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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 (*Accipter 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.

				FOREST MANAGEMENT					
		TREND		STAND SIZE			STAND SHAPE		
SPECIES	CONTINENT	RECENT	LONG-TERM	SMALL	MEDIUM	LARGE	SIMPLE	COMPLEX	RESIDUALS
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[a]
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	Postive	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

[a] 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 understories 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 Boreal Owl throughout its annual cycle. For instance, *Microtus* voles may not be available in some clearcuts 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.

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