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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.*

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							
	Low[a]			High[b]				
	$\bar{x}$	(± SD)	N	$\bar{x}$	(± SD)	N	Test Value	P
Breeding percentage	15	(9)	17	14	(15)	13	U = 139.0	0.22
Laying date	1.41	(19.44)	14	1.10	(21.98)	10	T = 0.04	0.97
Clutch size	5.43	(0.88)	14	5.20	(1.26)	11	T = 0.54	0.59
No. of fledglings	2.45	(1.26)	14	3.55	(1.39)	11	T = 2.06	0.05

[a] 18% (SD = 7%, range = 10–30%) of total area within 1.5 km of nest was clear-cut.
[b] 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).

	Proportion of Clear-cut Areas within Territory	
Phase of Vole Cycle	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 constrast, 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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