected the conclusion of Melo (1975), which was based upon a single nest observation, that logging activities could safely continue during the Osprey breeding season to within 30–35 m of the nest.

It is likely, though not quantified, that the large changes in beaver (*Castor canadensis*) populations over the past two centuries have greatly reduced the availability of snag trees over water, often preferred by nesting Ospreys. Intensive trapping led to severe depletion of beaver populations at various stages and regions over the past two centuries (Newman 1985, Dunstone 1993). In many northern parts of North America, Ospreys breed in snags in swamps formed as a result of beaver activity. Thus, this human trapping pressure almost certainly greatly reduced the number of suitable snags available for nesting Ospreys.

#### CURRENT FOREST-MANAGEMENT GUIDELINES FOR OSPREYS

With populations of Osprey and other raptor species at record low levels in many areas during the 1960s, due largely to the effects of organochlo-

rine pesticide accumulation, considerable attention turned towards restoration measures. Restrictions on the use of DDT and dieldrin were finally introduced in the early 1970s and many agencies then focused on habitat management for Ospreys. The first Osprey Management Area was designated at the Crane Prairie Reservoir in Oregon's Deschutes National Forest (Roberts 1969) and the management plan formed the basis for subsequent forest-management guidelines and recovery plans for Ospreys across the continent. These management guidelines vary considerably among areas, most notably in the distances they recommend for the various types of buffer or exclusion zones, but also in the suite of exclusions and various proactive conservation measures (Roberts 1969, Kahl 1972, Garber et al. 1974, Penak 1983, Gieck 1986, Henny 1986, Nova Scotia Dept. Lands and Forests 1987, U.S. Forest Service 1974, 1991).

**Nesting Habitat.** *Absolute buffer zone*—within a 40–200 m radius of an occupied nest tree, access is restricted year-round and limited to activities benefiting the nest site (e.g., nest support modification, collection of scientific data, tree safety pruning).

*Seasonal buffer zone*—within 100–800 m radius of an occupied nest, or up to 600 m beyond the periphery of the absolute buffer zone and for the duration of the breeding season (usually 1 April to 31 August), certain activities are restricted or banned. These include logging, road or pipeline construction, mining, peat extraction and some forms of recreation. Outside this breeding period, recreational activities and controlled tree harvesting and planting is permitted. Within clear-cuts, some small- and medium-sized trees should be retained in clumps, as well as some large snags. Some plans advise retaining >4 flat-topped tall dominant trees or snags, or all snags >36 cm dbh (U.S. Forest Service 1974), or even to remove the tops from some live large trees to create more suitable nesting trees.

*Riparian/lacustrine buffer zone*—for distances of 70–350 m back from the water's edge, the guidelines vary from no cutting, to retention of up to 5 snags and 5 clumps of tall trees, or the preservation of clumps of large living or dead trees, or >10 trees/ha. In addition, Kahl (1972) and Garber et al. (1974) recommend retention of all broken-top and other suitable nest trees up to 3.5 km beyond this 350 m buffer zone.

**Foraging Habitat.** Restrictions apply to develop-



ment which could degrade shallow-water fish habitat. Recommended bans on the use of chemical control of undesirable, nongame fish species. Water levels should be maintained so as to allow Ospreys access to fish.

**General Guidelines.** Early consultation with the area wildlife biologist is stressed by most plans and their approval required prior to any timber sale. Suitable training for field foresters in wildlife identification and the forest-management guidelines is recommended. Protective measures may be lifted after prolonged inactivity of a nest tree. The need for ongoing monitoring is stressed. Some plans recommend "guarding against the effects of pesticide sprays" (Penak 1983), which presumably refers to the persistent, yet highly effective and toxic organochlorine pesticides. Proactive measures are stressed especially by the early management plans in California, where dead and live trees were modified to provide stable nest supports for Ospreys, wherever human safety was not compromised.

Thus, there is wide variation in forest-management guidelines for Ospreys across North America. To a large extent this reflects the uncertainty in the response of Ospreys at the population level to different types of forest management and our lack of understanding of basic components of Osprey ecology in forested areas. This has naturally led to some confusion and questioning among resource managers. For example, Ontario's new Forest Planning Manual has 39 complex guidelines of this type, which many foresters find much too complex and ignore (Euler pers. comm.). Hence, although the Ontario guidelines for forest management in the vicinity of Osprey nests are relatively stringent (Penak 1983), we find that adherence is largely dependent upon the inclinations of individuals on the ground, both foresters and local wildlife biologists.

An interesting economic concern has been posed by Opper (1988). Based on 1980s mean timber values and forest yield parameters in Ontario pine forests, he has calculated that adherence to the provincial forest-management guidelines near an Osprey nest "preempts about 465 units of wood, which would produce approximately 280 tons of pulp. . . . thus costing about \$CAN 168,000 to protect a single Osprey nest." While accepting the principle of integrated and sustainable forest and wildlife resource management, Opper understandably questions ". . . the scientific or biological rationale upon which (such) wildlife pre-

scriptions are made." These questions highlight an urgent need for sound biological data to justify particular management guidelines for Ospreys, since we currently have only scattered and anecdotal evidence. This suggests that Ospreys at either the individual or population level exhibit variable tolerance to forest-management activities and associated disturbance of different types.

The protection of mature, over-mature and deadwood timber in riparian zones, or as isolated trees or small clumps in clear-cuts clearly provides Ospreys and Bald Eagles with suitable nest trees. But one might expect elevated nest predation rates in such strips/corridors, due to predators moving along such corridors or between clumps of trees. In clear-cut areas, retention of isolated tall trees or snags generally increases the exposure to wind and the likelihood of trees blowing down. Thus, it is important to retain a number of alternative sites/clumps and ideally to conserve some younger trees which would, in time, replace the suitable nest trees at the time of timber extraction.

Finally, we should remember that the decisions regarding conservation of trees for nesting Ospreys must be made in an ecosystem context. Many other important components of the forest wildlife community will benefit by retaining groups of larger and dead trees in any clear-cut areas and these decisions should clearly be made on an ecosystemic and long-term basis, not just for one species of raptor on a short-term basis.

#### RECOMMENDATIONS

There is a clear need for a systematic study of nesting Ospreys in relation to different forest-management activities. This need is as much from a forestry-economic perspective as from an Osprey-conservation angle. Such a study could well be done cooperatively with the forest industry and a suitable student/university/conservation or government agency. The ultimate objective would be to provide an objective assessment of the responses of nesting Ospreys to factors associated with timber extraction, both at an individual and population level and over the course of a few years (not just 1-2 yr). For example, the study should compare breeding productivity and nest occupancy rates over 3-5 yr at sites with different intensities and types of human disturbance, with different sizes and ages of clear-cuts, at various distances from water and with different numbers of alternative nest trees within the vicinity. Nest predation rates and



tree stability in narrow riparian corridors and at isolated clumps of trees should also be assessed. Such a study would require large study areas, but foresters are operating at this scale already. The benefits to the industry would be substantial if it were found that Osprey populations can generally adapt well to logging activities.

The final recommendations in relation to Ospreys should then be integrated with the results from any studies of other wildlife species with specific niche requirements (e.g., other raptors, cavity-nesting birds, mammals), to produce general guidelines for sustainable forestry which would accommodate the needs of a wide range of wildlife species and not just one or two top predators. If in doubt, I would strongly recommend erring on the cautious side by retaining more dead snags, larger clumps of dominant trees and broader nonintervention riparian strips.

#### GENERAL CONCLUSIONS

North American Osprey breeding populations in the 1980s–1990s appear relatively healthy and are still increasing in most areas, following the dramatic declines caused by the effects of organochlorine contaminants during the 1950s–1970s. Many factors are known or suspected to impact Osprey populations and their breeding productivity and the relative importance of these varies considerably across the continent. Prior to European colonization of North America, most Ospreys probably bred at the top of large trees, but as forests were cleared and the mean age of forests declined considerably, Ospreys have adapted to nesting on artificial structures, often over water. In many areas, they have also habituated to nesting in close proximity to humans. Artificial nesting structures are not a viable long-term alternative to natural, tall tree support structures for Osprey nests.

Many of the present guidelines for forest management in the vicinity of Osprey nests stem from advice used 15–25 yr ago, when Ospreys were classified as threatened or endangered in many parts of the range. In light of the dramatic population recovery since the mid-1970s, a review of these guidelines is appropriate. Forest-management plans should ensure, in an ecosystemic context, that sufficient large live trees and standing deadwood snags are retained after timber extraction to provide nesting Ospreys with a number of alternative nest trees close to shallow-water foraging areas. In relation to nest-site requirements, Ospreys

are relatively adaptable, compared to many other raptors and other animals of North American forests. The precise nature and extent of this adaptability needs to be confirmed and properly quantified for Ospreys nesting in commercial forests and more consistent guidelines adopted across the continent once this type of study has been completed. Current guidelines for Ospreys in some forest-management plans may be difficult to justify based on the needs of Ospreys, at least at the population level. However, retaining large residuals of mature trees benefits many other species in forest ecosystems, not only Ospreys, so we clearly need to adopt an ecosystem approach. Forest-management guidelines for wildlife should not restrict timber harvesting or recreational use of forests unnecessarily, yet they should ensure that the needs of the most sensitive components of the forest ecosystem are provided for, even if they are not so highly visible or adaptive as a top predatory species like the Osprey.

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## THE GREAT GRAY OWL (*STRIX NEBULOSA*) IN THE CHANGING FOREST ENVIRONMENT OF NORTHERN EUROPE

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**ABSTRACT.**—The Great Gray Owl (*Strix nebulosa*) breeds in northern Europe mostly in older coniferous forests. Nest sites are usually in twig nests of large hawks, sometimes on stumps, and occasionally on the ground. The availability and the quality of tree nest sites is generally lower in managed forests; however, use of artificial nests has partly compensated for declines in natural nest sites. The Great Gray Owl has increased in abundance in northern Europe over the last 30 yr. It was absent almost entirely from Finland from 1940–60, having been numerous there, especially from 1880–1910. It feeds mainly on field voles (*Microtus agrestis*), which are abundant in fields and grassy areas following forest clear-cuts. The area of clear-cuts has increased since 1950, providing more open hunting habitat and vole resources. Also, protection of all owls and increasing positive attitude toward birds of prey has coincided with the Great Gray Owl increases since the late 1960s. Forest management practices that may benefit the Great Gray Owl include shape of cuts which should be irregular and not broader than 400 m. Perch trees left in cut areas would expand the hunting area from the forest edge.

**KEY WORDS:** *Strix nebulosa*; Great Gray Owl; trends in distribution; breeding; diet; effects of forestry.

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El Gran Búho Gris *Strix nebulosa* en cambios del ambiente en los bosques de Norte Europa

**RESUMEN.**—El Gran Búho Gris *Strix nebulosa* se cría en el norte de Europa mas frecuente en bosques coníferos maduros, mas viejos. Sitios de nidos están muchas veces en nidos de ramita de halcones grandes, a veces en tocones, y de vez en cuando en el terreno. La disponibilidad y la calidad de árboles con nido es generalmente mas bajo en bosques manejados. Sin embargo, uso de nidos artificiales ha compensado un poco en la reducción de nidos natural. El Gran Búho Gris ha aumentado en abundancia en el norte de Europa sobre los últimos 30 años. Estuvo ausente casi completamente en Finlandia de 1940–1960, viendo sido numeroso allí, especialmente de 1880–1910. Se alimenta principalmente con ratones de labor *Microtus agrestis*, que son abundante en los labores y áreas pastosas después de cortes-completos de bosques. El área de cortes-completos ha aumentado desde 1950, proporcionando mas hábitat abierto para cazar y recursos de *Microtus agrestis*. También, protección de todos los búhos y aumentando el actitud positivo para los ave de rapiña ha coincidido con el aumento del Gran Búho Gris desde el fin de los 1960s. Costumbres del administración de bosques que puede dar beneficio al Gran Búho Gris incluye la forma de los cortes que deben ser irregular y no mas amplio que 400 m. Árboles de percha dejados pueden aumentar áreas de cazar de la orilla del bosque.

[Traducción de Raúl De La Garza, Jr.]

A number of raptor populations have declined during the past 50 yr (e.g., the Peregrine Falcon, *Falco peregrinus*, and the Osprey, *Pandion haliaetus*), largely due to pesticides. Many forest species, such as nonmigratory owls, have not experienced similar declines, but have been affected by rapid changes in forest structure caused by forestry practices.

Public attitudes toward raptors, especially owls, have improved in recent times. Killing by hunters

is now rare in the northern countries of Europe. In addition, ornithologists have prepared many nest boxes and other nesting structures for several species of owls. In Finland during 1994, 22 691 owl nest boxes were checked for occupancy (Saurola 1995).

The purpose of this paper is to review existing knowledge on the distribution and ecology of the Great Gray Owl in northern Europe and to discuss possible effects of forestry. The main topics cov-

ered are: changes in distribution, population size, causes of mortality, nest sites, diet and the possible effects of forestry.

#### NESTING AND FEEDING ECOLOGY

**Nesting Habitats.** The nesting-habitat requirements of the Great Gray Owl are fairly flexible, but most nests are found in older spruce-dominated coniferous or mixed forests. Great Gray Owls do not build their own nest structures. Nest location is, therefore, determined by nest-site requirements of large hawks, which build twig nests. Older forests may be preferred because the Northern Goshawk (*Accipiter gentilis*), the main nest-site producer, prefers this nesting habitat. The Great Gray Owl also nests in pure deciduous and pine forests. Nests in structures other than twig nests have in a few cases been in open habitats (e.g., almost open clear-cut area or open field).

Nest location is often near an opening such as a natural open bog, a clear-cut area or a small field (Pulliainen and Loisa 1977, Mikkola 1983, Hildén and Solonen 1987). When nests are 50–100 m from forest edges, the Great Gray Owl often perches at the forest edge. The most commonly used perch trees are often near the edge. Nests located in more exposed environments have shelter available nearby and young leave the nest relatively early to avoid direct sunlight (Helo 1984).

**Nest Sites.** Forest-management practices have decreased natural nest sites available for many large forest owls, including large stumps and holes, the former of which are used by the Great Gray Owl (Table 1). Natural twig nest sites used by the Great Gray Owl are mainly old goshawk or buzzard (*Buteo* spp.) nests, both occupied and abandoned. Nests on top of stumps (1–5 m in height) have been found in Finland, Sweden (Stefansson 1979) and Alaska (Osborne 1987). The Great Gray Owl also occupies artificial nest structures, either open boxes or platforms (Table 1). Use of artificial nests indicates a lack of natural nest sites, as in the case of the Kemi-Tornio area, but also indicates an ability to use a wide variety of nest sites and structures.

Stump nests are more common in southern areas (Hildén and Solonen 1987, Osborne 1987). This is observed to some extent in Finland, but more clearly in the U.S., where only stump nests were used in most southerly areas (Osborne 1987). Imprinting on nest structures by young (Hildén and Solonen 1987) and lack of large stumps in northern areas (Osborne 1987) are possible expla-

Table 1. Nest-site distribution (%) of the Great Gray Owl in three areas: all of Finland, western Finland and northeast of the northern Bothnian Bay (Kemi-Tornio area).

NEST SITES	WEST-		
	ALL OF FIN- LAND <sup>a</sup> %	ERN FIN- LAND <sup>b</sup> %	KEMI- TORNIO AREA <sup>c</sup> %
Hawk twig nest	72.7	88.9	42.6
Corvid nest	4.8	1.0	3.8
Other twig nest	4.4	—	0.8
Man-made twig nest	3.6	2.0	37.2
Man-made platform or open box	—	3.0	9.3
Stump	10.8	2.0	5.4
Ground	2.4	2.0	0.8
Cliff, stone, ant hill	0.8	1.0	—
Barn roof	0.4	—	—
Number of nestings	249	99	129

<sup>a</sup> Hildén and Solonen 1987.

<sup>b</sup> K. Huhtala unpubl. data, not included in "All of Finland."

<sup>c</sup> Liehu et al. 1995.

nations. In addition, because owls avoid long periods of exposure to sunlight (Osborne 1987), nests on low stumps may offer more shade, which is likely more important in southern areas. Many stump nests in Finland have been found in relatively warm springs (Mikkola 1983), but correlations with temperature need further investigation. Ground nests, which have been recorded several times in Finland (Table 1), may be a response to forests with no twig or stump nest sites or they may be a response to microclimatic factors.

**Nesting Density.** Nests were usually some distance apart. Saurola (1985) estimated a mean of 1 pair/100 km<sup>2</sup> for Finland. In several cases, however, two or more nests have been reported only 100–400 m apart (Mikkola 1981, 1983). Some group nestings are likely due to local abundance of field voles. In some other cases, old "goshawk forests" with several good alternative twig nests were the reason why two nests were situated only 100–200 m from each other. In some cases, male Great Gray Owls have been polygamous with the second female laying about 1 wk later than the first. Also, two pairs have nested only 100–300 m apart (Höglund and Lansgren 1968, Mikkola 1983) to use goshawk nests which were situated in groups in older forests.



Table 2. Composition of Great Gray Owl diet in northern Europe (%).

	SWEDEN 1955–64 <sup>a</sup>	NORTHERN EUROPE 1955–74 <sup>b</sup>	WESTERN FINLAND 1966–89 <sup>c</sup>	WESTERN FINLAND 1973 <sup>d</sup>	KOLA PENINSULA <sup>e</sup>
Field vole, <i>Microtus agrestis</i>	54.3	66.2	73.3	42.6	1.5
<i>M. oeconomus</i> and <i>M. spp.</i>	17.6	7.3	—	—	—
Bank vole, <i>Clethrionomys glareolus</i>	7.7	10.3	9.6	11.0	0.8
Grey-sided vole, <i>C. rufocanus</i>	1.5	2.9	—	—	93.8
<i>Clethrionomys spp.</i>	8.4	3.2	—	—	—
Water vole, <i>Arvicola terrestris</i>	1.5	1.7	4.3	1.0	—
Wood lemming, <i>Myopus schisticolor</i>	2.8	1.8	1.3	—	—
Common shrew, <i>Sorex araneus</i>	2.3	2.8	7.4	36.3	—
Soricidae spp.	2.5	1.7	2.2	2.3	0.8
Birds, Aves	0.8	1.0	0.6	0.8	—
Frogs, Amphibia	0.2	0.5	0.1	1.0	—
Other animals	—	0.4	2.1	5.0	3.1
No. items identified	1977	5177	4858	830	130

<sup>a</sup> Höglund and Lansgren 1968.

<sup>b</sup> Mikkola 1983.

<sup>c</sup> K. Huhtala unpubl. data.

<sup>d</sup> K. Huhtala unpubl. data.

<sup>e</sup> From Mikkola 1983.

#### Hunting Habitats and Diet in Northern Europe.

There are numerous observations of Great Gray Owls hunting in open habitats in Finland, but quantitative data are lacking. They may fly over open terrain like Short-eared Owls (*Asio flammeus*), but most observations have been of perching birds on trees, bushes or telephone poles at or near the edges of forests (Wahlstedt 1969, Mikkola 1981, 1983). In winter, hunting dive pits in the snow are usually <50 m from the forest edge.

The diet of the Great Gray Owl in northern Europe is mainly *Microtus* voles (*M. agrestis*, *M. oeconomus* in Lapland; Table 2). This specialization is surprising because of the owl's size and because there are also other numerous small mammals (*Clethrionomys* voles and *Sorex* shrews) available in its environment. Field voles (*Microtus* spp.) comprise an average of 72–74% of the diet, while 8–10% consists of bank voles (*Clethrionomys* spp.) and 5–10% of shrews. In most years other prey, such as birds, frogs and larger voles (*Arvicola* spp.) are only occasionally found in the diet. The diet of the Great Gray Owl suggests that it hunts mainly in grassy areas (fields, meadows, open bogs and clear-cut areas), where *Microtus* species are found. Although there are numerous shrews available in north European grasslands, they seem to be avoided.

A comparison with the diet of Tengmalm's Owl (*Aegolius funereus*) in the same area in western Fin-

land (Table 3) indicates that other small mammals as well as field voles are available in the same locality. Tengmalm's Owl hunts mainly in forests, but also at forest edges and in grasslands (Korpimäki 1981, 1988). However, it preys on field voles much less and feeds more on bank voles (37–46%) and shrews (15–24%). This confirms that the Great Gray Owl hunts mostly in open habitats and prefers *Microtus*.

The preference for field voles in open habitats may be partly due to the large size of the Great Gray Owl, which may make it difficult for the species to hunt in the dense forests of central Finland. This notion is supported by results of Pulliainen and Loisa (1977) in northeastern Finnish Lapland, where most old forests are rather open. There, *Microtus* and *Clethrionomys* voles are represented in the diet of the Great Gray Owl in the same percentages as are found from small mammal captures.

High abundance of *Microtus* voles in the species' diet may be overemphasized, because data are primarily based on its nesting diet and the species usually nests only in good *Microtus* years. Three samples of food from poorer *Microtus* years when the Great Gray Owl nested (Table 2) indicate that it is also capable of capturing other prey. Field voles, however, were still the main prey even in these exceptional samples from 1973–77. All three pairs nesting in central Ostrobothnia in 1973 fed

Table 3. Composition of Great Gray Owl and Tengmalm's Owl diet (%) in central Ostrobothnia (western Finland) in 1966, 1977 and 1989 (K. Huhtala unpubl. data).

	GREAT GRAY OWL			TENGMALM'S OWL		
	1966	1974	1989	1966	1974	1989
Field vole, <i>Microtus agrestis</i>	83.0	76.7	76.7	25.8	28.7	39.2
Bank vole, <i>Clethrionomys glareolus</i>	9.2	12.2	7.6	45.8	40.4	37.2
Wood lemming, <i>Myopus schisticolor</i>	—	1.2	2.3	—	—	6.7
Shrews, Soricidae	6.0	5.4	5.0	23.7	23.3	15.3
Birds, Aves	1.1	0.9	0.4	2.8	7.2	1.5
Other animals	—	1.4	0.4	1.9	0.4	0.2
No. items identified	283	1064	931	528	460	406

largely on shrews (33–41% of the diet compared to 1–6% of the diet in other years). Whereas the diet of great grays usually consists of only 0–2% frogs, 12% of the diet of a pair nesting on the island of Hailuoto in the Bothnian Bay in 1977 consisted of frogs. Similarly, the great gray diet consists of only 1–3% water voles but, in western Finland in 1977 it contained 8–15% water voles. More water voles were available, because Eagle Owls (*Bubo bubo*) also consumed more water voles in 1977 than normal.

#### DISTRIBUTION AND POPULATION TRENDS IN THIS CENTURY

In this century, the Great Gray Owl has nested in most of Finland, northern Sweden and occasionally in the far north of Norway (Mikkola 1983). It breeds rarely throughout Russian Karelia and is included in the Karelian Red Book on endangered animals (Shehter 1985). The most southwesterly

breeding localities in Europe are in Belarus and Poland (Mikkola 1983).

The nesting population in northern Europe has changed considerably in the past 100 yr (Fig. 1). One hundred years ago (1880–1910), there were several good nesting years and Finnish egg collections alone contain more than 10 clutches from several years. At that time, the population bred in the northernmost coniferous forests, mainly in northern Finland and in northeastern Norway (Fig. 2).

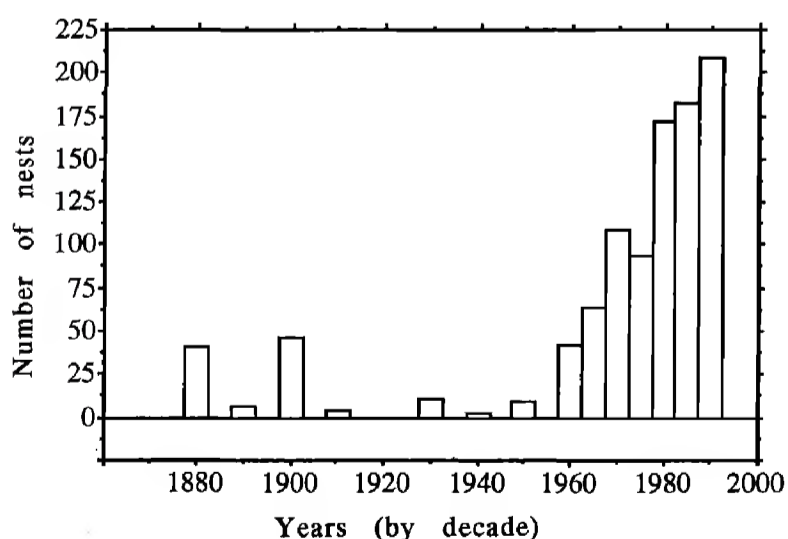


Figure 1. Number of Great Gray Owl nests found in Finland at 10-yr intervals in 1880–1960 and at 5-yr intervals in 1960–1995. Before 1940 data are from clutches in Finnish egg collections.

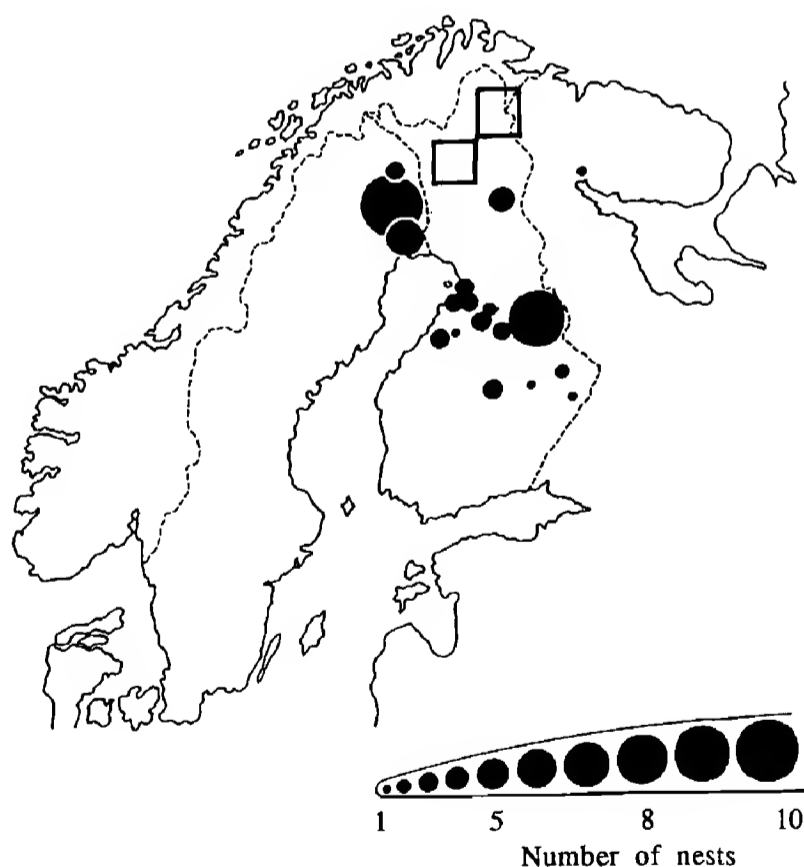


Figure 2. Distribution and relative density of Great Gray Owl nests in Finland and northern Sweden in 1955–1974 (adapted from Mikkola 1983). Squares show the main breeding areas in northern Finland and Norway in 1880–1910.

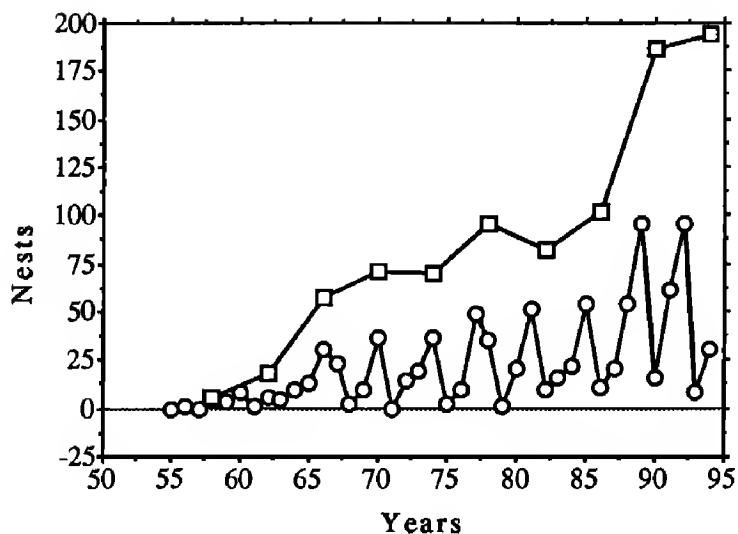


Figure 3. Number of Great Gray Owl nests found in Finland in 1955–1994, yearly (lower line) and at 4-yr periods (upper line).

From 1910–1930, few nests were reported in Finland. Some nests were again seen during the 1930s, especially in the far north of northeastern Finnish Lapland in 1938 (Haartman et al. 1963–72, Fig. 1). Breeding Great Gray Owls were then almost absent from Finland for about 10 yr from 1940–1950. A few nests were found in the 1950s farther south, in central Finland (Merikallio 1958, Mikkola and Sulkava 1969, Hildén and Helo 1981). Few nests were found during this period in Sweden (Curry-Lindahl 1961).

There have been several winter invasions of Great Gray Owls in south and central Finland, south of the normal breeding area. However, only occasional nestings occurred in spring following invasions. Invasion years were 1895–1896, 1907–1908, 1911–1913, 1935, 1949 and 1955 (Merikallio 1958, Haartman et al. 1963–1972).

The number of nests found has increased in Finland since the 1960s (Fig. 3). Regular breeding was reestablished in Finland in 1966–1967, and since then Great Gray Owls have been nesting in the two best years of every 4-yr vole cycle (Fig. 3). In Sweden, nesting was rare until 1973 and has increased since then (Fig. 4).

There has been a steady increase in number of nests found in Finland over the last 25 yr, especially in the last 10 yr (Fig. 3). There was a slight reduction in number of nests in the 1980s compared to the number found afterward. The 4-yr vole cycle, regular since the 1950s, became irregular in the early 1980s (Henttonen et al. 1987). Consequently, the field vole peaks were not high enough to allow all Great Gray Owls to breed.

The reported increase in the number of nests

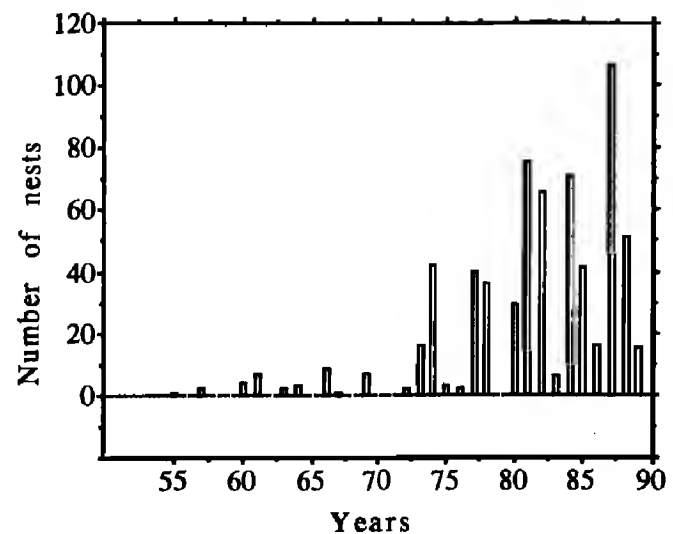


Figure 4. Number of Great Gray Owl nests recorded yearly in Sweden in 1955–1989, according to Mikkola (1983), Stefansson (1983) and Niemi (1989).

found in northern Europe in 1960–1994 was partially due to the increase in nest searching for all owls for ringing (banding) and monitoring (Saurola 1986) and for building of artificial nests (Table 1). No increase in the Finnish Great Gray Owl population was determined from 1966–1984 by Saurola (1985), but since then the numbers have been higher (Fig. 3). An increase in the Great Gray Owl population is also mentioned in other studies (Mikkola 1983, Helo 1984, Solonen 1986).

The breeding area of the Great Gray Owl after 1960 has been concentrated in central and southeastern Finland, 300–500 km south of the main area of breeding before 1940 (Mikkola and Sulkava 1969, Hildén and Helo 1981, Fig. 2). The main breeding area now is in the Oulu district and since 1980 also in the Kemi-Tornio area (Solonen 1986). Because extensive cutting in Lapland began 20–40 yr later, this move from Lapland to central Finland was not caused by forestry. After this range shift, clutch size was smaller ( $\bar{x} = 4.30$ ,  $SE = 0.10$ ,  $N = 70$ ) than in 1880–1910 ( $\bar{x} = 4.63$ ,  $SE = 0.12$ ,  $N = 80$ ;  $t = 2.16$ ,  $P < 0.05$ ). However, this potential decrease in offspring production has not affected an increase in the population in recent times.

#### EFFECTS OF FORESTRY PRACTICES

Effects of forest-management practices on owls vary, depending on the practices and the needs of the owl. Forest owls may lose nesting habitats and nest sites, but hunting for prey may be easier in cut areas. No numerical data are available on the effects of forestry on Great Gray Owls or their population in Finland. However, possible influences may be determined from indirect data on food



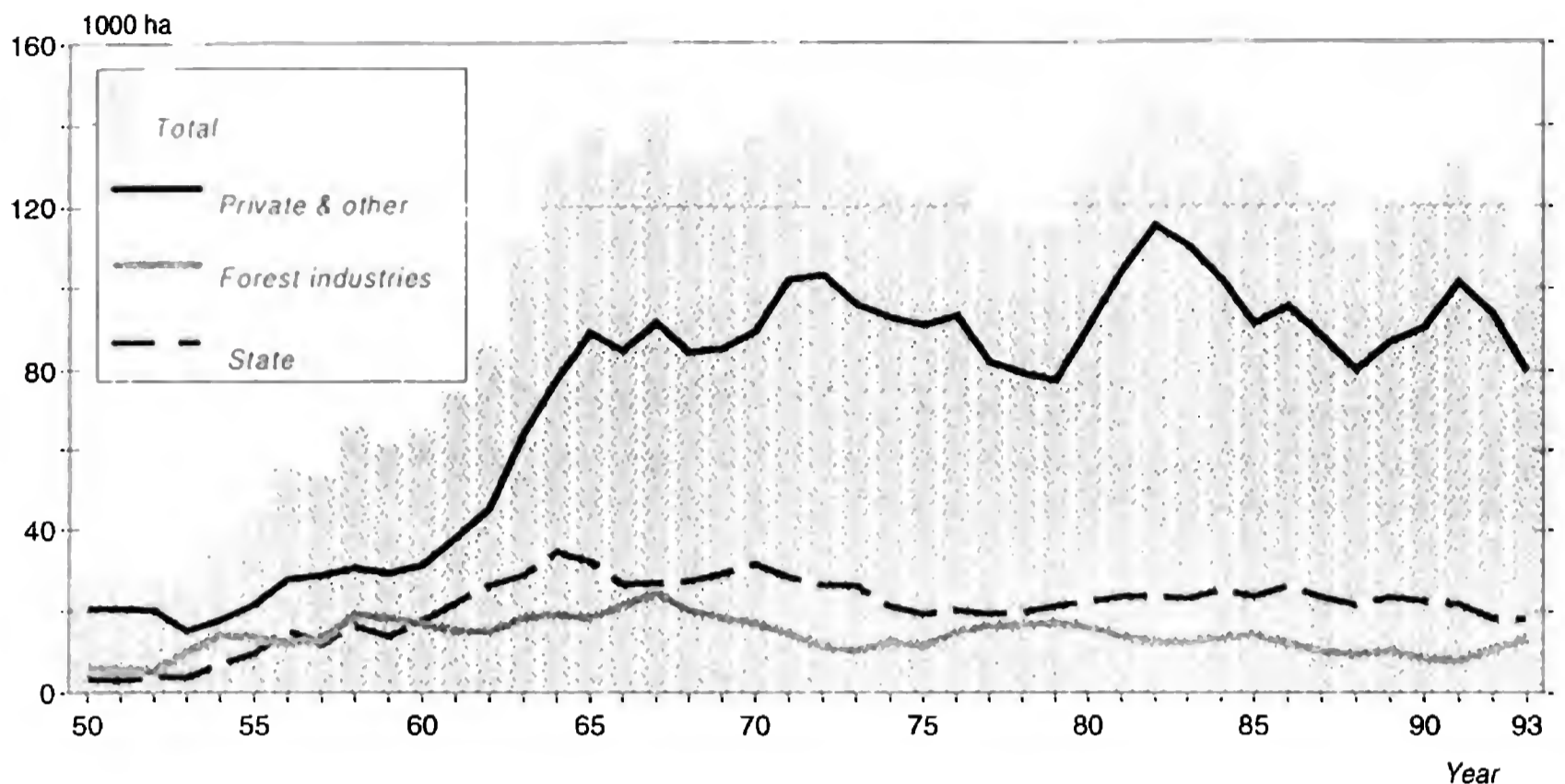


Figure 5. Area of clear-cut forest seeded or planted in Finland in 1950–1993 (total and by forest ownership category) (from Aarne 1994).

habits, changes in the environment, and from miscellaneous direct observations.

**Forestry Practices in Finland, 1950–1990.** The “modern and efficient” logging of forests began in northern Europe about 1950. Until that time, timber was harvested mostly by thinning the forests. Since then, forests have changed rapidly in many ways that may affect the Great Gray Owl. First, the area of old forests has rapidly decreased resulting in a decrease in large trees, in which diurnal birds of prey build their twig nests. Second, dead and broken trees have been removed resulting in a reduction in stump nest sites. Third, clear-cut areas have increased (Fig. 5) resulting in an increase in field vole production and an increase in food. Fourth, the area of young, dense forests has increased, decreasing the area available for hunting or nesting. Fifth, the area of drained wet bogs has increased, leading to a decrease in the area available for field vole production. Sixth, roads are being built in remote forest areas leading to increased disturbance (Fig. 7).

**Nesting Habitat Availability.** Large areas of clear-cutting (several km<sup>2</sup> at a time) indicate that the Great Gray Owl has lost considerable breeding habitat, which may reduce local breeding populations. It may be argued that, because of the species’ flexibility in nest habitat use, it will have adequate forests for breeding in northern Europe in the fu-

ture. The availability of nesting habitat may not be a limiting factor, although it is not known how large a forest a nesting pair of Great Gray Owls needs between cut areas.

**Decline in Availability and Quality of Nesting Sites.** The Great Gray Owl nests in a variety of structures (Table 1), but large twig nests and stumps are the main natural sites used. The numbers of these nest sites have decreased because of forestry practices for several reasons. First, the area of older forests that contain hawk nests has decreased because of clear-cutting. Second, the number of stump nest sites in forests has decreased because dead and broken trees have been removed in the course of forest management. Third, the number of alternative nests per hawk pair is probably smaller in young forests. Young trees have weaker branches and, consequently, nests collapse more often. In addition, poor quality of twig nests in young forests may lead to nest failures, but the extent of such losses is unknown.

The number of twig nest sites currently available seems to be sufficient in Finland. Solonen (1986) estimated that there were about 50 000 twig nests available in Finland in 1986, and even if 50% of these were outside the normal breeding area of the Great Gray Owl, the number would still probably suffice for the estimated 500–1500 Great Gray Owl pairs in the country. In addition, populations of

large hawks, goshawks, Honey-buzzards (*Pernis apivorus*) and buzzards (*Buteo* spp.) have been stable in Finland in recent times (Saurola 1985, Haapala et al. 1995). These species will likely produce enough new twig nests for Great Gray Owl use in the future, too, despite the fact that hawk nests are sometimes destroyed by the Great Gray Owl when it digs out the nest bowl. In the first digging phase in early spring, the owl often digs a 10–15 cm deep bowl. This perhaps dries the nest material; the final bowl for the eggs is only about 6 cm deep. Rapid wear of hawk nests used by Great Gray Owls has also been observed by Stefansson (1979) in Sweden.

The readiness of the Great Gray Owl to use various nest structures points to a lack of suitable nesting sites. Man-made nests are often used in North America (Nero 1980, 1982, Bohm 1985, Bull et al. 1987) and, in Finland, open box nests have been used in Kainuu (Helo 1984) and central Ostrobothnia. Almost half the Great Gray Owls reported in the Kemi-Tornio area in the 1990s occupied artificial nests composed of twigs (Liehu et al. 1995, Table 1).

**Increase in Hunting Habitat Availability.** To find enough *Microtus* voles, the Great Gray Owl needs open habitats with grasses, herbs and sedges. These habitats include hay fields (cultivated, temporarily unused or abandoned), open wet bogs, bog margins or clear-cut forest areas. The area in hay fields has increased, especially those unused or abandoned. Only a small proportion of abandoned fields have been planted with trees. The number of clear-cut areas of different ages has increased substantially since the 1950s (Fig. 5). The vegetation on most of these areas will support field vole populations. The common practice of plowing cut areas has increased the growth of grasses. The number of wet sedge bogs has decreased due to extensive draining for forestry or peat production (Aarne 1994). Drained areas are only partly suitable for field voles.

Clear-cutting is obviously the main factor which has increased hunting habitat availability to the Great Gray Owl in forest areas since the 1950s. Before 1950, timber was removed by selective harvest, but between 1950–1994, clear-cutting was the primary logging practice. Only in the last few years has “continuous cultivation” (selective harvest) of the forest been allowed again; clear-cutting is still the main practice. Before the early 1990s, clear-cut areas were mostly carefully cleared of all timber,

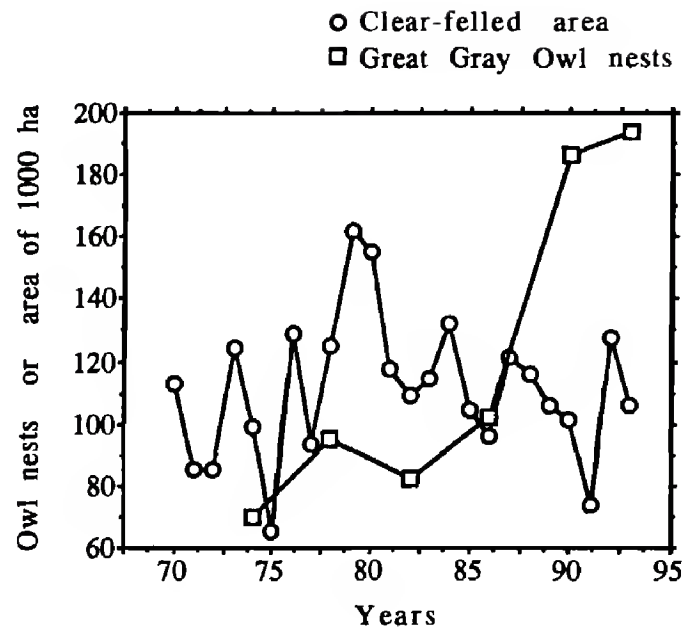


Figure 6. Total clear-cut area (in 1000 ha) in Finland from 1970–1993 (from Aarne 1994) and Great Gray Owl nests recorded at 4-yr intervals from 1970–1994.

including dead and young trees, and the land was often burned, ditched or plowed before it was seeded or planted (Fig. 5).

During the expansion of the Great Gray Owl population in Finland since the 1960s, clear-cut areas have provided more field voles for raptors than in earlier periods (Teivainen 1979). In state forests in northern Finland and in forests of timber companies in central Finland, the clearings have often been too large (more than 20 ha) and too open to be used as hunting grounds. The owls probably hunted only at the edges of these large openings.

The future may be better because new rules for forest management and cutting practices have been prepared and partly introduced in 1994–1995. Cut areas will be smaller in size (mostly not more than 5–10 ha) and groups of both live and dead trees will be left in cut areas. Also, forest strips will be left along lake shores and stream valleys.

**Prey Availability.** The Great Gray Owl requires a high density of voles (mostly field voles) to breed, and therefore generally breeds only in increasing and peak years of the northern vole population cycles which are more pronounced than in more southern areas of Europe (Hansson and Henttonen 1985). In the northernmost breeding areas of northern Europe (Fig. 2), *M. oeconomus* and even *C. rufocanus* may produce enough food for breeding (Table 1) because these species are often the most abundant voles in open habitats.

The increased vole resources due to clear-cuts (Teivainen 1979) have obviously been important to support the increase in Great Gray Owls in north-



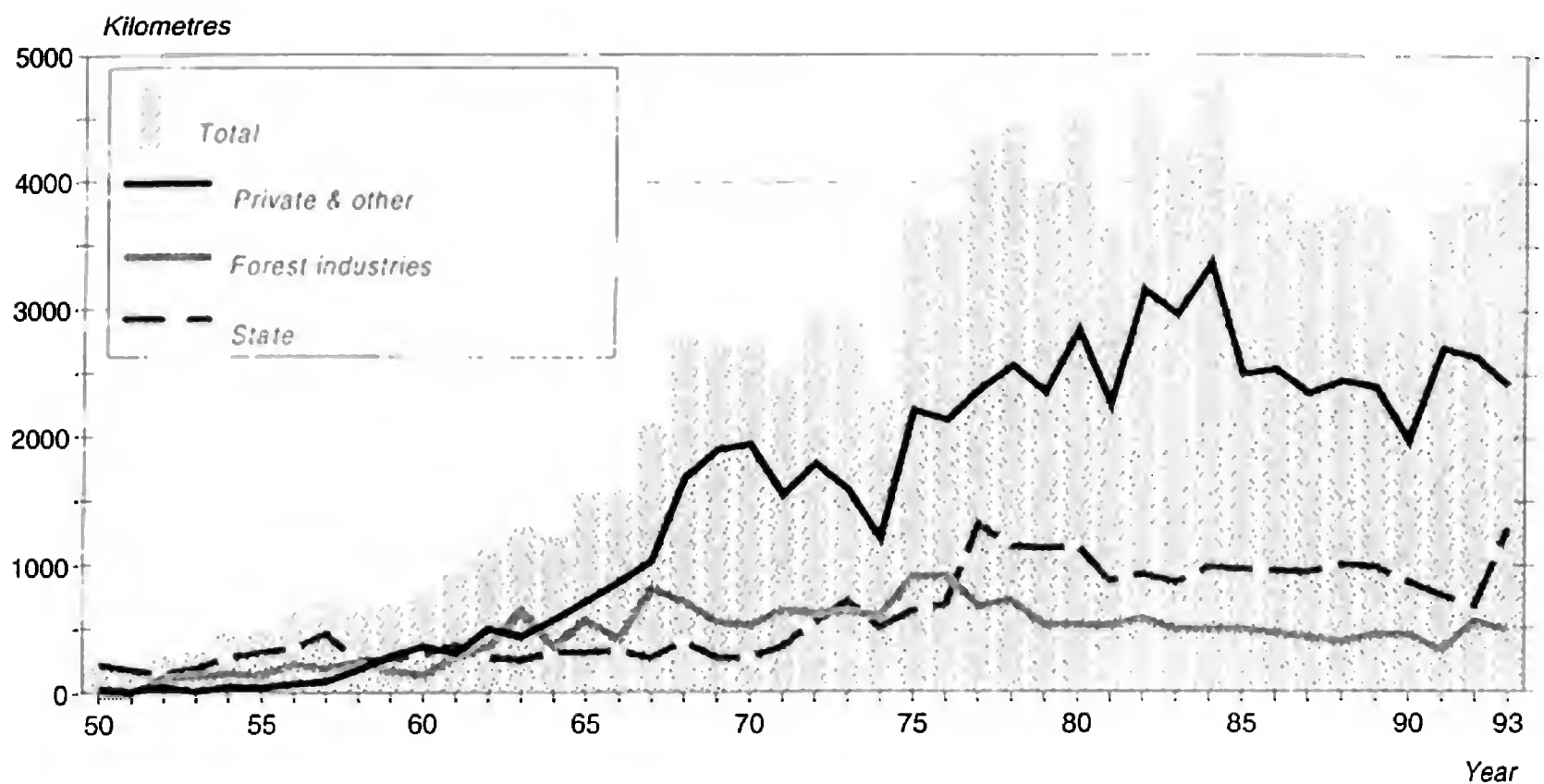


Figure 7. Permanent forest roads (in km) completed in Finland from 1950–1993 (total and by forest ownership category, from Aarne 1994).

ern Europe. In Germany, the number of breeding Tengmalm's Owls increased after extensive clear-cutting and decreased again with reforestation. This was due to the greater abundance of rodents in recently cut areas (Mebis 1987). The breeding population of Great Gray Owls seems to have grown more than what would be supported by only an increase in area of recent clear-cuts in Finland (Fig. 6). Since about 1980, the total area of clear-cuts has decreased slightly, but the number of nests of the Great Gray Owl identified has increased.

**Size, Shape and Distribution of Harvested Areas.** Our knowledge of the breeding and hunting requirements of the Great Gray Owl is still inadequate for precise recommendations on forestry practices. Its hunting habits in large openings and the amount of forest necessary for breeding are not sufficiently well known. The following descriptions of beneficial and detrimental forestry practices are therefore only approximate: (1) Most cuttings should be restricted to areas of 20 ha in size; cuts of 2–5 ha are probably the best size. Cut areas larger than 20 ha should be irregular in shape, not broader than 400–500 m, and with convoluted edges to give shelter when hunting at the edge. All cuts should have groups of trees left for perching. (2) Forest strips (corridors), 50–100 m wide, should be left between the cut areas for moving and sheltered resting places, and there should be

some larger forest areas, 5–10 ha in size, between the cut areas to provide nesting habitat.

Most detrimental for the Great Gray Owl would be large-scale clear-cuts of more than 100 ha that are circular or square in form, especially if they are totally treeless and with only small patches of forest remaining between them. In this situation, the species would not have appropriate food resources, nesting habitats or resting and perching places.

In practice, fairly diverse cut sizes are acceptable by the Great Gray Owl as long as small groups of live and dead trees are left and forest corridors are left along shores and streams, and between large cuts.

#### ACKNOWLEDGMENTS

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## GREAT GRAY OWLS (*STRIX NEBULOSA NEBULOSA*) AND FOREST MANAGEMENT IN NORTH AMERICA: A REVIEW AND RECOMMENDATIONS

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**ABSTRACT.**—Great Gray Owl (*Strix nebulosa nebulosa*) populations in North America have likely been stable over the past 10–100+ yr. Local populations fluctuate in response to food supply and/or nest-site availability. Breeding Great Gray Owls require preexisting nest structures in forest stands that are adjacent to open foraging habitat, preferably with hunting perches. Current forestry practices have the potential to affect about 75% of the Great Gray Owls' breeding range in North America. Intensive timber management typically removes large diameter and deformed nest trees, leaning trees used by juveniles for roosting before they can fly and stands with dense canopy closure used by juveniles and adults for cover and protection. Modified forest management can, however, create new foraging habitat by opening up large, dense forest stands. Specific recommended guidelines include restriction of harvest unit size ( $\leq 5$ –10 ha), but within a mosaic of multi-sized units, retention of forest stands within 300 m of known or potential nest trees/sites, provision of hunting perches in cut-over areas, ensuring irregularly shaped harvest units and maintenance of forested travel corridors between cut-over areas. Because Great Gray Owls can breed on home ranges up to 800 km apart in successive years, integration of local management regimes at a landscape scale is recommended. Ideally, spatio-temporal patterns of natural disturbance (e.g., fire) should be emulated in a management plan to sustain the region's natural biological diversity, including Great Gray Owls when appropriate.

**KEY WORDS:** *Strix nebulosa*; North America; forest management; habitat use; Great Gray Owl.

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El Gran Búho Gris *Strix nebulosa nebulosa* y administración forestal

**RESUMEN.**—Las poblaciones del búho *Strix nebulosa nebulosa* en norte américa han estado estable con seguridad los pasados 10 a 100+ años. Poblaciones locales fluctúan en reacción a suministros de comida y/o la disponibilidad a sitios de nido. Búhos en cría necesitan estructuras de nidos hechos en bosque que están pegados al hábitat de forraje libre preferible con perchas de cazar. Costumbres actualmente de forestales tienen la potencia para afectar casi 75% de el campo de cría de el búho en norte américa. La administración de madera con intensidad típicamente quita árboles con diámetros grandes y árboles deformados con nido, árboles inclinados usados por juveniles para percha antes que pueden volar, áreas con densidad cerrada usada por juveniles y adultos para cubrirse y protección. Administración de bosque modificados pueden, sin embargo, inventar nuevo hábitat de forraje con abriendo grandes y densas áreas de bosque. Recomendaciones específicos de las reglas incluyen: (1) restricciones de cosecha de cierta altura ( $< 5$ –10 ha), pero dentro de un mosaico de varios tamaños, (2) retención de áreas de bosque conocido o en potencia de árboles/sites con nido dentro de 300m, (3) provisión de perchas de cazar en áreas cortadas, sugiriendo conjuntos de cosecha con formas irreguladas, y (4) mantenimiento de corredores de viaje en áreas de bosque en parcelas cortadas. Porque búhos se pueden criar en campos naturales hasta 800 km aparte en años seguidos, integración de administración local con una escala de paisaje es recomendado. Idealmente, que muestras de spacio-temporal de disturbios naturales (e.g., lumbre) debe ser emulado en el proyecto de la administración para sostener las regiones, diversidad natural y biológica, incluyendo búhos cuando es oportuno.

[Traducción de Raúl De La Garza, Jr.]

In November 1995, a symposium on Holarctic raptor responses to forest management was held in Duluth, MN U.S.A. Presenters were asked to review information on a species according to guidelines

provided and in response to specific questions. This paper is a review of such information for the Great Gray Owl (*Strix nebulosa*) in North America.

The Great Gray Owl is unevenly distributed

across the Holarctic over 30 million km<sup>2</sup> of boreal forests in Eurasia and North America (Clark et al. 1987). Throughout its range it occupies forest habitat; however, it also successfully breeds north to within the transition zone between the boreal forest and the treeless tundra (Lang et al. 1991). In western North America, it extends its range south by occupying montane forests in the Rocky Mountains, the Cascade Range and the Sierra Nevada Range (Duncan and Hayward 1994). It is the largest northern forest owl, although not the heaviest. Its yellow eyes, set in a facial disk with nearly concentric gray and white rings, are framed by a large round head that lacks ear tufts. Two subspecies are currently recognized: *S.n. nebulosa* in North America and *S.n. lapponica* in Eurasia (Bull and Duncan 1993).

Great Gray Owls in the boreal forest region of North America have greater diet similarity (% similarity) to populations in Eurasia ( $\bar{x} = 95.3\%$ ,  $SD = 1.46$ ,  $N = 3$ , range = 94–96.9%) than to those in the southwestern U.S. that occur in montane forests ( $\bar{x} = 49.8\%$ ,  $SD = 13.9$ ,  $N = 9$ , range = 39–69.4, Duncan 1992). Great Gray Owls from both continents exhibit similar plasticity in selection of nest sites, although ground nesting is more frequently reported from northern Europe (Mikkola 1983). They appear to use similar foraging habitat in Eurasia and North America (Mikkola 1983, Duncan and Hayward 1994). Therefore, one would expect *S.n. nebulosa* and *S.n. lapponica* populations to respond similarly to forest changes that alter the availability of nest sites and/or foraging habitat. Eurasian Great Gray Owls are paler with more vertical barring, perhaps relating to habitat differences (Oeming 1955, Mikkola 1983); they also appear to be more aggressive toward humans at nest sites than North American Great Gray Owls (Nero 1980, Mikkola 1983).

Considerable attention has recently been directed toward evaluating the status of North American Great Gray Owl populations (Winter 1986, Hayward 1994). As with any species, this invariably requires an assessment of the habitats that are thought or known to sustain populations. Current forestry practices have the potential of affecting about three-quarters of the Great Gray Owls' breeding range in North America (Bull and Duncan 1993). McCallum (1994) provides a critical review of the complexities involved in determining owl-habitat relationships and the importance in distinguishing between habitat requirements, pref-

erence and use. To best evaluate the relationship between Great Gray Owl populations and forest management, one would ideally have knowledge of the species' habitat requirements and/or preference. Since these do not currently exist, except for a few habitat preference studies (e.g., Servos 1986), the following review of Great Gray Owls and forest management is based primarily on nesting and foraging habitat use data.

#### POPULATION TRENDS

Typically considered rare, the Great Gray Owl occurs at low densities within its range (Nero 1980, Bull and Duncan 1993). Nero estimated a continent-wide population of 5000–50 000 owls in North America; up to 25 000 breeding pairs have been estimated for Canada (Kirk and Hyslop pers. comm.). However, Great Gray Owls are easily overlooked and are probably more common. I estimate the current North American population of Great Gray Owls to be 20 000–70 000 breeding pairs. The range of this estimate reflects the dependence of this species on prey, primarily microtines (e.g., *Microtus* spp.), that exhibit unstable population fluctuations over 3–5-yr periods (Duncan 1992).

The degree to which local prey population fluctuations are synchronous over the Great Gray Owl's North American range is unknown. Extrinsic factors such as severe temperatures with little or no snow cover, occasionally synchronize (reduce) microtine populations over large geographic areas. More commonly, other factors (both intrinsic and extrinsic) appear to disrupt such synchronizing effects (Pruitt 1968, Lidicker 1988).

Great Gray Owls are most often seen in winter, and in more heavily settled areas along the southern portions of their breeding range. Irregular, large-scale, continental movements of bird populations are called irruptions (Collins 1980). The Great Gray Owl is one of several irruptive species of owls in North America. When large numbers of birds appear locally, it is commonly referred to as an influx or invasion. The fluctuations in winter occurrence of Great Gray Owls in these areas (Fig. 1) suggest that large-scale irruptions occur less frequently than local invasions. Large-scale irruptions are thought to be the product of one or more years of high Great Gray Owl reproductive success followed by a widespread decrease in prey availability on the breeding range. The recent apparent increase in Great Gray Owl winter occurrences is



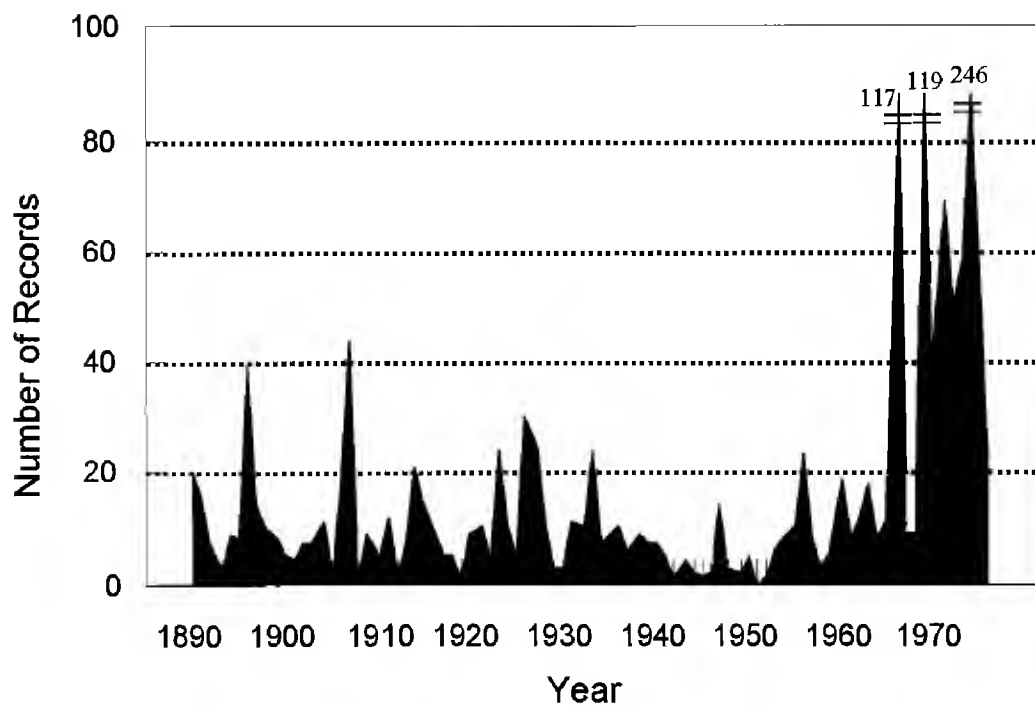


Figure 1. North American Great Gray Owl winter irruptions based on specimens and sight records, 1890–1976. Data from southern Canada and northern U.S.A. Modified from Collins (1980).

likely due to increased observer effort and increased access to winter habitat (Collins 1980).

The overall North American Great Gray Owl long-term (>10 yr) population trend is unknown. There are no long-term, rigorous or standardized Great Gray Owl breeding population trend data on a range-wide, regional or local scale. There is circumstantial evidence that some local and/or regional populations have either remained stable, increased or decreased over periods of <10 yr (Fyfe 1976, Collins 1980, Nero 1980, Nero et al. 1984, Winter 1986, Bryan and Forsman 1987, Franklin 1988, Collins and Wendt 1989, Bull and Henjum 1990, Duncan 1992). Ongoing local surveys are underway at a number of locations in Canada and the U.S. Nonetheless, it is useful to speculate on the relationship between forestry and local Great Gray Owl population trends.

Reliable population distribution data may only be available after widespread and standardized monitoring programs have been operating for several years. While classic “playback” survey techniques (Smith et al. 1987) can increase the number of Great Gray Owls detected by up to 40%, it is unlikely that they can yield data that identifies statistically significant population trends.

#### PRIMARY FACTORS ASSOCIATED WITH TRENDS

North American Great Gray Owl populations are relatively unaffected by human persecution or direct chemical effects (Nero 1980, Winter 1986, Hayward 1994), notwithstanding occasionally high

local human-caused mortality (Nero and Copland 1981). The availability of nest sites and suitable foraging habitat are considered the most important factors limiting Great Gray Owl populations (Duncan and Hayward 1994). I will address these first, but some discussion is warranted on the short-term (3–5 yr) influence of prey availability, which can profoundly affect conclusions drawn from short-term (<5 yr) local Great Gray Owl surveys.

**Diet.** Local Great Gray Owl breeding densities fluctuate considerably, primarily due to the instability of microtine prey populations (Henttonen 1986, Duncan 1992). Individual radio-marked owls in Manitoba and northern Minnesota have dispersed up to 684 km between breeding home ranges in response to prey population crashes ( $\bar{x}$  = 328.8, SD = 184.9,  $N$  = 27, range = 41–684 km); those marked birds that did not disperse ( $N$  = 11) did not survive (Duncan 1992).

In contrast, breeding Great Gray Owl populations in montane regions of the western U.S. are thought to be relatively stable (Winter 1986, Bull and Henjum 1990, Bull and Duncan 1993). In northeastern Oregon, the maximum distance travelled from nest sites by adult radio-marked Great Gray Owls averaged 13.4 km ( $N$  = 23, range = 2.4–43.2 km; Bull and Henjum 1990). Bull and Henjum (1990) speculate that in years when prey populations are low, Great Gray Owls in their study area remain as nonbreeding residents. In California, Winter (1986) suggested that under similar cir-

cumstances, Great Gray Owls possibly sustain themselves on pocket gophers (*Thomomys* spp.), as well as other prey species. Pocket gopher populations are relatively stable and noncyclical (Chase et al. 1982, Teipner et al. 1983).

Because breeding populations of Great Gray Owls in different parts of their North American range exhibit variable breeding dispersal strategies, owl surveys undertaken to determine distribution or local population trend data need to be conducted for at least as long as one prey population cycle to ensure reliable results. Therefore, ideally, one should concurrently monitor prey populations and Great Gray Owl diet. Great Gray Owls may or may not be present during years of low prey populations; if present at such times, they are less likely to respond to conspecific call playback used in surveys (Smith et al. 1987).

**Nest-site and Foraging Habitat Availability.** These factors are significantly affected by natural forest disturbances such as disease outbreaks, succession and the effects of fire and wind (Larsen 1980, Habeck 1994). The temporal and spatial scale of the impact of these ecological processes, and the relative stability of prey biomass productivity, have had a strong influence on the evolution of Great Gray Owl life history traits, such as breeding dispersal and post-fledging nest-site fidelity (Duncan 1992). Consequently, forest management does affect Great Gray Owl populations by altering natural disturbance regimes and by the application of management protocols. Anecdotal observations and current knowledge of Great Gray Owl ecology permit some speculation about how forest management likely impacts Great Gray Owl populations.

**Nest sites.** Great Gray Owls use preexisting structures for nesting, including deserted or vacant stick nests of some *Buteo* hawks, Northern Goshawks (*Accipiter gentilis*) and larger corvids (Duncan and Hayward 1994). They will also nest on a variety of artificial structures, in natural depressions in broken-topped snags or stumps, and, rarely, on the ground, on rock cliffs, or on top of haystacks (Mikkola 1983, Duncan and Hayward 1994). Nest-structure type or nest-tree species appears to be less important than nest-site habitat characteristics and the availability of foraging habitat (Duncan and Hayward 1994). Forest tree pathogens (e.g., ants and fungi) and fire can weaken trees, possibly resulting in tree death and subsequent snag or stump formation. More directly, dwarf mistletoe (*Arceu-*

*thobium* spp.) causes exaggerated branch configurations which are conducive to nesting and/or that promote nest-building activity by raptors and corvids (Bull and Henjum 1990). Nest-site availability generally increases with forest stand age (Duncan and Hayward 1994).

Tree pathogen outbreaks and other nest-site creating disturbances tend to have a clumped spatial and temporal distribution. The territories of the Northern Goshawk and Broad-winged Hawk (*Buteo platypterus*) often hold several stick nests (Palmer 1988, Goodrich et al. 1996). If nest sites are limiting and have a clumped distribution, perhaps it is no coincidence that Great Gray Owls have nested in what has been described as loose colonies (Wahlstedt 1976, Bull and Duncan 1993), a trait that undoubtedly also relates to their specialized diet (Mikkola 1983).

Nest-site availability appears to be important enough to Great Gray Owls that they have evolved the ability to relocate and use nest sites hundreds of kilometers apart over 2 or more yr (Duncan 1992). Therefore, forest management activities that reduce the number of nest sites (e.g., fire suppression, disease control and shorter rotation periods) have the potential to reduce Great Gray Owl breeding densities. Mitigation by installing artificial nest structures is impractical at larger spatial scales, but works well locally (Bull and Henjum 1990).

**Foraging habitat.** Voles and/or pocket gophers dominate the diet of Great Gray Owls (Duncan and Hayward 1994). Microtine voles generally occupy moist grass/sedge openings and open forests with herbaceous ground cover. Meadows considered in good ecological condition for voles, and hence Great Gray Owls, are dominated by a variety of climax perennial grasses, sedges, and forbes. Factors that reduce vole abundance (e.g., moderate to heavy grazing) decrease the suitability of foraging areas for Great Gray Owls (Winter 1986).

Great Gray Owl foraging habitat includes bogs, fens, muskeg, peatland, natural meadows, open forests and selective and clear-cut logged areas (Nero 1980, Mikkola 1983, Servos 1986, Winter 1986). Dense coniferous stands (e.g., jack pine, *Pinus banksiana* and black spruce, *Picea mariana*), open areas with few or no trees and habitats with dense shrub layers are avoided by hunting Great Gray Owls (Servos 1986).

Great Gray Owls hunt primarily from perches, listening for prey and watching the ground intent-



ly. When prey is detected the owl usually stoops only a short distance, generally no more than 50 m. Bull and Henjum (1990) recorded an average perch to prey distance of 10.5 m.

Bull and Duncan (1993) reported that Great Gray Owls also forage in open forests. In northeast Oregon, males foraged in stands with 11–59% canopy closure (Bull and Henjum 1990). These stands had meadowlike grass-dominated ground cover. Open tamarack (*Larix laricina*) stands with dense sphagnum/sedge/grass understory are often used by foraging Great Gray Owls in Manitoba.

While hunting, Great Gray Owls perch at varying heights, but usually 3–5 m above the ground, in both live trees and snags adjacent to or within open grassy areas (Duncan and Hayward 1994). Perch heights for male Great Gray Owls averaged 5.5 m in Oregon (Bull and Henjum 1990). In California, perch heights varied from 0–12.2 m above the ground ( $\bar{x} = 3.3$ ,  $SD = 2.3$ ,  $N = 143$ ; Winter 1986). Great Gray Owls rarely hunt while perched on the ground or while flying (Bull and Duncan 1993).

Successful Great Gray Owl reproduction depends on the availability of suitable foraging habitat within 1–3 km of nest sites (Bull and Henjum 1990, Duncan and Hayward 1994). Such habitat can be ephemeral over shorter periods (e.g., post-fire or post-cutting early succession habitat) or relatively permanent (e.g., sedge meadows, peatland and muskeg). Burned or cut-over areas can provide foraging opportunities for Great Gray Owls for 20 yr or more, depending on the rate of succession or on post-harvest management practices. Kirkland (1977) and Parker (1989) reported that meadow vole populations increase 3–18 yr after clear-cutting forests.

Great Gray Owl population declines from ancestral levels have been reported in California (Winter 1986). These were attributed to habitat changes, e.g., fire suppression and overharvesting of forests. Paradoxically, clear-cuts can create Great Gray Owl foraging habitat in dense forests in previously unoccupied areas.

#### FOREST MANAGEMENT RECOMMENDATIONS

Throughout its North American range, the Great Gray Owl thrives in a variety of habitats (Duncan and Hayward 1994). It is adapted to capturing prey in permanent open habitats and in early forest successional stages (Nero 1980). Older and mature forest habitats adjacent to foraging ar-

reas provide suitable nest structures. Therefore, Great Gray Owl populations can likely persist with some amount of forest cutting. The following recommendations are based on what is generally known about Great Gray Owl ecology and not on specific responses of owls to measured habitat changes. New information should alter these specific conservation strategies through an adaptive management approach. The large lifetime home ranges of Great Gray Owls, e.g., in Manitoba and Minnesota (Duncan 1992), suggest that a coordinated landscape-level perspective to management is needed to maintain viable populations. With this in mind, I suggest the following management recommendations.

**Occurrence Data.** The occurrence of Great Gray Owls is poorly documented in many parts of its range (Duncan and Hayward 1994). A review of historic site-specific occurrence information (e.g., literature, specimen data and personal communications) is an appropriate first step. It should be determined if Great Gray Owls currently occur in the management area because pre- and post-harvest occurrence information can be used to adapt harvest guidelines accordingly. Secondly, the presence or absence of Great Gray Owls may influence the degree to which forest resources are managed. Assuming that forest resources are to be managed for this species (e.g., the management area is within suitable habitat and is within or adjacent to its expected North American range) then one must decide to implement a landscape-level or a specific management regime only at sites where Great Gray Owls are known to occur. The efficiency of various survey techniques have not been rigorously tested and survey methods may not be practical over large expanses and in remote areas. Therefore, in the absence of Great Gray Owl occurrence data, an appropriate landscape-level management recommendation would be the retention of a 300 m buffer area around natural openings such as meadows or fens (Winter 1986, Bouchart 1991).

**Clear-cut Size.** Clear-cuts up to 10 ha in size are probably ideal for Great Gray Owls, but these should occur within a mosaic of multi-sized units across a landscape. Great Gray Owls will use larger clear-cuts, but typically they catch prey within 50 m of hunting perches. While they hunt from isolated perches in open areas farther than 50 m from edges, in these situations they are more vulnerable to avian predators such as Northern Goshawks and



Great Horned Owls (*Bubo virginianus*) (Duncan 1987).

**Clear-cut Shape.** Because Great Gray Owls frequently hunt from forest edges, irregular cut shapes with convoluted or scalloped-shaped edges would reduce mortality from avian predators. This design will therefore also increase access to newly created open foraging habitat. Because they catch prey within 50 m of hunting perches, larger cuts should therefore be elongated so that the maximum distance across the cut is <100 m.

**Nest-site Availability.** Timber management has reduced nesting opportunities for all forest raptors, including Great Gray Owls (Habeck 1994). Therefore, the impact of management practices on nest-site availability needs to be assessed.

Some types of nest structures (e.g., mistletoe brooms and snags) used by Great Gray Owls are either directly or indirectly created by tree pathogens (e.g., insects and fungi). These pathogens can cause significant financial losses on commercial forest land. Likewise, fire-killed trees can provide Great Gray Owl nest sites (e.g., snags), but fire also destroys valuable timber. Great Gray Owls often nest in stick nests built by large corvids and diurnal raptors. These sites occur more frequently in older forest stands with larger trees. Shorter rotation periods or selective removal of large-diameter trees has reduced nest-site availability. Forest pathogen control, fire suppression and shorter rotation periods are economically important forest management practices that impact Great Gray Owl nesting opportunities. The provision of artificial nest structures, while locally effective, is labor intensive and costly (Bohm 1985). Their use may still be justified in certain situations.

**Influence of Residuals and Optimal Mix, Including Dispersal Corridors.** Leaving residuals in cutovers (e.g., live trees and dead snags) provide important hunting perches. In Manitoba, the smallest Great Gray Owl nest stand was 4 ha ( $N = 18$ , median = 232 ha) and there were at least 69 ha ( $N = 15$ , median = 136 ha) of foraging habitat within 1 km of nest sites. Bull and Henjum (1990) reported that 52–99% of the area within 500 m of nest sites in Oregon was forested. While Great Gray Owls have successfully nested on the edge of foraging habitat, the distance to the nearest opening averaged 256 m in Manitoba (Bouchart 1991) and 143 m in Idaho and Wyoming (Franklin 1988). Therefore, retention of forest stands within 300 m of known or potential Great Gray Owl nest sites is

recommended as a minimum guideline (see also Winter 1986, Bouchart 1991). The provision or retention of leaning trees used by juveniles for roosting before they can fly and stands with dense canopy closure (>60%) for cover and protection (from heat stress and predators) of adults and juveniles is also thought to be critical (Duncan and Hayward 1994). Maintenance of forested travel corridors between nesting habitat is considered necessary to minimize predation of dispersing adults and juveniles.

Because Great Gray Owl breeding dispersal can be significant (e.g., up to 800 km, Duncan 1992), a coordination of local management regimes at a landscape scale is recommended. Ideally, spatio-temporal patterns of natural disturbance (e.g., fire) should be emulated in management plans to sustain a region's naturally occurring biological diversity, including Great Gray Owls when appropriate.

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## HAWK OWLS IN FENNOSCANDIA: POPULATION FLUCTUATIONS, EFFECTS OF MODERN FORESTRY, AND RECOMMENDATIONS ON IMPROVING FORAGING HABITATS

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**ABSTRACT.**—Hawk Owls (*Surnia ulula*) are diurnal raptors found across the northern hemisphere in open boreal forest habitats. In Fennoscandia (Finland, Sweden and Norway), their diet consists mainly of microtine rodents. The population densities of these microtines usually peak every 3–4 yr and fluctuations are geographically asynchronous. Hawk Owls respond by concentrating and breeding where and when microtine abundance is high. The resulting strong temporal and spatial short-term variation in Hawk Owl density in Fennoscandia makes any long-term population trends difficult to detect. Hawk Owls locate their prey visually from elevated perches and need ample space for long-range scanning and attack. Therefore, harvesting old forest by clear-cutting is believed to benefit the Hawk Owl. However, this may depend on the values of several variables, such as clear-cut size and shape, height of trees in clear-cut edges, density and height of residual trees left in clear-cuts after logging, type and extent of ground cover and prey species composition and abundance in clear-cuts compared to old forest. Based on data on the Hawk Owl's attack range, recommendations are made for spacing of residual trees as hunting perches. No single habitat in Fennoscandian forests seems to be superior for foraging Hawk Owls throughout the year and the effects of modern forestry on Hawk Owls, although probably positive, at present are difficult to predict.

**KEY WORDS:** *Foraging, forestry, habitat, Hawk Owl, management, Surnia ulula.*

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Búho Halcón en Fennoscandia: fluctuaciones de poblaciones, efectos de forestal moderno, y recomendaciones en mejorando hábitat de forraje

**RESUMEN.**—El Búho Halcón *Surnia ulula* son rapaces del día encontrados a través del hemisferio norteño en hábitat abierto en bosques boreal. En Fennoscandia (Finland, Sweden y Norway), su dieta consiste por mayor de "roedor microtine." La población densidad de estos "microtines" normalmente llega su mas alto cada 3–4 años, y fluctuaciones son geográficamente sincronizados. Búho Halcón responde en concentraciones y criando donde y cuando abundancia de "microtine" esta alto. El resultado del temporal fuerte y variación especie de corto tiempo en la densidad del Búho Halcón en Fennoscandia hace cualquier tendencia de duración larga de población difícil a descubrir. Búho Halcón localiza su cazado visualmente en percha elevada, y necesitan espacio amplio para visualizar de larga distancia y ataque. Por eso, cosechas de bosques viejos con cortadas-completas es creído dar beneficios al Búho Halcón. Sin embargo, esto puede depender en el valor de varios variables, como el tamaño de corto-completo y forma, altura de árbol en orillas de corte-completo, densidad y altura de árboles residuales dejados en áreas de cortes completos después de la cosecha, tipo y extenso de terreno, composición y abundancia de especie de cazar en cortes completos comparado a bosques viejos. Basado en los datos del alcance de ataque del Búho Halcón, recomendaciones están hechas para el espacio de árboles residuales como perchas de cazar. Ningún hábitat singular en bosque de Fennoscandia, parece ser superior para el forraje del Búho Halcón a través de todo el año, y los efectos de forestales moderno en los Búho Halcón, aunque problemamente positivo, en el presente es difícil pronosticar.

[Traducción de Raúl De La Garza, Jr.]

Hawk Owls (*Surnia ulula*) are medium-sized (body mass about 0.3 kg) diurnal raptors which range across the northern hemisphere in open boreal forest habitats (Glutz von Blotzheim and

Bauer 1980, Cramp 1985, Norberg 1987). In the western Palearctic region their diet consists almost exclusively of small mammals, mainly microtine rodents (Mikkola 1983, Cramp 1985, Hogstad 1986,



Sonerud 1986), which they locate visually from elevated perches (Sonerud 1980, 1992).

In Fennoscandia (Finland, Sweden and Norway), the original role of fire and storms as the major disturbance agents in the boreal forest (see Zackrisson 1977) has been gradually superseded by humans during recent centuries. During the past 30–40 yr, modern forestry has transformed most of the semipristine and continuous forest, shaped by selective harvesting of the largest trees, into a mosaic of patches interspersed with clear-cuts and plantations (see Rolstad and Wegge 1989). This transformation may affect Hawk Owls in three major ways. First, Hawk Owls mostly use cavities or broken tops of snags for nesting (Cramp 1985) and may therefore experience more limited breeding opportunities in modern forests with fewer old trees as nesting sites. Second, Hawk Owls locate prey by sight (Norberg 1977, 1978, Sonerud 1986) and find suitable conditions in open habitats created by clear-cutting, where long-range scanning for and attack of ground-dwelling small mammals is enhanced. However, Hawk Owls also require elevated perches from which they search for prey (Sonerud 1980) and such perches are often lacking in clear-cuts. Third, clear-cuts support greater populations of voles than are found in old forest, especially populations of the *Microtus* voles (Henttonen et al. 1977, Larsson and Hansson 1977, Hansson 1978), although the availability of these voles may be low for much of the year (Sonerud 1980, 1986, Nybo and Sonerud 1990, Jacobsen and Sonerud 1993).

In this paper I will describe short- and long-term population fluctuations of Hawk Owls in Fennoscandia by reviewing the literature and presenting personal data, identify factors associated with these fluctuations, evaluate whether modern forestry, which emphasizes clear-cut harvesting, creates a habitat where Hawk Owls hunt more efficiently compared to old forest and suggest strategies that would improve clear-cuts as foraging habitat for Hawk Owls.

#### METHODS

In a 50 km<sup>2</sup> (4 km × 12.5 km) area in the boreal forest at 550–750 m elevation in southeastern Norway (61°N, 11°E) the annual number of breeding Hawk Owls were recorded during 1971–95. Each year, all nest boxes and known natural cavities were checked at least once to reveal nesting attempts by Hawk Owls and Tengmalm's Owls (*Aegolius funereus funereus*). Further information on

the area and the nest-visit procedure is given by Sonerud (1985, 1986).

Information on microtine abundance was obtained from observations made when checking nest boxes and from snap-trapping in a permanently established trap line system at the southern end (60°56'N, 11°08'E) of the Hawk Owl nesting area since 1977. This system covers about 40 ha in a clear-cut and the surrounding old forest stands, as described by Sonerud (1986, 1988). During spring (mid- or late-May) in 1977–78 and 1981–95, summer (late July or early August) in 1977 and 1981–90 and fall (late September or early October) in 1977 and 1981–95, about 300 traps (type "Rapp") baited with stained cocoa fat were put out 5 m apart in seven separate lines and checked on each of the following four days (Sonerud 1986, 1988).

In the same clear-cut as microtines were snap-trapped, I also recorded Hawk Owl foraging behavior during 1976–92. The clear-cut covers 20 ha (800 m × 250 m) and contains an average mix of the dominant boreal forest types in Fennoscandia. Before I started recording Hawk Owl foraging behavior, I experimentally modified the clear-cut. First, I removed all trees and snags remaining after logging, except 10 mature Scotch pines (*Pinus sylvestris*). I then divided the clear-cut into eight squares, and within four of these a total of 178 artificial poles with a top-mounted perch were erected. The poles were of three different heights, providing perches 1.5 m (61 poles), 3.0 m (59 poles) and 6.0 m (58 poles) above ground. Within each square, the poles were spaced 20 m apart in a grid. The positions of the different heights were assigned randomly. On the borders between the squares another 23 poles with a top-mounted nest box for owls with a perch height of 4.5 m were erected 40 m apart and 14 m from the nearest adjacent pole. The pines varied in height from 13–20 m, and were within two of the squares containing poles. Thus a total of 211 perches with heights from 1.5–20 m were provided on approximately half the area of the clear-cut.

In this clear-cut, I recorded the foraging behavior of 10 Hawk Owls (Table 1). These were the only ones available for observation, as Hawk Owls are not resident over a longer time in any part of their range. The behavior of the owls was observed from a permanent blind on a hill in the middle of the clear-cut using 7× or 10× binoculars and a 25–40× spotting scope and recorded by the focal-animal method (Altmann 1974). The owls were observed at all times of the day and as long as they remained foraging within the clear-cut. In most cases only one owl was foraging in the clear-cut at a time. The exceptions were nesting pairs. If both mates were available for observation, I always observed the male (Sonerud 1992).

The Hawk Owls always searched for prey by perching. Hovering was employed only as an interruption of an attack upon prey and generally for a few seconds only. The owls were never observed to attack prey while flying between perches. They abandoned perches either to move to another perch or to attack prey. I only recorded perch records of the latter type, which were made when the ground was snow free and for which the perch height and the corresponding horizontal attack distance were known. This sample included 246 attacks (Table 1).

The heights of perches other than poles were estimat-

Table 1. Individual characteristics, sample period and sample size used in this study, of 10 Hawk Owls observed in an experimentally modified clear-cut. Attack records included were those made on snow-free ground and for which both the horizontal attack distance and the height of the perch from which the attack was launched were known.

IND.	SEX	PROVIDING MATE OR NEST-LINGS	SAMPLING PERIOD	NUMBER OF ATTACK RECORDS
1	Male	No	28 Sept.–3 Oct. 1976	2
2	Unknown	Yes	26–28 June 1977	36
3	Unknown	No	1 Sept. 1977	2
4	Male	Yes	26 April–11 June 1981	69
5	Unknown	No	1–30 Oct. 1983	17
6	Male	Yes	20 April–3 June 1984	22
7	Female	Yes	7–22 June 1984	39
8	Female	No	26 Aug.–6 Nov. 1984	11
9	Male	Yes	14 May–16 June 1985	44
10	Unknown	No	29 Sept.–1 Oct. 1992	4

ed by using a clinometer. Horizontal attack distances were either paced or calculated from the map of the grids, while those outside the grids were paced. Some of the long attack distances (>50 m) were measured on a specially made aerial orthophoto of the study area (area-correct scale 1:5000). Flight time elapsed from launching an attack to capturing (or missing) prey was recorded by using a stopwatch. Horizontal attack distances that I was unable to measure, but for which the corresponding flight time had been recorded, were estimated from the perching height and the real attack distance; the latter was in these cases estimated from a linear equation between flight time and real attack distance calculated for each individual.

POPULATION TRENDS

Hawk Owls in the western Palearctic are thought to fluctuate in synchrony with their microtine prey (Cramp 1985). In my study area Hawk Owls were found nesting in only seven of the 25 yr from 1971–1995 (Fig. 1). These 7 yr were all within the 12-yr period 1977–88. All nestings occurred when microtine density was increasing or in peak years, although Hawk Owls were not present in all such years (Fig. 1). Hawk Owls were observed outside the nesting season here in an additional 5 yr (1976, 1982, 1983, 1989 and 1992).

In an area in western Finland (63°N, 23°E), Hawk Owls nested in only 5 of the 14 yr from 1979–90 and only when microtines were abundant.

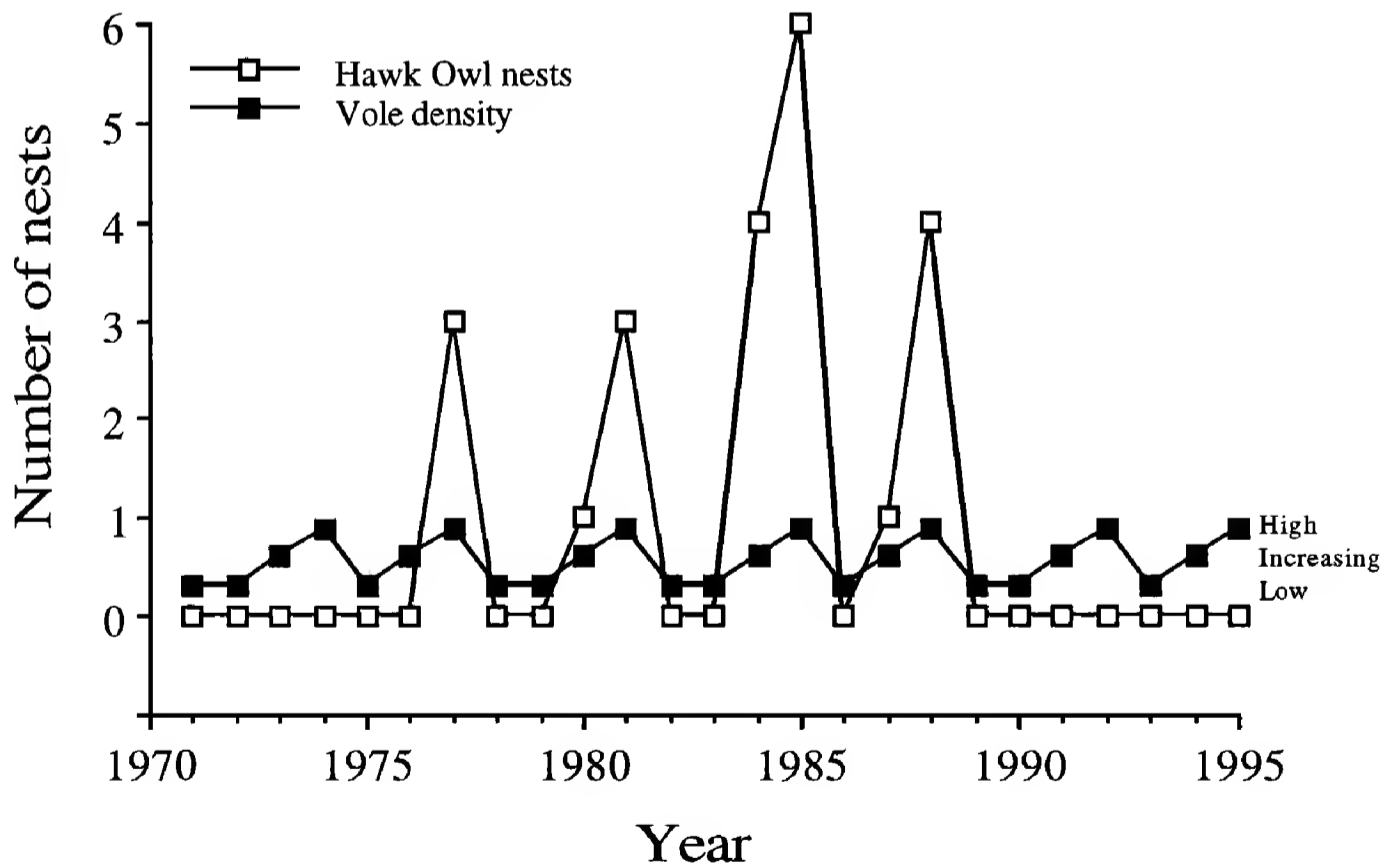


Figure 1. The number of recorded Hawk Owl nests and the population density of microtines in a 50 km² study area in the northern boreal zone in southeastern Norway during 1971–95. The microtine density is scored as low, increasing and high.

Hawk Owls held winter territories here in an additional 3 yr (Korpimäki 1994).

In Fennoscandia, population densities of microtines fluctuate widely, usually with peaks every 3–4 yr (Fig. 1, Hansson and Henttonen 1985). These microtine population fluctuations are geographically asynchronous (Hagen 1956, Myrberget 1965, Myllymäki et al. 1977, Christiansen 1983), even over a scale of less than 100 km (Steen et al. 1996). Because Hawk Owls seem to depend on high microtine densities for nesting (Fig. 1, Korpimäki 1994), the large temporal and spatial variations in microtine densities in Fennoscandia probably select for Hawk Owls with high capabilities of tracking microtine populations. Although the nomadic life of Hawk Owls is accepted as fact (Mikkola 1983, Cramp 1985), documentation is limited to records of invasions (Hagen 1956, Byrkjedal and Langhelle 1986) and scattered ringing (banding) recoveries. Hawk Owls ringed as nestlings in Fennoscandia have dispersed up to 1900 km in all directions, including east into Russia (Glutz von Blotzheim and Bauer 1980, Cramp 1985, Sonerud 1994). Recoveries of Hawk Owls ringed as breeding adults include examples of both males and females residing in an area from one nesting season to the next when microtine abundance remained high and of both sexes leaving when microtine populations declined. There are no examples of Hawk Owls residing in an area from one microtine peak to the next (Sonerud 1994).

In Fennoscandia the number of Hawk Owls at any time is determined largely by the arrival of nomadic owls from Russia and the level of local reproductive output. In this century, large populations were noted in the fall of 1912, 1950 and 1983 (Hagen 1952, 1956, Edberg 1955, Byrkjedal and Langhelle 1986, Risberg 1990). The relative roles of immigration and local reproduction will vary between Hawk Owl population peaks because these factors are determined by the current microtine rodent population phase in Russia and Fennoscandia, respectively. The unprecedented population peak in 1983 seemed to mostly include owls from outside Fennoscandia (Mikkola 1983, Byrkjedal and Langhelle 1986). The dispute about the origin of the Hawk Owls which made up the large population in the southern parts of Fennoscandia in fall 1950 (Edberg 1955, Hagen 1956), however, illustrates the difficulty in determining the relative importance of immigration and local reproduction

for the current size of the Fennoscandian Hawk Owl population.

The number of breeding Hawk Owls in Fennoscandia seems to have peaked in years when immigration from the east during the preceding fall occurred when the local microtine population was increasing toward a peak. The highest recorded number of breeding Hawk Owls in the central and southern parts of Norway and Sweden occurred in the microtine peak years 1984 and 1985, after the unprecedented immigration of Hawk Owls in fall 1983 (Byrkjedal and Langhelle 1986, Risberg 1990). This influx occurred at a time when the local microtine populations were increasing (Sonerud 1988, Lindström and Hörnfeltdt 1994). Similarly, a rather large influx of Hawk Owls into Finland from Russia in fall 1957 coincided with a microtine peak in Finland and many owls stayed to breed there in 1958 (Mikkola 1983).

The total number of Hawk Owls present in Fennoscandia at any time may vary over two orders of magnitude, from a few hundred up to tens of thousands. The temporal and spatial variation in Hawk Owl population density in Fennoscandia makes an estimate of the total population difficult. The numbers of Hawk Owls during peak years have been estimated at 3600 pairs in Finland (Merikallio 1958, cited in Cramp 1985), 10 000 pairs in Sweden (Ulfstrand and Högstedt 1976) and 10 000 pairs in Norway (Sonerud 1994).

Information on long-term population changes of Hawk Owls is sparse, especially from the northern parts of Fennoscandia where Hawk Owls occur more commonly and regularly than in the southern parts (Haftorn 1971, Hyttiä et al. 1983, Risberg 1990), but where few people live. In southern and central parts of Norway and Sweden the Hawk Owl has been more common in the last 25 yr, especially during the period 1975–1989, than in the preceding 25 yr (Risberg 1990, Sonerud 1994). In Finland, the Hawk Owl was thought to have declined from the 19th century until the 1950s (Merikallio 1958, cited in Cramp 1985). In southern Norway, Hawk Owls were less frequent during 1914–1948 than during 1880–1913; in fact none were recorded nesting here between 1913 and 1949 (Hagen 1952). In conclusion, the Hawk Owl seems to have been more common in Fennoscandia during the first and last quarters of the past 100 yr than in the intervening time.



## FACTORS ASSOCIATED WITH FLUCTUATIONS IN HAWK OWL NUMBERS

One explanation for the decline in the number of breeding Hawk Owls in Finland from the 19th century until the 1950s was thought to be human persecution (Merikallio 1958, cited in Cramp 1985). Hawk Owls are easy targets because they are diurnal, use exposed perches and are relatively tame. Earlier in this century Hawk Owls were often shot in years of population peaks in Norway (Hagen 1952). Nowadays, Hawk Owls are protected by law in Fennoscandia and fewer are killed.

Hawk Owls usually nest on top of broken trees, in cavities made by the Black Woodpecker (*Dryocopus martius*), in nest boxes and sometimes in nests made by corvids (Cramp 1985, Sonerud 1985). Since modern forests contain fewer trees old enough to provide cavities suitable as nesting sites for Hawk Owls, the breeding opportunities of Hawk Owls might locally be limited where the forest has been intensively managed. One reason for the decline in the number of breeding Hawk Owls in Finland from the 19th century until the 1950s was thought to be the disappearance of hollow trees (Merikallio 1958, cited in Cramp 1985).

Two factors appear to explain why Hawk Owls have been more common in the central and southern parts of Norway and Sweden during the past 25 yr. The first is the occurrence of a moderate invasion in fall 1975 and a large invasion in fall 1983 (Risberg 1990). The second factor is probably the opening of the forest by clear-cutting that has taken place the past 30–40 yr. This has made larger areas of the forest suitable for the Hawk Owl (Norberg 1987). In addition, clear-cuts support greater populations of microtines than does old forest (Henttonen et al. 1977, Larsson and Hansson 1977, Hansson 1978).

## HOW SHOULD CLEAR-CUTS BE DESIGNED TO SUIT HAWK OWLS?

Harvesting old forest by clear-cutting may benefit the Hawk Owl by creating habitats that are more profitable for hunting than the natural or the selectively cut old forest. Due to its dependence on vision for locating prey, the Hawk Owl is capable of using open forest with ample space for long range scanning of and attack at ground-dwelling small mammals (Norberg 1987). However, due to the Hawk Owl's dependence on elevated perches from which it searches for prey (Sonerud 1980), clear-cuts may not offer suitable types and densities

of hunting perches. In the experimentally modified clear-cut (see Methods), the four blocks provided with perches were utilized more for hunting by Hawk Owls, Common Buzzards (*Buteo buteo*) and European Kestrels (*Falco tinnunculus*) than the four blocks without perches (Sonerud 1980). In Sweden, clear-cuts experimentally provided with perches were utilized more by Common Buzzards than clear-cuts without perches (Widén 1994). By knowing the size of the Hawk Owl's search range from hunting perches, it may be possible to calculate an optimal interperch distance and to design clear-cuts where Hawk Owls can forage effectively.

**Size of Clear-cuts.** To know how wide clear-cuts lacking residual trees may be without being inaccessible to Hawk Owls, I estimated how far into a clear-cut a Hawk Owl's search range extends from a perch in the forest edge. An appropriate estimate of the search range may be the distance containing all recorded attack distances or all but the most extreme ones (90th percentile). Use of the latter is justified because very long attack distances may be traveled under special conditions, and because successful attacks tended to be made at shorter distances than unsuccessful ones when the ground was snow free (Sonerud 1992). From perches  $\geq 9$  m above the ground, as typically found at the edges of clear-cuts, the estimated search range of the Hawk Owls in the experimental clear-cut would be about 70 m if taken as the 90th percentile and 110 m if taken as the longest of the recorded attack distances from such perches on snow-free ground ( $N = 29$ ). Thus, even if clear-cuts are 140 m wide, Hawk Owls hunting from perches in the remaining forest seem able to utilize all the area for hunting in the snow-free season.

**Shapes of Clear-cuts.** The results above suggest that square-shaped clear-cuts up to about 2 ha in size may be accessible for Hawk Owls from perches at the forest edge. Rectangular clear-cuts of all sizes may be accessible from the edge provided the short side does not exceed 140 m. If no residual trees remain in a clear-cut after logging so that Hawk Owls are left only with the perches made up by the forest edge, larger parts of the clear-cut will be available to Hawk Owls as the edge-area ratio becomes larger. Thus, complex clear-cuts with convoluted edges may be more beneficial to Hawk Owls than simple clear-cuts with linear edges.

**Residual Trees.** The results above suggest that if clear-cuts are made wider than 140 m and no re-

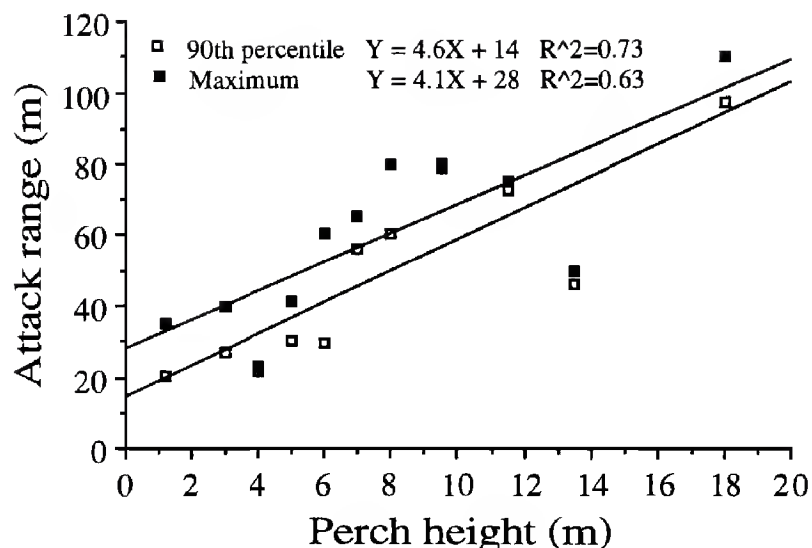


Figure 2. Search range of Hawk Owls in relation to perch height, estimated as the 90th percentile and the longest of the recorded horizontal attack distances, respectively.

sidual trees are left, the central areas  $>70$  m from the edge may be inaccessible to Hawk Owls. Therefore, stumps, snags and other trees of little economic value should be left as hunting perches for Hawk Owls. If such residuals are provided, there may be no upper size limit on clear-cuts that may be utilized by Hawk Owls, unless the Hawk Owl's vulnerability to other raptors increases in large clear-cuts. Most documented Hawk Owl kills in Fennoscandia are made by Eagle Owls (*Bubo bubo*), which also hunt in open habitats (Mikkola 1983).

An important issue is to estimate how far apart the residual trees in a clear-cut may be spaced without making some of the clear-cut inaccessible to Hawk Owls. If we assume that the search area from a single perch is confined within a circle around that perch (Andersson 1981) and that all parts of the clear-cut are to be covered by the search areas from the perches there, then the longest acceptable interperch distance for perches of a certain height is the estimated search range from that height multiplied with  $\sqrt{2}$ .

When the ground was snow free, the horizontal attack distance of the Hawk Owls foraging in the experimental clear-cut increased with the height of the perch from which the attack was launched (Sonerud 1992). I therefore estimated the search range, both as the 90th percentile and as the maximum of the recorded horizontal attack distances for different perch heights (Fig. 2). Perches of similar height were combined in some cases to obtain sufficiently large samples. These estimates of the search range increase with increasing perch height (Fig. 2).

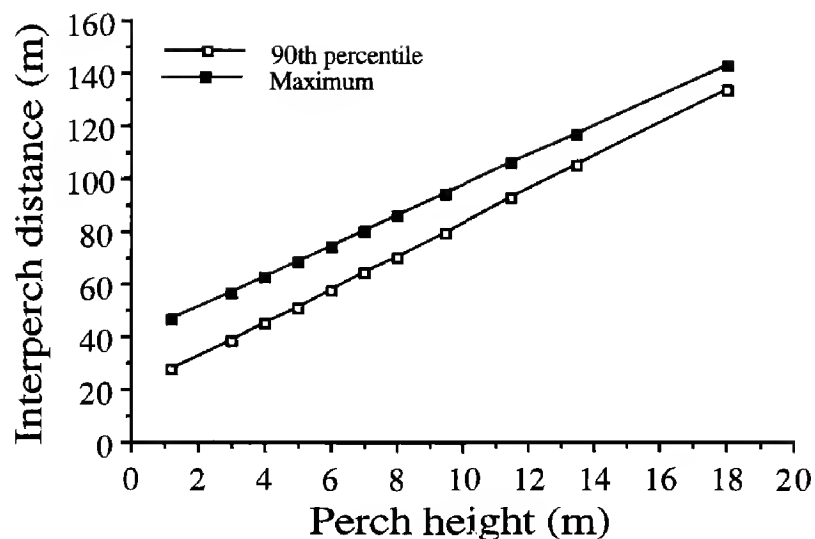


Figure 3. Maximum acceptable distance between residual trees, left as hunting perches for Hawk Owls in clear-cuts, as a function of their height. The values are taken as the search range values given by the regression line in Fig. 2 multiplied with  $\sqrt{2}$ .

To obtain a simplified picture of the Hawk Owl's search range as a function of perch height, I regressed the search range estimates for each group of perch heights on the average perch height of the actual group (Fig. 2). Thereafter, I calculated the longest acceptable interperch distances by multiplying the search range values as given by the regression line with  $\sqrt{2}$  (Fig. 3). If the search range is taken as the 90th percentile of the recorded attack distances, the maximum acceptable interperch distance increases from about 30 m for residuals  $\leq 3$  m high to about 130 m for residuals  $\geq 15$  m high (Fig. 3). Thus, an array of residuals should be left with a density varying from  $\geq 14$  per ha for the shortest ones to  $\geq 0.6$  per ha for the tallest ones. If the search range from a certain perch height is taken as the longest recorded attack distance from that height, the maximum interperch distance increases from about 50 m for residuals  $\leq 3$  m high to about 140 m for residuals  $\geq 15$  m high (Fig. 3). Thus, an array of residuals should be left with density varying from  $\geq 5$  per ha for the shortest ones to  $\geq 0.5$  per ha for the tallest ones.

Because these estimates are based on data from one clear-cut only, forest managers should use flexible strategies for the spacing of residuals. As a rule of thumb, I would suggest that in parts of clear-cuts  $>100$  m from the forest edge residuals should include about 1 per ha for tall ( $>15$  m) residuals, and about 10 per ha for short ( $<3$  m) residuals.

**Effect of Seasonal Change in Vegetation Height.** When I estimated the Hawk Owl's search range



above, I disregarded any seasonal change in the cover for voles provided by the field vegetation. However, a Hawk Owl's view of voles moving along the ground would be expected to be more obstructed in late summer and fall than in spring just after the snow has disappeared and before the vegetation has leafed out (Jacobsen and Sonerud 1993). Thus, the maximum acceptable interperch distance, as estimated above based on data from the whole snow-free season, may be too long in late summer and fall.

**Effect of Snow Cover.** Hawk Owls live in areas where the ground may be snow covered for half the year or more. Because they rely on sight to locate prey, Hawk Owls nearly always attack prey exposed on top of the snow (Sonerud 1986, Nybo and Sonerud 1990). Voles are more visible when moving on top of the snow than when moving in the vegetation. In fact, the Hawk Owl's search range is longer for prey moving on top of the snow than for prey moving on snow-free ground (Sonerud 1980, 1992). Thus, the maximum acceptable interperch distance, as estimated above based on data from the snow-free season, would allow Hawk Owls access to all parts of a clear-cut in winter as well.

#### OPTIMAL HABITAT OF HAWK OWLS IN MODERN FORESTS

Hawk Owls usually switch their diet from mostly bank voles (*Clethrionomys glareolus*) to mostly *Microtus* voles as snow disappears in spring, probably because bank voles move on top of the snow cover more frequently than do *Microtus* voles (Sonerud 1986, Nybo and Sonerud 1990, Jacobsen and Sonerud 1993). In Fennoscandia, *Microtus* voles are almost exclusively found in clear-cuts, whereas *Clethrionomys* voles, especially the bank vole, occur in a wide range of habitats but more commonly in forest than in clear-cuts, especially during spring (Henttonen et al. 1977, Larsson and Hansson 1977, Hansson 1978, Sonerud 1986). Thus, variation in diet suggests that Hawk Owls switch major hunting habitat from forests to clear-cuts as snow disappears and that Hawk Owls may find best foraging opportunities in forest habitats during the winter, provided the forest is open enough to allow the Hawk Owl to take full advantage of its long search range on snow.

In Fennoscandia, the overall density of voles is usually higher in clear-cuts than in forest, primarily because *Microtus* voles reach higher densities than *Clethrionomys* voles (Henttonen 1989). Except just after snow melt and before the vegetation leafs out,

vegetation cover is on average more luxurious and offers more protection for voles in clear-cuts than in forest (Sonerud et al. 1986). Hence, for Hawk Owls prey availability is greater in clear-cuts than in forest only from just after snow melt until the new vegetation leafs out; thereafter the relative prey availability in clear-cuts compared to forest declines (Jacobsen and Sonerud 1993). When snow starts accumulating, prey availability soon becomes higher in forest than in clear-cuts. Thus, the relative prey availability in clear-cuts compared to forest is lowest when snow covers the ground, highest just after snow melt and declines gradually throughout the snow-free season.

Because neither forest nor clear-cuts can serve as the best foraging habitat for Hawk Owls throughout the year in Fennoscandia, the optimal forest landscape for Hawk Owls would be a mix of old forest and clear-cuts. The area ratio between these two main habitat types that maximizes the Hawk Owl's intake rate cannot be determined at present because the change in relative prey availability in each habitat throughout the year is not sufficiently known. However, if clear-cut areas too large to be covered by the Hawk Owl's attack range from the forest edge are left with a sufficiently dense array of snags, stumps and other residuals after logging, and if trees with potential nesting cavities for Hawk Owls are left after logging, the species may benefit from modern forestry.

The Hawk Owl is unlikely to show any evolutionary response to modern forestry or other logging operations by man in Fennoscandia because any genetic effect is probably swamped by the long dispersal undertaken by young and old birds of both sexes. Therefore, Hawk Owls in Fennoscandia are mainly adapted to the forest habitats in Siberia, which probably have been shaped mainly by fires until recently.

#### ACKNOWLEDGMENTS

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## THE LONG-EARED OWL (*ASIO OTUS*) AND FOREST MANAGEMENT: A REVIEW OF THE LITERATURE

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**ABSTRACT.**—In North America, 13 of 20 breeding season studies reporting on Long-eared Owl (*Asio otus*) reproduction were conducted in open country habitats, four in woodland or edge habitats and three in predominantly woodland habitat. Sixteen of 22 nonbreeding season studies that reported communal roost sites were located in forest/edge habitats, five reported locations in open space and one was found within forest habitat. There is currently little data to indicate either a negative or positive effect of forest-management practices on this species. Although there appears to be some evidence of population declines in specific geographic areas, these impacts have been attributed to loss of riparian vegetation, conversion of foraging areas to agricultural fields and reforestation of open habitats. The Long-eared Owl's ecomorphology is suggestive of a species that inhabits open country. Additionally, its primary food is small mammals (e.g., microtine and heteromyid rodents) which inhabit open country. Should the Long-eared Owl be considered a forest owl? Research data would suggest no; however, studies from extensive deciduous and coniferous woodlands are needed.

**KEY WORDS:** *Long-eared Owl; forestry; habitat; diet; ecomorphology; Asio otus.*

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El búho (*Asio otus*) y administración forestal: un reviso de la literatura

**RESUMEN.**—En norte américa, 13 de 20 estudios de tiempos de cría reportadas en el búho *Asio otus* fueron evaluados en hábitat del campo amplio, cuatro en bosques o orillas de hábitat, y tres en mayoría de hábitat de bosque. Dieciséis de 22 estudios en tiempos sin cría que reportaron sitios de percha comunal fueron localizadas en bosque/hábitat de orilla, cinco lugares reportados en espacio abierto, y uno fue encontrado dentro de un hábitat de bosque. Actualmente poca información indica si los afectos de la administración de bosques son negativo o positivo en el especie. Aunque parece que un poco de pruebas con reducción de poblaciones en áreas específicas geográficamente, estos impactos están atribuido a la falta de vegetación cerca de los ríos, conversión de áreas de forraje a parcela agrícolas, y repoblación forestal de hábitat abiertos. La eco-morfología del buho evoca una especie que ocupa el campo abierto. También, su comida principal es mamíferos pequeños (i.e. microtine y roedor heteromyid) que ocupan campos abiertos. ¿Debe ser el búho considerado un búho del bosque? Información investigada sugieren que no, sin embargo, estudios de bosque conífero y de hoja caduca extensa es necesaria.

[Traducción de Raúl De La Garza, Jr.]

The Long-eared Owl (*Asio otus*) is a widely distributed Holarctic species, with six recognized subspecies (Cramp 1985). In the Northern Hemisphere, it ranges from approximately 30–65° latitude, with isolated populations occurring in North and East Africa, the Azores and Canary Islands (Mikkola 1983, Marks et al. 1994). Some aspects of Long-eared Owl natural history have been well studied in the U.S. and some European countries, but most studies have been short in duration, averaging about two seasons.

In North America, two subspecies are currently recognized (*A. o. wilsonianus* and *A. o. tuftsi*; see Marks et al. 1994 for further discussion). The

Long-eared Owl has been considered an open country species, inhabiting areas such as grasslands, shrubsteppe, marshes and woodland patches near open areas. Most studies seem to support this. To my knowledge, there have been no attempts to evaluate the affects of forestry practices on this species. Herein, I review the literature and use some inferences from my ongoing 10 yrs of study to address some of the questions concerning the impacts of forest management on Long-eared Owls.

### POPULATION TRENDS

Few data exist for population trends of Long-eared Owls in North America over the past 10, 25,

Table 1. Status of the Long-eared Owl in North America.

PROVINCE/REGION OR STATE	STATUS	POPULATION TREND <sup>a</sup>
CANADA (Fyfe 1976)		
British Columbia	Low	Unknown
Maritime	Low/Medium	Fluctuating
Northwest Territory/Yukon	Unknown	Unknown
Ontario/Quebec	Low/Medium	Fluctuating
Prairie	Low/Medium	Fluctuating
NORTHEASTERN UNITED STATES (Melvin et al. 1989)		
Connecticut	Special Concern	
Delaware	Unknown	
Massachusetts	Special Concern	
Maryland	Decreased	
Maine	Unknown	
New Hampshire	Special Concern	
New Jersey	Unknown	
New York	Unknown	
Pennsylvania	Decreased	
Rhode Island	Special Concern	
Vermont	Special Concern	
MIDWEST (Petersen 1991)		
Illinois	Endangered	Unknown
Indiana	Uncommon	Declining
Iowa	Threatened	Unknown
Kansas	Uncommon	Stable
Michigan	Special Concern	Unknown
Minnesota	Regular	Unknown
Missouri	Special Concern	Unknown
Nebraska	Unknown	Unknown
North Dakota	Special Concern	Unknown
Ohio	Unknown	Unknown
South Dakota	Rare	Declining
Wisconsin	Special Concern	Unknown
WEST (Marti and Marks 1989)		
California	Special Concern	Declining
Colorado	Common	Stable
Idaho	Common	Unknown
Montana	Special Concern	Unknown
Nevada	Common	Stable
Oregon	Common	Stable
Utah	Common	Unknown
Washington	Unknown	Unknown
Wyoming	Common	Unknown

<sup>a</sup> Trend data not known for northeastern U.S.

50 or 100 yrs, but there are some regional data. The Breeding Bird Survey (BBS) does not include the Long-eared Owl in its data set from 1966–89. For inclusion, a species must have been detected on >10 BBS routes in a physiographic region; 25 or more detections in the three biomes (Eastern, Central, Western); 35 or more detections in Can-

ada; or 50 detections in the U.S. and Canada (Droege pers. comm.).

In Canada, Fyfe (1976) reported population trends and relative abundance of raptors for provinces or specific geographic areas (Table 1). There were no data to support these designations. Also in Canada, Christmas Bird Count (CBC) results



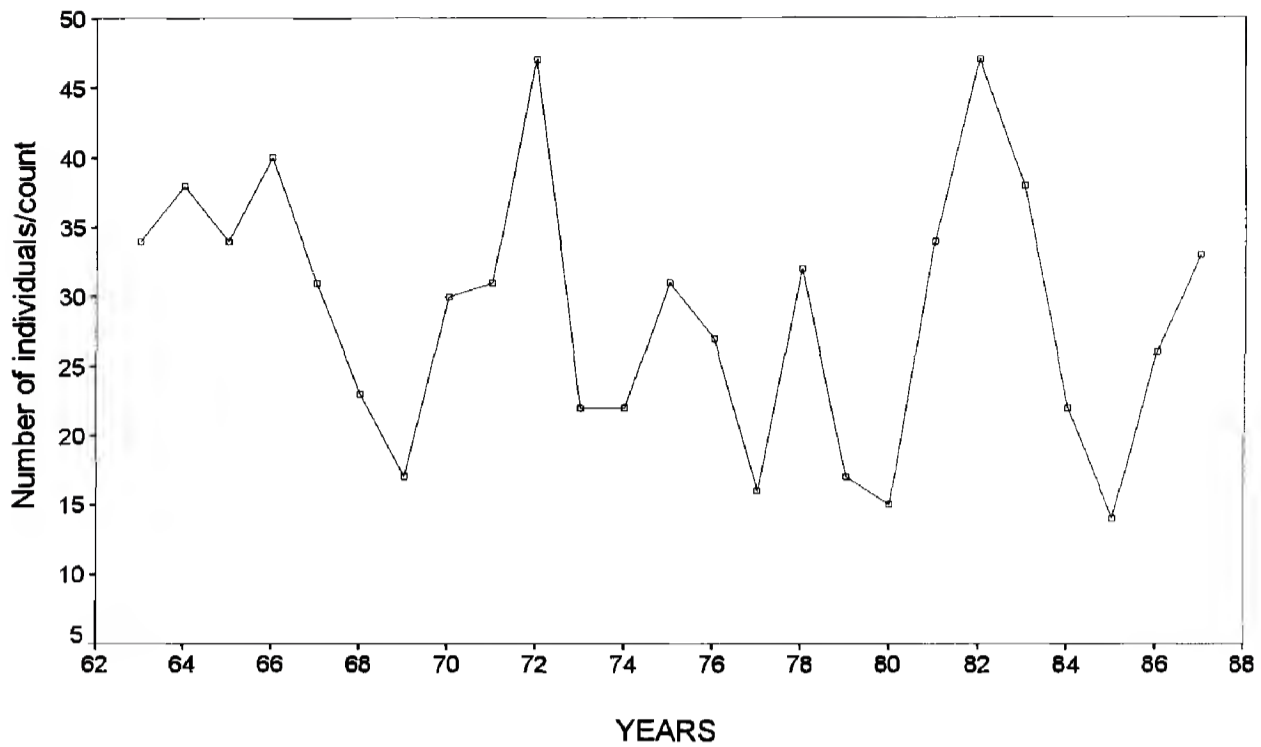


Figure 1. Summary of winter counts of Long-eared Owls from Christmas Bird Counts in the northeastern U.S., 1963–87 (after Melvin et al. 1989).

showed a significant decline in Long-eared Owl numbers, but these data should be interpreted cautiously (Kirk et al. 1994).

In the northeastern U.S., Melvin et al. (1989) reported that the Long-eared Owl was listed as a species of special concern in all the New England states except Maine and decreasing in Maryland and Pennsylvania (Table 1). Within the northeast-

ern states, Melvin et al. (1989) concluded that no clear population trend could be detected for Long-eared Owls, although numbers seemed to fluctuate about every three to six yr (Fig. 1). In New Jersey, Bosakowski et al. (1989, 1989a) analyzed 31 yr (1956–86) of Long-eared Owl Christmas Count Data reporting one or more Long-eared Owls and concluded that the species was declining (Fig. 2).

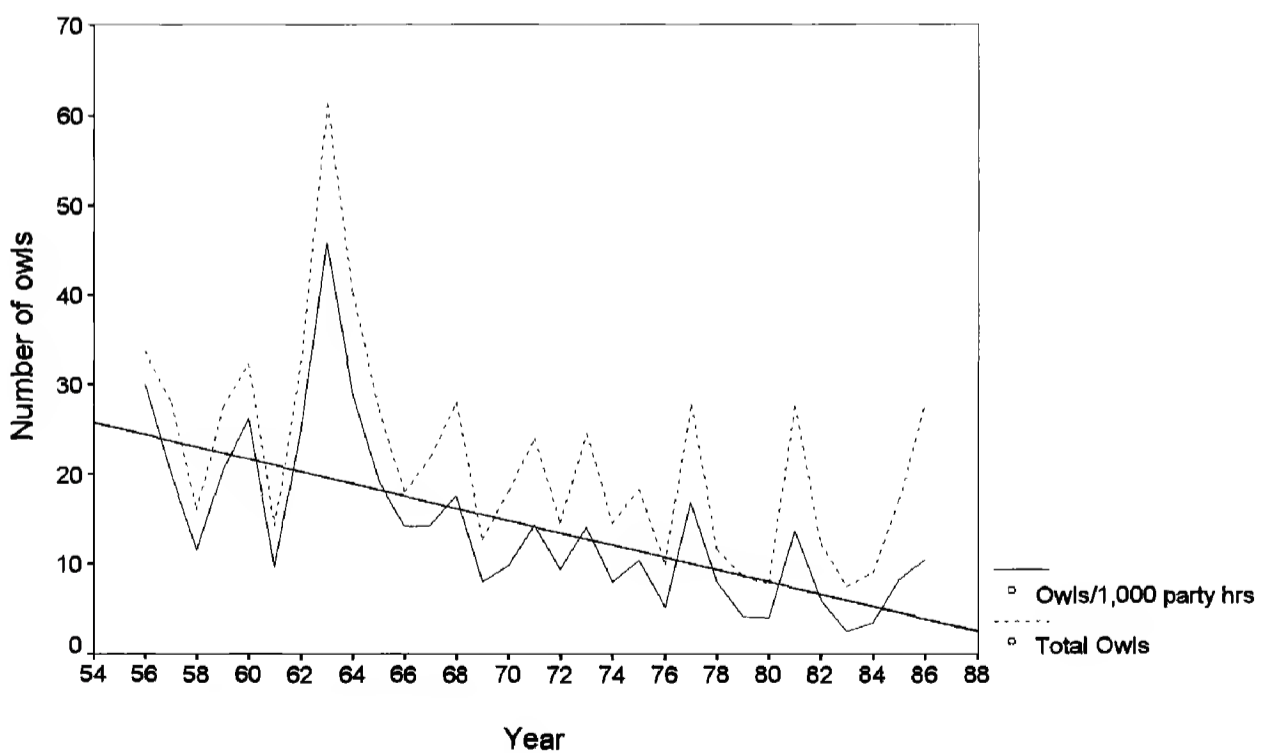


Figure 2. Long-eared Owls reported on New Jersey Christmas Bird Counts (dotted line) and per 1000 party hours (solid line). Regression line (dashed),  $Y = -0.70x + 25.5$ ,  $P < 0.0001$ ,  $r = 0.67$  for party hours is significant. Regression line,  $Y = -0.629x + 31.9$ ,  $P = 0.005$ , for total owls had a lower correlation ( $r = 0.50$ ) (after Bosakowski et al. 1989a).

In the midwestern U.S., Petersen (1991) reported that Long-eared Owls have declined in Indiana and South Dakota, are stable in Kansas and are of unknown status elsewhere (Table 1). This was based on state and regional birding publications and raptor survey forms. In Minnesota, however, Evans (*in* Marks et al. 1994) noted a decline in migrant Long-eared Owls in his study area from 1976–93 (Fig. 3).

In the western U.S., White (1994) reported the Long-eared Owl as stable, but with some local losses in the far west. He did not report how these species designations were assigned. Marti and Marks (1989) reported a Long-eared Owl population decline in California and a stable or unknown population status in the rest of the west (Table 1). In coastal southern California, Bloom (1994) has shown the Long-eared Owl to have been extirpated in some areas, with small remnant populations still occurring inland. The number of historic nesting areas have declined by 55% (Bloom 1994). In Montana, Long-eared Owls were listed as a species of special concern (Marti and Marks 1989). I have shown yearly fluctuations in numbers during CBC counts and breeding seasons (Figs. 4 and 5) with a consistent research effort in the same areas. In Mexico, the status of the Long-eared Owl has not been reported (Enriquez-Rocha et al. 1993).

In summary, realistic population trends for North American Long-eared Owls are difficult to determine. The use of CBC data to determine avian population trends has been controversial, but Root (1988) has presented some of the strengths and weaknesses to this approach.

Population demographics for Long-eared Owls are uncertain because of the paucity of data on mortality, emigration, immigration, migration and other factors. Because Long-eared Owls are highly migratory in some areas, nocturnal, difficult to locate and appear to show food-based nomadism, it is very difficult to determine their status. For example, five notable recoveries of banded owls in Mexico >800 km from banding sites illustrate the Long-eared Owls' high degree of mobility. These long distance recoveries include: one owl banded in Saskatchewan, Canada and recovered 4000 km away in Oaxaca, Mexico; one owl banded in Montana and recovered 3200 km away in Guanajuato, Mexico; and one owl banded in Minnesota and recovered 3100 km away in Puebla, Mexico. Long-term breeding season studies in Montana show little site fidelity by Long-eared Owls. Of 77 breeding

pairs intensively monitored for 9 consecutive yr, only 11 males and two females have returned to the same breeding site more than once. Additionally, no mate fidelity has been recorded. These data buttress the argument for highly migratory and nomadic tendencies in Long-eared Owls.

#### PRIMARY FACTORS RESPONSIBLE FOR LONG-EARED OWL POPULATION TRENDS

In most cases, there were insufficient data to convincingly conclude which factors influence population trends. Population declines have been attributed to habitat alteration, forest succession, urbanization, competition with Great Horned Owls (*Bubo virginianus*), loss of habitat for prey species, rodenticides (Bosakowski et al. 1989a), shooting and habitat loss (Marks et al. 1994) and loss of riparian habitats and grasslands (Bloom 1994).

Some forestry practices are also thought to have affected Long-eared Owls. In New Jersey, Bosakowski et al. (1989a) suggested that forest removal and thinning affected wintering Long-eared Owls and caused them to abandon the area.

On the contrary, many of the nonbreeding and breeding season studies from the eastern U.S. were located at roost sites in plantations of exotic conifers or other man-made habitats such as cemeteries (Tables 1 and 2). In the western U.S., shelter-belts planted for wind and snow breaks, as well as cover and food for wildlife have allowed Long-eared Owls new winter and breeding sites. In other instances, Long-eared Owls have been radiotracked (Ulmschneider 1990) and found to be using forest clear-cuts as foraging areas.

#### AFFECTS OF PAST AND PRESENT FOREST MANAGEMENT PRACTICES ON LONG-EARED OWLS

There is insufficient information to conclude that forest management has affected Long-eared Owl populations. There is some data from New Jersey, Minnesota and California that show declines. In New Jersey and California, habitat loss or change appears to have affected Long-eared Owls. Bosakowski et al. (1989a) theorized that Long-eared Owls in New Jersey were probably rare breeders prior to European settlement. After the clearing of forests in the 18th and 19th centuries, Long-eared Owl populations increased and expanded in range. When forests were reestablished in the 20th century, Long-eared Owl numbers declined (Bosakowski et al. 1989b). In Minnesota, no explanation for the apparent decline has been given.

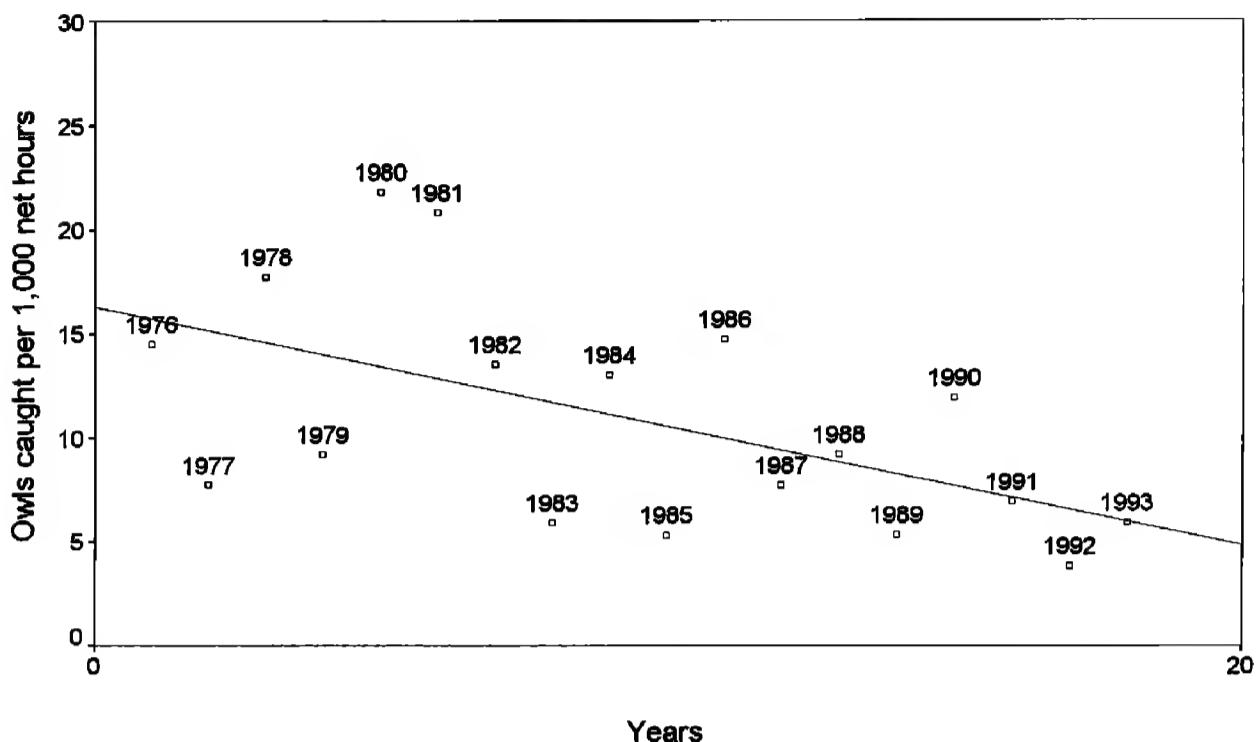


Figure 3. Long-eared Owls caught per 1000 net hours in the fall at Duluth, Minnesota (D. L. Evans, in Marks et al. 1994). Regression line indicates a downward trend ( $Y = 16.25 - 0.59x$ ).

Many studies, however, indicate that exotic and domestic conifer plantations, wind-rows and shelterbelts planted near or within open areas provide additional nesting and winter roosting habitats that are beneficial to Long-eared Owls.

HOW WOULD LONG-EARED OWLS BE AFFECTED BY SIZE, SHAPE, AND RESIDUALS OF FOREST CUTS?

This is unknown, but a few studies have data which may be relevant. Craig et al. (1988) reported

that two pairs of radio-tagged Long-eared Owls in Idaho avoided scattered areas of juniper (*Juniperus* spp.) trees within open sagebrush shrubsteppe habitats. The owls generally foraged 1–3 km from their nests, with males using about 240–325 ha and females using about 235–425 ha during nightly forays. Also in southwestern Idaho, Hilliard et al. (1982) reported that one radio-tagged Long-eared Owl (sex unknown) foraged over 70 ha during three consecutive nights in winter, and a second

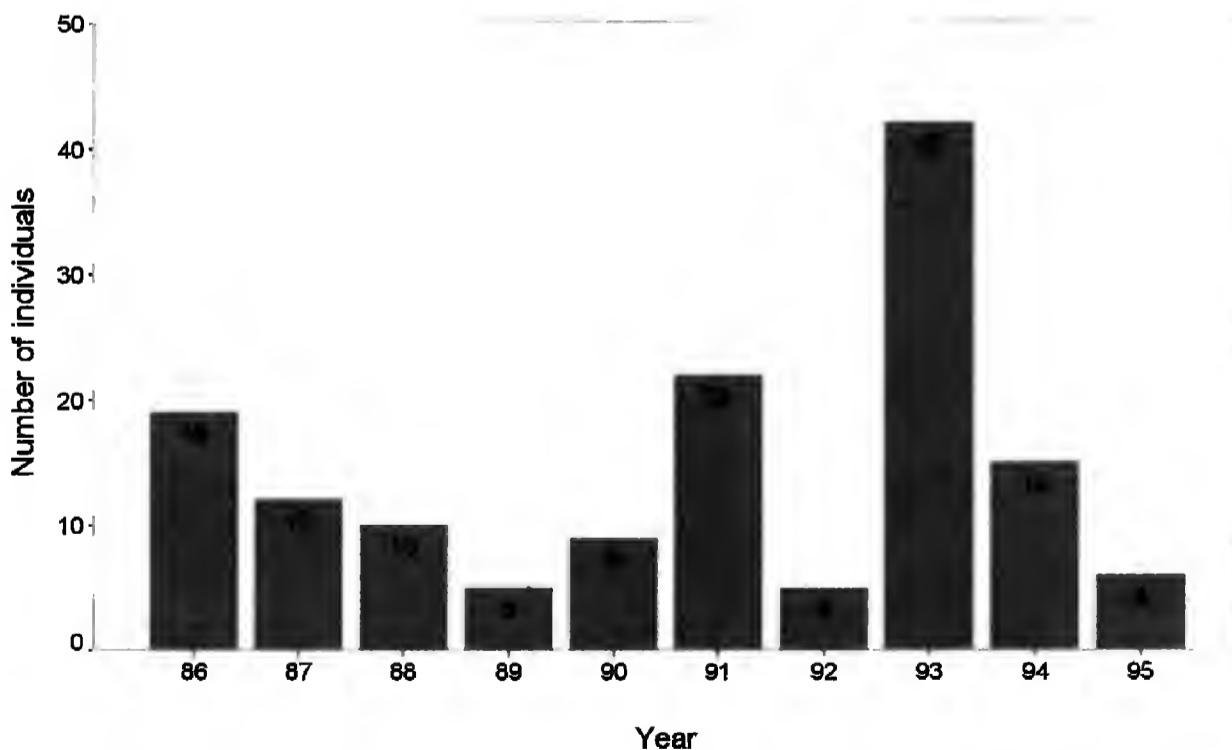


Figure 4. Long-eared Owls recorded on Christmas Bird Counts in western Montana, 1986–95 (D. Holt unpubl. data).



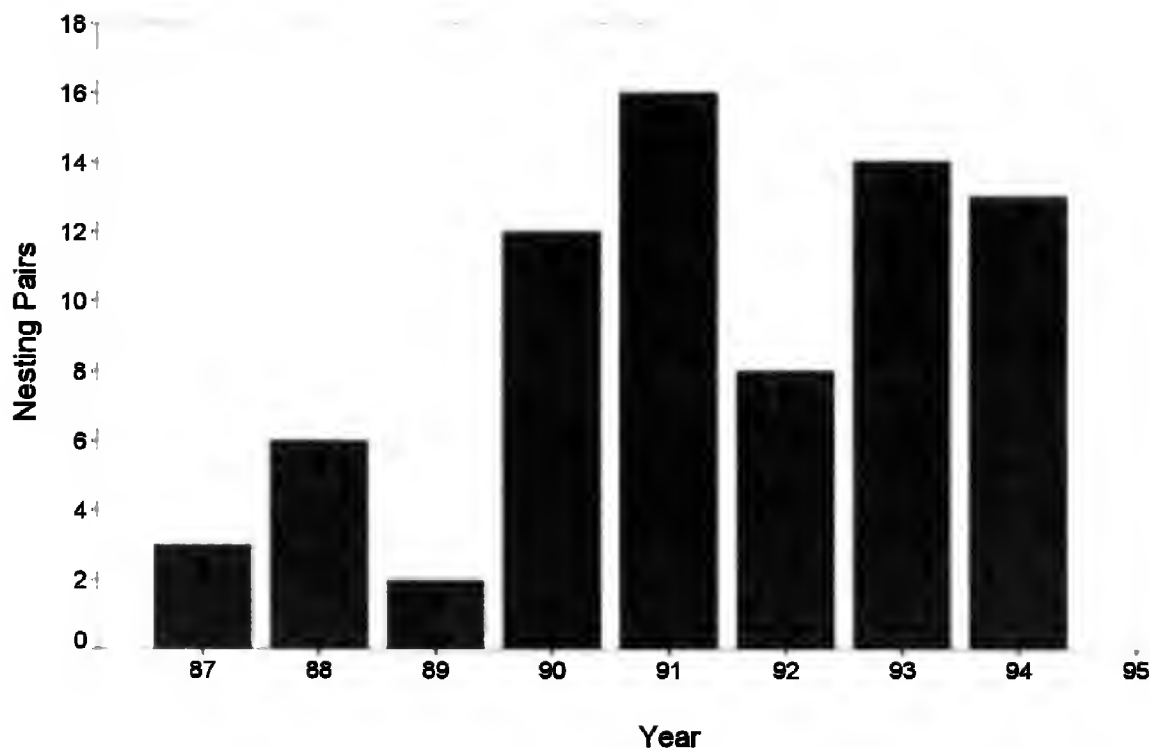


Figure 5. Breeding pairs of Long-eared Owls observed in western Montana, 1987–95 (D. Holt unpubl. data). There were no nests found in 1995.

Long-eared Owl (male) foraged over 190–220 ha each night for five nights in spring. Ulmschneider (1990) reported that seven of 13 radio-tagged Long-eared Owls traveled 73–97 km, and one owl moved 125 km from a shrubsteppe sagebrush breeding area to forested mountains. All the owls were at first in open country and heavily logged areas, four later moved into forest habitat with small openings where three stayed within 1 km of an active logging site and the fourth stayed near a 1-yr-old clear-cut. The three owls near the active logging site stayed for several weeks. She felt the owls had chosen the active logging sites and recently logged sites over older ones.

In Montana, Long-eared Owls nesting in steep mountain hillsides of second growth Douglas-fir (*Pseudotsuga menziesii*) forests and mixed ponderosa pine (*Pinus ponderosa*) forests adjacent to open lands foraged at dusk in nearby clear-cuts and grasslands, respectively (Holt and Hillis 1987). These observations suggest that certain logging practices may benefit Long-eared Owls.

#### IS THE LONG-EARED OWL A FOREST SPECIES?

I reviewed studies from across North America and tried to address information on habitat associations, diets and ecomorphology of Long-eared Owls. I separated diet into breeding and nonbreeding seasons. Habitat was separated into grassland, edge and forest. For ecomorphology (the relationship between an animal's ecology and morpholo-

gy), I found only two studies pertaining to Long-eared Owls (Poole 1938, Mueller 1986), but then incorporated that into literature directly related to ecomorphology of birds in general and owls in particular.

**Habitat Associations.** Of 20 studies providing breeding habitat information, only three (Craighead and Craighead 1956, Bull et al. 1989, Bloom 1994) reported that the Long-eared Owl was associated with forest habitat and only Bull et al. (1989) defined the breeding habitat as extensive forest. Four other studies (Wilson 1938, Armstrong 1958, Reynolds 1970, Enriquez-Rocha et al. 1993) described Long-eared Owls as associated with forest or edge, while the remaining 13 studies reported Long-eared Owls to be associated with open habitats (Table 2). Seventeen breeding season studies were conducted in the western Great Plains, Great Basin, Rocky Mountains, West Coast and Mexico; six of these were from Idaho. In general, these studies suggest that Long-eared Owls primarily breed in open spaces (but see Peck and James 1983, in Johnsgard 1988). Other good anecdotal information refers to Long-eared Owls heard calling from extensive forest stands (Hayward and Garton 1988).

Of 22 studies providing nonbreeding season information, 15 reported that edge habitats were occupied and five reported open habitats occupied (Birkenholz 1958, Bosakowski 1984, Marti et al.

Table 2. Breeding and non-breeding season habitat associations for Long-eared Owls in North America.

HABITAT	LOCATION	SOURCE
<b>BREEDING SEASON</b>		
Forest	Michigan	Wilson (1938)
	Michigan	Craighead and Craighead (1956)
	Michigan	Armstrong (1958)
	Oregon	Reynolds (1970)
	Oregon	Bull et al. (1989)
	Mexico	Enriquez-Rocha et al. (1993)
	California	Bloom (1994)
Edge	Michigan	Wilson (1938)
	Michigan	Armstrong (1958)
	Oregon	Reynolds (1970)
	Mexico	Enriquez-Rocha et al. (1993)
Open	Nevada	Johnson (1954)
	Arizona	Stophlet (1959)
	Colorado	Marti (1969)
	Washington	Knight and Erickson (1977)
	Idaho	Craig and Trost (1979)
	Idaho	Marks and Yensen (1980)
	South Dakota	Paulson and Sieg (1984)
	Idaho	Thurow and White (1984)
	Idaho	Marks (1986)
	Idaho	Craig et al. (1988)
	Idaho	Ulmschneider (1990)
	Manitoba, Canada	Sullivan (1992)
	Montana	Holt (unpubl. data)
	<b>NON-BREEDING SEASON</b>	
Forest	Michigan	Armstrong (1958)
	Mexico	Enriquez-Rocha et al. (1993)
Edge	Illinois	Cahn and Kemp (1930)
	Wisconsin	Errington (1932)
	Michigan	Spiker (1933)
	Ohio	Randle and Austing (1952)
	Kansas	Rainey and Robinson (1954)
	Michigan	Craighead and Craighead (1956)
	Michigan	Stapp (1956)
	Michigan	Getz (1961)
	Iowa	Weller and Fredrickson (1963)
	New York	Lindberg (1978)
	Iowa	Voight and Glenn-Lewin (1978)
	Pennsylvania	Smith (1981)
	Massachusetts	Andrews (1982)
	Massachusetts	Holt and Childs (1991)
	Connecticut	Smith and Devine (1993)
	Mexico	Enriquez-Rocha et al. (1993)
	Open	Illinois
New Jersey		Bosakowski (1984)
New Mexico		Marti et al. (1986)
Washington		Denny (1991)
Montana		Holt (unpubl. data)



Figure 6. Geographic distribution of breeding (●) and non-breeding (◆) season studies in North America.

1986, Denny 1991). One each reported forest (Armstrong 1958) or forest and edge (Enriquez-Rocha et al. 1993) (Table 2). In contrast to the western breeding studies, 18 nonbreeding studies were conducted in the midwest and northeast, except for four: one in New Mexico (Marti et al. 1986), Washington (Denny 1991), Montana (D. Holt unpubl. data) and Mexico (Enriquez-Rocha et al. 1993). The geographic distribution of these studies (Fig. 6) is almost nonoverlapping.

**Diet.** Of 21 nonbreeding season studies representing 45 671 prey, 17 studies reported a *Microtus* vole to dominate the long-ear diet. These voles are open country inhabitants (Table 3). The remaining prey species also inhabit open country. Results were similar for the breeding season but with slight differences in prey composition. Of 14 studies representing 13 858 prey, all except Bull et al. (1989) reported an open country prey species (Table 4). Bull et al. (1989) reported that Long-eared Owls nested in extensive stands of Grand Fir (*Abies grandis*) and that the prey species comprising the majority of the diet was the northern pocket gopher (*Thomomys talpoides*). This species is primarily an open country inhabitant, but also occurs within openings in closed canopy forests and may move into recent clear-cuts (Ingles 1967).

These data are further supported by Marti's (1976) extensive review of the feeding ecology of

Long-eared Owls. He included data from North America, several European countries and Iraq. He concluded that Long-eared Owls feed on small rodents found in open country with *Microtus* voles eaten most frequently, followed by *Peromyscus* mice and Heteromyid rodents.

**Ecomorphology.** I reviewed the literature to determine if the Long-eared Owl's morphology was consistent with adaptive radiation for particular habitats. Bird groups in general have similar flight morphology, as do birds living in similar habitats. For example, open country bird species like the Long-eared Owl and Snowy Owl (*Nyctea scandiaca*) have more pointed wings for better agility than forests owls. Forest owls such as the Great Gray Owl (*Strix nebulosa*) and Boreal Owl (*Aegolius funereus*) which live in dense vegetation, have short broad wings and a large wing area which aid in maneuverability (see Rayner 1988).

Owls generally exhibit low wing loading and low aspect ratio and are among birds with the lowest wing loading (Norberg 1987). Relative wing loading is defined as the owls' body mass divided by the wing area or;  $Mg/S$  (mass  $M$  multiplied by the acceleration of gravity  $g$ , divided by wing area  $S$ ), and aspect ratio is defined as wingspan divided by mean chord length, or  $b^2/S$  (wingspan  $b$  squared, divided by wing area  $S$ , or wingspan divided by mean wing chord) (Norberg and Norberg 1986).



Table 3. Non-breeding season diet of Long-eared Owls in North America.

HABITAT	DOMINANT GROUP	N	LOCATION	SOURCE	
Edge	<i>Peromyscus</i>	1198	Illinois	Cahn and Kemp (1930)	
	<i>Microtus</i>	210	Iowa	Errington (1933)	
	<i>Microtus</i>	1261	Ohio	Randle and Austing (1952)	
	<i>Peromyscus</i>	249	Indiana	George (1954)	
	<i>Microtus/Sigmodon</i>	1087	Kansas	Rainey and Robinson (1954)	
	<i>Microtus</i>	952	Wisconsin	Craighead and Craighead (1956)	
	<i>Microtus</i>	1000	Michigan	Stapp (1956)	
	<i>Microtus</i>	2995	Michigan	Armstrong (1958)	
	<i>Microtus</i>	2328	Illinois	Birkenholz (1958)	
	<i>Microtus</i>	126	Iowa	Weller and Fredrickson (1963)	
	<i>Microtus</i>	301	New York	Lindberg (1978)	
	<i>Microtus</i>	2112	Iowa	Voight and Glenn-Lewin (1978)	
	<i>Microtus</i>	915	Massachusetts	Holt and Childs (1991)	
	Open	<i>Microtus</i>	3272	Wisconsin	Errington (1932)
		<i>Microtus</i>	199	Michigan	Spiker (1933)
<i>Perognathus</i>		2821	New Mexico	Marti et al. (1986)	
<i>Microtus</i>		18 956	Montana	Holt (unpubl. data)	
Unknown	<i>Microtus</i>	108	Iowa	Scott (1948)	
	<i>Microtus</i>	1494	Pennsylvania	in Latham (1950)	
	<i>Microtus</i>	2495	Nebraska	in Latham (1950)	
	<i>Microtus</i>	1622	Pennsylvania	Smith (1984)	

Among owls, forest species tend to have much lower aspect ratios than open country species (Norberg 1987), because foraging within vegetation is favored by those species with short wings, large wing area and low wing loading. This enables these species to have slow, maneuverable flight (Norberg 1987). Contrasting this are open country migratory species such as the Long-eared Owl, Snowy Owl and Short-eared Owl (*Asio flammeus*) which have

long wings for sustained flight, yet have relatively low wing loading (Norberg 1990).

#### CONCLUSION

Is the Long-eared Owl a forest species? These data suggest that the Long-eared Owl may not be a forest species; however, more forest studies are needed. Long-eared Owls obviously depend on trees and shrubs for nesting and roosting. In large

Table 4. Breeding season diet of Long-eared Owls in North America.

HABITAT	DOMINANT GROUP	N	LOCATION	SOURCE
Forest	<i>Thomomys</i>	1123	Oregon	Bull et al. (1989)
Edge	<i>Microtus</i>	1935	Michigan	Wilson (1938)
	<i>Microtus</i>	274	Michigan	Armstrong (1958)
	<i>Microtus</i>	153	Oregon	Reynolds (1970)
Open	<i>Microtus</i>	114	Nevada	Johnson (1954)
	<i>Microtus</i>	129	Wyoming	Craighead and Craighead (1956)
	<i>Perognathus</i>	315	Arizona	Stophlet (1959)
	<i>Peromyscus</i>	993	Colorado	Marti (1969)
	<i>Perognathus</i>	171	Washington	Knight and Erickson (1977)
	<i>Peromyscus</i>	346	Idaho	Marks and Yensen (1980)
	<i>Peromyscus/Dipodomys</i>	4208	Idaho	Marks (1984)
	<i>Peromyscus</i>	1000	Idaho	Thurrow and White (1984)
	<i>Perognathus/Peromyscus</i>	3977	Idaho	Craig et al. (1985)
	<i>Microtus</i>	3020	Montana	Holt (unpubl. data)

open grasslands or shrubsteppe habitat, Long-eared Owls nest and roost in predominately shrub-like vegetation. In smaller openings in forests and along forest edges adjacent to open areas, Long-eared Owls use trees (often conifers) to nest and roost. Data from this review emphasize that perhaps too much forest may cause Long-eared Owls to leave an area (Bosakowski et al. 1989b), while patches of open areas within or near forest edges may benefit them. Unfortunately, forest age and stand structure requirements are not known for this species. Thus, the impacts of forest management cannot be ascertained at this time. Additionally, forest managers may need to define what a forest owl species is. Perhaps the Long-eared Owl can best be defined as an edge species, when found in or near forest habitats. It may be presumptuous at this point in time to suggest forest-management guidelines regarding the Long-eared Owl, particularly since no conclusive data exist pertaining to effects of present or past forestry practices.

Given the recent interest of metapopulation analysis (Levins 1969), which includes the core-satellite (Boorman and Levitt 1973) and sink and source (Pulliam 1988) models, forest-management considerations must include results of long-term studies from several geographic areas. Within these studies, comparative data of the Long-eared Owl natural history is essential for these models to be useful. Specifically, the following data are needed: Long-eared Owl residency, mating system, reproductive success and home ranges; Long-eared Owl prey species populations, how these effect owl residency, density and home range and how prey species are affected by forest practices; quantitative measures of nest sites; vegetative cover for adult and nestling owl roosting areas; and seasonal use of habitats because different habitats may be important at particular times of the year and avoided at other times.

Therefore, forestry practices may have to be staggered over space and time and perhaps from a few to hundreds of kilometers of habitats must be managed simultaneously or alternately to cover the Long-eared Owls' migratory or nomadic tendencies. The use of artificial nest sites as a management tool must be carefully considered before implementation—what is the biological justification for their use? Consideration of how forestry practices affect the interspecific relationships between Long-eared Owls and invader species must also be taken into account.

To adequately address the questions concerning impacts of forestry, research needs to cover longer periods of time and must also research the species year-round. Although many short-term studies provide useful information, they simply cannot provide enough data to answer questions such as those addressed herein. Given that Long-eared Owls are migratory and nomadic, and often dependent on small mammal cycles three to four yr long (e.g., voles), studies should at the least cover this duration, and preferably several cycles.

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## NORTHERN HAWK OWLS (*SURNIA ULULA CAPAROCH*) AND FOREST MANAGEMENT IN NORTH AMERICA: A REVIEW

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**ABSTRACT.**—Northern Hawk Owl (*Surnia ulula caparoch*) populations in North America likely have been stable over the past 10–100+ yr. Population trends are impossible to quantify due to this species' remote breeding range, low breeding densities and erratic distribution and numbers during winter irruptions in inhabited areas. Mortality due to incidental trapping and shooting is unknown, but its diurnal habits and lack of fear of humans make it vulnerable to persecution. More than 50% of the hawk owl's breeding range occurs in northern forests that are currently noncommercial. Until recently, the majority of the hawk owl's breeding range was unaffected by forestry practices. In the last 20 yr, forestry activities have expanded in commercial northern forests. Modification of clear-cut logging practices have the potential to enhance hawk owl habitat. Variable-sized cuts of <100 ha, interspersed with forest patches and staggered over time, are thought to be optimal. If cuts contain suitable numbers of stumps, snags and trees for hunting perches and nest sites, they will offer year-round habitat. Other factors, such as cut shape and juxtaposition, are probably less important to this striking sentinel of our northernmost forests.

**KEY WORDS:** *Surnia ulula; North America; forest management; habitat use; Northern Hawk Owl.*

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El Búho Halcón del norte *Surnia ulula caparoch* y administración forestal en Norte América: un reviso

**RESUMEN.**—Poblaciones de Búho Halcón *Surnia ulula caparoch* en norte américa ha estado estable en los últimos 10 a 100+ años. Tendencias de población están imposible para cuantificar por los campos remotos de cría de la especie, densidad baja de cría, y distribución y cantidad variable durante irrupciones del invierno en áreas inhabitadas. Mortalidad a causa de trampas y disparos es desconocido, pero sus costumbre de volar en el día y falta de tener miedo a gente lo hace vulnerable a persecución. Más de 50% de los campos de cría del Búho Halcón ocurren en bosques en el norte que están actualmente no-comercial. Hasta recientemente, la mayoría de campos de cría del Búho Halcón estaban sin afectación por costumbre de los forestales. En los últimos 20 años actividades forestales han expansionado en bosque comerciales en el norte. Modificaciones en costumbre de corta-completa tienen la potencia para aumentar hábitat de Búho Halcón. Cortadas variables de <100 ha, introducidas en parcelas de bosque escalonado con tiempo, es pensado ser óptimo. Si cortadas contienen cantidad conveniente de tocones, ramas sueltas y árboles con perchas de cazar y sitios de nido, pueden ofrecer un hábitat por todo el año. Otros factores, con forma de cortar y yuxtaposición, es probable menos importante para este centinela de los bosques más norteños.

[Traducción de Raúl De La Garza, Jr.]

There are very few published papers on the ecology of the Northern Hawk Owl (*Surnia ulula*) in North America; this is in contrast to Europe where the majority of studies have been done (Clark et al. 1987). The intent of this paper is to review the literature regarding the effects of forestry on hawk owls in North America and to make management guidelines to maintain hawk owl populations. Unfortunately, the effects of forestry on the hawk owl

are poorly understood and there are virtually no published reports on this subject. With this in mind, the management guidelines we have presented are hypothetical and based on the limited information that is available and from our own experiences in the field with this enigmatic owl. We have focused on the species in North America only and, by doing so, have pointed out the serious lack of information on hawk owls in the New World.

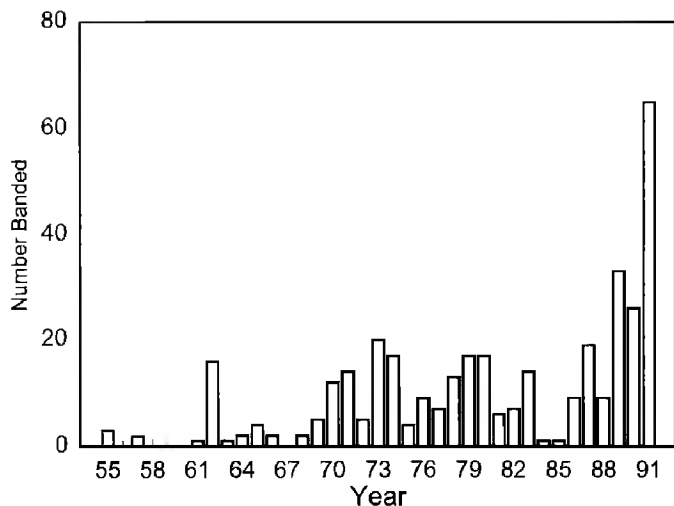


Figure 1. Number of Northern Hawk Owls banded during winter in North America, 1956–1992 ( $N = 363$ ). Unpublished data from the Bird Banding Office, Canadian Wildlife Service, Ottawa, Canada.

#### ESTIMATED POPULATION SIZE AND TRENDS

Accounts of Northern Hawk Owl population size and trends in North America are largely anecdotal. Trends are difficult to impossible to assess due to the remote breeding range, rare winter irruptions and low densities (Newton 1976). Fyfe (1976) reported that in the maritime provinces, the population trend was unknown and relative abundance was rare. For Ontario and southern Quebec, the trend was fluctuating, with relative abundance rare to low. The prairie provinces and British Columbia also reported fluctuating populations, with low to medium relative abundance. Analysis of Breeding Bird Survey data showed a nonsignificant decrease for Labrador and the central prairie provinces from 1966–77 to 1978–83 (Collins and Wendt 1989). The number of hawk owls banded between 1956–92 (Fig. 1) reflects low owl numbers, although banding effort was variable and not standardized (Canadian Wildlife Service data). Irruption years presumably relate to regional variation in food availability and hawk owl reproduction. Based on the hawk owl's North American breeding range (American Ornithologists' Union 1983), we hypothesize that its overall North American population has remained stable at 10 000–50 000 pairs over the past 10–100+ yr, with local or regional populations showing fluctuations in owl numbers.

#### HABITAT NEEDS

Of the three major habitat regions (Rowe 1972) within the boreal forest, the northernmost Forest and Barren Region is likely where the majority of hawk owls occur and breed. This region is char-

acterized by open, stunted forests interspersed with bogs and muskeg (Rowe 1972). Typical breeding habitat of the hawk owl is described as open to moderately dense coniferous or mixed coniferous-deciduous forests bordering marshes or other open areas, including those cleared by logging (American Ornithologists' Union 1983). In mountainous areas, its range extends to timberline as high as 2650 m elevation (Campbell et al. 1990). Open hunting areas such as muskegs, dry ridges, burn areas, clearings and swampy valleys or meadows with suitable perches also characterize breeding habitat. Areas with stumps, snags or dead trees with bare branches serving as hunting perches are favored; impenetrable spruce-fir forests are avoided (Henderson 1919, Smith 1970, Kertell 1986, Lane and Duncan 1987). Nest sites are located in cavities in decayed trees, open decayed hollows where tops have broken off (Lane and Duncan 1987) and rarely in stick nests or on cliffs (Bent 1938).

We believe forest regions south of its breeding range are important for the Northern Hawk Owl's survival during southward irruptions and for occasional breeding. The winter range of the hawk owl is more extensive than its breeding range (American Ornithologists' Union 1983). In winter, hawk owls may be found in wooded farmlands, open areas of parkland and prairie regions where haystacks, posts, trees or bushes are used as perches (Jones 1987). It also hunts in old burns, cutovers and riparian areas surrounded by agricultural land, old hay fields, open spruce forests and along roadsides with large rights-of-way (Lane and Duncan 1987, Rohner et al. 1995). Second growth woodlands and lake shores are used in British Columbia (Campbell et al. 1990).

#### FACTORS ASSOCIATED WITH TRENDS

**Long-term North American Population Trends.** More than half of the breeding range of the hawk owl is currently noncommercial forest (Godfrey 1986). Therefore, one would expect that hawk owl populations have remained stable over the last 10–100+ yr.

Northern forests are subject to natural fires which usually are left unchecked if far from human settlements. Burns may benefit hawk owls because they are known to hunt and nest in old burns (Mindell 1983). In some habitats (e.g., deep sphagnum moss), small mammalian prey species frequently survive forest fires and populations recover



quickly (Kelsall et al. 1977). Fire suppression near populated areas or in areas with merchantable timber reduces the availability of suitable nest sites.

Hawk owls occur throughout the year in the commercial forest region of Canada (numbers and distribution varies year to year). During the past 20 yr, clear-cut harvesting in boreal forests has increased. In the short-term, hawk owls may be negatively affected by large cuts (>100 ha), where no perches remain within the cut, or later, by regenerating dense forests (Sonerud pers. comm.). The current trend in forestry is for more numerous, smaller clear-cuts. Given its preference for open areas for hunting and breeding, habitat has likely improved for the hawk owl as long as suitable hunting perches are available. However, expansion of current practices over many years may reduce habitat quality, (e.g., fewer late successional forests that provide nest sites).

**Short-term Population and Local Fluctuation Trends.** Northern Hawk Owl numbers fluctuate locally (Kertell 1986, Lane and Duncan 1987, Rohner et al. 1995). When prey populations crash, hawk owls may be forced to leave breeding areas and wander in search of food. Irruptions have been well documented in North America (Thompson 1891, Barrows 1912, Roberts 1932, Bernard and Klugow 1963, Green 1963, Lane and Duncan 1987, Speirs 1985).

**Other Factors Associated with Population Trends.** Reports of hawk owls in northern areas are infrequent and incidental; during southern irruptions the hawk owl is vulnerable to human-induced mortality (K. McKeever pers. comm.). Predators include the Great Horned Owl (*Bubo virginianus*), Northern Goshawk (*Accipiter gentilis*), marten (*Martes americana*), fisher (*Martes pennanti*) and weasels (*Mustela* spp.).

#### EFFECTS OF FORESTRY ON HAWK OWL HABITAT

**Primary Effects.** Logging practices have the potential to enhance hawk owl habitat. Because hawk owls prefer open habitat, cut-overs with perches attract them. Furthermore, if cut-overs contain enough stumps and trees for nest structures, they offer year-round habitat.

**Secondary Effects.** The secondary effects of forest harvesting include their impacts on prey populations such as meadow voles (*Microtus pennsylvanicus*). Meadow vole populations increase 3–18 yr after clear-cutting forests (Kirkland 1977, Parker 1989). In Saskatchewan, deer mice (*Peromyscus*

*maniculatus*) are more abundant after clear-cutting than after fire.

**Hypothetical Specific Forestry Effects. Cut size.** There are no published studies on the influence of cut size on hawk owl habitat use. We hypothesize that suitable cuts should be <100 ha in size, interspersed with forest stands and staggered over time. Forest stands will provide hunting perches and nest sites, as well as cover.

**Cut shape.** We suspect that edge irregularity increases the availability of perches and provides cover as well as access to open foraging habitat.

**Residuals.** It is important to leave residuals such as live trees and dead snags for hunting perches and nest sites. Thus, small residual stands within cuts would be beneficial. Without these, the use of cut-over areas by hawk owls is limited to cut edges.

**Phenology.** We have observed hawk owls in Saskatchewan and Manitoba in 5–10 ha cuts from 3–10-yr-old. Bortolotti (pers. comm.) observed owls hunting in cuts 8–10-yr-old in Saskatchewan. In Ontario, Russell (pers. comm.) found disproportionate use of cuts that were 11–15-yr-old. The time lag in cut use by hunting hawk owls is likely a factor of prey availability. For example, Kirkland (1977) and Parker (1989) reported that meadow vole numbers increased 3–18 yr after harvest. Dense regeneration growth after approximately 20 yr would limit prey availability.

#### CONCLUSIONS

North American boreal forests are, for the most part, being harvested for the first time and are not intensively managed. Most regenerating cut-overs contain a variety of tree species. A noteworthy trend in North America is toward increasingly intensive forest management, resulting in reduced rotation ages and more homogeneous forest stands (Environment Canada data). It is expected that such a trend may negatively impact hawk owl populations, if no perches are left within these cut areas. Furthermore, as the demand for wood increases, forests in remote areas will be used. This will only emphasize the need to better integrate timber and wildlife management objectives into regional forest use plans.

We presume hawk owl populations to be stable in North America due to its remote range, about half of which is currently noncommercial forest. The species appears to use a variety of cut sizes and shapes, provided that hunting perches and breeding sites are retained. We emphasize the need for

further research on this boreal forest owl in North America. A lack of information on the ecology of the hawk owl and its responses to forestry practices precludes us from recommending definitive forest management guidelines or from forecasting its future status.

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## CONCLUDING REMARKS ON RAPTOR RESPONSES TO FOREST MANAGEMENT: A HOLARCTIC PERSPECTIVE

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### RECENT AND HISTORICAL TRENDS

Participants were asked to provide perspectives on the current (past 30 yr) and historical (past 100+ yr) population trend for each species (Table 1). Both Pertti Saurola and Peter Ewins present strong evidence that Osprey (*Pandion haliaetus*) populations have increased in both North America and Europe since the 1960s when populations of many fish-eating birds declined due to the ingestion of pesticides such as DDT. Historically, however, Osprey populations varied considerably over the past 100+ yr on both continents.

Per Widén has shown that the Northern Goshawk (*Accipiter gentilis*) has likely declined during recent years in Fennoscandia, possibly due to fragmentation of forests and reductions in total amounts of mature forest and associated prey populations such as grouse. In North America, Patricia Kennedy found no evidence for a decline in this species based on its range, population demographics (density, fecundity and survival) and population trends. She suggested that a more detailed meta-analysis is required to further address this question. The historical trend for this species is unknown on either continent, although she speculated that the Northern Goshawk may have been more abundant in the eastern U.S. prior to the extinction of the Passenger Pigeon (*Ectopistes migratorius*) and the deforestation in this region at the end of the 19th century.

Like most of the raptor species included here, there is little information on Long-eared Owl (*Asio otus*) trends for North America. Based on admittedly sparse data, Denver Holt hints at a possible recent decline in the species in some parts of North America. Nothing is known about historical population trends for this species. No paper was included for this species from Europe.

Neither Greg Hayward nor Harri Hakkarainen were willing to speculate as to whether there were recent or historical population trends for the Boreal Owl (*Aegolius funereus*) in North America and

Europe. Hayward stated that although the Boreal Owl was not known as a breeding bird in the lower 48 U.S. until the early 1970s, the increased observations over the past 20 yr is likely due to increased search efforts rather than a population increase. In Fennoscandia, especially in Finland, an increase in nest boxes for owls (22 691 nest boxes for owls checked in 1994) has likely increased populations in many areas and also our understanding of this species' biology.

Geir Sonerud presents data showing an apparent recent increase in Northern Hawk Owl (*Surnia ulula*) populations in northern Europe during the last part of this century. Over the past 90 yr, the population was high in the early part of the century, followed by a decline, and then a recent increase. In North America, Patricia Duncan and Wayne Harris speculate that the population appears to be relatively stable but that it fluctuates in response to available food supplies.

There is relatively strong evidence for an increase in the Great Gray Owl (*Strix nebulosa*) population in northern Europe over the past 30 yr, but Seppo Sulkava and Kauko Huhtala present evidence that the long-term trend is highly variable. They suggest that the recent increase is due to a combination of factors including reduced killing of owls by humans, increased availability of artificial nest sites (hundreds of twig nests and nest platforms), but warn that although regional Great Gray Owl populations have been relatively stable both recently and historically, local populations fluctuate widely with available food supply.

### FOREST MANAGEMENT

**Stand Size and Shape.** In general, we know very little on how species might respond to variations in the size and shape of logged stands (Table 1). The Osprey is likely not affected directly by stand size and shape. However, availability of suitable nest trees, effects of logging on aquatic systems and fish supply and populations of major nest predators (e.g., Eagle Owl, *Bubo bubo*, in Europe or Great



Table 1. Summarization of trends and possible responses to forest management of six forest raptors in Europe and North America.

SPECIES	CONTINENT	FOREST MANAGEMENT							
		TREND		STAND SIZE			STAND SHAPE		RESIDUALS
		RECENT	LONG-TERM	SMALL	MEDIUM	LARGE	SIMPLE	COMPLEX	
Osprey	Europe	Increase	Variable	Neutral	Neutral	Neutral	Neutral	Neutral	Essential
	N America	Increase	Variable	Neutral	Neutral	Neutral	Neutral	Neutral	Essential
Northern Goshawk	Europe	Decline	Unknown	Negative	Negative	Negative	Unknown	Unknown	Negligible
	N America	No evidence	Possible decline in Eastern US	—	—	—	—	—	Unknown <sup>a</sup>
Long-eared Owl	N America	Possible decrease	Unknown	Positive	Unknown	Negative	Negative	Positive	Negligible
Boreal Owl	Europe	Unknown	Unknown	Unknown	Unknown	Positive?	Neutral	Positive	Essential
	N America	Unknown	Unknown	Unknown	Unknown	Unknown	Unknown	Positive	Essential
Northern Hawk Owl	Europe	Possible increase	Possible decrease	Positive	Unknown	Negative	Neutral	Positive	Positive
	N America	Stable	Stable	Positive	Unknown	Negative	Neutral	Neutral	Positive
Great Gray Owl	Europe	Increase	Variable	Positive	Unknown	Negative	Negative	Positive	Positive
	N America	Stable	Stable	Positive	Unknown	Negative	Negative	Positive	Positive

<sup>a</sup> All factors were not examined for this species because of the focus on the species demography.

Horned Owl, *Bubo virginianus* in North America) may indirectly affect Osprey populations. Pertti Saurola points out that young Osprey vocalizing for food in a single tree in the middle of a clear-cut is a dinner bell to an Eagle Owl. Although more is known about the ecology of Ospreys relative to the other five species included here, Peter Ewins points out that remarkably little is known about Osprey nesting ecology relative to timber extraction. He concluded based on his review that there is a need for a systematic field study and no firm generalizations can be made. His discussion on the discrepancy between protection standards for nesting Ospreys and the potential costs associated with that protection are thoughtful. The recently developed guidelines on Osprey nests presented by Pertti Saurola provides a step toward improving this situation.

Although his conclusions are based on admittedly sparse data, Per Widén finds that the Northern Goshawk has declined in Fennoscandia due to the loss of mature forests and consequent reductions in available foraging areas and food resources. Northern Goshawks forage primarily on grouse (many species of which are also declining in Fennoscandia), squirrels and lagomorphs; the former two of which are found primarily in mature forests. Per Widén emphasizes that the species primarily forages in mature and older forests with open un-

derstories where it makes short flights between perches. The species seldom uses recently cut areas for foraging presumably because of the dense understories where prey is hard to detect. He also suggests that the Northern Goshawk prefers larger tracts of forest for foraging and, hence, is further affected by fragmentation of forested areas. Therefore, logging of forests, especially clear-cuts that reduce foraging area and fragment large blocks of mature forest, appears to be contributing to declines of the Northern Goshawk in Fennoscandia.

Based on a variety of evidence for Northern Goshawks across North America, Patricia Kennedy concludes that there is no strong evidence to support the contention that goshawk populations are declining. She emphasizes two possible conclusions based on her analysis: (1) either the goshawk is not declining or (2) current sampling techniques are insufficient to detect population trends. Reynolds et al. (1992) provide comprehensive guidance on forest management for the Northern Goshawk in the southwestern U.S. In addition, Kenward (1996) points out additional complexities in understanding Northern Goshawk ecology, especially differences that may be operating in North America and Europe. He indicates that further study is needed on interspecific interactions, winter diet and life history information between fledgling and breeding periods. Clearly, additional data are needed on

responses of this species to forest management practices that will help us understand how to maintain adequate populations of Northern Goshawks, yet provide sustainable and ecologically sound harvest levels. These studies, however, will not be easy, must be long-term, and will not be cheap because the Northern Goshawk has relatively low population levels, a large home range and a food base that varies substantially. Moreover, despite some of the differences that exist between North America and Fennoscandia (e.g., available food supply), there appear to be many opportunities to better our knowledge on how Northern Goshawks react to variations in forest management by additional comparisons and coordination of studies on the two continents.

Again using a limited amount of published information on the ecology of Long-eared Owls, Denver Holt suggests that forest management measures producing relatively small and open cut areas in which owls can forage juxtaposed with forested areas with nest sites provide ideal habitat. Hence, this species may be negatively affected by large cuts, unless the shape is relatively complex to provide access to forested areas. There is some question on the extent to which the Long-eared Owl uses contiguous forested areas because data from these areas are limited. Forest management that provides habitat for prey, plus roost and nest-site cover for Long-eared Owls will be most beneficial.

Summaries by Greg Hayward and Harri Hakkarainen for Boreal Owls in Fennoscandia and North America are enigmatic. Harri Hakkarainen and his colleagues show that, in Fennoscandia, nesting success is highest in landscapes with relatively large proportions of recently clear-cut areas (e.g., 35–70%) compared with landscapes with small proportions of clear-cut area (10–30%). However, in their studies, nest boxes were provided presumably due to the lack of natural nest cavities. In contrast, Greg Hayward states that clear-cutting creates stands without habitat value for Boreal Owls for a century or more. Harri Hakkarainen reasons that clear-cut areas in Finland create suitable habitat for field voles (*Microtus* spp.), the primary prey for the Boreal Owl in this region. Those factors (stand and landscape characteristics) that contribute to high vole densities appear to be most critical for successful nesting of the Boreal Owl. In contrast with these data, Sonerud (1986) and Jacobsen and Sonerud (1993) emphasize the considerable variation in prey availability and foraging habitat for the Bo-

real Owl throughout its annual cycle. For instance, *Microtus* voles may not be available in some clear-cuts in winter when the snow has a hard crust or in summer when the vegetation is too thick. During these times, mature forests provide the best cover and available prey populations.

Greg Hayward's data for the Rocky Mountain region suggest that Boreal Owls primarily forage in mature and older spruce-fir forests in the western U.S. In these forests, the red-backed Vole (*Clethrionomys gapperi*) is the dominant prey. Similar to Sonerud (1986), he suggests that there is less snow crusting in mature and older forests relative to openings and young forests and, therefore, less prey is available in openings and young forests during winter months. He emphasizes that the ecology of this species appears to vary considerably geographically, such as northern and southern populations of the Boreal Owl in North America (Hayward and Verner 1994).

It is obvious that studies from northern Europe and western North America may not be comparable, although greater quantification of nesting and foraging habitat, landscape context of nesting habitat and improved understanding of the food base for the Boreal Owl on both continents would aid comparisons. In northern Europe, nest boxes, hunting perches and adequate food have allowed Boreal Owls to nest near clear-cuts. However, providing nest boxes over large geographic areas is a daunting task and likely not an economically viable means to manage a species. The work by Hakkarainen and Korpimäki (1996) also illustrates the influential role of interspecific interactions with other owl species, Boreal Owl distribution and reproduction. Data like these are not available for North America and nest-box studies are likely the only way to address these questions. Although papers on the Boreal Owl from the two continents may be enigmatic, they are fascinating in terms of providing insights on complexities involved in studies for just one species in regard to forest management issues.

Based on limited knowledge on Northern Hawk Owl ecology, Patricia Duncan, Wayne Harris and Geir Sonerud conclude that this species likely benefits from relatively small and complex cut sizes in forests. Key issues for this species are hunting perch availability, nest trees and cover for protection within a logged landscape. Geir Sonerud describes a relatively intense, albeit with limited spatial replication, study of foraging by Northern



Hawk Owls. He emphasizes that hunting perches within logged areas are required. If no live or dead residuals are left in clear-cuts, the only hunting perches that allow this species to use these areas for foraging are trees remaining along the edges. The species can tolerate larger clear-cut areas if the shape is convoluted providing edges or if many suitable hunting perches are left distributed within the cut areas allowing access to most of the clear-cut area. In addition, suitable areas for cover and nesting are also required.

As with the Northern Hawk Owl, evidence presented by James Duncan, Seppo Sulkava and Kauko Huhtala show the Great Gray Owl responds favorably to relatively small and complex cuts that provide suitable foraging perches along edges and suitable cover for nesting and protection in the adjacent forest habitat. We do not know how the species would respond to intermediate-sized cuts but, based on the species' ecology, large clear-cuts with no hunting perches would be of little use. Larger cuts with well-distributed hunting perches, convoluted edges and adjacent areas that provide cover and nesting may be suitable. Little is known of the size requirement of a forest area for nesting or cover. In addition, the nesting forest requirements of large raptors which produce most nesting platforms for the Great Gray Owl also need to be considered.

**Residuals.** With the possible exception of the Northern Goshawk and Long-eared Owl, the remaining four species require residuals in logged areas for the species to use this habitat (Table 1). For species that often use residuals for nesting such as the Osprey and Boreal Owl, they are essential. It is unclear to what extent the Northern Goshawk or Long-eared Owl require residuals as hunting perches. Certainly these species use them occasionally as hunting perches or resting sites, but their importance to their overall fitness is unclear.

Based on the evidence from Fennoscandia, the Boreal Owl, Northern Hawk Owl and Great Gray Owl all use residuals left within logged areas for hunting perches to forage for small mammals (especially *Microtus* voles). Seppo Sulkava and Kauko Huhtala suggest that the Great Gray Owl population has increased in many parts of Finland because of the increased populations of *Microtus* voles and the ability of the Great Gray Owl to forage in these logged areas.

The extent to which either the Northern Hawk Owl or Great Gray Owl use residuals within clear-

cut areas for nesting is unclear. In Finland, some nests have been found in open habitats (e.g., clear-cuts) or near openings. Geir Sonerud indicates that few breeding opportunities exist in recently cut areas because of the lack of suitable older trees for nest sites. He points out that the decline in Northern Hawk Owls in Finland from the 19th century to the 1950s was thought to be due to the disappearance of suitable nest trees. Patricia Duncan and Wayne Harris suggest that areas that offer year-round habitat are cut-overs containing enough stumps and trees for nest structures. Hence, it would appear that recently logged areas may be suitable nesting areas for both the Northern Hawk Owl and Great Gray Owl if suitable residuals are left. On a local scale it is also possible to actively manage for these species by placing nest boxes (Northern Hawk Owl) or nesting platforms (Great Gray Owl), but several authors point out that this type of mitigation is impractical at larger spatial scales.

In northern Europe, Boreal Owls nest successfully in a landscape with a high proportion of clear-cuts when provided with suitable nest boxes. Nevertheless, Harri Hakkarainen and his colleagues point out that modern forestry practices must provide suitable snags and patches of old mature forest with large trees dense enough to support the hole-nesting Black Woodpecker (*Dryocopus martius*). The Black Woodpecker excavates most natural nest cavities for the Boreal Owl in Finland. Greg Hayward points out that, in North America, availability of nest cavities depends upon available nest trees (especially aspen, *Populus* spp.), insects and pathogens necessary to create suitable, weakened trees and primary cavity nesters such as Pileated Woodpecker (*Dryocopus pileatus*) to create cavities. In a nest-box experiment in Idaho, he found that the Boreal Owl selected nest boxes within forests of more complex structure (e.g., multiple canopy layers and many tree size classes) and did not use boxes in forests with a more simple structure (e.g., single canopy layer and more uniform tree diameters). More information is needed to address the combination of nesting, foraging and cover needs of the Boreal Owl.

In general, residuals in logged areas are clearly beneficial to a variety of forest raptors, including most of those considered here. Quantitative data obtained through replicated field studies are needed to address specific issues on species, sizes, spatial distribution and number of residuals (dead or



alive) required in logged areas. For instance, leaving a few dead trees in the middle of a clear-cut for Ospreys may be detrimental. If a goal of forest management is to simulate natural forest conditions to the extent possible, then the natural disturbance forces for most of the northern boreal forests considered here are fire, insect outbreaks and wind (Pastor et al. 1996). In these systems, residuals in the form of burned trees, patches of unburned forest, charred trees from fire, dead trees from an insect outbreak or trees with broken tops from excessive wind were much more common in the past.

#### CONCLUSIONS

Although only six species of raptors were considered here, they illustrate that forest management aimed toward logging will benefit some species, while alternative management measures aimed at the maintenance of mature and old forest will benefit other species. For instance, clear-cutting in small units (2–5 ha) has increased populations of *Microtus* voles in Fennoscandia and this habitat intermixed with suitable forested areas for nesting and cover are beneficial to the Northern Hawk Owl and Great Gray Owl. There is a potentially important role of large fields and large clear-cuts in supplying source populations of *Microtus* voles to the smaller, isolated clear-cuts. In contrast, reduction in mature and old forest may lead to reduced populations of the Northern Goshawk.

The key is to understand predator and prey responses to forest changes at a variety of spatial scales including microhabitat, landscapes and landscape mosaics. Individual species responses could then be incorporated into forest change simulation models that consider both spatial and temporal scales (Pastor et al. 1996). These simulation models will allow us to assess the effects of a range of management scenarios on species populations, other species complexes (e.g., plants, insects, mammals, etc.), ecological processes (e.g., nutrient cycles, plant growth and decomposition) and commodity production. The models should be developed with the best available knowledge and applied with an understanding of the degree of uncertainty produced with the output. The models can be improved as our knowledge of these organisms and processes increase. Similarly, factors that contribute most to output uncertainty should provide a framework for prioritizing additional research activity.

Raptors, by virtue of their position in the forest food chain and their potentially important role in ecological processes of forests, will always be of high concern in forest resource management decisions. If we are to maintain healthy forest ecosystems, then it is imperative for society to increase its investment in understanding these systems.

#### ACKNOWLEDGMENTS

We appreciate the constructive comments on these concluding remarks from many of the contributors to this issue including Patricia Duncan, James Duncan, Harri Hakkarainen, Greg Hayward, Denver Holt, Patricia Kennedy, Geir Sonerud, Seppo Sulkava and Per Widen. We thank the following organizations for their financial support of the symposium and this issue of the *Journal of Raptor Research*: US Bureau of Land Management; the North Central Forest Experiment Station in St. Paul, Chequamegon National Forest, Chippewa National Forest, Nicolet National Forest, Ottawa National Forest and Superior National Forest; Boise-Cascade, White Paper Division; Georgia-Pacific Corporation; Lake Superior Paper Industries; National Council of Stream and Air Improvement Inc.; Potlatch Corporation, Northwest Paper Division; Minnesota State Legislature (through the Minnesota Environment and Natural Resources Trust Fund as recommended by the Legislative Commission on Minnesota Resources); and the University of Minnesota through its Natural Resources Research Institute, Raptor Center, Department of Biology and University College. This is contribution number 207 of the Center for Water and the Environment, Natural Resources Research Institute, University of Minnesota, Duluth.

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## BOOK REVIEWS

EDITED BY JEFFREY S. MARKS

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### **Demography of the Northern Spotted Owl.**

Edited by Eric D. Forsman, Stephen DeStefano, Martin G. Raphael and R.J. Gutiérrez. 1996. *Studies in Avian Biology*, No. 17. v + 122 pp., 40 figures, 42 tables, 1 appendix. ISBN 0-935868-83-6. Paper, \$20.00.—An unprecedented amount of effort has gone into studying the demographics of the Northern Spotted Owl (*Strix occidentalis caurina*), largely because of controversy surrounding its use of commercially valuable old forests in the Pacific Northwest. This volume results from a 12-d workshop held in Fort Collins, Colorado in December 1993. The workshop was requested jointly by the Secretaries of Agriculture and Interior for the purpose of examining all existing demographic data resulting from mark-recapture studies of Northern Spotted Owls. Some researchers declined to participate, but the results of 11 demographic studies conducted by federal and university scientists were included in analyses completed at the workshop. To give some idea of the magnitude of the effort represented by these studies, the study areas covered an area of 45 846 km<sup>2</sup>, including an estimated 20% of the range of the Northern Spotted Owl. A summary report was prepared following the workshop, submitted to the aforementioned secretaries and included as an appendix in land-management planning documents. This volume expands on that treatment by including background papers not included in the summary report.

The volume is organized in three main sections: Introduction and Methods, Demography of the Northern Spotted Owl and Synthesis. It also contains a comprehensive list of references and an appendix that lists the symbols and acronyms used in the text.

The introductory section contains three chapters. "Biology and Distribution of the Northern Spotted Owl," by R.J. Gutiérrez, provides a brief overview of natural history. The level of information provided seems appropriate for this volume. The review is not intended to be exhaustive, or to supplant existing

literature reviews, so it will add little for readers already familiar with the owl. "History of Demographic Studies in the Management of the Northern Spotted Owl," by R.J. Gutiérrez, E.D. Forsman, A.B. Franklin and E.C. Meslow, provides a good overview of watershed events in the management and conservation of the owl and of how demographic data were used in major planning efforts and decisions. This interesting and informative chapter makes a strong case for the utility of demographic data for management planning and for stimulating new areas of research. The third chapter discusses "Methods for Collecting and Analyzing Demographic Data on the Northern Spotted Owl" (A.B. Franklin, D.R. Anderson, E.D. Forsman, K.P. Burnham and F.W. Wagner). This chapter provides an overview of the demography study areas included in the workshop, field methods used in those studies and analytical methods used in the workshop. Methods, underlying assumptions and potential biases are clearly discussed, making this section highly relevant to readers interested in the Northern Spotted Owl and to those interested in demographic analysis in general.

The demography section contains nine chapters that discuss the 11 study areas included in the workshop (some chapters include two areas). The list of authors includes most (but not all) of the researchers who have been heavily involved with Northern Spotted Owls. Each chapter includes a section on study area(s), field and analytical methods (especially where they deviate from the methods discussed by Franklin et al.), results, discussion and summary. Thus, there is considerable redundancy. This was unavoidable given the nature of the material, however.

This demography section is the heart of the volume in the sense that the chapters present and discuss the results of the individual studies. The chapters are interesting and generally well written, and they contain many details about features unique to individual studies that are lost in the summary chapters. Nevertheless, because these studies parallel each other to such a great extent, I suspect that the average reader will find the summary chapters more interesting.



The synthesis section consists of two concluding chapters. In "Meta-analysis of Vital Rates of the Northern Spotted Owl," K.P. Burnham, D.R. Anderson and G.C. White used all of the demographic data available on the Northern Spotted Owl to estimate vital rates (survival and fecundity) and current status of the population. One of the strengths of the demography studies was that methodology was standardized across studies, so that data sets could be combined in a meta-analysis (a technique for combining results of separate but similar studies). This analysis has greater statistical power than analyses based on individual studies and yielded two lines of evidence suggesting that the population of Northern Spotted Owls is declining: an annual rate of population change ( $\lambda$ ) less than 1 and a declining trend in survival rates of adult females. Further, the authors argue that the spatial extent of the studies combined with replication across study areas allows inferences derived from the meta-analysis to be extended to the overall population of Northern Spotted Owls, rather than be restricted to populations of banded birds on each of the study areas.

These results are extremely important from a conservation planning standpoint, but the authors of the chapter on the meta-analysis pointedly refrained from speculating on their implications to land managers. Consequently, a separate set of authors close the volume with a chapter on "Use, Interpretation, and Implications of Demographic Analyses of Northern Spotted Owl Populations" (M.G. Raphael, R.G. Anthony, S. DeStefano, E.D. Forsman, A.B. Franklin, R. Holthausen, E.C. Meslow and B.R. Noon). This chapter provides an excellent and stimulating discussion of the uses, interpretation, limitations and potential biases of demographic data, as well as recommendations for additional analyses. It should provide abundant food for thought for land managers and researchers, and the concepts discussed are relevant to other raptors.

In summary, this is an interesting, useful and important document. The development of strong research programs and techniques may be the most positive result of the controversy surrounding the Northern Spotted Owl and land management. The demographic studies described in this volume are unique because of their spatial extent, the intensive long-term sampling (up to nine years) involved in at least some of the studies and the standardization of methods across studies. These studies, many of which are ongoing, have already made signifi-

cant contributions to land management and to both applied and theoretical research.

The workshop discussed here also was unique. It brought together a wealth of expertise on both Northern Spotted Owls and demographic analysis. The analytical approach was rigorous and thorough, and methods, assumptions and potential biases were clearly documented. Consequently, this volume represents the state-of-the-art in terms of demographic analysis of Northern Spotted Owls. It should thus be a valuable reference for anyone concerned with the biology and conservation of the Northern Spotted Owl. At least parts of this document should be of general interest as well, including the introductory and synthesis sections. The methods and concepts discussed are relevant to anyone interested in analyses of raptor populations.—**Joseph L. Ganey, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Flagstaff, AZ 86001 U.S.A.**

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**Eagle Studies.** Edited by B.-U. Meyburg and R.D. Chancellor. 1996. World Working Group on Birds of Prey and Owls, Berlin, Germany. xiii + 549 pp., numerous figures and tables, 2 color photographs. ISBN 3-9801961-1-9. Paper, \$30.00.—This volume contains 64 papers. The first examines genetic differentiation in five *Aquila* species in Europe, and the final paper discusses satellite tracking of nine eagle species in Europe, Asia and Africa. The other studies deal with 10 species (seven papers cover two species): Osprey (*Pandion haliaetus*; 3 papers), White-tailed Sea-Eagle (*Haliaeetus albicilla*; 18), Bald Eagle (*H. leucocephalus*; 2), Steller's Sea-Eagle (*H. pelagicus*; 1), Lesser Spotted Eagle (*Aquila pomarina*; 18), Imperial Eagle (*A. heliaca*; 10), Golden Eagle (*A. chrysaetos*; 8), Greater Spotted Eagle (*A. clanga*; 4), Steppe Eagle (*A. nipalensis*; 1) and Bonelli's Eagle (*Hieraaetus fasciatus*; 1). Most of the papers (46) are in English; 16 are in German and two in French (the German and French papers contain brief English summaries). Papers range in length from 1 to 44 pages.

Most of the papers were presented at three meetings: the International Symposium on the White-tailed Sea Eagle and the Lesser Spotted Eagle, in 1991 at Zielonka, Poland; the IV World Conference on Birds of Prey and Owls, in 1992 at Berlin, Germany; and the Third International Meeting of the Imperial Eagle Working Group, in 1993 at Királyrét, Hungary. The majority of studies originated in Europe or Asia, including the former Soviet Union, the former Eastern Block, Scandinavia, Japan, Pakistan, India and Israel. The editors recognize the variable quality of the papers and state in the Preface: "Since a large number of the manuscripts were not written in their authors' mother tongue a considerable amount of editorial work was also required. . . ." Considering this enormous task, I found no difficulty overlooking the occasional punctuation errors, awkwardness and verbosity.

Causes of eagle population declines or extirpation and partial recoveries in some areas are reported in many of the papers. Conservation programs described range from the need to protect nest trees to more extensive problems with foraging or migration habitats. For example, for the White-tailed Sea-Eagle in Southern Moravia, authors Mrlík and Horák stress: ". . . the preservation of sufficiently extensive tall and old forests near large water surfaces . . . and the elimination of any wood cutting or other disturbance at breeding sites during nesting . . ." In most areas the problems are complex and broad. Author Rodziewicz reports: ". . . in Poland the nests and their surroundings have been protected by law since 1984, and foresters have a positive attitude towards this protection, at least in some regions . . . in 1987 the Administration of State Forests in Olsztyn (northeastern Poland) employed two ornithologists to deal solely with the protection of rare raptors. Thus more dangerous are the threats to foraging habitat. The great political and consequent economic changes will result in development of agricultural methods with greater intensity. So the problem is not of protecting individual territories, but one of general agricultural policy in the regions of highest Lesser Spotted Eagle density." The essential importance of sustaining prey populations is interestingly described in several papers. Authors Vlachos and Papageorgiou characterize the key to the future of the Lesser Spotted Eagle in Dadia, Greece, as habitat management that will continue to sustain a high density of reptiles. Authors Bahat and Mendelssohn describe fascinating habitat in the Ei-

lat Mountains (southern Negev), Israel, in which two pairs of Golden Eagles foraged primarily on the spiny-tailed lizard (*Uromastix aegyptius*).

The book could be criticized for lacking any apparent theme in a hodgepodge of studies and status reviews. However, there is interesting information on eagle behaviors and distributions that previously has been unknown, or nearly so. The document also may provide valuable baseline records for many areas, especially in countries where research has been difficult to accomplish because of political turmoil. Authors Abuladze and Eligulashvili describe a conservation program they believe is needed for the White-tailed Sea-Eagle in the Transcaucasus, but lament that the program: ". . . is at present impossible because of various political, economic, and social problems." Author Abuladze describes a long-term program for raptor conservation in the Republic of Georgia. He states: "Unfortunately the present political and economic situation prevents this from being implemented. In such conditions, problems concerning wildlife are of little concern. Due to the most recent political circumstances, the research group of professional ornithologists has broken up. One can only hope that the present crisis will not last for ever, so that one day the work begun can be continued with greater efficiency."

Considering the logistical and political difficulties involved in many of the areas, it is impressive that so much good work has been done. In that context, I view this book as an apt tribute to persevering researchers, naturalists, managers and lay people who continue to struggle for the appreciation and protection of raptor populations and their habitats in Europe and Asia. Although this book may not be a high priority for personal purchase in most cases, it should be in university libraries.—**B. Riley McClelland, P. O. Box 366, West Glacier, MT 59936 U.S.A.**

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**The Striated Caracara *Phalacrocorax australis* in the Falkland Islands.** By Ian J. Strange. 1996. Available from I.J. Strange, The Dolphins, Stanley, Falk-



land Islands. 56 pp., 17 color photos, 10 black-and-white photos, 9 figures, 2 tables. Paper, \$17.00.—Printed on glossy paper with two-column format, this publication resembles a high-quality brochure. Seventeen full-page color photographs portray the “Johnny Rook,” as it is known locally—now on a promontory surveying a vast colony of albatrosses, now investigating the author’s rucksack for scraps of food or bright objects to steal, now a flock of 30 or so devouring the beached carcass of a penguin. Mr. Strange, the author of a book on the Falklands (where he has lived most of his life), has studied caracaras with assistance from the National Geographic Society and others. Previous observations on this bird are scanty; some of the best were by none other than Charles Darwin.

After summarizing the history and distribution of *P. australis*, the latter including small islets off Cape Horn, Mr. Strange touches upon all aspects of the general natural history of this bird (e.g., nesting, fledging, behavior of adults and immatures, food and foraging habits). Smaller, fully labeled photographs, as well as the larger ones in color, convey much information. Once with a bounty on its head, or rather beak, the Johnny Rook now exists in tolerable numbers only on a few islets where one lands at the risk of shipwreck. Even on these remote locales, the insatiable demands of the world’s teeming masses for protein and fuel are despoiling the once limitless seas down to their very depths. The seabirds and seals are already showing the effects, and if they go, so goes the caracara. Ian Strange is among the outnumbered few who are striving to save at least a vestige of this wildlife.—**Dean Amadon, Ornithology Department, American Museum of Natural History, Central Park West at 79th Street, New York, NY 10024 U.S.A.**

dix. ISBN 0-691-01105-2. Cloth, \$24.95.—In this book, Max Terman provides a chronicle of the first seven years of interaction between himself and an “imprinted” Great Horned Owl (*Bubo virginianus*). The story remains unfinished, with Terman and “Stripey” (the name provided to the owl by one of Terman’s students at Tabor College) still in contact with each other in a barn on Stripey’s territory near the Flint Hills of Kansas. The book is remarkable for several reasons, not least of which is that Terman, through diligence and luck (and the use of radiotelemetry), was able to follow Stripey’s life from inept youth in captivity to membership in the local breeding population of wild owls.

The book is a refreshing blend of natural history observation, muse and candor; in the process of sharing in Stripey’s development we get to know something about Max Terman. Terman begins his narrative by taking us with him to the Hillsboro city park to retrieve a four-wk-old owlet, apparently abandoned by its parents and now starving. From there, we follow Stripey and Terman through the next several years of growth and discovery. Along the way, Terman shares his thoughts regarding the behavior and development of Stripey and other “imprints,” his concerns regarding Stripey’s ability to fit into owl society once released from captivity, his frustrations with his undertaking (especially the ups and downs of using radiotelemetry to follow Stripey’s movements), and his justified satisfaction when he finally witnesses Stripey’s wild offspring after years of effort by Stripey to secure a territory and mate.

Whether or not an imprinted owl can survive and reproduce in the wild is a question near the forefront of Terman’s thoughts, and he belabors this question throughout the book. By book’s end, we know that a young captive owl can “make it” in the wild as an adult, but is Stripey really an owl version of Konrad Lorenz’s greylag geese? I found myself questioning if an owl already four wk of age when exposed to humans is an imprint. I suspect not. I also question that the avoidance of humans was wired into Stripey’s system (p. 16). Nevertheless, because the book is written almost as a dialogue of discovery between Terman and himself, with the imprint question unfolding in parallel with the development of Stripey, his thoughts on this topic (especially regarding the period of fledgling dependency) are informative and fun to follow. And, much to my relief, Terman concludes (p. 146) that many birds considered imprints are ac-



tually "deficit birds," birds not imprinted on humans but lacking a full repertoire of normal acquired behaviors. Terman feels that many deficit birds can make it on their own, and as successfully as wild individuals, if they are carefully monitored upon release and gradually weaned from feeding stations while they learn to hunt. Whether or not this is true, these thoughts should be of special practical interest to rehabilitators.

A few comments peripheral to the book's main topic are incorrect. The Sutton Avian Research Center near Bartlesville, Oklahoma is not a raptor rehabilitation center, but was a center for raptor research, especially the reestablishment of the Southern Bald Eagle (*Haliaeetus l. leucocephalus*), and has since expanded its work to include population-level studies of prairie birds. Margaret Morse Nice was not "reborn as a naturalist" in Columbus, Ohio, but experienced her ornithological epiphany several years earlier on the banks of the Canadian River near Norman, Oklahoma. These inaccuracies detract not a whit from Terman's story of Stripey.

The book is mostly free of typos; I noted only one ("opprotunity", p. 190). The black-and-white photographs enhance the narrative (who else has pictures of Stripey on his territory in Kansas?) and help make the bird and setting more personal.

Some, such as Stripey catching food (hot dogs and such) in the air (p. 76), are downright enlightening, especially for people unfamiliar with the ability of Great Horned Owls to capture bats on the wing. A few photographs are of such poor quality, however, that I question whether they should have been published. For instance, the leg-mounted transmitter shown on p. 17 is difficult to discern in the fuzzy photograph, leaving someone unfamiliar with such devices still unfamiliar; the photograph of the author radio-tracking Stripey (p. 84) also contributes little. The computer-generated map of Terman's farm and surroundings (where Stripey was released) helps the reader put place-names mentioned in the text in geographic perspective (although I don't understand why north was oriented to the right), but the visual attractiveness of the map suffers.

*Messages from an Owl* is entertaining, educational and exposes the reader to the thought processes of a scientist trying to get answers to some perplexing questions. It should appeal to the same professional and lay readership that enjoyed Bernd Heinrich's *One Man's Owl*, although the story of Stripey is carried much farther than that of "Bubo." Also, there is a "surprise ending" that I won't divulge.—**Paul Hendricks, Montana Natural Heritage Program, 909 Locust Street, Missoula, MT 59802 U.S.A.**

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*The Journal of Raptor Research* is distributed quarterly to all current members. Original manuscripts dealing with the biology and conservation of diurnal and nocturnal birds of prey are welcomed from throughout the world, but must be written in English. Submissions can be in the form of research articles, letters to the editor, thesis abstracts and book reviews. Contributors should submit a typewritten original and three copies to the Editor. All submissions must be typewritten and double-spaced on one side of 216 × 278 mm (8½ × 11 in.) or standard international, white, bond paper, with 25 mm (1 in.) margins. The cover page should contain a title, the author's full name(s) and address(es). Name and address should be centered on the cover page. If the current address is different, indicate this via a footnote. A short version of the title, not exceeding 35 characters, should be provided for a running head. An abstract of about 250 words should accompany all research articles on a separate page.

Tables, one to a page, should be double-spaced throughout and be assigned consecutive Arabic numerals. Collect all figure legends on a separate page. Each illustration should be centered on a single page and be no smaller than final size and no larger than twice final size. The name of the author(s) and figure number, assigned consecutively using Arabic numerals, should be pencilled on the back of each figure.

Names for birds should follow the A.O.U. Checklist of North American Birds (6th ed., 1983) or another authoritative source for other regions. Subspecific identification should be cited only when pertinent to the material presented. Metric units should be used for all measurements. Use the 24-hour clock (e.g., 0830 H and 2030 H) and "continental" dating (e.g., 1 January 1990).

Refer to a recent issue of the journal for details in format. Explicit instructions and publication policy are outlined in "Information for contributors," *J. Raptor Res.*, Vol. 27(4), and are available from the editor.

## 1997 ANNUAL MEETING

The Raptor Research Foundation, Inc. 1997 annual meeting will be hosted by Georgia Southern University and will be held October 30 through November 2 at the Marriott Riverfront in Savannah, Georgia. Details about the meeting and a call for papers will be mailed to Foundation members in the spring of 1997. For more information, contact Michelle Pittman (912/681-5555, e-mail: meeden@gsvms2.cc.gasou.edu) or Steve Hein (912/681-0831) at Georgia Southern University.

### RAPTOR RESEARCH FOUNDATION, INC., AWARDS Recognition for Significant Contributions<sup>1</sup>

- The **Dean Amadon Award** recognizes an individual who has made significant contributions in the field of systematics or distribution of raptors. Contact: **Dr. Clayton White, 161 WIDB, Department of Zoology, Brigham Young University, Provo, UT 84602 U.S.A.** Deadline August 15.
- The **Tom Cade Award** recognizes an individual who has made significant advances in the area of captive propagation and reintroduction of raptors. Contact: **Dr. Brian Walton, Predatory Bird Research Group, Lower Quarry, University of California, Santa Cruz, CA 95064 U.S.A.** Deadline: August 15.
- The **Fran and Frederick Hamerstrom Award** recognizes an individual who has contributed significantly to the understanding of raptor ecology and natural history. Contact: **Dr. David E. Andersen, Department of Fisheries and Wildlife, 200 Hodson Hall, 1980 Folwell Avenue, University of Minnesota, St. Paul, MN 55108 U.S.A.** Deadline: August 15.

### Recognition and Travel Assistance

- The **James R. Koplín Travel Award** is given to a student who is the senior author of the paper to be presented at the meeting for which travel funds are requested. Contact: **Dr. Petra Wood, West Virginia Cooperative Fish and Wildlife Research Unit, P.O. Box 6125, Percival Hall, Room 333, Morgantown, WV 26506-6125 U.S.A.** Deadline: established for conference paper abstracts.
- The **William C. Andersen Memorial Award** is given to the student who presents the best paper at the annual Raptor Research Foundation Meeting. Contact: **Ms. Laurie Goodrich, Hawk Mountain Sanctuary, Rural Route 2, Box 191, Kempton, PA 19529-9449 U.S.A.** Deadline: Deadline established for meeting paper abstracts.

### Grants<sup>2</sup>

- The **Stephen R. Tully Memorial Grant** for \$500 is given to support research, management and conservation of raptors, especially to students and amateurs with limited access to alternative funding. Contact: **Dr. Kimberly Titus, Alaska Division of Wildlife Conservation, P.O. Box 20, Douglas, AK 99824 U.S.A.** Deadline: September 10.
- The **Leslie Brown Memorial Grant** for \$500-\$1,000 is given to support research and/or the dissemination of information on raptors, especially to individuals carrying out work in Africa. Contact: **Dr. Jeffrey L. Lincer, P.O. Box 1675, Valley Center, CA 92082 U.S.A.** Deadline: September 15.

<sup>1</sup> Nominations should include: (1) the name, title and address of both nominee and nominator, (2) the names of three persons qualified to evaluate the nominee's scientific contribution, (3) a brief (one page) summary of the scientific contribution of the nominee.

<sup>2</sup> Send 5 copies of a proposal ( $\leq 5$  pages) describing the applicant's background, study goals and methods, anticipated budget, and other funding.