Chapter 11

Conservation Status of Boreal Owls in the United States

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INTRODUCTION

Previous chapters outlined the biology and ecology of boreal owls as well as the ecology of important vegetation communities based on literature from North America and Europe. That technical review provides the basis to assess the current conservation status of boreal owls in the United States. By conservation status, we mean the demographic condition of the species as it relates to the likelihood of local and national persistence of wild populations over the long term. Are populations of boreal owls in the United States currently threatened? Are current land management practices likely to lead toward the peril of local or regional populations?

Like any scientific story, our understanding of boreal owl ecology is incomplete. In the face of incomplete knowledge, I will evaluate the status of boreal owls by asking a series of critical questions about the species and its habitat. My goal is to synthesize evidence necessary to build a case for one of the following conclusions: 1) populations of boreal owls in the United States are secure and will likely remain so given current land management practices; 2) populations of boreal owls are in peril (declining or experiencing some demographic trauma) or are likely to be in peril in the future given current land management practices; or 3) there is insufficient evidence to determine the species' conservation status.

Populations of boreal owls differ in biology and ecology depending on geographic setting (Korpimaki 1986, Hayward *et al.* 1993). Therefore, for this assessment, when answering the critical questions, I rely first on investigations from North America and use European studies to a lesser extent. A minimum of references are presented here as the literature was thoroughly reviewed in the previous chapters.

Is the Distribution and Abundance of the Boreal Owl Declining in All or Part of Its Range?

Distribution

The boreal owl is broadly distributed in North America, and its distribution likely has remained the same over the past few decades. The extensive geographic range of the species contributes toward species persistence.

During the past 15 years, numerous published reports have extended the recognized range of boreal owls in western North America. In 1980, the southern extent of the species' breeding range was thought to end in Canada. Today, evidence exists for breeding populations throughout the Rocky Mountains south to southwestern Colorado and northern New Mexico. Breeding boreal owls have also been documented in northern Minnesota. Do these records indicate an extension of the species' range?

The weight of evidence suggests that the actual distribution of boreal owls has not changed recently; rather, our knowledge of the species has changed radically. Several indirect lines of evidence support the contention that the extension of the species' recognized range stems from an increase in survey effort. First, historical records indicate that boreal owls were recorded in the western United States but not recognized as breeding. A close look at the literature indicates that boreal owls were documented as far south as Colorado for nearly 100 years (see Ryder *et al.* 1987). Historical records of boreal owls in Wyoming, Idaho, and Colorado were thought to represent nonbreeding "visitors." Despite the occurrence of boreal owls in the western United States, checklists and field guides did not list the species, even after breeding populations were documented in 1983.

Second, human use of boreal owl habitat has increased recently, raising the probability of documenting existing breeding populations. Winter recreation in high mountain lands has increased since the 1970's, bringing more people into boreal owl habi-

tats during the owls' most vocal period. Coincident with increased interest in winter sports (cross country and downhill skiing) has been an increase in roads in high mountain areas. Furthermore, biologists working with land management agencies have conducted surveys directed toward finding boreal owls. An increase in roads accessing high elevation forests and interest in the owl have facilitated location of breeding owls. In 1984 alone, during the first extensive surveys in the Northern Rocky Mountains, agency personnel found boreal owls on nine western national forests where the owl was not recognized previously.

Third, biologists in Europe have also located new populations of boreal owls and attributed these to increased interest in the species. Cramp (1977) describes extensions of the recognized range in Europe but does not believe the species has actually broadened its distribution.

Abundance

Local and regional trends in boreal owl abundance cannot be assessed with available data. Breeding populations of boreal owls were only recently documented throughout most of the species' range in the United States. In most cases, estimates of density or an index to abundance have not been made, 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 assessment of trend within the next 5 years (see Hayward *et al.* 1992).

Do Habitats Vary in Their Capacity to Support Boreal Owl Populations or to Support Particular Activities of the Owl? What Are the Important Characteristics of Those Habitats?

Study of boreal owl habitat use is limited. Investigators in Europe who have studied boreal owls for 2 decades have not focused on habitat use. In North America, only three studies have intensively examined habitat use. Despite this limited knowledge, the evidence supports the contention that boreal owls favor particular habitat characteristics at a variety of geographic scales. Consistently occupied habitat generally is mature or old spruce or spruce-fir forest.

The combined results of three, multiyear studies of boreal owls in North America indicate that boreal owls choose sites for nesting, roosting, and foraging nonrandomly (Bondrup-Nielsen 1978, Palmer 1986, and Hayward *et al.* 1993). Knowledge of habitat use in North America stems largely from these studies. Studies from Europe corroborate the conclusion that boreal owls choose specific habitats at a variety of spatial scales. In general, habitat studies were observational, rather than experimental, and suffered from small sample sizes. Furthermore, none of the North American studies compared the relative fitness or productivity of individuals using various habitats. Despite these shortcomings (which are the norm in vertebrate ecology) these investigations were sound mensurative studies that showed boreal owls use habitats differentially for important life functions.

Regional

At the regional scale, knowledge of boreal owl distribution indicates particular habitat associations. Boreal owls occur only in subalpine forest habitats in the western United States (e.g., Hayward *et al.* 1993). Breeding populations have not been found more than 100 m below the spruce-fir zone in the Rocky Mountains. East of the Rocky Mountains, boreal owls do not occur south of boreal and transition boreal-temperate forests. These distributional boundaries suggest strong physiological, behavioral, or ecological barriers limiting the boreal owl. What characteristics of these forests are important in determining the broad distribution pattern of boreal owls is unknown but reasonable hypotheses were outlined in Chapters 9 and 10.

Landscape

At the landscape and home range scales, limited evidence indicates boreal owls use sites with particular forest characteristics (e.g.,Sonerud 1986, Korpimaki 1988, Hayward *et al.* 1993). In both Europe and North America, quality foraging habitat is characterized as mature and older spruce or spruce-fir forest. During prey population declines in Finland, owl home ranges with a high proportion of spruce forest are consistently occupied while other ranges are only used during prey peaks. The regularly occupied home ranges also produce more fledglings than other sites, indicating a match between preferred habitat and productivity (Korpimaki 1988). In Idaho, nest sites of radio-marked owls occurred in the lowest elevation portion of home ranges (edge of elliptical home ranges) indicating the spatial segregation of habitats used for nesting vs. foraging and roosting (Hayward *et al.* 1993). Nest sites occurred in old aspen and old, mixed-conifer stands while roost and foraging sites were often in mature and older spruce-fir forest.

Microhabitat

At the microhabitat scale, boreal owls appear to use a nonrandom subset of sites for nesting, roosting, and foraging. The strength of evidence for habitat choice varies among investigations, each of which was conducted in a very different geographic setting. In some studies, selection was not demonstrated, while in others, used habitat was simply described.

Boreal owls are obligate cavity nesters. One study suggests that boreal owls select among available nest sites when a range of sites is available. In an experimental study in Idaho, suitable nest sites in lodgepole pine forest were not used when alternates were available in the old mixed-confer forest (Hayward *et al.* 1993). In the same study, an analysis comparing 28 nest sites and 101 random sites indicated the owls used forests with multiple canopy layers, large diameter trees, and high basal area.

Although boreal owls have been shown to choose particular forest habitats for nesting, the species will accept a broad range of nest sites. Simple descriptive studies demonstrate this range. Nests have been found almost exclusively in aspen in Canada and Minnesota, in spruce and lodgepole in Colorado, and lodgepole and spruce-fir forest in Montana. Nest boxes placed in clearcuts in Idaho and Sweden have been used. In these cases, spruce or spruce-fir forest occurred nearby.

The importance of specific roosting habitat seems to vary depending upon the threat of predation and degree of thermal stress. In Canada, owls did not select particular sites for roosting. In Idaho, boreal owls exhibited symptoms of summer heat stress and were shown to choose cool microsites for roosting. Mature and old spruce-fir forest was chosen for summer roosts. These stands had higher basal areas, higher crown closures, and higher tree densities than random sites. During winter, these same owls were less selective in roost choice.

Microhabitat characteristics of boreal owl foraging habitat have not been studied. Therefore, despite evidence for foraging habitat choice at broader scales, the microhabitat characteristics of quality foraging habitat have not been identified.

Do Habitats Vary in Their Capacity to Support Principal Prey Species?

Primary prey of boreal owls in North America include red-backed voles (*Clethrionomys* spp.), field voles (*Microtus* spp.), deer mice, shrews, flying squirrels (*Glaucomys sabrinus*), and pocket gophers (*Thomomys talpoides*). Most important among these are red-backed voles and field voles, both of which occur in specific habitats. In the western United States and Canada, red-backed voles are most abundant in old spruce-fir forests and rarely occur in unforested habitats. Major foods of red-backed voles in the western United States are scarce in young forest stands. In contrast, red-backed voles in the eastern United States occur in a variety of forest age classes but (similar to western areas) are most common in mesic forest. Field voles rarely occur in forest stands and are most abundant in mesic meadows. Forest management practices significantly influence the abundance of these and other small mammal prey species (Campbell and Clark 1980, Ramirez and Hornocker 1981, Halvorson 1982, Scrivner and Smith 1984). Although the outcome of particular management practices is poorly understood, stand replacement treatments (e.g., clear cut harvests) lead to the most dramatic changes.

If the Boreal Owl or Its Prey Select Particular Habitats, Are These Habitats Declining or Being Stressed by Current Management?

Studies from a few geographic areas indicate boreal owls and their prey demonstrate selection for particular habitats. The paucity of research on this owl and its prey makes the geographic extent of this pattern unclear. Furthermore, the characteristics of high quality habitat for the owl's prey are not known sufficiently to set management guidelines.

The available evidence (see Chapter 9 concerning nesting, roosting, and foraging habitat) does suggest that mature and older forest in the spruce-fir zone provides the highest quality habitat for boreal owls and their prey. These forests occur as the upper forested zone on mountains in the western United States. As such, if global climate change shifts lifezones upward in elevation (as is predicted to happen), these habitats will decline (see Chapter 10).

Climate change portends consequences beyond a potential future change in the elevation of life zones. The mature and older forests used by boreal owls today became established centuries ago, under different climatic circumstances. As pointed out by Knight (Chapter 10), "Conceivably, climatic conditions now are less favorable for seedling establishment than they were two or three centuries ago, when the harvested forest became established. At high elevations it may not be possible to count on clearcut or burned forests eventually growing back to the kind of old forests that boreal owls currently use." If timber harvest and other land management

practices are accelerating the rate of stand replacement and changing the distribution of forest age classes, the abundance of old forest stands may be declining faster than under a natural disturbance regime dominated by gap forming disturbance such as disease and blowdown.

Compared to recent historic times, old spruce-fir forests are likely less abundant (Chapter 10). While fire suppression has promoted an increase in older successional stages, timber harvest, using even-aged methods, has reduced the area of old forest. A long-term consequence of fire suppression, however, is fuel build-up that may lead to larger, more intensive fires, ultimately reducing the area of old forest. Overall, in the western United States, where most is known of boreal owl biology, the area of high quality habitat is likely declining and will continue to decline as forest management is carried out as currently outlined in forest plans. A review of 14 National Forest plans from Regions 1 and 4 indicated a reluctance to initiate uneven-aged management in many spruce-fir stands (Hayward *et al.* 1993). Our interpretation of 14 plans in 1989 indicated even-aged management would dominate on all but one forest.

The quality of habitats used by the owls and primary prey is likely declining as well as the area. Alexander (1987) indicated that spruce now leads all species except ponderosa pine in annual volume cut in the central and southern Rocky Mountains. Current knowledge is not sufficient to quantify the rate or extent of habitat decline. Patterns of subalpine forest dynamics described in Chapter 10 indicate some potential consequences of timber harvest dominated by large clearcuts. While insects and wind were the most frequent disturbance agents in subalpine forests prior to European settlement, the effects of clearcuts are similar to fire, which was a less common disturbance agent. Tree mortality due to insects and wind lead to gap processes that support the boreal owl food web. Natural disturbance patterns also resulted in a more heterogeneous forest than occurs with prolonged fire suppression and clearcut harvesting. The mosaic forest would support a variety of small mammal species and abundant red-backed voles (Chapter 9). The loss of large snags and large downed logs associated with standard forest practices likely lowers habitat quality for the owl and its prey. Forest practices that reduce arboreal lichen, particularly *Bryoria* spp., also likely reduce habitat quality.

Do the Life History and Ecology of the Boreal Owl Suggest That Populations Are Vulnerable to Habitat Change?

Cavity Nesting

Boreal owls require large tree cavities or artificial nest structures to breed. This is the most obvious habitat requirement of the species and one that has important consequences. Unless artificial structures are provided, boreal owls will not persist in landscapes where trees are too small to produce the large cavities required by the owl or where primary cavity excavators are missing. Natural tree cavities (produced by branch loss or other breakage) are used occasionally by boreal owls but unlikely to be common enough to support a population of owls. Rotations of 70-120 years will not produce the size class of trees necessary for natural nest sites.

Information is not available indicating in what geographic areas boreal owls may be cavity limited. Owl populations in regions south of the breeding range for pileated woodpeckers (*Dryocopus pileatus*) are more likely candidates for cavity limitation.

Changes in cavity availability have likely occurred during the past century due to forest management. The extent of these changes and their consequences have not been documented. Timber harvest prescriptions that removed all trees, or all large trees and snags, have eliminated existing cavities and precluded new cavities on the site for up to two centuries depending on tree growth. Harvest rotations that prevent the development of snags >38 cm dbh permanently preclude nesting from the site. In contrast to the consequences of timber management, in the short term fire suppression has likely increased the availability of large cavities by reducing the loss of old forest through fire. The long-term consequence may be different, however, if fire suppression leads to larger, higher intensity fires that burn stands on mesic and moist microsites that were less likely to burn under the natural fire regime.

Changes in forest conditions that lead to reductions in large diameter snags or large live trees with heart-rot will lead to cavity limitation. Similar consequences will occur with changes that reduce habitat quality for primary cavity nesters.

Productivity

Boreal owls in the western United States exhibit variable year-to-year productivity and appear to have relatively low average clutch sizes. These factors have been associated with decreased probabilities of population persistence (Goodman 1987, Pimm, *et al.* 1988). Variable productivity in boreal

owls stems largely from year-to-year variation in available prey. In Europe, extreme variation in the number of breeding pairs and clutch size have been documented. In North America few investigators have documented productivity over multiple years but variation due to changing prey populations has been reported. Variation in winter and spring weather may also lead to variation in productivity. Small, isolated populations of owls would be most susceptible to a series of years with extremely low reproduction.

The average and maximum productivity of boreal owls recorded in the western United States are much lower than records from Europe. This suggests that populations studied in the United States may produce fewer surplus individuals even in good breeding years. The ability of source populations to supplement less productive populations therefore may be less than in Europe. Our understanding of the comparative demography of boreal owls is not sufficient to assess the influence of productivity on the relative stability of various populations.

The degree to which productivity is density dependent, especially at low population densities, is important in assessing boreal owl demography. We do not know to what extent productivity is density dependent or whether boreal owls are likely to experience an Allee affect (Allee 1931) at modest population sizes. A strong Allee affect could result if boreal owls experience difficulty in locating mates at low population densities.

Survival

Limited information on boreal owl annual survival gives an unclear picture of the impact this life history parameter may have on population growth. The few estimates of adult and juvenile survival have potential for bias and are imprecise. Estimates range from about 45 to 80% adult survival and 20-50% for juveniles. Both year-to-year variability and average survival rates are important in assessing the status of boreal owl demography. Furthermore, the degree of inverse density dependence in this parameter is important. Neither is known for any population. In populations where average survival is high and not variable, concern over low relative productivity is reduced. Low survival rates, however, would lead to greater concern over the relatively low clutch sizes recorded in the western United States.

The environment occupied by boreal owls is variable and harsh. Therefore, the probability for catastrophic events leading to increased mortality may be high. The nomadic nature of boreal owls is a testament to this variability (Andersson 1980). During periods of environmental stress, boreal owls move to new locations. These movements could contribute to periodic extinction within local habitats. It is unknown, however, whether nomadism increases or decreases persistence among linked small populations.

Home Range Size

Home range sizes of boreal owls in the western United States are large; winter and summer ranges both average over 1,000 ha and home ranges as large as 3,390 ha have been estimated. These areas are large for a medium size predator. Boreal owl home ranges are comparable to those used by the much larger spotted owl (*Strix occidentalis*). Whether large ranges are the norm for the species in the United States is unknown.

Several factors likely contribute to large boreal owl home ranges. In some regions, no single vegetation type provides optimum nesting, roosting, and foraging habitat, and these vegetation types are geographically disjunct. Therefore, geographic features may lead to a broad dispersion of resources, forcing the owls to move long distances to fulfill life requirements. In addition, low productivity of small mammals may also contribute to large owl ranges. Lindstedt *et al.* (1986) showed that home range size among carnivores is related to prey production.

In any case, large home ranges lead to high energy expenditure during daily movements. Boreal owls in some areas appear to need large areas to meet seasonal needs. Hirons (1985) has shown that, at least for the tawny owl (*Strix aluco*), clutch size is limited by energy available to the female prior to laying. The large home ranges and low clutch sizes observed in boreal owls in the western United States seem to fit this pattern.

The use of large home ranges by boreal owls is a conservation concern for two reasons. Populations of individuals requiring large ranges may be energetically stressed and less resilient to further stress. Also, land management must provide habitat within large areas to meet individual as well as population needs.

Trophic Position

Boreal owls are likely the most important avian predator of small mammals in subalpine forests in the western United States As such, they rely on the integrity of 2-3 trophic levels. As described in Chapter 9, the boreal owl's food web in subalpine forests is linked strongly to the detritus system and involves many direct and indirect linkages among trees, insects, pathogens, fungi, and vertebrates. This sys-

tem appears to support larger prey biomass in older forests (Hayward *et al.* 1993). The food web is poorly understood but the boreal owl certainly occupies a top trophic position. The probability for persistence of species at higher trophic levels is thought to be less than for primary producers or primary consumers.

Metapopulation Structure

Boreal owls in western North America occur in relatively small, semi-isolated populations (see figure 1 in Chapter 9) and therefore, individual populations are vulnerable to extinction due to demographic and environmental stochasticity (Pimm *et al.* 1988). Therefore, the natural distribution pattern of the species south of the boreal forest places individual populations at risk due to their relative small size. Why is this the case?

Boreal owls are the only Strigiform in the western United States that occurs almost exclusively in subalpine forest. Because these forests occur only in high mountain areas, populations exist in patches limited by the extent of subalpine forest, separated from other patches by montane forest and nonforested habitats (see figure 1, Chapter 9 for an example). For example, within USDA Forest Service Region 1, ~9% of the forested land supports spruce-fir forest 15 cm dbh or larger (J. W. Laux, pers. comm.). On seven forests in Idaho south of the Salmon River, spruce-fir forest covers ~7% of the forested landscape (H. A. Cheatham, pers. commun.). These figures demonstrate the limited extent of boreal owl populations despite their broad geographic range. Demographic linkage among patches likely depends on long-distance juvenile dispersal and adult emigration. The nomadic nature of boreal owls should facilitate this linkage. The degree of connectivity, characteristics of the demographic relationships, and processes that control the connectivity, however, are not known.

Small isolated populations of any organism are expected to experience lower persistence probabilities than larger or more linked populations (MacArthur and Wilson 1967, Pimm *et al.* 1988). This is hypothesized to occur for several reasons. Small populations may drift to extinction due to random demographic events (demographic stochasticity; e.g., Shaffer 1981). Similarly, an environmental catastrophe affecting a relatively small area (e.g., stand replacement fire) is more likely to influence a large proportion of individuals in a small, rather than large, population. Isolated populations are also less likely to experience demographic rescue than connected groups (Brown and Kodric-Brown 1977). Therefore, compared to other owl species, individual boreal owl populations may have lower persistence probabilities due specifically to natural distribution patterns.

Any environmental change that reduces the average size of habitat islands occupied by boreal owls is likely to decrease the probability of population persistence in the larger boreal owl metapopulation. An increase in fire frequency in subalpine forests, or reduction in forest area through timber harvest, could lead to reduced habitat area. Our understanding of owl-habitat and prey-habitat relationships is not sufficient to adequately predict what range of habitat alterations (e.g., silvicultural prescriptions) lead to reduced habitat area; however, short rotation, even-age management will clearly be detrimental. We also do not understand how large boreal owl populations must be before stochastic events become less of a concern.

Similarly, environmental change that reduces the linkage among populations is likely to decrease the probability of population persistence in the larger boreal owl metapopulation (due to demographic and genetic problems). Habitat conditions in the matrix surrounding occupied owl habitat will influence the probability of successful dispersal among populations. Furthermore, the productivity of individual populations will influence the number of individuals dispersing to other groups. What factors control successful dispersal and how those factors interact, however, is unknown.

WHAT IS THE CURRENT AND PROJECTED CONSERVATION STATUS OF THE BOREAL OWL?

The current conservation status of boreal owls is unknown. Knowledge of the species in North America is far from sufficient to adequately assess the species' status. Fifteen years ago, the owl was not recognized as a breeding resident of the lower 48 states. To date, only three studies have examined the species' habitat and/or demography; each of these were small, short-term investigations. Based on existing information, however, I tentatively conclude that except in local situations, boreal owls are currently secure but are likely to be in peril in the future given current land management practices. Therefore, I suggest that a conservation strategy is needed for boreal owls. These conclusions are based on the following points.

- Boreal owls currently are well distributed across a large geographic range and therefore the species is not in any immediate peril in the United States or worldwide. Furthermore, based on the only two

populations where nest occupancy and productivity is being monitored in the United States, nest occupancy and productivity are remaining constant.

• Populations of boreal owls in Fennoscandia have persisted and appear to be demographically vigorous despite human disturbance and a long history of forest management. These populations rely on artificial nest structures and exist in a very different ecological setting (boreal forest) than most populations in the United States. Still, the persistence of these populations suggests that, with proper forest management, boreal owls can co-occur with resource development including timber harvest. This statement must not be taken to indicate that all populations of boreal owls will respond similarly to environmental change. Boreal owls use habitat differently and have different demographic characteristics, throughout their range. Therefore, the response to forest management must be expected to differ in different ecological settings. Populations in the southern portion of the species' range have lower productivity and appear to use old forest habitats that are declining in aerial extent.

• In productive forest habitats, boreal owls have a high potential rate of population growth based on their dramatic numeric and functional response to changing prey populations. Therefore, populations can recover following declines if habitat is intact and prey are abundant.

• Conservation concerns for boreal owls arise when one considers long term persistence and/or focuses on individual populations. These concerns are based on the available information on boreal owl habitat use, the dynamics of those habitats, trends in forest management, and the species' life history. Specifically:

— The available data indicate that boreal owls, in at least some populations in the United States, use mature and older forest for foraging, roosting, and nesting. Primary prey of boreal owls also are more abundant in mature and older forests. The relative abundance of mature and older forest declines under traditional forest management programs as demonstrated in the Pacific Northwest and Northern Rockies. Therefore, habitat that provides necessary life requisites (food, thermal cover, and nesting substrate) has been declining and will continue to do so under current management plans, jeopardizing the long-term persistence of boreal owls in the United States.

— Habitats used by boreal owls develop slowly after deforestation due to the short growing season in subalpine environments. Therefore, forest stands may require several centuries to become quality foraging or nesting habitat after stand removal; recovery of degraded habitat will be an extremely long-term process. As outlined in National Forest plans, clearcutting is the dominant management direction in subalpine forests in the northern Rockies. Development of mature and old forest from this management is questionable and, to date, has not been observed (see Chapter 10). If timber harvest decreases in the Pacific Northwest and shifts to the northern Rockies the threat to boreal owl habitat will increase.

— Populations of boreal owls studied in the western United States are less productive than most of those documented in Europe. Further reductions in productivity due to declines in habitat quality will reduce the average persistence time for populations.

— Individual populations of boreal owls in the United States are relatively small and dispersed due to the naturally patchy distribution of subalpine and boreal forest habitats. The populations have lower individual persistence probabilities than would larger populations. The persistence of individual populations, then, will be influenced by relatively small land management activities.

— Because of the high temporal variability in boreal owl productivity and the nomadic nature of the species, persistence of individual populations may rely heavily on neighboring populations. Due to this metapopulation structure, the persistence of individual populations and (potentially) large segments of the metapopulation could rest on particular key populations that provide surplus dispersing individuals or act as stepping stones for exchange among populations. The identity or even existence of such key populations is unknown and therefore their protection is not assured.

— Land management in the matrix of habitat surrounding subalpine forests will influence the success of dispersing owls. Therefore management outside the species' primary habitat will have consequences for the owl.

WHAT ARE THE MANAGEMENT CONSIDERATIONS?

A thorough discussion of management considerations of this assessment would be largely redundant with previous sections. A brief outline of the most relevant considerations follows.

Boreal owls occupy forest habitat. The future condition of forest structure will influence populations of this avian carnivore. The link between forest structure and composition and the status of boreal owl

populations is strong but indirect. Forest structure influences the availability of suitable cavities, the quality of roost sites, the foraging movements of individual owls, and prey availability. Landscapes without forest cannot support boreal owls; in forested lands, forest structure influences owl population status. Management of forest structure from the stand to landscape scale in subalpine and boreal to boreal-transition forest, then, will influence the long-term conservation status of this species. Because forest succession is slow in spruce-fir and boreal forests, management must acknowledge that clearcut 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. Scientific understanding of boreal owl habitat relationships has not advanced sufficiently to devise sophisticated habitat management guidelines for any region. It is clear, however, that large clearcuts eliminate boreal owl habitat for many years and that clearcutting does not mimic the dominant natural disturbance agents in this system. Modification of these forests in ways that remove characteristics of mature and old forests should be done with caution. Monitoring the consequences of forest change at the stand and broader scales will be important in improving management (i.e., adaptive management involving researchers and managers).

Management of forest structure for any single life requisite (nesting, roosting, or foraging) will not assure suitable habitat to conserve boreal owl populations. Therefore, management should not be framed in terms of "management for nesting habitat" or another life requisite. Instead, management for boreal owls will be most successful if placed in an ecosystem context. The boreal owl depends on a plethora of other forest organisms: primary cavity nesters, small mammals, fungi, lichen, insects, and the dominant forest trees to name just a few (see figure 5, Chapter 9). Therefore, boreal owl management is a component of ecosystem management in subalpine forests in the western United States and boreal/boreal-transition forests in the east.

Conservation of boreal owls will require a regional approach to habitat management. Because populations of boreal owls in the United States likely occur in a complex metapopulation structure, the status of any single population is determined in part by many other populations. Management of individual populations outside the context of the larger metapopulation ignores the fact that most boreal owl populations are small and therefore have low probability of persistence in isolation. Even if high quality habitat remains within any small owl population, the population is likely to become extinct without dispersal from other groups. Identification and maintenance of source populations within a region will be a key to boreal owl management.

Finally, the knowledge necessary to build a conservation strategy is lacking and without a conservation strategy, persistence of this owl over the long term is questionable. Many key aspects of boreal owl demography, habitat use, and the owl's relationship with the forest system (primary cavity nesters, prey, predators, etc.) have not been investigated for any population. Most of the links represented in figure 5 (Chapter 9) are inferred and not backed by direct empirical information. Much of what we do know results from investigations in Europe. How this knowledge relates to particular populations in North America is unknown. Therefore, anything but the most general analysis of management impacts will not be possible without further knowledge.

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