The Northern Spotted Owl

A Status Review Supplement

U.S. Fish and Wildlife Service
April 21, 1989

Photo: The Oregonian, Roger Jensen

The Spotted Owl

THE NORTHERN SPOTTED OWL STATUS REVIEW SUPPLEMENT 1989

U.S. Fish and Wildlife Service
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THE NORTHERN SPOTTED OWL

I. INTRODUCTION

In December 1988, the Fish and Wildlife Service (Service) initiated a supplemental analysis of information that the Service had reviewed as part of an earlier process to determine whether listing the northern spotted owl (Strix occidentalis caurina) was warranted under the Endangered Species Act of 1973. The following report is a supplement to the Northern Spotted Owl Status Review (status review) that was completed by the Service in December 1987 (USDI 1987a and b). That earlier review was a summary of the data then available to the Service on the owl and its habitat. The following supplement both updates and interprets information summarized in the 1987 review and new information gathered since that time.

An analysis team of 12 Service biologists was established by the Service to carry out this supplemental analysis (see Appendix C for the full list of names and associations of team members). During this analysis, the team reviewed all available and applicable information and data on the northern spotted owl pertaining to its ecological requirements, its habitat, management, and population viability analyses. This review included the status review (USDI 1987a), all information contained within the official administrative record compiled by the Service in the fall of 1987 for that earlier review, comments and information provided in response to the supplemental review, and all new data and other information pertaining to this issue that has been gathered by the Service since December 1987. Specific information from the administrative record, used within this supplement, is noted in the text with a full citation in the reference section.

From this information, specific issues were identified for analysis and discussion that the team felt would provide a comprehensive overview of the status and trends of the northern spotted owl's population and habitat, including the major issues and ecological theories pertaining to this subspecies considered appropriate in determining its biological status. In the process of conducting this review, all information was updated to 1989, as available. In addition, the 1987 status review (USDI 1987a) was also reviewed by the research community for possible errors; only minor errors were reported (see errata sheet in Appendix B).

II. SPOTTED OWL HABITAT

A. Association and Preference

The northern spotted owl is known from most of the major types of coniferous forests in the Pacific Northwest (Forsman et al. 1977, 1984, Forsman and Meslow 1985, Gould 1974, 1975, 1979, Garcia 1979, Marcot and Gardetto 1980, Solis 1983, Sisco and Gutierrez 1984, Gutierrez et al. 1984). Data indicate that spotted owls are not randomly distributed across the landscape, but rather are concentrated in certain "preferred" old-growth habitats. A preferred habitat is one which is used a significantly greater proportion of time than would be expected by random use (use of habitat in proportion to its availability in the environment). Ruggiero et al. (1988) state, "It is likely, in fact, that habitat preferences are indicative of the long-term needs of a species, since each species (and each ecotype within a species) has become adapted to its environment over thousands of years of varying environmental conditions."

Old-growth forest habitat used by spotted owls is generally characterized by the presence of multi-layered stand structure, dense tree canopy closure, and large trees with cavities or broken tops. Stands tend to have a high degree of decadence with abundant standing and down dead trees, and supporting a high density of prey species (Forsman 1976, 1980a, Gould 1977, Postovit 1977, Barrows and Barrows 1978, Garcia 1979, USDA 1986, 1988, Barrows 1981, Solis and Gutierrez 1982, Forsman et al. 1984, Gutierrez et al. 1984, Carey 1985, Ruediger 1985).

Northern spotted owl preferences for old-growth[1] forests have been established

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[1] For the coniferous forest within the range of the northern spotted owl,

using different types of information, including relative abundance, proportion of occupied sites containing old growth, and allocation of time. Forsman et al. (1977) computed the relative abundance of spotted owls in Oregon, and found the densities of spotted owl pairs were 12 times higher in old growth than in young-growth forests. Of 1,502 spotted owl sites[2], Forsman et al. (1987) determined that 1,282 were in old growth, 22 in mature forest, 131 in old-growth/mature forest, and 67 in stands less than 100 years of age, demonstrating an overwhelming preference for old growth (Figure 1).

Pairs were evident at 928 of these 1,502 sites. Other studies by Forsman et al. (1984, 1987) analyzed the habitat characteristics of spotted owl sites in Oregon, and observed that more than 90 percent of sites occupied by owls contained a major component of old-growth forest. Similar studies conducted by Marcot and Gardetto (1980) in northern California found that 95 percent of spotted owl sites were in old-growth stands. Ninety-seven percent of the spotted owl population in Washington was found in old-growth/mature forest; there were no known reproductive pairs in managed second growth (Allen 1988).

In 1976 and 1986 (Forsman et al. 1977 and Forsman 1986, respectively), surveys for spotted owls were conducted in the northern third of the Oregon Coast Ranges, a region largely devoid of old-growth forests (north of Siuslaw National Forest). Spotted owls were located at two sites in mature/old-growth forest and five sites in young-growth forest. Old growth and mature trees were intermixed with younger trees in three of the five young-growth forest sites (Forsman 1986). The reproductive status of the birds in the young-

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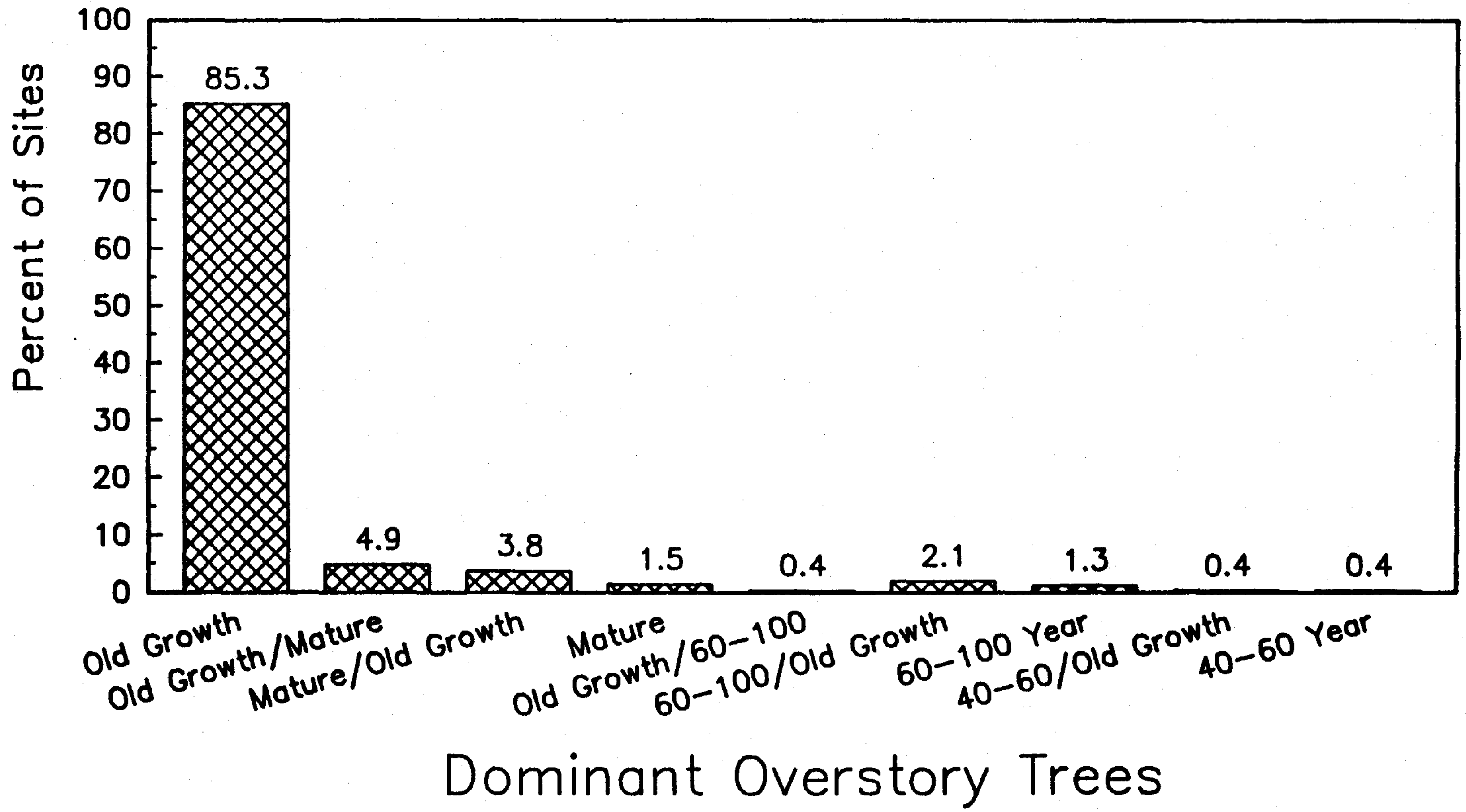
young or second-growth forest is generally defined as less than 100 years of age, mature forest as stands from 100 to 200 years old, and old growth as forest more than 200 years old.

[2] Site = an area where an individual or pair of owls was located.

Figure 1: Percent of Spotted Owl Sites in Oregon by Dominant Cover Type



(data adapted from Forsman et al. 1987)

growth sites could not be determined. In one of the two mature/old-growth forest sites, owls successfully fledged owlets (Forsman 1986). During 1987 and 1988, Irwin et al. (1989a) surveyed 1,566 miles of transects within 40- to 120-year-old managed forests in southwestern Washington, a region also largely without original forests. They located nine birds in 1987 and three birds in 1988, including one pair each year. No evidence of breeding in the two pairs was observed (Irwin 1989a). These surveys emphasized the low density of spotted owls within this portion of their range and the paucity of old-growth habitat in this area. Such low densities suggest that this type of habitat (e.g., 40- to 120-year-old managed forest or predominantly young-growth forest) is not preferred habitat.

Many apparently suitable sites are not occupied every year. Marcot and Holthausen (1987) compared percent occurrence of occupancy to amount of area in old growth at each site. The results of their analysis demonstrated that probability of use is positively correlated with the percent of area containing old-growth forest types. In another study in western Washington involving 22 owls at 20 sites, 63.3 percent of spotted owl occurrences were in habitat that contained from 33 percent to more than 95 percent old growth (Postovit 1977). In comparison, uniform young-growth forests contained only 3.3 percent of the spotted owl observations (Postovit 1977).

Forsman et al. (1984) analyzed data for eight radio-equipped adult spotted owls in the H.J. Andrews (HJA) study area on the west slope of the Cascade Range. Whereas the percent of old-growth conifer forest in their home ranges[3] varied from 33 to 66 percent, the percent of time spent foraging in old growth

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[3] home range = a restricted area to which the annual activities of an animal are confined; it is known as a territory when actively defended.

by the eight owls ranged from 85 to 99 percent, demonstrating a non-random use and preference for old growth. All eight owls foraged in old-growth conifer forest significantly more than expected based upon the habitat's availability. Use of 5- to 60-year-old stands was significantly less than expected except in the case of all but one bird. For this owl, use of a small portion of 31- to 60-year-old forest within its range was in direct proportion to availability. Recent clearcuts or burned areas were rarely used (Forsman et al. 1984).

Similar preference patterns for old growth were found on Bureau of Land Management (BLM) lands in the Coast Ranges of Oregon (Forsman et al. 1984). Six radio-equipped adult owls spent 64 to 98 percent of their foraging time in old-growth conifer forest stands within their home ranges; this was significantly more than would be expected on the basis of the proportion of old growth in these home ranges (20 to 54 percent). Forest stands 25 to 60 years old were used significantly less than expected by availability for all but one bird that used the 25- to 35-year-old forest within its range in proportion to its availability (Forsman et al. 1984). Data from the individual owls in the HJA study cited above and the six radio-equipped birds in this study area (Forsman 1980b) clearly demonstrate the owls' preference for old growth when compared to the availability of such habitat in the home ranges (Figure 2).

In another radiotelemetry study, Solis (1983) found that old-growth and mature forests were used significantly more than the proportion of the habitat they comprised. Stands dominated by small and medium-sized trees (e.g., those from 5 to 15 dbh)[4] were used less than expected by the seven spotted owls he studied. Reid et al. (1987) followed nine radio-equipped owls on the Oregon

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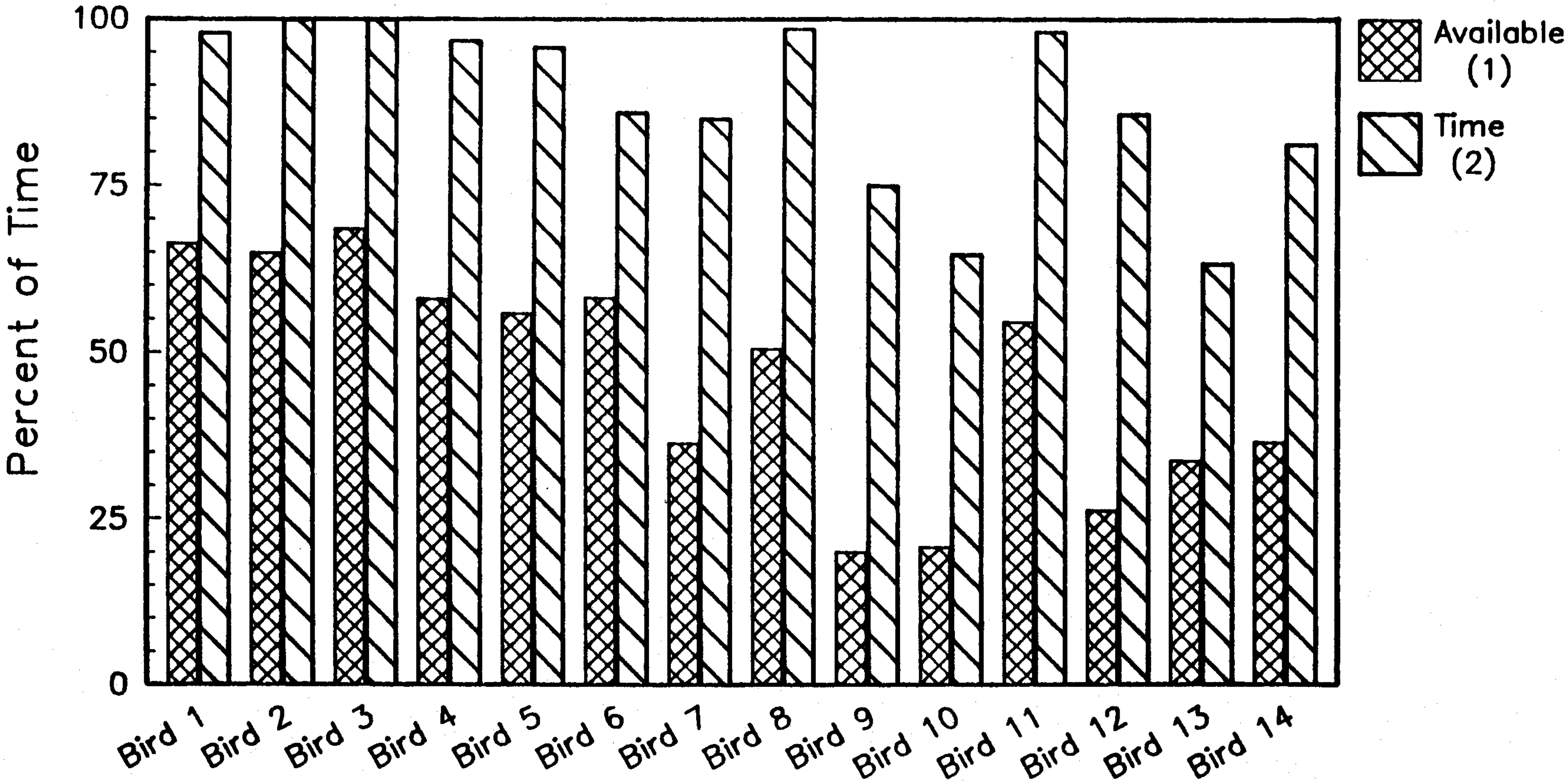
[4] dbh - diameter at breast height

Figure 2: Proportion of Time Spent in Old Growth
In Relation to the Amount of
Old Growth Available



(1) Proportion of Old Growth Available in Each Pair's Home Range
(da[illegible] from Forsman 1980 a and b)

(2) Proportion of Time Spent by Individual Spotted Owl's in Old Growth within Home Range

Coast Ranges for 5 to 12 months. Of the eight forest stand conditions present, only old growth was used significantly more than its relative availability in the area by each owl. Mature stands were used in proportion to their percent occurrence in the landscape. While foraging, owls preferentially selected old growth, avoided young age classes (those with dominant trees less than 50 cm dbh), and either avoided or were indifferent to mature forests (those with dominant trees to 59 100 cm dbh) (Reid et al. 1987).

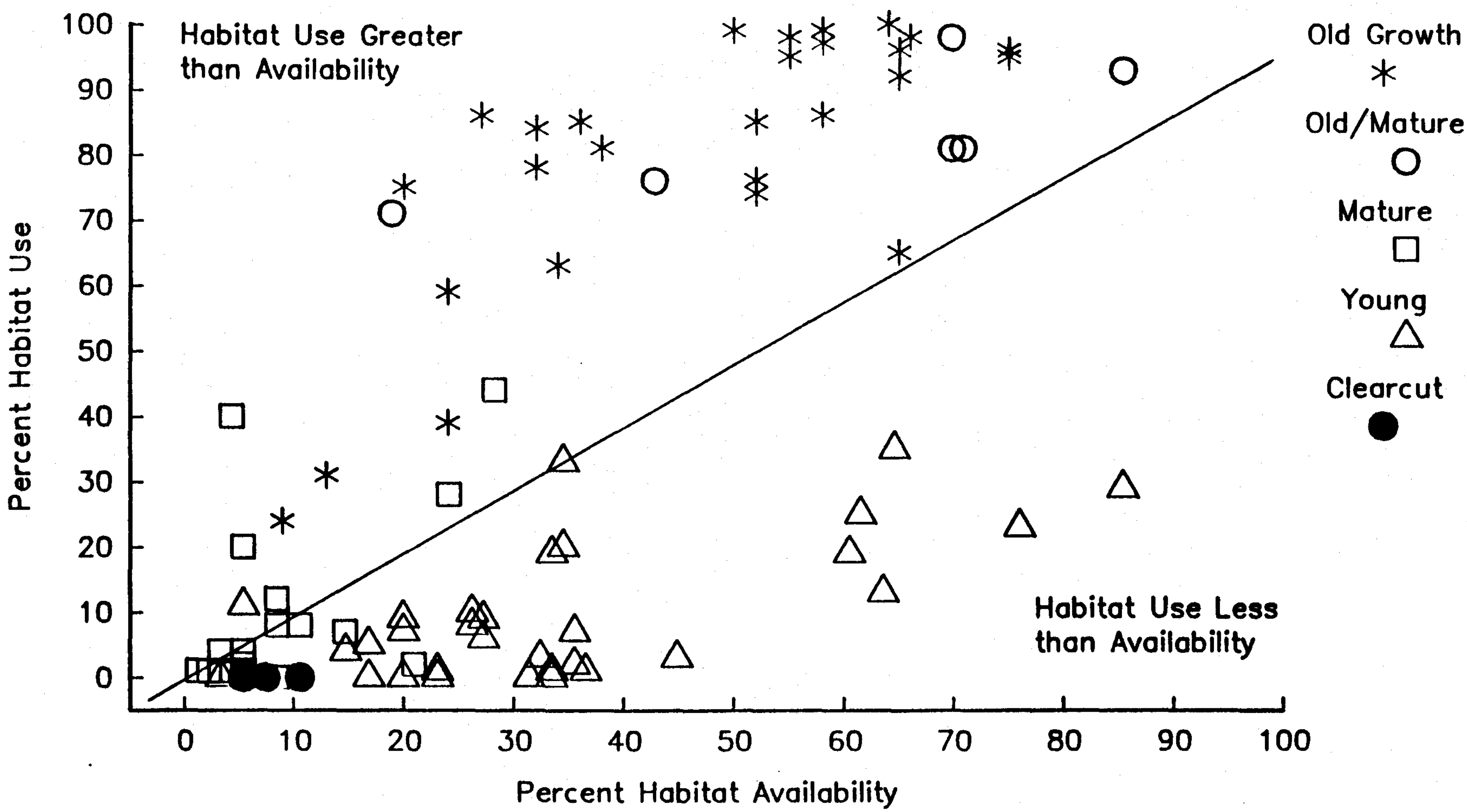
In areas of mixed-conifer and mixed-evergreen forests in southwestern Oregon that have been intensively managed for timber, Meslow et al. (1986) assessed spotted owl habitat use at 5 study sites on BLM land interspersed with private land. Past harvesting had removed or partially removed much of the original forest on these 5 study sites in the Klamath and Cascade Mountains. In 3 of the 5 home ranges examined, old growth ranged from 3 to 7 percent of the area, but the percent use of this type of habitat was significantly higher (range: 22 to 33 percent) (Meslow et al. 1986). Old growth comprised about 31 percent of the fourth home range, and was used 35 percent of the time (approximately in proportion to its availability). In the fifth home range, no old growth was present and the birds primarily selected mature forest, the successional stage preceding old growth. In this case, mature forest comprised 41 percent of the home range, and young growth was used significantly less than expected based on availability (Meslow et al. 1986).

There is limited evidence regarding the abundance of prey and its relation to the distribution of spotted owls. In the Oregon Cascades on the HJA study area, the abundance of northern flying squirrels (Glaucomys volans), a major prey item in segments of the owl's range, is similar within both old growth and young forest stands, suggesting that prey abundance may not be the determining factor in selecting for old-growth forests (Rosenberg and Anthony 1989, Anthony et al. 1988). Ward and Gutierrez (1989) compared the abundance of five prey species at foraging sites of reproductively successful and unsuccessful spotted owls in northwestern California. Although they found no significant differences in the abundance of prey species between the successful and unsuccessful groups, they noted that their sample sizes of spotted owls were small and that additional study was needed (Ward and Gutierrez 1989).

In addition to foraging habitat, a preference for old growth has been evident from observations of roosting behavior as well as during the dispersal period by juveniles. In analyzing dispersal patterns by juvenile owls, Miller (1989) found that the 18 radio-equipped individuals he studied used a variety of habitats. However, 12 of the 18 birds (66 percent) selected old-growth/mature forests significantly more than expected based on availability. Forsman et al. (1984) reported that 97.6 percent of 1,098 adult spotted owl roost sites in the central Oregon Cascades were in old-growth forest; 91 percent of 555 roost sites on BLM Coast Ranges forests were in old growth.

Although the literature strongly supports the generalization that owls preferentially select old-growth forests over young growth (Figure 3), there are records of owls using young-growth forests. These data on young-growth forests have led to questions on the importance of old-growth habitat to spotted owl populations (e.g., Irwin 1987). Kerns (1988) observed spotted owls in northwestern California in a variety of vegetative types, including second growth (young growth). He concluded that the second growth with spotted owls resembled old-growth habitat in physical characteristics such as

Figure 3: Habitat Use Versus Availability for Different Forest Age Classes by Adult Spotted Owls



(data from Forsman 1980a and b, Solis 1983, Reid et al. 1987, Friesen and Meslow 1988) large-sized trees, diverse species composition, and multi-story composition. In addition to the studies noted earlier (Irwin et al. 1989a), Irwin et al. (1989b) examined the immediate vicinity surrounding and including 29 nest sites on the Wenatchee and Okanogan National Forests in the Washington Cascades. Each of these nests apparently had successfully fledged at least one young in 1987 and/or 1988. Selective logging practices occurred in 30 percent of these areas (i.e., 5 nest sites were partially logged over 40 years ago, and 4 sites were logged more recently).

The authors noted that while characteristics of many of these sites did not completely coincide with the general description of old growth, most of the sites retained dense, multi-layered canopies; no estimate was made of the amount of old growth within the home ranges of the owls whose nest sites were included in the analysis. As noted earlier, the presence of a dense, multi-layered canopy is an important structural and physical characteristic typical of old-growth forests.

Irwin (1987) suggested that it might be possible to create suitable habitats for owls through silvicultural practices. He reasoned, based on ecological theory and the sensory capability of owls, that individual owls probably select habitat using visual cues. In other words, owls may key into old growth not because of the age of the trees per se, but rather because of the structural and physical features of old-growth stands. Some silvicultural strategies (see Section III. A) may produce habitat with the characteristics and variability of old-growth forests, although this has not yet been demonstrated. So far, the only feasible means of creating suitable habitats in the near-term is by maintaining old-growth areas or to allow young-growth stands to mature into old-growth stands. From the available evidence, the foraging, roosting, and nesting activities of northern spotted owls are strongly associated with old-growth forests, and all relevant studies have shown that owls have clearly and repeatedly demonstrated a significant preference for old growth.

B. Home Range Size

Home range data for spotted owls have been obtained with the aid of radio telemetry. To date, more than 200 owls (Meslow and Forsman pers. comm.) have been fitted with radio transmitters, and have contributed to the accumulating data base on home range size, shape, composition, and use by spotted owls. Home range data on pairs are preferred to those on individuals, because the pair represents the minimum reproductive unit considered for management. In addition, data on annual (12-month) home range sizes are gathered because they encompass the habitat use over the annual biological cycle (Allen et al. 1987, Irwin 1986, USDA 1988). From the studies cited below, home range sizes, in general, are smallest during the spring and summer (reproductive period), largest during the fall and winter (non-reproductive period), increase from south to north, and increase with elevation. Home range sizes and the included amount of preferred habitat of single birds are less than for paired birds for each physiographic province (USDA 1988).

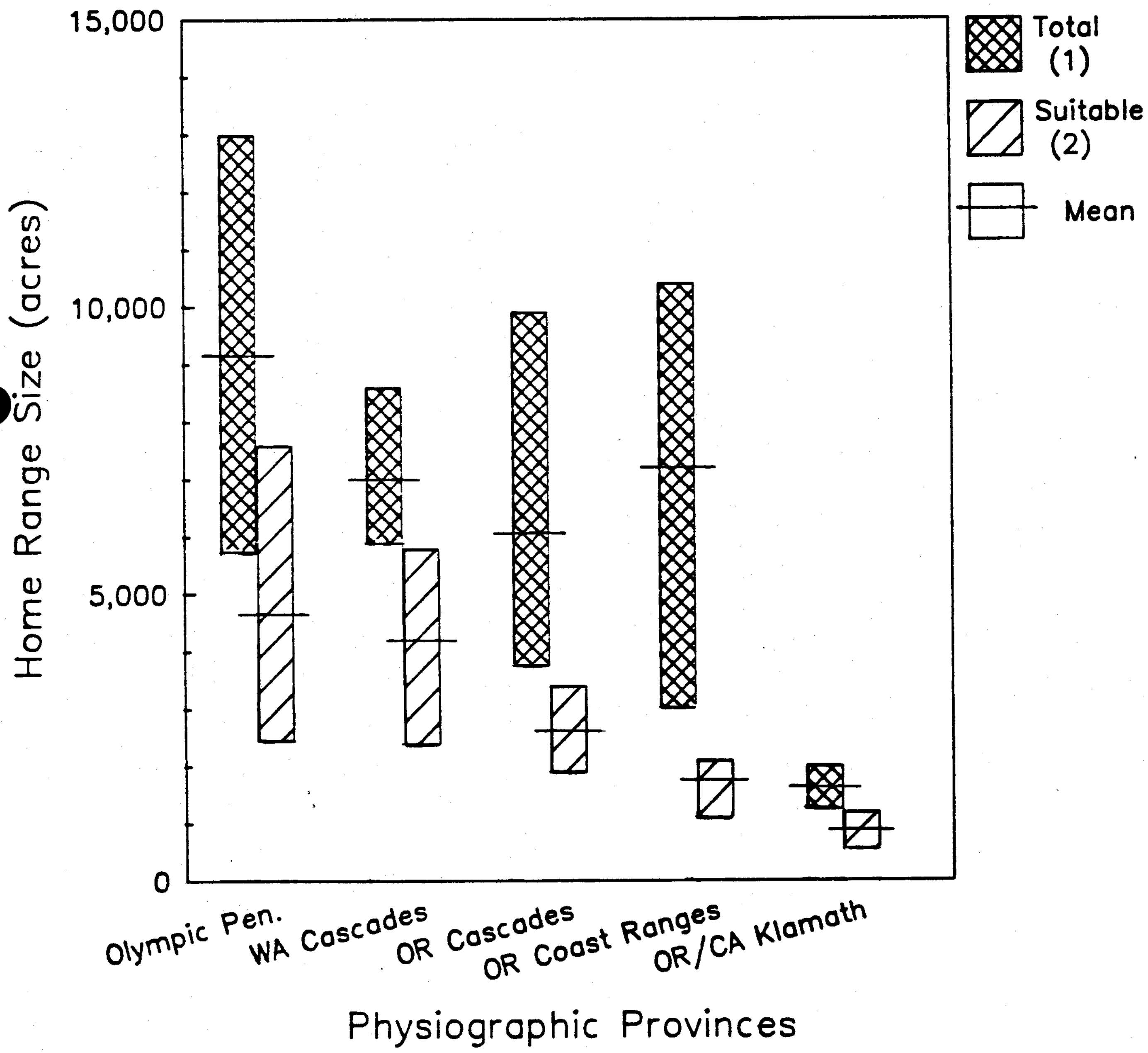
The amount of old-growth forest within a home range is important, since most owl pairs select for old-growth habitat. Timber management decisions, therefore, will have a significant bearing on availability, distribution, and amount of old growth contained within the home range of paired owls (see Section III. A). Concomitantly, such decisions may affect the total home range size and population density, and, ultimately, may influence reproductive performance and survival.

Marcot's summary of available information on home range size (USDA 1986, Marcot 1987) is illustrated in Figure 4[1]. Home range data from the east side of the Cascade Range in Washington are not included because data spanning a 12-month period were available for only one pair of owls. Since the 1987 status review was completed, additional annual home range data have been collected for owl pairs in each physiographic province (Forsman pers. comm., Friesen and Meslow 1988, Reid et al. 1987, Wagner and Meslow 1988, Tilghman and Paton 1988, Miller and Meslow 1988, Hamer 1988). The amount of old-growth forest was not reported for every measured home range, nor are calculations of home range sizes complete for each forested area being studied. The data for annual home range sizes for paired owls are illustrated in Figure 5.

These recent data (Figure 5) on home range sizes are consistent with and comparable to the earlier data set (Figure 4); i.e., the mean home range size by physiographic province is similar. For example, in an intensively studied area of the Cascade Mountains in Oregon (H. J. Andrews Study Area), the home range sizes reported by Forsman et al. (1984) are almost identical to those reported for the same area in a study conducted several years later by Miller and Meslow (1988). Carey (pers. comm.) compiled additional data for a total sample of 14 pairs of owls in the Coast Ranges that incorporates the previously published data. Mean home range size from his data set for 1987 to 1988 was 5,425 acres. This is not statistically different from the mean home range size of 5,745 acres shown in Figure 4. Carey, using this larger sample size calculated that the mean amount of old growth contained within the mean home range was 2,549 acres, a value considerably higher than the 1,863 acres estimated in 1984 (Figure 4).

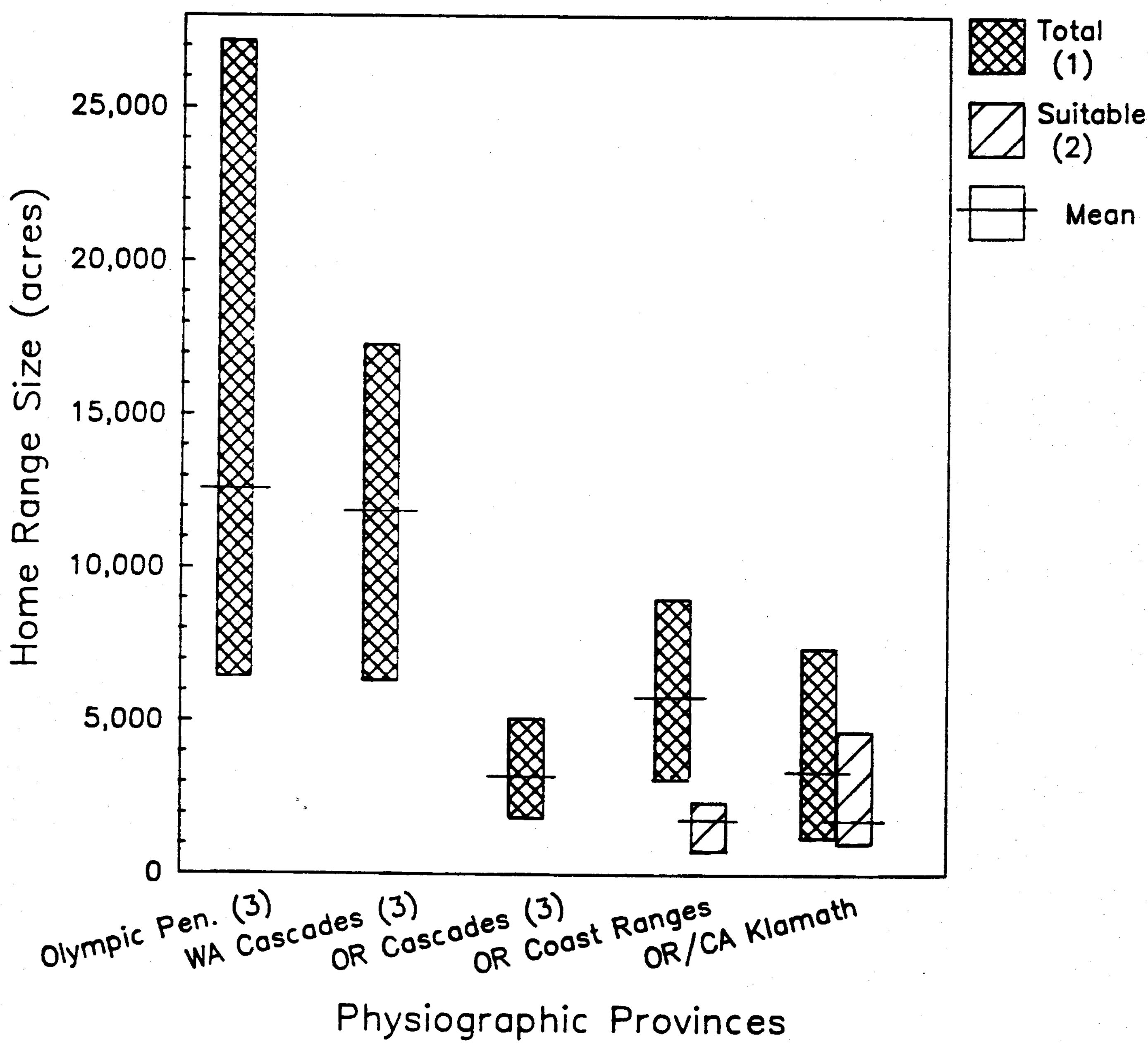
1/ Data in this paper are mostly reported by physiographic province for convenience of reporting.

Figure 4: Annual Home Range Size and Habitat Components of Spotted Owl Pairs (Prior to 1987)



(1) Range of total home range size
(2) Range of suitable habitat in home range (old growth and old growth/mature mix)

Figure 5: Annual Home Range Size and Habitat Components of Spotted Owl Pairs (1987 & 1988)



(1) Range of total home range size
(2) Range of suitable habitat in home range (old growth and old growth/mature mix)
(3) Suitable component not reported

The data presented in Figures 4 and 5 also illustrate that mean home range sizes of the northern spotted owl increase from south to north. Whether this clinal change in home range size is due to the northern areas being near the periphery of the subspecies' range, or is the result of variation in habitat quality and resource (prey) availability from south to north, is unknown. Brown (1984) theorized that the density of a species should be greatest in the center of its range where habitat quality would be higher, and decline gradually toward the periphery of its range. This pattern may apply over a range of spatial scales from steep environmental gradients (elevation) within local regions to the entire geographical range. Studies in northern California seem to support this theory (Tilghman and Paton 1988). Tilghman suggested that spotted owl home range sizes in her study increased with elevation because habitat quality decreased with elevation.

Most of the historically more productive floodplain and lowland forests have been subjected to heavier harvests than higher elevation forests (Greene 1988, Harris 1984, Harris et al. 1982), and thus, spotted owl populations may have been reduced disproportionately at lower elevations because of habitat loss. Therefore, remaining owls tend to be found at higher elevations where old growth and mature forests are more extensive, albeit fragmented, than lower elevation forests. This may add to the large home range sizes observed.

Significantly, the data indicate that spotted owls on the Olympic Peninsula and Oregon Coast Ranges consistently utilize larger home ranges in comparison with owls in the other provinces. The much larger home range sizes reported for owl pairs in these areas and on the west side of the Cascade Range in Washington (Figures 4 and 5) may reflect: (1) the adverse influence of forest fragmentation (declining habitat quality) resulting from timber harvest; and

(2) the fact that the Washington locations are near the periphery of the subspecies' range. Forests within these provinces are highly fragmented and have the least amount of old-growth forest remaining (see Figures 13 and 14, Section IV. A). For example, on the Siuslaw National Forest, located within the Coast Ranges of Oregon, the remaining old-growth timber is broadly distributed in relatively small parcels (Harris 1984). In the central Oregon Coast Ranges, the owls utilize the available old growth in a highly fragmented and patchy environment (Friesen and Meslow 1988). This pattern is probably true for the Olympic Peninsula as well. The above findings and those of Allen and Brewer (1985), Forsman et al. (1984), Carey (1985), Dawson et al. (1986), suggest that home range size increases as quality and quantity per unit area of preferred habitat decline (see Sections III. C and V.).

Although not the subject of this review, it is noteworthy that home range sizes reported for the California spotted owl (S. o. occidentalis) averaged 6,232 acres for paired owls, which included an average of 2,063 acres of old-growth forest (Gutierrez and Call 1988). In another study, home range sizes of single California spotted owls averaged 6,095 acres (Neal et al. 1989). Mexican spotted owls (S. o. lucida) had annual home ranges averaging 2,092 acres for paired owls, which included 995 acres of old-growth timber (Ganey 1988). Analysis of these data suggests that all subspecies of spotted owls have relatively large home ranges and that old-growth forest is a significant component of their home ranges.

C. Distribution and Trend

Western Oregon and Washington were covered by approximately 24 to 28 million acres of forest at the time of modern settlement (early to mid-1800's), of which about 70 percent (14 to 19 million acres) may have been old growth (SAF

Task Force 1983, Franklin and Spies 1984, Harris 1984, Haynes 1986, USDI 1987c, Greene 1988, USDA 1988, Spies and Franklin 1988, Wilderness Society 1988, Norse 1988). Historical estimates for northwest California are not as precise, but suggest between 1.3 and 3.2 million acres of old-growth Douglas-fir and mixed conifer, and about 2.2 million acres of old-growth coastal redwood (SAF Task Force 1983, Laudenslayer 1985, Green 1985, Fox 1988, CA Dept. of Forestry and Fire Protection 1988, Wilderness Society 1988).

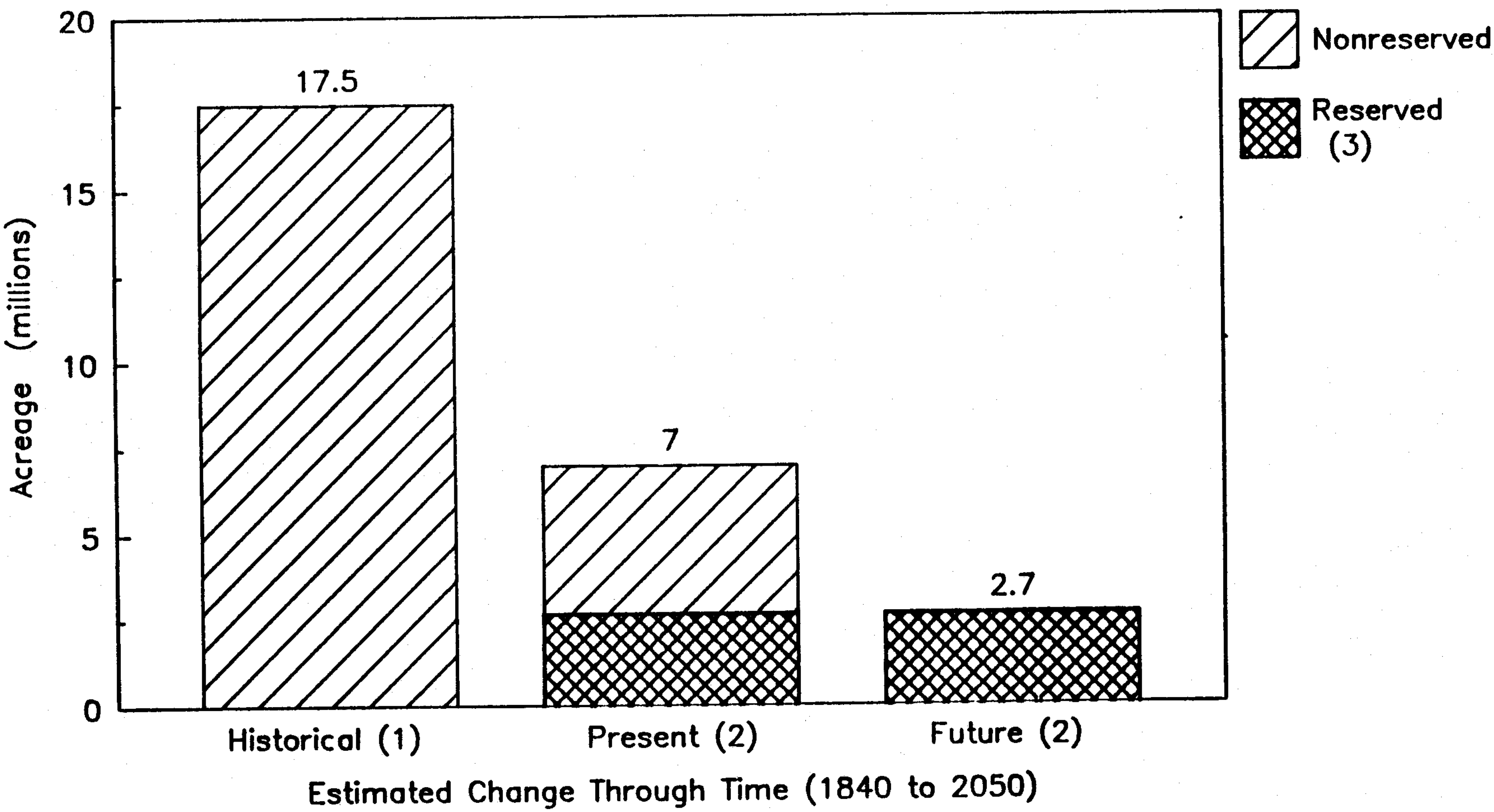
Habitat reduction has not been uniform throughout the range, but concentrated at lower elevations and the Coast Ranges. These authors estimated a 60 to 70 percent reduction in old-growth forests in the Pacific Northwest (Oregon and Washington) in modern times (SAF Task Force 1983, Franklin and Spies 1984, Harris 1984, Haynes 1986, Greene 1988). Old-growth forests in the Douglas-fir/mixed conifer region of northern California may have undergone a reduction of about 45 to 80 percent since the mid-1800's, while old-growth redwood may have undergone a reduction of about 90 percent during the same period (Laudenslayer 1985, Green 1985, Fox 1988, CA Dept. of Forestry and Fire Protection 1988). The loss of these old-growth forests, accelerating since the 1950's, is largely attributable to timber harvesting and land conversion practices, in addition to natural perturbations such as forest fires (Harris 1984).

Some recent estimates, using the Old-Growth Definition Task Group's (1986) interim definition of old growth (Spies and Franklin 1988, Morrison 1988, Norse 1988, Wilderness Society 1988), suggest this reported decline may have been as high as 83 to 88 percent. These latter figures may be more accurate since they were derived using a standardized definition of old growth. Timber base estimates, particularly Forest Service estimates, are neither very accurate nor up-to-date, with some estimates over 18 years old (Haynes 1986, Norse 1988).

Based upon knowledge of the species' habitat preferences and associations, we hypothesized that the distribution of the northern spotted owl was closely correlated with the historical distribution of old-growth forests. The distribution and acreage figures for British Columbia are unknown and were not included. Although current surveys and inventories have shown that spotted owls are not found in all old-growth forests, nor only in old-growth forests, they are overwhelmingly associated with forests of this age (see Section II. A). Therefore, trends in amount and distribution of old-growth forests may be used as an indicator of trend in the abundance and distribution of spotted owl populations and habitat over time, although they may be conservative since we don't know the quality or full extent of historical owl habitat.

Figure 6 illustrates the trend in old-growth forest and spotted owl habitat reduction from the mid-1800's projected to the middle of the next century, under current policies and forest management plans. Past and present habitat figures are based upon published references (see above and Tables 1 and 2). We chose not to address the continuing argument over old growth definitions and, therefore, used the spotted owl habitat estimates provided by the Forest Service (USDA 1988, Gunderson pers. comm., Robertson 1989) and BLM (USDI 1987c, 1987d, Logan pers. comm., Smithey pers. comm., Foisy pers. comm., Lint pers. comm., Bonn pers. comm., Thomas pers. comm. 1989) to estimate the present amount of spotted owl habitat in Oregon and Washington. Morrison (1989), from his analysis of Forest Service data, believes that the Forest Service has overestimated owl habitat by 42 to 59 percent for the six National Forests he studied. However, he used a stricter definition of old growth

Figure 6: Habitat Trends in Estimated Old Growth and Spotted Owl Habitat (Washington, Oregon, and NW California)



(1) Averaged historical habitat estimate in acres of old growth (for all estimates)

(3) does not include SOHA/SOMA acres

(2) Habitat estimates in acres of old growth and old growth/mature mix (future acres all reserved)

(based upon timber attributes) that does not account for the presence of spotted owls in this or other age classes of forest.

The Forest Service has estimated suitable habitat (mature and old-growth forests) based upon presence of spotted owls. While the Forest Service's approach can be a more accurate method of making habitat estimates if thorough inventories have been completed, it also does not evaluate the success of owl pairs within different habitat age classes. Hence, the actual amount of remaining habitat suitable for successful reproduction and, thus, long-term viability, is unknown. For the most part, habitat for BLM lands was estimated from the totals of known acres of mature and old-growth forests containing spotted owls within its area of jurisdiction (Neitro pers. comm.). Habitat estimates for northern California are only rough approximations of old growth containing spotted owls (Simon-Jackson pers. comm., Gould pers. comm.).

For future projections, we used the harvest rate estimates presented in Tables 3 and 4 (see Section III. A) to extrapolate to the year 2050, the time at which it is estimated if current harvest rates continue, that most commercial old-growth forests (those available for commercial logging) will have been logged and converted to younger stands. These estimates are similar to other published estimates (see previous references), but yield greater estimates of remaining old growth and owl habitat than those published by Morrison (1988, 1989), the Wilderness Society (1988), or Norse (1988).

Since over 90 percent of presently known spotted owl occurrences and habitat are found on federally-managed lands (Forsman et al. 1987), future estimates are based upon average annual logging rates and published trend estimates for federal lands only. Actual acreage figures and logging rates for old-growth forests on non-federal lands were not available and were not included in future projections. Very little old growth presently exists on private, State, or tribal lands (SAF Task Force 1983, Old-Growth Definition Task Group 1986, Haynes 1986, Morrison 1988, Spies and Franklin 1988, Wilderness Society 1988, CA Dept. of Forestry and Fire Protection 1988, Thomas et al. 1988, Greene 1988). Non-federal lands no longer constitute a significant portion of owl habitat, primarily because forest stands are too young, logging practices consist of clearcutting and even-aged management, and short logging rotations are not expected to contribute to future old-growth conditions. Inclusion of non-federal lands would thus not significantly change the estimated amount or rate of decline of preferred and suitable spotted owl habitat unless logging practices were to change and it were to be demonstrated that these lands can contribute to viable populations of spotted owls. However, these lands historically may have contained a significant amount of owl habitat. Importantly, these lands still offer the opportunity to provide vital linkages between islands of federally-managed habitat in many areas.

Acreage totals (Figure 6 and Table 1) that are noted as reserved or unsuited for harvest do not include estimates of spotted owl habitat planned for in Spotted Owl Habitat Areas (SOHA) or Spotted Owl Management Areas (SOMA) (see Section IV. A), because federal agency management plans designating such areas have either not been finalized or fully implemented (Forest Service), or represent only short-term interim plans (BLM). Therefore, final acreages for these categories and their future applicability are unknown. Inclusion of these acreage figures may increase the total amount of reserved acreage by about 20 to 25 percent, thus leaving a slightly larger remaining base. However, the rate of decline to that reserved base may not be significantly reduced under current policies and plans.

Since the data illustrated in Figure 6 are only approximations, they are not intended to denote exact acreage figures. The importance of Figure 6 lies in its portrayal of the trend under current plans and policies in habitat decline over time and the impact that this trend may have on the viability of spotted owls within remaining habitat. Consideration of these data indicates that, if current harvest rates continue, the preferred and suitable habitat of the northern spotted owl throughout its range is expected to decline by about 50 to 60 percent between 1989 and 2050, from an estimated 7 million acres to about 2.7 million acres. This would be a total decline of at least 80 to 85 percent from the amount of spotted owl habitat originally estimated for the western part of the Pacific Northwest, including northern California.

The figures used to derive this estimate (Figure 6) do not include any young-growth forest acreages that may develop old-growth characteristics or conditions during the next 60 years. As noted earlier, conversion of younger habitat to mature or old growth is not expected to be significant unless current logging practices change (Beuter 1976, Heinrichs 1983, SAF Task Force 1983, Harris 1984, Spies and Franklin 1988). Moreover, some authors (Harris 1984, Harris et al. 1982, Morrison 1988, 1989, Wilderness Society 1988, Norse 1988) have estimated that the biologically effective habitat for the spotted owl (i.e., habitat patches of sufficient size to support reproductively successful owls) is less than 50 percent of the total habitat remaining today. They speculate that this percentage will continue to decrease if present logging patterns continue, thus resulting in future biologically effective habitat of less than 10 percent (estimated 4 to 8 percent) of historical levels (see later sections for further discussion on habitat fragmentation and isolation). The impact on spotted owls is uncertain, though assumed to reduce fitness and result in lower population densities.

As currently planned, the distribution of spotted owl habitat remaining by the year 2050 will closely coincide with that of federally-managed forests on reserved areas (wilderness, parks, research areas - see Figure 7) and other remaining forests that are not considered for harvesting for other reasons (lands unsuited for timber production, roadless areas, hydrologic protection, etc.), but only to the extent that these areas contain habitat suitable for spotted owls. Remaining habitat on these forests outside of wilderness and parks will no longer be continuous, but will exist as islands of varying size and suitability spread over the range of the subspecies. Many of the wilderness areas and parks are high elevation lands above timberline, while lands unsuited for timber production may have poor soil conditions or often are steep lands or rocky areas (Harris 1984, Greene 1988, USDA 1988). Such areas generally are less suitable habitat for spotted owls. The extent of suitability or effectiveness of habitat to support successfully reproducing pairs of owls on these lands is currently unknown.

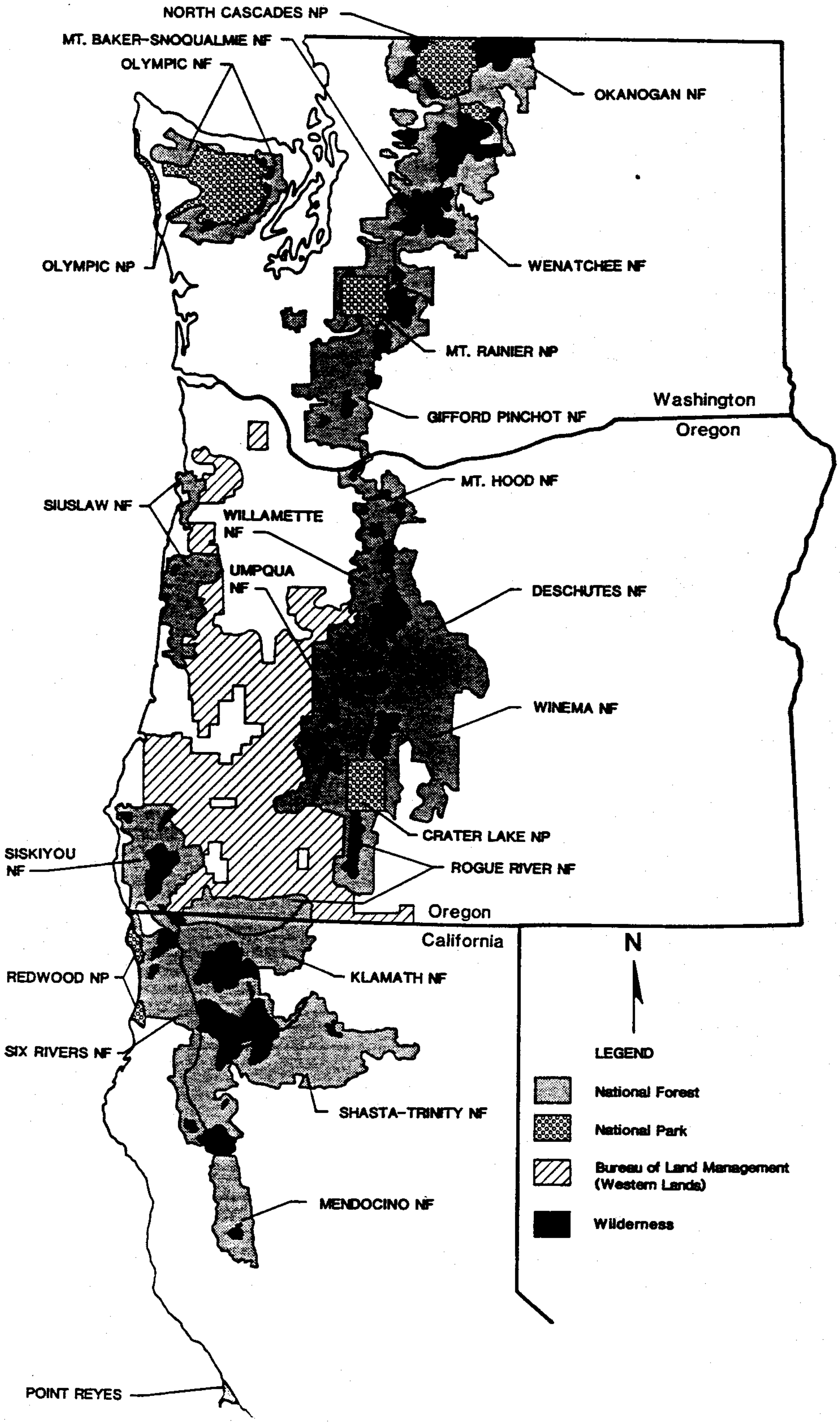


Figure 7: Distribution of Federal Lands in the Range of the Northern Spotted Owl
(only western edges of Deschutes and Winema NFs)

TABLE 1: ESTIMATED ACRES OF PRESENT SPOTTED OWL HABITAT[1/]

STATE/ OWNERSHIP	RESERVED[2/] & UNSUITED FOR TIMBER HARVEST	NONRESERVED: AVAILABLE FOR TIMBER HARVEST	TOTALS
Washington			
Forest Service	739[3/]	998 (202-281)[4/]	1,737
Nat. Park Service	480	--	480
State	--	118	118
Tribal[5/]	65	4	69
Private[5/]	--	124	124
Subtotals:	1,284	1,244 (202-281)	2,528
Oregon			
Forest Service	848	1,563 (173-196)	2,411
BLM	160[2/]	696 (203)	856
Nat. Park Service	50	--	50
State	3	62	65
Tribal	--	49	49
Private	--	91	92
Subtotals:	1,061	2,462 (376-399)	3,523
California (Northwest)			
Forest Service	294	512 (225)	806
BLM	7	3	10
Nat. Park Service	45	-	45
State	47	-	47
Tribal	5	42	47
Private	--	8	8
Subtotals:	398	565 (225)	963
TOTALS:	2,743	4,271 (803-905)	7,014

1/ Sources: USDA 1988, Robertson 1989, Logan pers. comm., Smithey pers. comm., Lint pers. comm., Bonn pers. comm., Thomas pers. comm., Gould pers. comm., Palmer 1989, Larson pers. comm., Simon-Jackson pers. comm., Gunderson pers. comm., Decker pers. comm.)

2/ Reserved category includes all owl habitat within wilderness areas and all other areas legally set aside, such as for roadless and natural areas, or for visual, hydrological reasons, etc.; most BLM timber estimates are still part of timber base

3/ All numbers in thousands of acres and rounded to nearest thousand

4/ Number of potential acres of nonreserved forest that may be designated for SOHAs or SOMAs (see above references)

5/ Updated figures for most tribal and private/industry commercial forests were not available

TABLE 2: ESTIMATED ACRES OF PRESENT SPOTTED OWL HABITAT BY LAND OWNERSHIP AND PHYSIOGRAPHIC PROVINCE[1/]

PROVINCE	FOREST SERVICE	BUREAU OF LAND MANAGEMENT	NATIONAL PARK SERVICE	STATE	TRIBAL[2/]	PRIVATE[2/]	TOTAL
Washington							
Olympic Pen.	259	--	323	64	4	20	670
Cascades	1,478	--	157	51	65	104	1,855
Coast Range	--	--	--	3	--	--	3
Subtotal:	1,737	--	480	118	69	124	2,528
Oregon							
Cascades	1,883	151	50	22	49	18	2,172
Coast Ranges	135	262	--	43	--	62	502
Klamath	393	443	--	--	--	12	848
Subtotal:	2,411	856	50	65	49	92	3,523
California							
NW California[3/]	806	10	45	47	47	8	963
Totals:	4,954	866	575	230	165	224	7,014

1/ Sources: (same as Table 1)
2/ Current data for tribal and private/industry lands were not available
3/ California figures include Klamath and Coast Range provinces

III. FOREST ENVIRONMENT

A. Timber Management and Policy

Historically, logging has been fairly localized, particularly at lower elevations, with practices which included selective[1] and clearcut methods (Harris 1984, Green 1985, Thomas et al. 1988). However, the primary objective of present and future timber management on private and public lands in Oregon, Washington, and northern California is to produce wood at a non-declining rate. This entails intensively managing forests of even-aged trees with average cutting rotations of mostly 70 to 120 years (USDI 1984, USDA 1988, Spies and Franklin 1988, Beuter et al. 1976, Harris 1984, Norse 1988). In addition, current preferred timber harvest systems by the BLM and Forest Service as well as most private, state, and industry groups emphasize dispersed clearcut patches for even-age management as the pattern of harvest (Beuter 1976, USDA 1988, USDI 1987c, CA Dept. Forestry and Fire Protection 1988), resulting in an increasingly fragmented forest. Thus, forested lands that are intensively managed for timber production, in general, will no longer develop or retain the variation or old-growth characteristics which require about 200 years of development. Old-growth forest reduction, conversion of older forests to younger, even-aged stands, and fragmentation of remaining forests and old-growth stands are expected to continue under current agency policies and practices (USDA 1988, USDI 1987c, 1987d).

Annual cutting rates of old-growth and old-growth/mature age classes of trees have been established by the Forest Service and the BLM (Tables 3 and 4). During the decade of the 1980's, the BLM has been harvesting old-growth and

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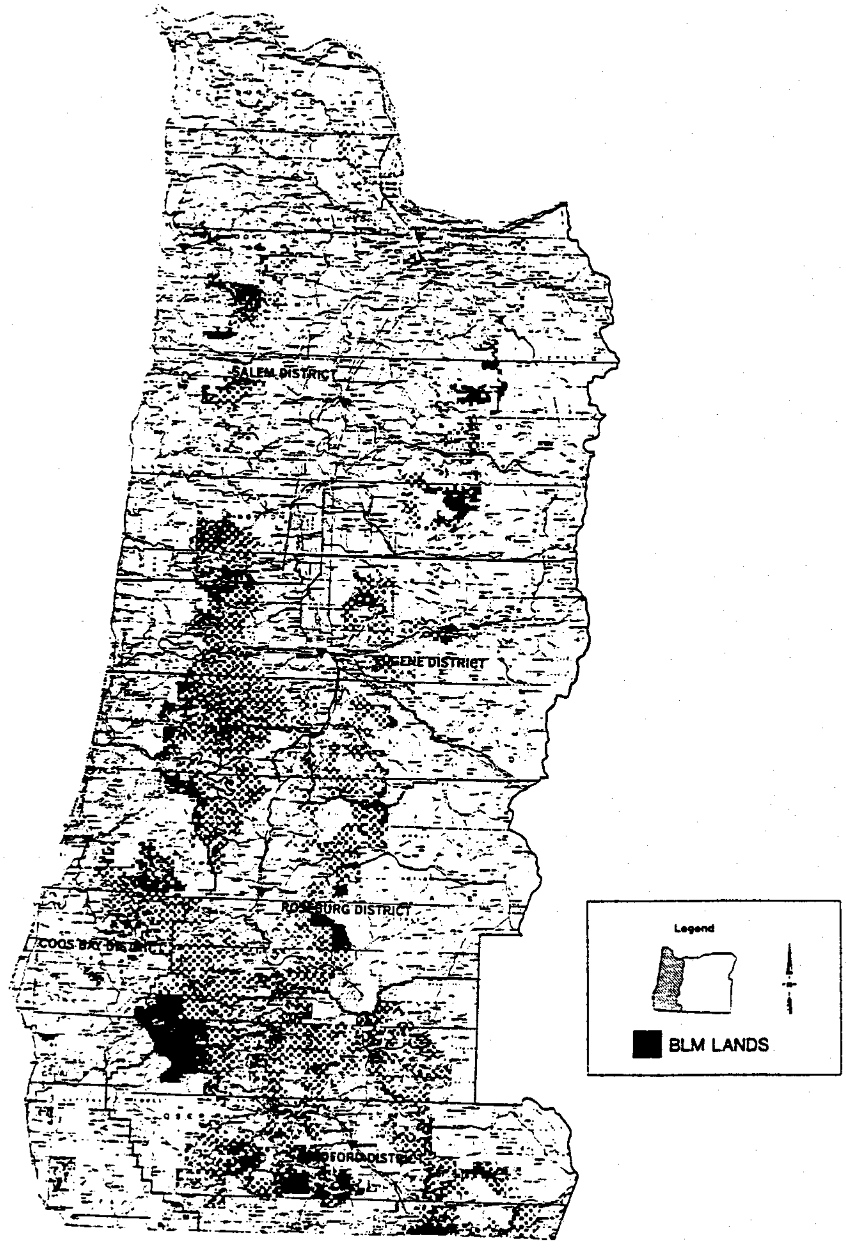
[1] Selective logging is a timber harvest method whereby selected trees would be removed from an area leaving residual old growth in a younger-aged forest.

Figure 8: Distribution of Bureau of Land Management Lands in Western Oregon showing Checkerboard Ownership Patterns



(adapted from USDI 1984)

old-growth/mature trees at the rate of about 22,000 acres per year for Oregon. The Forest Service estimates its harvesting of spotted owl habitat (mature and old-growth classes) at the rate of about 36,000 to 40,000 acres per year in Oregon and Washington combined, and 12,000 acres in northwest California. Although several legal actions against the Forest Service and the BLM delayed harvest in 1988 and 1989, the originally planned level of harvesting is expected to continue in the near future (Mays pers. comm., Neitro pers. comm.).

Unless these cutting rates, or patterns of cutting, are greatly altered, most spotted owl habitat that is available for timber harvest on public lands will be gone within about 60 years (see Table 3 and 4, Section II. C). Logging rates on private, tribal, or State lands were not available. Since very little old growth exists on private or State lands, it is estimated that very little biologically effective habitat remains on these lands (Harris et al. 1982, Morrison 1988, Franklin and Forman 1987, Wilderness Society 1988); most may be gone by the year 2000 (Harris 1984).

TABLE 3: ESTIMATED ANNUAL HARVEST[1/] OF SPOTTED OWL HABITAT ON FOREST SERVICE LANDS BY PHYSIOGRAPHIC PROVINCE

PROVINCE	TOTAL ACRES OWL HABITAT	ACRES OWL HABITAT SUITED FOR HARVEST	POTENTIAL ACRES ANNUAL HARVEST	ESTIMATED YEARS REMAINING
Washington				
Olympic Penin.	259.1[2/]	167.3 (65%)[3/]	4.4[4/]	38
Cascades	1,478.1	830.6 (56%)	8.1	102
Subtotals:	1,737.2	997.9 (58%)	12.5	Average: 80
Oregon				
Cascades	1,883.6	1,195.5 (63%)	21.0	57
Klamath Mts.	392.9	262.0 (67%)	1.9	138
Coast Ranges	134.8	105.9 (79%)	1.8	59
Subtotals:	2,411.3	1,563.4 (65%)	24.7	Average: 63
California				
NW California	805.8	511.9 (64%)	11.8	Average: 43
Totals:	4,954.3	3,173.2 (64%)	49.0	Average: 65

1/ source: USDA 1988, Robertson 1989, Gunderson pers. comm., Mays pers. comm., Simon-Jackson pers. comm.
2/ all habitat numbers in thousands and rounded to nearest hundred
3/ percentages indicate the portion of the total owl habitat that is suited for harvest
4/ annual logging rate equivalent to mid-range of harvest targets as reported by Forest Service; SOHA acres not subtracted from acres available for harvest

TABLE 4: ESTIMATED ANNUAL HARVEST[1/] OF SPOTTED OWL HABITAT ON BUREAU OF LAND MANAGEMENT LANDS IN OREGON BY DISTRICT

DISTRICT	TOTAL ACRES OWL HABITAT	ACRES OWL HABITAT SUITED FOR HARVEST	AVERAGE ACRES ANNUAL HARVEST	ESTIMATED YEARS REMAINING
Salem	79.0[2/]	55.2 (70%)[3/]	2.5[4/]	22
Eugene	49.1	45.6 (93%)	3.7	12
Roseburg	168.6	150.1 (89%)	5.7	26
Coos Bay	116.6	70.0 (60%)	3.2	22
Medford	443.0	375.4 (85%)	7.2	52
TOTALS:	856.3	696.3 (81%)	22.3	Average: 31

1/ source: USDI 1987c, 1987d, Neitro pers. comm.

2/ all habitat numbers in thousands and rounded to nearest hundreds

3/ percentages indicate the portion of the total owl habitat that is suited for harvest

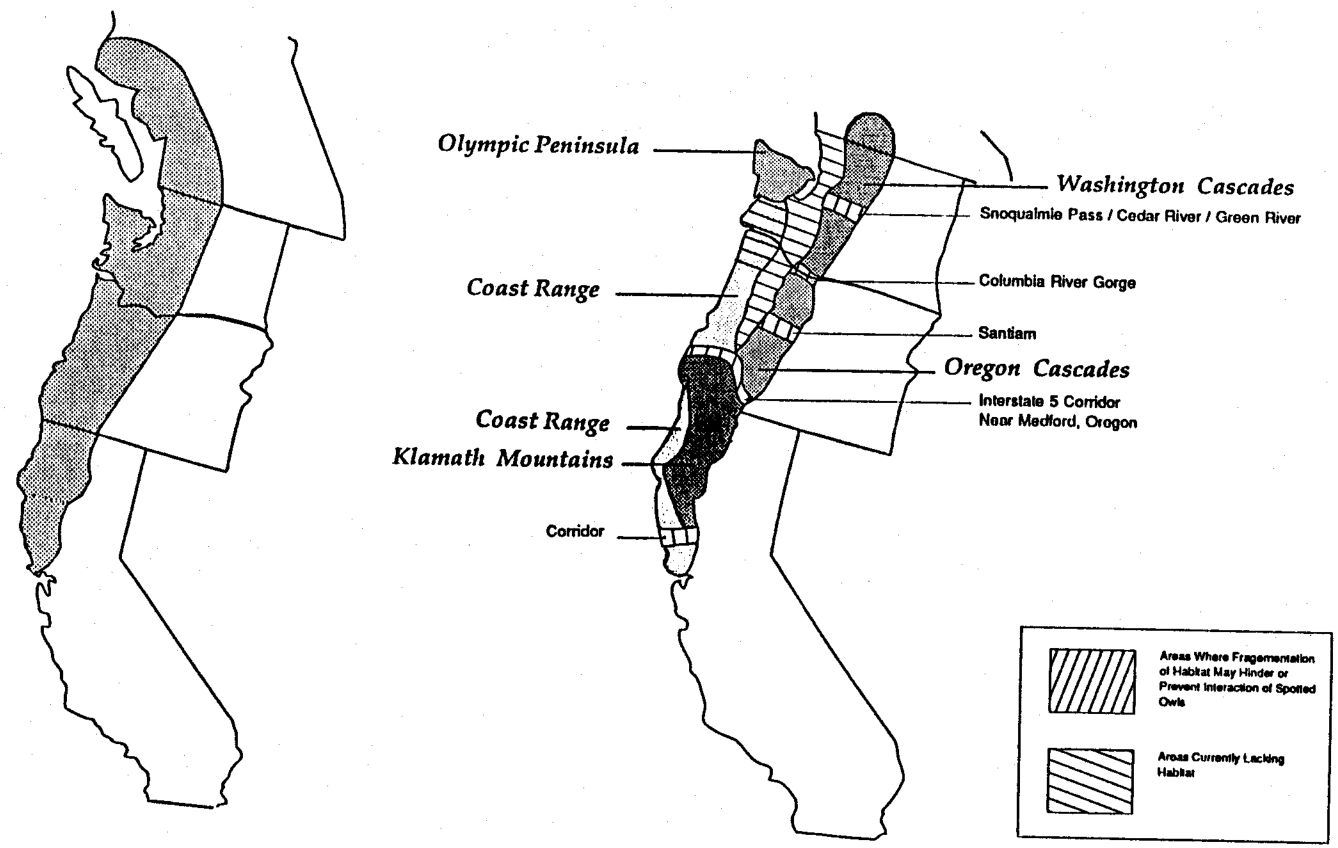
4/ annual logging rate based upon past annual harvest rates as reported by the BLM; Salem figures not updated to 1989; SOMA acres not subtracted from acres available for harvest

B. Isolation

Potential isolation of subpopulations of northern spotted owls (Figure 9) is of considerable concern (USDA 1988, Dawson et al. 1986). The central problem resulting from isolation of portions of the range of the spotted owl is one of maintaining local population levels in the absence of genetic or demographic contributions from other populations (see Appendix A for a discussion on genetic concerns). The smaller a population or subpopulation and the greater its isolation from other such populations, the greater the risk of its elimination as a result of demographic and environmental stochasticity (random) or genetic effects (Shaffer 1987b). Although topographical obstacles such as ridges and small rivers do not appear to significantly impede the movements of adults or dispersing juvenile owls, nor contribute to isolation (Gutierrez et al. 1985, Laymon 1985), of concern are areas where present or future habitat loss may result in isolation of those areas.

The Olympic Peninsula may be isolated demographically, and perhaps genetically, from other spotted owl populations, since there does not appear to be a self-sustaining population in adjacent lands in either southwestern Washington or the northwestern Oregon Coast Ranges (Irwin et al. 1988, 1989a, Potter pers. comm., Forsman et al. 1977, Forsman 1986, Logan pers. comm.). Marcot (1988b) believes that, because of distributional concerns, the Olympic Peninsula population is in greater jeopardy of decline and local extinction than other regional populations of owls. The Olympic peninsula population is at least 60 miles from known birds in the Washington Cascades. We note that although studies of over 70 dispersing juvenile owls revealed that young owls could move as far as 62 miles, none of the juveniles studied survived to breed (Gutierrez et al. 1985, Miller and Meslow 1986, Miller 1989). Their ability

Figure 9: Comparison of Historical and Present Spotted Owl Range



1. Estimated Historical Range (adapted from USDA 1988)

2. Estimated Present Range Identifying: Physiographic Provinces and Distribution Concerns

to successively navigate over long distances between habitat patches or through areas without suitable habitat is unknown. Irwin et al. (1988, 1989a) reported the presence of 12 owls over 2 years of surveys in southwestern Washington, including 2 pairs. Whether some or all of these birds were residents in that area or dispersing to or from the Olympic Peninsula through the Coast Ranges is unknown.

While the population in the Oregon Coast Ranges may not be currently isolated due to the connection to the Cascade population at the southern part of the range (through the checkerboard pattern of BLM lands - see Figure 8), the scale of habitat fragmentation throughout the Coast Ranges is of great concern. As one moves north along the Oregon Coast Ranges, habitat ownership (checkerboarding of BLM lands) and remaining old growth becomes more fragmented (Harris 1984), thus leading to isolation of individual pairs.

During the next 10 to 15 years, given the existing direction of land management, isolation of the Olympic Peninsula and of portions of the Oregon Coast Ranges province is likely to worsen because most intervening habitat is privately owned (Allen 1988, Bruce pers. comm.). Linkages between these areas on both public and private lands will become more important as habitat continues to decrease. This also applies to the need to maintain linkages between the checkerboarded lands managed by the BLM (Coast Ranges and connection with Klamath and Cascades provinces), and Forest Service (Santiam Pass and I-90 corridors) (Marcot 1988c, USDA 1988).

The Washington and Oregon Cascade populations of owls may be demographically isolated from each other by the Columbia River corridor (Meslow pers. comm., Juelson 1985). The section of the Columbia River upstream of Bonneville Dam, with the associated transportation and urban/agricultural corridor downstream from Bonneville Dam, may serve as a significant dispersal barrier to the north-south movement of owls since little habitat remains near the river, especially on the Washington side. In addition, the Columbia River downstream from Portland in the Coast Ranges of Oregon and Washington is very wide with little or no preferred habitat adjacent to the river, nor is there a viable owl population in this area (Logan pers. comm., Forsman et al. 1977, Forsman 1986, Potter, pers. comm.).

In California, isolation of spotted owl pairs may be as great in the tri-county area of Marin, Sonoma, and Napa Counties as it appears on the Olympic Peninsula or in the Oregon Coast Ranges (Bontadelli 1989, Gould pers. comm. 1988). Owls in this area of California depend on public land not only to provide habitat, but for links to other populations. The situation is especially critical in California since public lands support only a portion of the population, and links to the main portion of the population are across private lands where there currently are no management actions or regulations to preserve owls.

C. Fragmentation

Most privately as well as much of the publicly owned lands in the range of the owl no longer provide continuous parcels of old growth primarily due to agency logging practices (Brown 1985). Such practices may result in isolation and fragmentation of forest habitat (Harris et al. 1982, Harris 1984, Spies and Franklin 1988, Franklin and Forman 1987, Thomas et al. 1988).

Habitat fragmentation is the breakup of contiguous tracts of forest habitat into smaller, more isolated parcels (Figure 10). Harris (1984) applied island biogeography theory to interpret the possible consequences of continued old-growth harvest. He recognized that old-growth harvest eventually leads to a situation where parcel sizes are so small as to be influenced by edge effects (windthrow, invasion by alien species, microclimatic changes, etc.). When these edge effects occur, the original parcels may no longer be able to sustain the species or the community originally found in the larger and contiguous tracts of habitat (Morrison 1988, 1989, Spies and Franklin 1988, Franklin and Forman 1988, Thomas et al. 1988).

The Old-Growth Definition Task Group (1988) hypothesized that habitat patches of stands less than 80 acres in size were not viable as wildlife habitat due to edge effects and vulnerability to environmental disturbances. Fragmentation of old-growth forest on six northwest National Forests was recently examined by Morrison (1988, 1989). He hypothesized that the quality (biological effectiveness of the habitat to support successful reproduction) of remaining old-growth stands in these six forests is less when the effects of adjacent roads and clearcuts are considered (encroaching edge effect). He mentions, for example, that approximately 38 percent of remaining old growth occurs in stands less than 80 acres in size or are influenced by adjacent clearcuts, roads, or young forest plantations. This problem is serious enough on at least one National Forest, the Gifford Pinchot, that if old growth logging continues at current rates, and takes place in now unfragmented areas, virtually no unfragmented old-growth stands would remain in this forest in less than 3 years (Morrison 1988).

Impacts from edge effects and environmental disturbances may be most noticeable in areas where little old growth currently remains, for example, in the Oregon Coast Ranges (Spies and Franklin 1988). Harris (1984) estimated that only 3.3 percent of the Siuslaw National Forest in the Oregon Coast

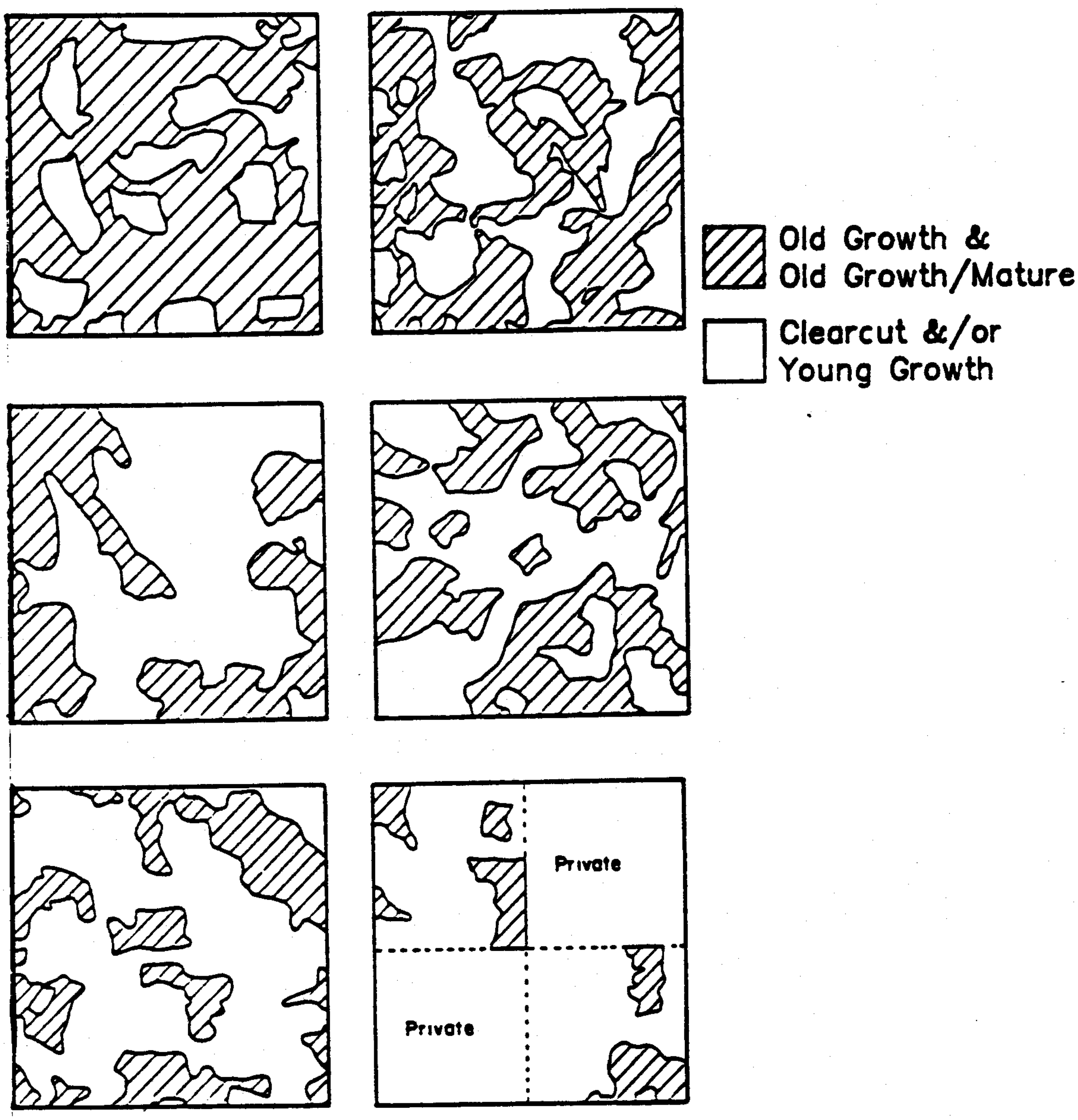


Figure 10: Patterns of Forest Fragmentation

(representation adapted from Harris et al. 1982)

Ranges is old growth. He reported that the average patch size was less than 68 acres in size; very few pairs of owls now are found in that area (Robertson 1989). A similar situation exists on the Olympic Peninsula where very little old growth remains outside of the Olympic National Park and is highly fragmented (USDA 1988, Robertson 1989, Marcot 1988c, Allen 1988, WDW 1988). Laudenslayer (1985) noted an average patch size of 31 acres on National Forests in northwest California (see Table 2, Section II. C and Figure 14, Section IV. A for amounts of spotted owl habitat for each physiographic province).

Fragmentation of habitat can adversely affect spotted owls by: (1) directly eliminating key roosting, nesting, or foraging stands; (2) indirectly reducing the survival of dispersing juvenile owls; (3) perhaps increasing competition or predation, and (4) reducing population densities and interactions between individuals. Fragmentation can also have harmful genetic consequences through its effect on the effective population size. If blocks of SOHAs become isolated from one another so that metapopulation effects become significant, the outlook for maintaining genetic viability becomes less optimistic (see Appendix A for discussion on genetics of isolated and fragmented populations).

Although natural habitat is never constant, the original old-growth forest habitat probably was fairly stable and continuous over much of the owl's historical range. Natural perturbations would generally have been small and localized, creating occasional openings in an otherwise fairly continuous and closed-canopy forest environment. The current habitat situation for spotted owls continues to change from the original condition where unsuitable habitat patches were small and isolated, to the reverse where preferred and suitable habitat now occurs in small and isolated patches. These factors all interact to decrease habitat suitability or effectiveness (quality) for supporting self-sustaining and well-distributed populations of wildlife such as spotted owls over time (Greene 1988, Harris 1984, Harris et al. 1982, Meslow et al. 1981, Spies and Franklin 1988, Thomas et al. 1988).

The patchwork pattern of even-age, clear-cut timber harvest systems employed by public land-managing agencies and private timber concerns has imposed a checkerboard pattern of old-growth forests on remaining lands. This fragmentation of remaining suitable spotted owl habitat is occurring range-wide, and may be even more noticeable on BLM lands which are additionally checkerboarded because of land ownership patterns (see Figure 8, Section III. A). Forest Service modeling (USDA 1988) predicts that the mortality of dispersing juvenile owls will increase whenever the density of suitable habitat areas decreases. As local populations become isolated from other populations, each local population and the whole have a lower chance of surviving random demographic, genetic, and environmental events (USDA 1988, Dawson et al. 1986).

As spotted owl habitat becomes less abundant, more fragmented, and more isolated, catastrophic events are likely to have even more profound effects on remaining populations by eliminating additional patches of habitat. Chance environmental events such as fires, windstorms, volcanic eruptions, and insect tree damage can have considerable impact and even totally eliminate the habitat of smaller isolated populations (USDA 1988). Windstorms, volcanic eruptions, and huge wildfires have affected significant amounts of spotted owl habitat in the Northwest since 1980 (USDA 1988). Natural disasters will likely have an increasingly greater impact on small habitat patches resulting from the clearcut, even-age timber harvest management practiced by public agencies, then they would have had historically (USDA 1988, Ruediger 1985, Harris 1984, Spies and Franklin 1988, Franklin and Forman 1987, Thomas et al. 1988).

D. Predation and Competition

Predation by great horned owls (*Bubo virginianus*) has been identified as a major source of juvenile mortality (USDI 1987a, Dawson et al. 1986, USDA 1986, 1988, Simberloff 1987). Concern has been expressed that increased habitat fragmentation may subject spotted owls to greater risks of predation as they move into or across more open terrain, or come into more frequent contact with forest edges where horned owls may be more numerous.

Hamer (1989) has been studying spotted owl and great horned owl interactions in the north Cascades of Washington. His survey of the 145-square-mile Mt. Baker study area showed that great horned owls were more common than spotted owls. He found, based upon a limited sample size, that spotted owls avoided areas intensively used by pairs of horned owls. In young-growth forests in southwestern Washington, Irwin et al. (1989a) reported that great horned owls, along with the western screech owl (*Otus asio*), were the most commonly found owls, and that spotted owls were infrequently found. Specific impacts of great horned owl predation on the overall spotted owl population are unknown, but remain an issue of concern.

The barred owl (*Strix varia*), has undergone rapid range expansion over the past 20 years into the range of the spotted owl in the northwest United States (Hamer 1988, Figure 11). Gould (pers. comm.) indicates that the species now occurs as far south as Mendocino County. Furthermore, the barred owl has at least replaced, and possibly displaced, the northern spotted owl in some instances (Forsman and Meslow 1986, Allen et al. 1985, Hamer and Samson 1987). Hamer (1988, 1989) noted that the barred owl seems to be more prevalent in more cut- over areas than spotted owls. On his study area in the northern Cascade Mountains of Washington, the barred owl is now 2.1 times more numerous than the spotted owl.

The barred owl's adaptability and aggressive nature seem to allow it to take advantage of habitat perturbations, such as those that result from habitat fragmentation, and to expand its range where it may compete with the spotted owl for available resources. The long-term impact to the spotted owl is unknown, but of concern. Continued examination of the role and impact of the barred owl as a congeneric intruder in historical spotted owl range and its relationship to habitat fragmentation is warranted. The potential for interbreeding of the two species also merits concern.

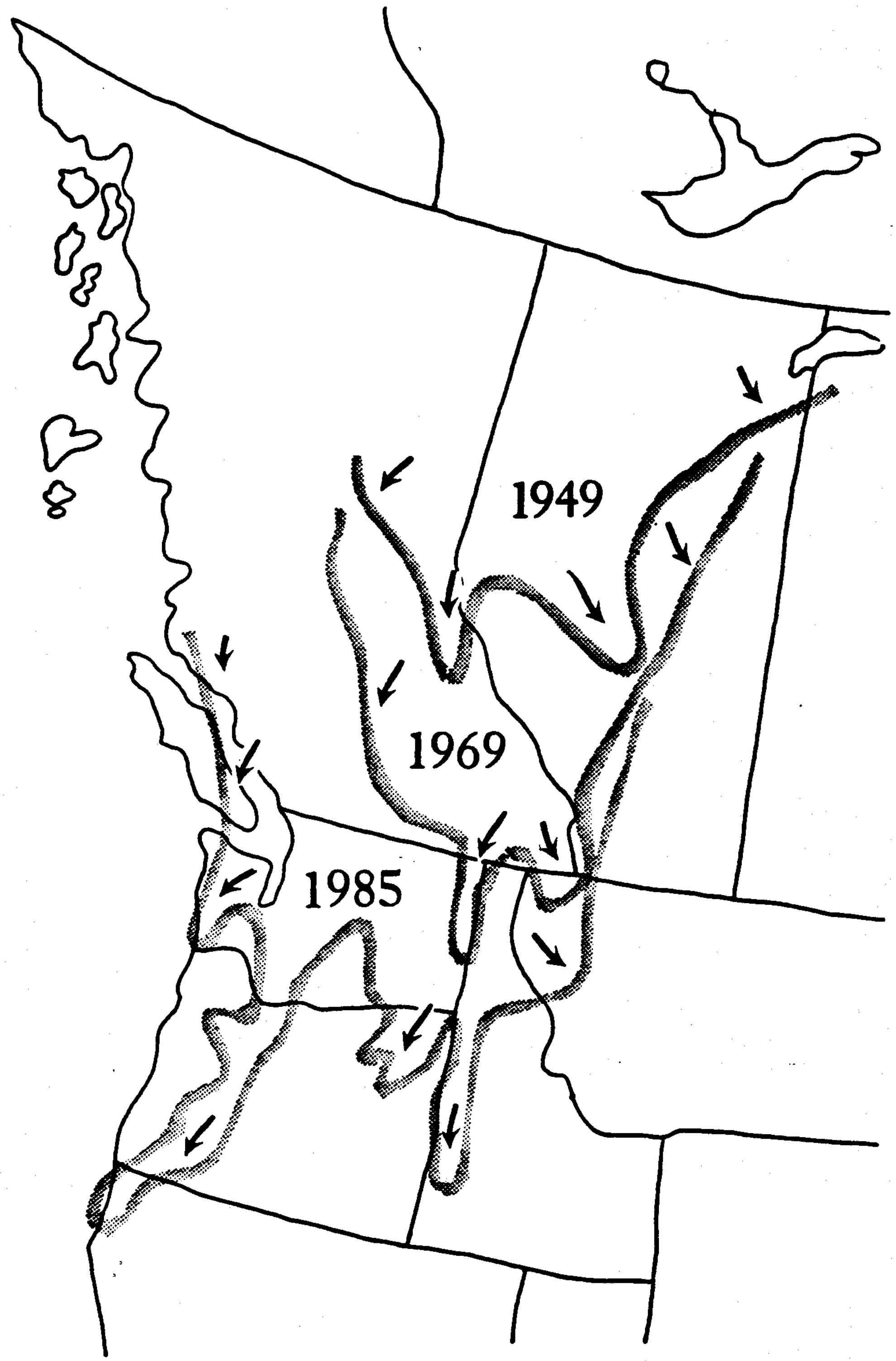


Figure 11: Range Expansion of the Barred Owl

(adapted from Hamer and Allen 1985)

IV. SPOTTED OWL POPULATION

A. Management and Planning

Federal land management agencies currently administer over 90 percent of existing spotted owl habitat (see Figure 15 for comparison between land ownerships, Section IV. B). This includes about 30 to 40 percent of the total amount of federally-managed forested habitat within the range of the northern subspecies and about 40 to 50 percent of wilderness areas and parks; about 30 percent of all commercially available forests in the Northwest, including northern California (USDA 1988, USDI 1987d, Robertson 1989, Logan pers. comm., Smithey pers. comm., Foisy pers. comm., Bonn pers. comm., Lint pers. comm., Thomas pers. comm.).

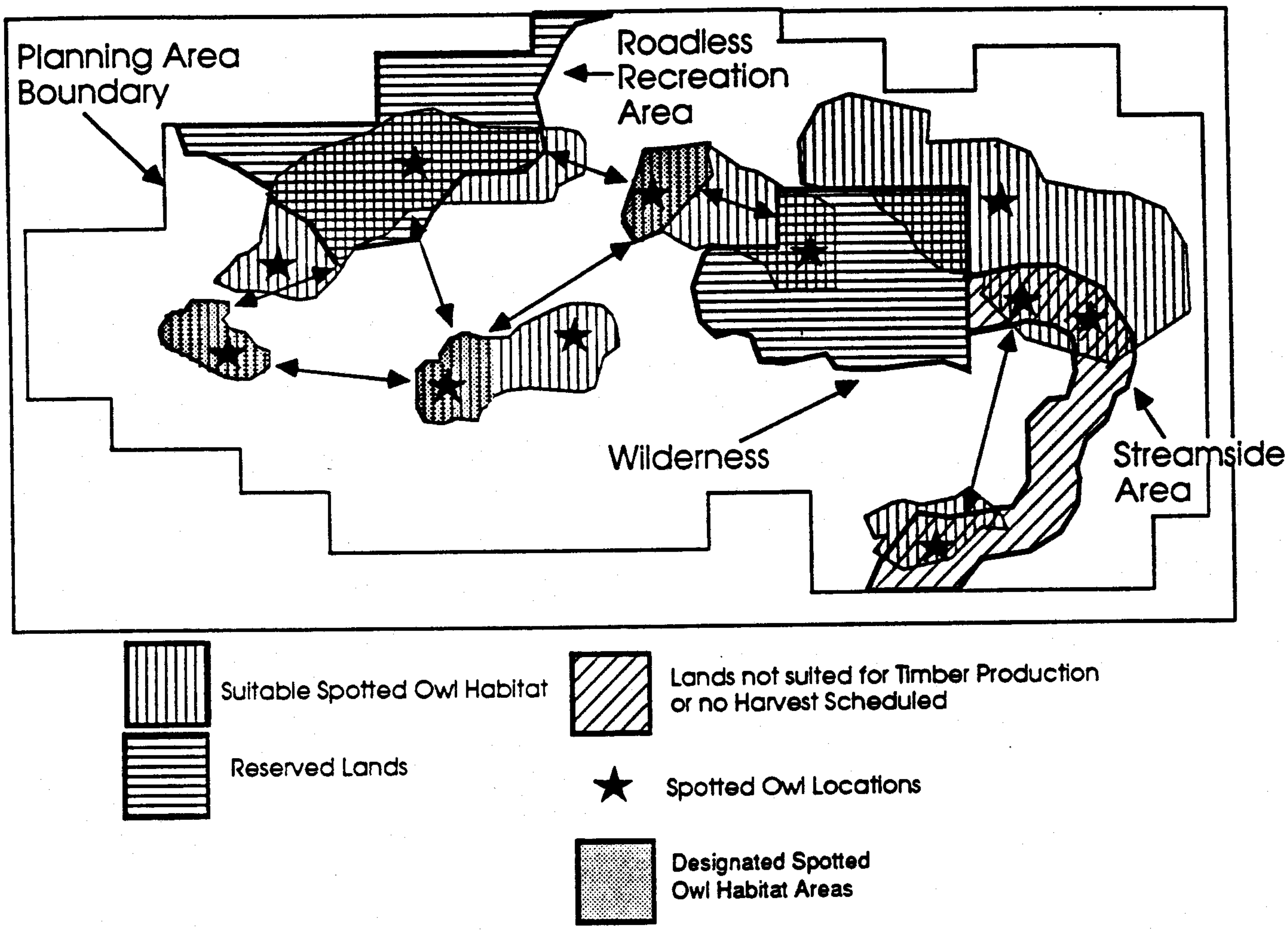
With the possible exception of the Bureau of Land Management's Oregon and California railroad grant (O&C) lands in Oregon, there are clear federal and State agency laws, regulations, policies, or interagency agreements that allow or require management of species such as spotted owls and spotted owl habitat. Federal and State agencies have deliberated owl habitat needs for many years, and in some instances, various interim spotted owl habitat management guidelines or policies have been drafted or implemented. However, guidelines and policies have changed frequently during field resource management planning. Since two different public agencies (Forest Service and BLM) manage large acreages of spotted owl habitat, implementation of uniform habitat management, including timing and design of timber harvests, has been difficult. Often little formal coordination takes place between the agencies while planning timber harvests affecting owl habitat.

In late 1988, the Forest Service made its final decision on spotted owl management guidelines for National Forests in Washington and Oregon (Robertson 1989). The decision provides guidance (habitat amount, location, juxtaposition) to set aside a network (see Figure 12) of selected Spotted Owl Habitat Areas (SOHAs), totaling approximately 374,000 to 477,000 acres in Washington and Oregon forests. This decision also decreased the overall amount of old-growth timber available for harvest on the Olympic National Forest from that shown in the Final Supplemental Environmental Impact Statement (FSEIS) (USDA 1988, Robertson 1989). In addition, the overall timber harvest base has been adjusted by the Forest Service. The Forest Service's Record of Decision set a time table of 5 years for a full review of the Forest Service's owl management program, continued implementation of a $5 million annual Research, Development, and Application Program (RDA), and reaffirmed the Forest Service's commitment to coordinate and cooperate with other agencies. This is the basis of the Forest Service's adaptive management strategy, designed to incorporate the most current research findings into management planning on a 5-year time table to help meet their goal of ensuring population viability for the spotted owl (Robertson 1989).

The Forest Service's Record of Decision (USDA 1988) on spotted owl habitat guidelines is the subject of several current lawsuits. Whether or not the current habitat guidance will stand is unknown. In addition, the final Forest Service spotted owl decision (FSEIS Alternative F and Record of Decision - USDA 1988, Robertson 1989) only addresses regional standards and guidelines for spotted owl management. The actual implementation of owl management will be based on individual forest plans once they are finalized. A thorough assessment of the impacts of the Forest Service's selected alternative for each forest is not possible at this time since the actual arrangements (location and juxtaposition) of management areas (SOHAs) have not been

Figure 12: Future Proposed Spotted Owl Management Scenario

(representation adapted from USDA 1988)



(all other lands not setaside or reserved are available or suitable for timber production, including nondesignated spotted owl habitat) available for interagency or public review and Forest plans have not been finalized.

The Forest Service is implementing a similar habitat management plan for both subspecies of spotted owls located in California. However, since Forest plans are not yet finalized and the success or failure of this type of management has not been tested, an assessment is premature. This program is also part of the 5-year RDA and adaptive management strategy (Robertson 1989).

In Oregon, the BLM manages O&C lands (see checkerboard pattern Figure 8, Section III. A). The law requires management of these lands for permanent forest timber production. These lands cannot be withdrawn or set aside for other long-term management objectives unless other applicable statutes permit. However, short-term (10-year) restrictions can be placed on certain tracts during a 10-year planning period (Neitro, pers. comm.). Currently, the BLM has timber harvest restrictions on 110 spotted owl sites (SOMAs) that are managed by that agency under a cooperative agreement with the Oregon Department of Fish and Wildlife through 1990. The intent is to provide linkages and habitat for 90 pairs of owls between Forest Service lands in the Oregon Cascades and Coast Ranges and to preserve the integrity of these sites for the next planning period. A new plan for the next 10-year planning period is being developed (Vetterick 1988). The BLM only manages small parcels of owl habitat in California.

The success or viability of spotted owl pairs (as measured by survival and reproductive output) is predicated largely on the sufficiency of their habitat to support the full range of physical, behavioral, and nutritional needs of the subspecies as expressed by measurement of owl use (see Section V.). Selected SOHA or SOMA size proposed under the FSEIS or the Bureau of Land

Management/Oregon Department of Fish and Wildlife agreement is generally less than the mean amount of preferred habitat documented within the home ranges of paired owls studied in all physiographic provinces (Table 5, and see Section II. B). Some of those pairs may not persist in less than average-sized habitats (Ruggiero et al. 1988).

To counteract the loss of habitat caused by chance environmental events, Ruediger (1985) believes that management of suitable spotted owl habitat needs to be both flexible and pro-active. He recommends that more than a minimum number of sites be managed for spotted owls so that substitute sites would be available in the event that some sites (especially important linkage areas) are lost by chance environmental events. According to regional guidance, the Forest Service does not quantitatively provide for long-term contingencies for these catastrophic events. Similarly, current spotted owl habitat management by the BLM does not take into consideration or provide for such events.

In the past, there was no formal, standardized evaluation, or follow-up to verify if interim spotted owl habitat management guidance was being uniformly implemented in the field. Currently, there has been little oversight to provide habitat management protection or owl population monitoring quality control or verification except under an interagency agreement between the Fish and Wildlife Service, Forest Service, BLM, and the National Park Service (USDI 1988). An implementation plan has not been developed.

The spotted owl subcommittee of the Oregon-Washington Interagency Wildlife Committee developed a similar Spotted Owl Management Plan in 1987 (Spotted Owl Subcommittee 1988). This plan is similar to the Forest Service's plan, although it recommends larger areas or blocks of habitat be managed for higher densities of owls and to accommodate catastrophic events. However, though an earlier plan was partially adopted, this updated version was not formally adopted nor implemented by participating agencies.

The cumulative impact of current timber cutting practices by land-managing agencies increases and exacerbates the fragmentation of existing owl habitat (see Section III. C). In addition, both the Forest Service's and BLM's proposed owl management plans are untested. Under current harvest plans, the rate of change from old growth to young, even-aged forest management will continue. However, the outcome of recent legal actions on future plans is uncertain. Further, as agencies concentrate their clearcutting outside of designated spotted owl habitat or management areas, future habitat management options will be lost if currently planned habitat networks prove to be deficient.

TABLE 5: COMPARISON BETWEEN SOHA AND SOMA SIZES, THE RANGE OF MEAN HOME RANGE SIZES, AND HOME RANGE OLD-GROWTH COMPONENT

Physiographic Province	Amount of[1/] Suitable Habitat in FS SOHAs	Amount[1/] in BLM SOMAs	Range of[2/] Mean HR Size(ac)	Range of Mean[2/] Old-Growth Component(ac)
Olympic Peninsula	3,000	N/A	9,152-13,442	3,800
Washington Cascades	2,200	N/A	7,021-11,732	4,203
Oregon Coast Ranges	2,000	2,000	5,745- 7,208	1,820-2,549
Oregon Cascades	1,500	2,000	3,132- 6,020	2,709
Klamath Mtns (OR & CA)	1,000	2,000[3/]	1,692- 3,200	800-1,439

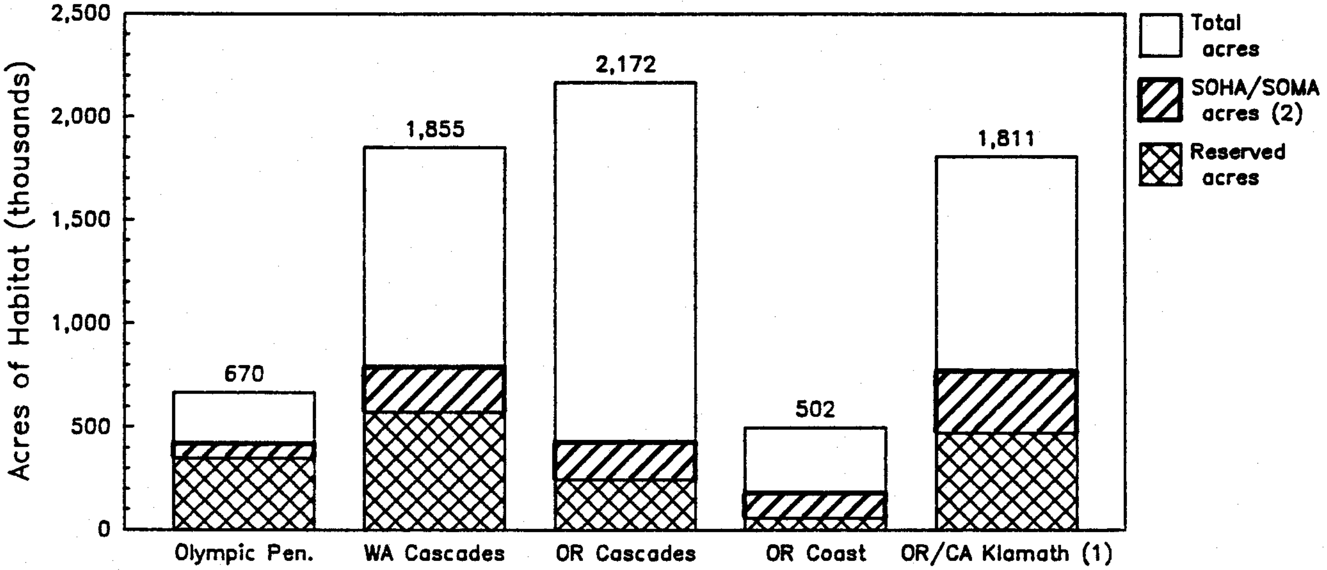
1/ Sources: USDA 1988, Robertson 1989, Neitro pers. comm.
2/ Home Range data from Figures 4 and 5 (Section II. B)
3/ BLM - Oregon Klamath province only

B. Status and Distribution

Estimates of the historical population size and distribution for the northern spotted owl within preferred and suitable habitat do not exist, although spotted owls are believed to have inhabited most old-growth forests throughout the Pacific Northwest and northwestern California (see Figure 9, Section III. B). Spotted owls are still found within their historical range in most areas where preferred and suitable habitat exist, although they are largely restricted to the distribution of mature and old-growth forests on federally-managed lands in these areas (Figures 7 and 9, and Sections II. C and III. B). Over 90 percent of the known number of spotted owls have been located on federally-managed lands (Forsman et al. 1987, USDA 1988, Gould pers. comm.).

The owl population and occupied habitat are not evenly distributed throughout its present range (see Figures 13 and 14) nor by land ownership (see Figure 15). The bulk of the population is found in the Cascades of Oregon and the Klamath Mountains in southwestern Oregon and northwestern California (USDA 1988, Gould pers. comm., Robertson 1989); this area probably represents the core of the present range of this subspecies. Analysis of the data seems to indicate higher densities and more consistent and higher reproductive success in the preferred and suitable habitat in these areas than elsewhere in its range (Franklin and Gutierrez 1988, Franklin et al. 1989, Miller and Meslow 1988, USDI 1987a, Lint pers. comm., Bonn pers. comm., Robertson 1989). Habitat in southwestern Oregon begins to change south of Roseburg to a drier Douglas-fir and mixed conifer habitat with a corresponding change in prey base from flying squirrels to woodrats (Forsman et al. 1984). In addition, historical logging practices in the mixed conifer zone resulted in more selective timber harvesting than in other areas, leaving remnant stands of old

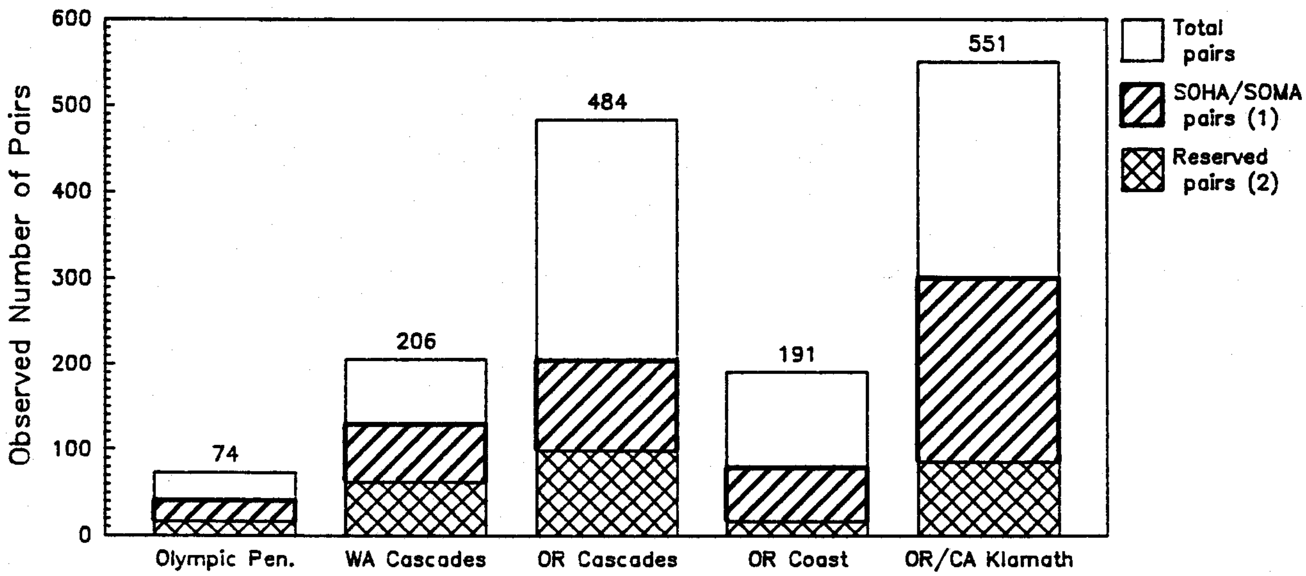
Figure 13: Estimated Spotted Owl Habitat by Land Designation and Physiographic Province



(1) CA Klamath includes CA Coast Range (separate figures not available)

(2) SOHA/SOMA acres are reported as the estimates proposed by FS and BLM

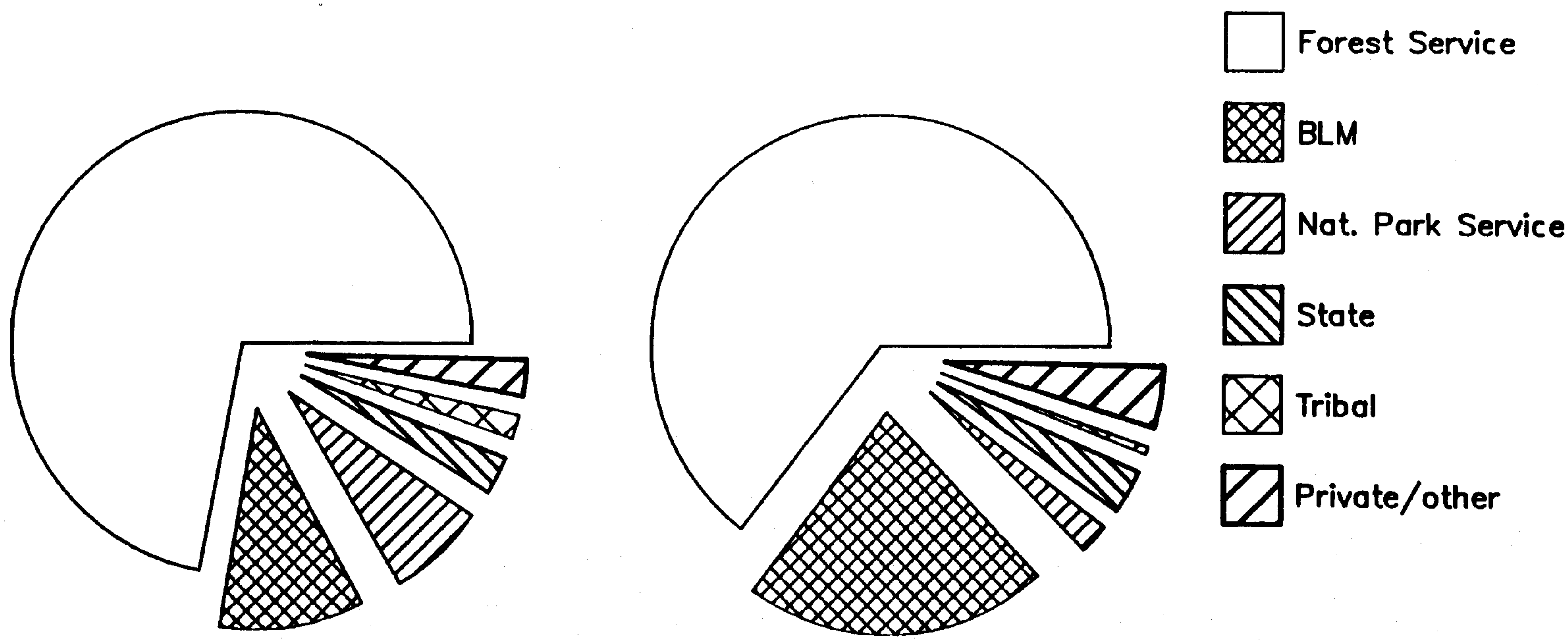
Figure 14: Observed Spotted Owl Pairs by Land Designation and Physiographic Province



(1) SOHA/SOMA pairs estimated from reported expected occupancy rates (58–82%/province)

(2) Inventories in OR/WA wilderness and parks less complete than in other areas

Figure 15: Distribution of Spotted Owl Habitat and Number of Observed Pairs by Land Ownership (in proportion of total numbers reported)



Habitat in millions of acres (1)

Observed number of owl pairs (2)

(1) Total estimated acreage of owl habitat (7.0 million acres)

(2) Total number of observed pairs (1507 pairs)

growth or stands of varying ages with old-growth characteristics; this situation is also present along the east side of the Cascades in Washington.

Northern Washington and southern British Columbia represent the northern extent of the range of the northern subspecies; population densities and numbers are lowest in these areas. Very few pairs have been located in British Columbia; all have been located near the United States border (Forsman pers. comm.). Very few owls (pairs or singles) are presently found in the Coast Range in southwestern Washington or in the northwestern Oregon Coast Ranges (north from the southern portion of the Siuslaw National Forest) (Logan pers. comm., O'Halloran pers. comm., Irwin 1988, 1989a). The population also decreases in size and density toward its southern extreme along the coast range in Marin, Napa, and Sonoma Counties, California (Gould pers. comm.). Gould reports that probably less than 10 percent of the observations in California of northern spotted owls occur in the coastal redwood region of northern California. Few data on numbers and distribution on private, State, or tribal lands in these areas are available, although the spotted owl may have been nearly extirpated from much of these lands due to reduction of old-growth habitat (Forsman 1986, Forsman et al. 1987, Forsman pers. comm., Gould pers. comm.).

We reviewed four different indicators of population size of the northern spotted owl: (1) the number of spotted owl sites (observations) recorded over time; (2) the number of pairs of owls observed at these sites within the past 5 years; (3) the projected capability of the habitat to support pairs of owls over time (USDA 1986, 1988); and (4) the extent of loss of preferred habitat (see Section II. C). Current population figures by land ownership and physiographic province have been updated to 1989 and are presented in Tables 6 and 7. These figures represent a valid update of the number of pairs on known sites throughout most of the range. This is the result of intensive, rangewide monitoring and inventory programs conducted by the BLM and the Forest Service over the past few years.

Data contributing to estimates of present population size of the northern spotted owl have been collected for almost 20 years, with counts of owls increasing over that period as greater areas of habitat were surveyed (Gould 1985, Gould pers. comm., Forsman et al. 1987, USDA 1988, Robertson 1989, Vetterick 1989). However, the increase in numbers of spotted owls counted in these surveys reflects an increase in inventory effort and cannot be used as an indication of any upward population trend. Early surveys were not conducted to estimate total population size. In addition, agency funding efforts and inventory methods have improved dramatically in recent years, resulting in counts representing a larger fraction of total population size (of pairs of owls) than previous counts. However, this cumulative increase in inventoried owls may actually mask population declines that are suggested over this same period (Gould 1985, Forsman et al. 1987, and following section).

Present information about the population size of the northern spotted owl have been derived largely from counts of the number of territorial spotted owls (pairs) that have been located over the range of the subspecies. These counts are not complete, since not all suitable habitat has been fully surveyed. For example, inventories in wilderness areas, particularly in Oregon and Washington, are especially difficult and incomplete. Much habitat is not readily inaccessible, inventories on private lands are incomplete (except where intermingled with BLM lands), and it is difficult to inventory non-territorial birds (non-paired adults or subadults). However, agency biologists believe that about 70 to 80 percent of the spotted owl population has been inventoried in most areas (Potter pers. comm., Logan pers. comm., Smithey pers. comm., Bonn pers. comm., Lint pers. comm., Gould pers. comm., Simon-Jackson, pers. comm., Forsman pers. comm.). Counts on Forest Service lands in parts of the Oregon and Washington Cascades are lower than on other federal lands, because past surveys have not been as intense (Forsman pers. comm., O'Halloran pers. comm.).

These counts also have not been corrected for differing intensities of inventory effort, sites lost through habitat reduction or conversion, loss and recolonization of sites by new or displaced pairs, new sites found through recent inventories, double counting of non-banded birds, etc. These counts thus underestimate true population size to some unknown degree. However, the present counts are very similar to the habitat capability estimates (to support pairs of owls) for these lands that have been determined by the Forest Service (USDA 1986, 1988).

Tables 6 and 7 and Figure 14 illustrate the present estimated abundance and distribution of northern spotted owls. Of particular interest is the difference between the number of sites visited that contained or were expected to contain spotted owls, the estimated capability of the habitat (based on present habitat estimates and hypothesized carrying capacity), and the actual number of pairs of owls observed at those sites in the past 5 to 7 years. Based upon the intensity of recent surveys, the lack of banding (to avoid duplication in counts), and the continued loss of habitat, we believe the actual number of pairs is somewhere between these two quantities (number of sites and number of pairs observed at these sites). The estimate of Marcot (1988a and USDA 1988) of habitat capability is probably a fairly reliable estimator of the number of pairs of owls.

However, we note that the number of pairs is not a fair representation of the population. Very little data exist on the non-territorial birds that are also an important part of this population (i.e., future breeders, gene pool); these may become more important to population viability in the future as habitat is further fragmented and reduced. There is not an effective method for determining the number of non-territorial individuals given present techniques and lack of banding and radio-tracking of juveniles. Only the BLM is presently banding adults and juveniles; over 800 owls including 260 juveniles have been banded over the past 4 to 5 years; only 9 juveniles out of 181 banded on 3 Districts have been relocated during this period (Neitro pers. comm., Logan pers. comm., Vetterick 1989).

Although the actual number of remaining sites and pairs on all lands is unknown, we note that total numbers of owls (pairs or singles) are not the only important indication of the subspecies' long-term survival. A more important measure than the total number of pairs may be the number of breeding pairs within the population. Though reproduction is variable, the number of nesting pairs observed annually varies around 40 to 60 percent for all pairs observed, with less than 30 to 40 percent of all pairs breeding successfully (USDI 1987a, Robertson 1989, Vetterick 1989, Franklin et al. 1989, Miller and Meslow 1988). It is unknown whether this rate of success is adequate to maintain a stable or increasing population, however, data seem to indicate that it is not (see following sections).

Population persistence, the ability of the population to sustain itself over time, is the more critical measure to determine (Ruggiero et al. 1988). Total population size is primarily a function of the total amount, distribution, and suitability of habitat available to sustain successfully reproducing pairs of spotted owls through time. It is these territorial pairs of successfully reproducing owls that contribute most to the survival of the spotted owl, and they, therefore, are the best available indicator of population levels and trends over time. An estimate of population trends in relation to habitat over time is likely to provide a better understanding of the status of this or any habitat specific species than just total numbers of individuals and pairs.

As spotted owl habitat continues to be reduced by current timber harvest practices, the current population is expected to decline correspondingly, and, perhaps disproportionately, since the remaining amount and distribution of suitable habitat will not be able to support higher population densities. It is unknown whether the amount and distribution of spotted owl habitat remaining at the end of commercial harvest under current plans (see Tables 4 and 5, Section III. A) will be adequate to support a viable population of the northern spotted owl. Demographic information contributing to a determination of population trend and the various population viability analyses for the subspecies (USDA 1988, Lande 1988a) address this issue and are discussed in the following sections.

TABLE 6: ESTIMATED CAPABILITY OF PRESENT HABITAT TO SUPPORT PAIRS OF SPOTTED OWLS[1/]

STATE/ OWNERSHIP	ESTIMATED CAPABILITY ON RESERVED LANDS[2/]	ESTIMATED CAPABILITY ON NONRESERVED LANDS[3/]	TOTALS
British Columbia	N/A	50	50
Washington			
Forest Service	106	278 (174)[4/]	384
Nat. Park Service	68	--	68
State	--	22	22
Tribal	15-20	5	20-25
Private	--	3	3
Subtotals:	189-194	307 (174)	497-502
Oregon			
Forest Service	167	737 (191)	905
BLM	--	329 (110)	329
Nat. Park Service	3	--	3
State	--	33	33
Tribal	--	13	13
Private	--	3	3
Subtotals:	170	1,115 (301)	1,286
California (Northwest)			
Forest Service	56	351 (212)	407
BLM	7	18 (1)	25
Nat. Park Service	25	--	25
State	21	--	21
Other	7	9	16
Private	--	100	100
Subtotals:	116	478 (213)	594
TOTALS:	569	1,698 (688)	2,427-2,432

1/ Capability of the habitat to support pairs of spotted owls (USDA 1988); Forest Service estimates were based upon analysis of habitat capability on their lands; all other land ownerships are either based upon the number of observed pairs or estimates of pairs expected and updated to more closely reflect the number of pairs presently found (see pers. comm.); updated figures for private lands unkn.

2/ Reserved category includes known owl habitat within wilderness, parks, natural areas, etc.; SOHA and SOMA totals are not included

3/ Nonreserved includes forest available and unsuited for timber harvest

4/ Potential number of SOHAs/SOMAs planned by federal agencies for nonreserved lands; actual percent occupancy by pairs will vary (58-81%)

TABLE 7: COMPARISON BETWEEN NUMBER OF SITES INVENTORIED, ESTIMATED HABITAT CAPABILITY, AND NUMBER OF OBSERVED PAIRS

PROVINCE	INVENTORIED SITES 1/	ESTIMATED CAPABILITY 2/	OBSERVED PAIRS 3/
British Columbia	15	50	7
Washington			
Olympic Peninsula	N/A 4/	106	68-74 5/
Cascades	N/A	391-396	200-206
Coast Range	N/A		1
Subtotals:	461	497-502	269-281
Oregon			
Cascades	N/A	808	484
Klamath Mts.	N/A	254	155
Coast Ranges	N/A	224	191
Subtotals:	2,000-2,100 6/	1,286	830
California			
NW California	820	594	396
TOTALS:	3,296-3,396	2,427-2,432	1,502-1,514

1/ The number of sites where presence of spotted owl had been documented at least once over the period (1969 to 1988); totals have been updated to 1989 (Juelson 1989, Forsman pers. comm., Gould pers. comm., Potter pers. comm.)

2/ Capability of the habitat to support pairs of spotted owls (USDA 1988); BLM, NPS, and tribal figures were updated to reflect the number of pairs presently found or estimated on those lands (Palmer 1989, Thomas pers. comm., Bonn pers. comm., Larsen pers. comm., Logan pers. comm., Lint pers. comm., Smithey pers. comm., Moorhead pers. comm.)

3/ The number of pairs that have been observed within the past 5 to 6 years on known sites (Robertson 1989, Simon-Jackson pers. comm., O'Halloran pers. comm., and above)

4/ Data by province not available

5/ Differences in observed number of pairs due to differences in reporting observations of unbanded birds

6/ Data compilation incomplete (Forsman pers. comm.)

C. Demographic Trends

Information about population trends for spotted owls is provided by three different kinds of data: (1) changes in spotted owl habitat: (2) changes in spotted owl population size, and (3) survival and reproductive rates. Regarding habitat, we have already discussed both the close association between the spotted owl and old-growth forests, and the dramatic reductions in old growth that have occurred during the last century. Under current harvest rates, this loss of old-growth habitat would continue, with projected losses on federal lands of about 1.5 percent per year (USDA 1988) or greater (Morrison 1988, 1989). This continued loss of habitat leads to the expectation of further reductions in spotted owl population size.

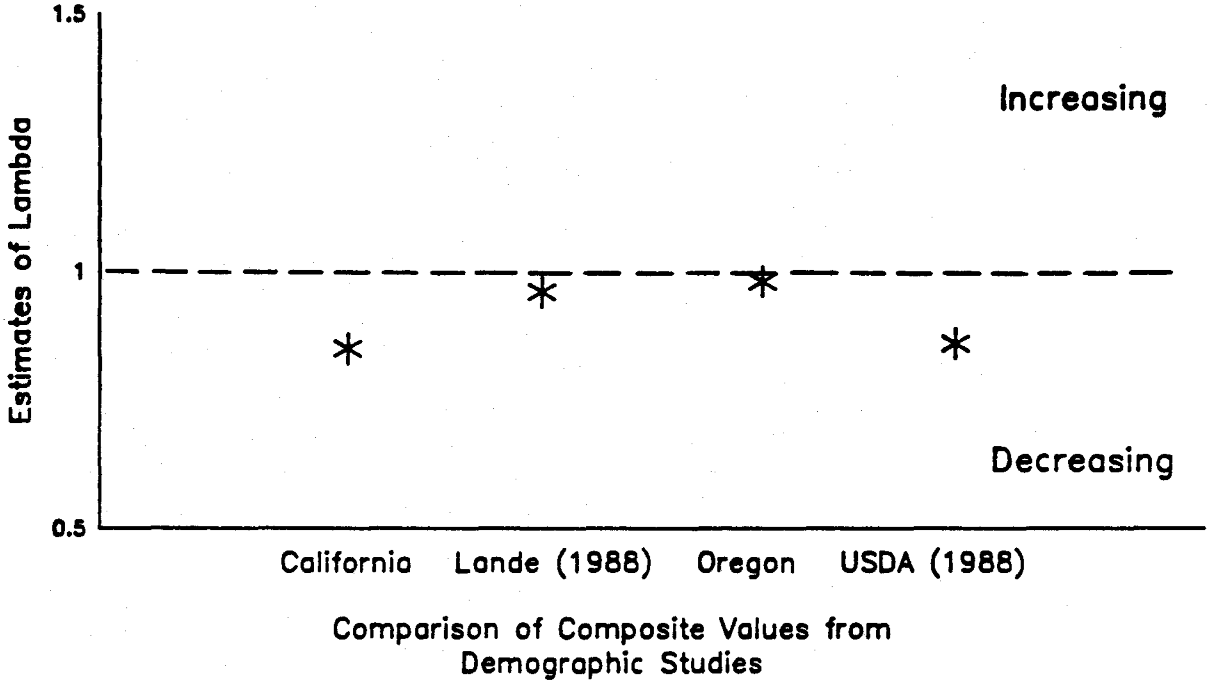
The most frequently cited evidence of population trends in spotted owls (Forsman et al. 1984, 1987, Gould 1985) needs to be critically examined. Both Forsman et al. (1984, 1987) and Gould (1985) apparently based their estimates of population trend on the proportion (denote this proportion p) of an initial group of sites at which pairs of owls were located at some time (t), that contained pairs of owls at some later time ($t+\Delta$). The actual trend, expressed as percent decline per year, was then computed as $100(1-p)/\Delta$. One criticism of this statistic is minor, and involves the fact that population change is typically viewed as a multiplicative process. This leads to the following estimator of annual rate of change in population size, lambda = λ (which can also be computed as population size in year t+1 divided by population size in year t): $\lambda = p^{1/\Delta}$. This approach leads to slightly greater estimates of population decline ($1-\lambda$) than the approach of Forsman et al. (1984, 1987) and Gould (1985). However, p is conditioned on an initial group of sites containing spotted owls, and rates of decline computed from p thus do not include the possibility of new sites (not occupied in year t) being "colonized" by owls. If such colonization occurs, then the estimates of trend based on p or related statistics will be too low.

Most biologists knowledgeable about spotted owls believe that populations have declined in many areas, commensurate with declines in preferred habitat. Perceived declines were an important reason underlying the establishment of the American Ornithologists' Union Blue Ribbon Committee on the spotted owl (Dawson et al. 1986). Regarding specific situations, Franklin (pers. comm.) reports, "there are strong indications that the population of northern spotted owls in northwestern California is declining." Similarly, Meslow (pers. comm.) reports that spotted owl populations in many portions of Oregon have declined in recent years.

The third line of evidence regarding population trends involves data on survival and reproductive rates. As noted by Dawson et al. (1986), "the observed demographic data alone give cause for great concern." One means of making formal statements about population trends expected to result from a specific set of survival and reproductive rates is to assume that these rates remain constant over time and to compute the asymptotic finite rate of increase, λ, defined by these rates. This approach has been followed by USDA (1988), Lande (1988a), and Noon and Biles (in review). Demographic data used in these three analyses represent composites of estimates from throughout the spotted owl's range (Table 8). Asymptotic rates of increase computed from these largely-overlapping data sets range from 0.85 to 0.96 (Table 8). In addition to these published estimates of λ, we compiled demographic data for two specific areas within the range of the spotted owl, Oregon (Meslow, pers. comm.) and northern California (Franklin et al. 1989), and computed independent estimates of λ using equation (2) of Lande (1988a) and equation (11) of Noon and Biles (in review). Resulting estimates of λ were 0.98 for Oregon and 0.86 for northern California. All estimates show $\hat{\lambda}<1.0$ (Table 8 and Figure 16), indicating declines for populations characterized by those survival and reproductive rates.

We offer several cautions about these computed values of $\hat{\lambda}$. First, they are not independent, as they all (with the exception of the Oregon and northern California values, which are independent of each other) rely heavily on the same demographic estimates. Second, variances of these estimates have only been computed in one instance (Lande 1988a). In this case, the variance of $\hat{\lambda}$ was almost certainly underestimated, yet it was still sufficiently large that the null hypothesis of $\lambda = 1.0$ could not be rejected (Lande 1988a). Third, computed values of $\hat{\lambda}$ were based on a deterministic model which assumed constancy of all demographic parameters for an indefinite period of time. If temporal and demographic (sensu Shaffer 1981) variation of these survival and reproductive rates could be estimated and these estimates incorporated into a stochastic model, then the realized long-term growth rates would tend to be smaller than the $\hat{\lambda}$ based on deterministic models (e.g., see Lande 1988a). A fourth and final point involves the neglect of immigration in the computation of $\hat{\lambda}$. The complements of some of the adult and subadult survival estimates in Table 8 likely include some amount of permanent emigration. The rate at which adult and subadult spotted owls leave a study area for good is likely small, but is not known. However, the reproductive rates used in the computations in Table 8 are based solely on reproduction and do not include possible immigration into the population. Thus, the estimates of λ may include some movement by adult and subadult birds out of the local population but do not include possible movement in. This asymmetrical treatment of movement may

Figure 16: Spotted Owl Reproductive and Survival Rate Estimates



Asymptotic finite rates of increase defined by the reproductive and survival rate estimates presented in Table 8. Lande (1988a) and USDA (1988) represent composite values with estimates coming from throughout the range of the spotted owl. The California and Oregon values are based upon Franklin et al. (1989) and Meslow (pers. comm.), respectively, and are independent of each other. Values less than 1.0 reflect a declining population.

lead to underestimates of λ. Thus, the incorporation of temporal and demographic variation would lead to smaller estimates of $\hat{\lambda}$ than indicated by our estimates in Table 8, whereas complete treatment of movement might increase $\hat{\lambda}$. The net result of these changes is not known. Nevertheless, when the best available estimates of spotted owl survival and reproductive rates are combined to compute asymptotic rates of increase, resulting values point to a declining population.

TABLE 8: DEMOGRAPHIC DATA AND CORRESPONDING ASYMPTOTIC RATES OF INCREASE FOR NORTHERN SPOTTED OWL POPULATIONS

			This Assessment	
Parameter[1/]	USDA (1988)	Noon & Biles (in review) and Lande (1988)	Oregon spotted owls[2/]	NW California spotted owls[3/]
S_0	0.11	0.11	0.20	0.06
S_1	0.96	0.71	0.95[5/]	0.77
S	0.96	0.94	0.95	0.84
b	0.24	0.24	0.24	0.33
T	2	3 (2)[4/]	3	2
W	15	∞	∞	∞
λ	0.85	0.96	0.98	0.86

1/ S_0 = first-year survival rate
S_1 = second-year survival rate
S = annual adult (>2 years) survival rate
b = female fledglings produced per adult female in the population
T = age (years) at first reproduction
W = age (years) at which reproductive senescence occurs (b = 0)
λ = asymptotic finite rate of increase computed from above variables
2/ Oregon data were provided by Meslow (pers. comm.)
3/ Northern California data from Franklin et al. (1989)
4/ T = 2 and T = 3 both yield approximately the same λ
5/ Second-year survival set at adult rate; value is probably high (Meslow pers. comm.)

V. RELATIONSHIP BETWEEN HABITAT AND POPULATION DYNAMICS

Habitat associations and preferences of the spotted owl provide valuable insight into the animal's life history. Moreover, when habitat preferences are interpreted in the context of ecological theory, there is a means of assessing the likely population response to future habitat changes.

Ecological theory concerning habitat selection holds that individual spotted owls are likely to have higher fitness, indicated by higher survival and reproductive rates, in old growth than in young-growth forests. The theory developed by Fretwell and Lucas (1969) recognizes a hierarchy of habitat preference with the most suitable habitat used first, followed by the next most suitable, and so on. A wider range of habitats comes into use when populations increase (with respect to habitat capacity), and the reverse occurs during a decrease (O'Connor 1986). A consequence of the theory is that the most suitable (i.e., preferred) habitats will have a higher density of breeding adults and, thus, will produce more young per unit area then less suitable habitats. Fretwell and Lucas also recognized situations where social interactions between individual birds lead not only to a higher density of breeding adults, but also higher per capita reproductive rates in more suitable habitats. Data collected on a variety of bird species (e.g., Robertson 1972, Nilsson 1976, Stjernberg 1979, Lundberg et al. 1981, Moller 1982, O'Connor 1986) support the theory that reproductive success is positively related to habitat suitability.

The dynamic aspects of this theory lead to several predictions about the effects of continued harvesting of old-growth habitats on the future demographic performance of spotted owls. Given the data, it is likely that continued harvest of old-growth forests will adversely affect spotted owl populations. As more old-growth forests are removed and fragmented, we can expect the following to occur: (1) individual owls will have to use habitats comprised of a higher proportion of young forests, and will increase their home range size to meet their energetic and nutritional requirements; (2) owl densities will be lower; and (3) as more owls have to use less suitable habitats, there will be a decrease in the average reproductive success of the population. Analysis of available information for spotted owls supports these theoretical predictions (see previous sections).

Several investigators found spotted owl home ranges to be larger in fragmented habitats, comprising relatively large proportions of young-growth forests, than in old-growth forests. Solis and Gutierrez (1982) believed that home range size was directly correlated with both the availability, patchiness, and suitability of the habitat. According to them, as preferred habitat (i.e., old-growth forests) becomes increasingly fragmented, home range size increases correspondingly. Forsman (1980a, 1980b) also reported that spotted owls occupying areas with a high proportion of young forests had larger mean home ranges than did owls occupying homogeneous stands of old or mature growth. In studies conducted in Oregon by Miller and Meslow (1988), home range size increased substantially in the portion of the forest that was most heavily fragmented by timber harvest activities. The larger home range sizes reported for owl pairs on the Olympic Peninsula, Oregon Coast Ranges, and the west side of the Cascade Range in Washington (see Figures 4 and 5, Section II. B) may reflect the adverse influence of forest fragmentation, and the relatively small amount of old-growth habitat remaining in those provinces (Friesen and Meslow 1988, USDA 1988, Robertson 1989).

The data indicate that per capita reproductive rates may, in fact, vary in different habitats in a manner that supports the theoretical predictions. No study has been designed specifically to investigate habitat specific reproductive performance, but Forsman et al. (1984) reported on 10 spotted owl pairs that used sites comprised of mostly young-growth forests. Two of the 10 pairs initiated nesting. One of these pairs initiated nesting in three different years, but none of the nests was successful. The other pair nested in two consecutive years and hatched young in both years. Thus, of five nests initiated by two pairs, 40 percent were successful in hatching at least one owlet. In comparison, of the pairs that used sites comprised primarily of old growth, about 70 percent attempting nesting were successful in hatching at least one young. Thus, based on this evidence, it appears that per capita reproductive rates may be significantly higher in old-growth forests than in young forests.

Variation in per capita reproductive rates between habitats of different suitability implies that the 10 percent of owls using young-growth forests may actually contribute proportionately less than 10 percent to population recruitment. Because of apparent differences in reproductive rates, it would be incorrect to assume that a given owl population, normally concentrated in old-growth forests, could be maintained for any length of time on a relatively larger area of less suitable, young forests. The data on spotted owls suggest that owl use of young forests is dependent on the presence of old-growth stands in their home range.

Several authors (Lidicker 1975, Van Horne 1983, Pulliam 1989) argue that, for many animal populations, less suitable habitats may be "sinks" where local mortality exceeds local reproduction. Populations may persist in sinks, but only because of immigration from other, more suitable, productive habitats (i.e., "sources") nearby or because individuals are relatively long-lived. Thus, the density of individuals in sinks may mislead one to overestimate their importance and suitability, and to overlook the fact that other source habitats are critical to continued persistence of the population. Van Horne (1983) cited several examples of sinks in natural populations of birds and mammals, and cautioned that management decisions must be based on knowledge of the fitness of individuals in different habitats and on the dynamic interaction between different habitats and populations.

Spotted owl assessments performed to date have not explicitly considered habitat differences in reproductive rates and how different fitnesses of owls in different habitats would affect population dynamics. In particular, the life table and population viability analyses (see Sections IV. C and VI.) that have been performed to date may present an optimistic view of the future status of spotted owl populations for two reasons. First, the population viability analyses conducted by the Forest Service were based on a single frequency distribution of reproductive rates, with a mean value from owl pairs in the most preferred habitats. However, theory and empirical data suggest that spotted owl pairs in less suitable, younger habitats may have significantly lower per capita reproductive rates. Therefore, as more old-growth forests are cleared, population growth rates may be reduced to values lower than were used in existing models. Second, the Forest Service's population viability analyses assume that a given SOHA will be occupied with a probability proportional to the amount of old-growth forest in the SOHA. However, the assumed relationship is based on the existing landscape configuration, the existing amounts of old growth, and the existing spatial relationships between old-growth ("sources") and young-growth ("sinks") forests. The assumed SOHA occupancy probabilities are likely to decline as surrounding old growth is cleared and SOHAs become more isolated from other suitable large patches of preferred habitat. These points emphasize the fact that the models should be interpreted cautiously, and that planning for the owl should include built-in safety factors to ensure that future habitat requirements for a viable population are not underestimated (see following sections).

VI. POPULATION VIABILITY ASSESSMENTS

If a population exhibits a finite rate of increase (lambda = λ, population at time t+1/population at time t) that averages less than 1, the population will go extinct with an expected time to extinction that is a function of initial population size, the magnitude of its average rate of increase and the variability in this rate. However, a population that exhibits an average rate of increase greater than 1 may still go extinct if the variability in this rate is sufficiently large in comparison to the average, and if its initial population size is sufficiently small. Population viability analysis (PVA - Gilpin and Soule 1986) is a form of risk analysis that can be applied to determine the likelihood of population extinction in relation to the population's size and growth rate, and to the various factors that can affect the variability of its growth rate.

If the northern spotted owl's current rate of increase is less than 1, as empirical information suggests (see Figure 16, Section IV. C), then a PVA is not necessary and the expected time to extinction can be calculated for the subspecies. However, it may be argued that the current population decline is commensurate with habitat reduction (as it also appears to be: see Section II. C) and that once habitat reduction is halted, the population will stabilize with a rate of increase that is either 1 (stable) or fluctuates around 1. Under such a scenario, a PVA is appropriate as there will still be some likelihood of extinction for the subspecies as explained above.

The Forest Service and the BLM manage the bulk of remaining old-growth forests in western Washington and Oregon, and northwest California, which is the preferred habitat of the northern spotted owl. The Forest Service and the BLM have considered various alternatives for retaining some spotted owl habitat on the lands that they each manage (see Section IV. A). The Forest Service, in particular, has given extensive consideration to various alternatives as described in the DSEIS (USDA 1986) and the FSEIS (USDA 1988). Implementation of any of the Forest Service alternatives, and current BLM guidelines, will result in an altered distribution and abundance of spotted owl habitat in comparison to the current pattern. Consequently, it is appropriate to ask how these proposed alterations of the amount and configurations of habitat will affect the viability of the subspecies in the Pacific Northwest at various times in the future. The Forest Service chose to address this question by using the concepts and tools of PVA.

A. Review of Current Viability Assessments

The administrative record contains two population viability assessments (PVAs) for the northern spotted owl. The first is that conducted by the Forest Service as described in the DSEIS (1986) and the FSEIS (1988). The second is that developed by Lande (1988a, 1987a and b). Both of these PVAs indicate that implementation of the Forest Service's preferred alternative (FSEIS Alternative F and Record of Decision, USDA 1988) will not provide a high probability of persistence for the spotted owl over the next 50 to 100 years, at least in significant portions of its range.

Two of these PVAs (USDA 1986, Lande 1987a) were critiqued by Shaffer (1987a) for the earlier status review (USDI 1987a). This critique was, in turn, reviewed by various experts in population modeling, population ecology, demography, and conservation biology (Nichols 1987, Soule 1987, Wilcox 1987, and Goodman 1987a). In addition, Boyce (1987) independently reviewed the Forest Service's PVA. The results of these efforts are summarized in the following paragraphs. Further details can be found in Shaffer (1987a). Both the Forest Service's PVA and Lande's analysis were criticized on conceptual and empirical grounds. That is, both the structure of the PVAs and the data they employ may not be sufficiently realistic or complete to adequately describe the likelihood of population survival of the northern spotted owl under the various habitat management alternatives considered by the Forest Service.

1. PVA Structures

a. Forest Service

The Forest Service PVA separately assesses four factors (random fluctuations in survival and reproductive rates, levels of inbreeding, habitat suitability, and habitat juxtaposition) related to population viability. Realistically, as habitat is increasingly reduced and fragmented, the interaction of these four factors likely decreases the probability of a population's persistence (Shaffer 1985, Gilpin and Soule 1986, Gilpin 1987). Consequently, the Forest Service's (USDA 1986, USDA 1988) estimates of population viability are likely optimistic for these reasons. For example, population sizes and densities would likely drop with decreasing habitat quantity and suitability. Also, as population sizes become smaller, demographic and genetic effects become more pronounced. Increased fragmentation and isolation of population subunits would also accentuate the importance of demographic and genetic effects (see Appendix A).

There is also some question about the incorporation of variability into the stochastic life table simulations that were part of the Forest Service's PVA (USDA 1988). The standard deviation of the reproductive and survival rates used in the Forest Service PVA were "calculated from the above studies," and derived from empirical information (field research) or literature (USDA 1988). If these standard deviations were computed from the point estimates provided by different studies, then they likely contain variance components associated with geographical variation, sampling (the so-called error of estimation) variation, and demographic (the binomial variation associated with the death process) variation. However, it is the temporal (year-to-year) and demographic variation that are appropriate for use with stochastic models of this type. It is not clear whether standard deviations associated with these two variance components would be smaller or larger than those used in the Forest Service PVA.

In addition, the treatment of survival and reproductive rates as uniform random variates with endpoints plus or minus three standard deviations from the mean was nonstandard and resulted in greater variation for simulated rates than the values that were input (i.e., the standard deviations of the simulated rates must have exceeded the estimated standard deviations that were used as input to the simulations). As a result, the method of generating random variates introduced more variation in survival and reproductive rates than indicated by the empirical estimates. However, it is not clear whether the empirical estimates themselves were too large or too small. Although there are problems associated with the incorporation of variation into the stochastic life table simulations presented in the Forest Service PVA, it is not clear whether these problems would lead to overestimates or underestimates of population extinction probabilities.

Boyce (1987) criticized the Forest Service PVA for failing to include any density-dependent effects. He developed an alternative model, presumably for illustrative purposes, in which both adult fecundity and juvenile survival were modeled as functions of density. Simulated populations never went extinct under some scenarios and exhibited low extinction probabilities under others. However, the density-dependent functions used by Boyce (1987) have no empirical basis. In fact, when the population is at carrying capacity (a point at which survival and reproduction should be adversely affected by density), the values of adult fecundity and juvenile survival are higher than any empirically based estimates available for the spotted owl (see summary of such estimates in Table 2 of Noon and Biles, in review). At small population sizes, Boyce's (1987) functions yield values for adult fecundity and juvenile survival that are, respectively, three and four times larger than the largest empirical estimates. Thus, the differences between the results of Boyce (1987) and the Forest Service PVA are not just from the incorporation of density-dependence, but involve the strength of the density-dependent functions and the resultant very high values of adult fecundity and juvenile survival used by Boyce (1987).

Even if the density-dependent functions used by Boyce (1987) were modified to yield more reasonable values, we believe such mechanisms as Boyce (1987) envisions are unlikely to be operative in the current scenario of continued habitat reduction and fragmentation. Density-dependent increases in survival and reproduction can be expected for many vertebrate populations where the population is being reduced in relation to a constant or increasing resource base (e.g., food, water, territories, etc.). This often occurs where populations are being harvested. However, the opposite is occurring for the spotted owl. That is, the resource base itself is being reduced (e.g., old-growth habitat) and there is little likelihood that per capita resources are increasing for those owls remaining. In fact, we envision the likelihood of a density-dependent suppression of survival and reproduction at low levels of suitable habitat availability. Goodman (1987a) also points out the importance of understanding density-dependent relationships, but his comments are directed to future "equilibrial populations" (e.g., those populations remaining after old growth harvesting has ended), not to the current conditions which he believes are unlikely to be at equilibrium because of declining habitat. It is possible that high levels of population viability (i.e., low probabilities of extinction) could be achieved with an adequate amount and distribution of appropriately sized habitat areas, but the necessary population models and associated estimates of between-patch dispersal capable of assessing the effects of various geographic patterns of habitat areas on population viability are not available to address this issue.

b. Lande's Population Analysis

Lande's (1987a, 1988a) PVA is the first attempt at assessing the importance of the geographic structure of the habitat necessary for the persistence of the spotted owl. That is, it is a metapopulation model which is the appropriate form of model to be applied to populations whose habitats are patchily distributed across the landscape. However, his metapopulation analysis does not include all those sources of variation (demographic and environmental variability and natural catastrophes) that are thought to set the limit to the viability of small populations (Goodman 1987b, Shaffer 1987b). Thus, Lande's (1987a, 1988a) estimates of the proportion of remaining old growth necessary for the owl's survival are likely less than would be actually required if these forms of variability had been included in his PVA. Moreover, his model is only intended to assess the proportion of the regional landscape necessary for a species survival and cannot be used to assess the viability of specific configurations.

In our judgment, appropriate modifications of the structural features of both PVAs to increase their realism are likely to result in lower estimates of population survival for a given habitat management alternative. In other words, they are likely to require a larger amount of old-growth habitat to be managed for the owl in order to achieve a given probability of population survival.

2. Database Considerations

The impact of refinements to the database on projections of population viability are equivocal, depending on whether such refinements show higher or lower levels of survival and reproduction and the degree of variability in these parameters. Higher levels of survival and reproduction with limited variability would be expected to increase estimates of population viability. Conversely, lower rates of survival and reproduction, or higher levels of variability in these parameters, would be expected to lower current estimates of population viability. Nichols (1987), Boyce (1987), and Goodman (1987a) believed that the current estimates of survival and reproduction and the temporal variances of these quantities used in both models have either wide or unstated confidence intervals; that is, the true values of these variables are not well established owing to limited sample sizes. However, Soule (1987) and Wilcox (1987) feel further refinements to the database are unlikely to affect their overall judgment that the subspecies' future viability is precarious, at best. Presumably, this view is based on the reasoning that, although most estimates of survival and reproduction do have wide confidence intervals, there have been a sufficient number of studies indicating the same general pattern that it is unlikely more intensive work will greatly alter the current estimates.

Goodman (1987a) is of the opinion that neither the structure of the two PVAs done to date, nor the data they employ, are sufficiently realistic to make adequate projections of the subspecies' future viability under the various Forest Service management alternatives. In fact, he does not believe the current analyses or data are even sufficient to indicate whether more or less old-growth habitat would be required than that identified as the preferred alternative in the FSEIS or in Lande's PVA. Boyce (1987) seemed to share Goodman's view.

However, Goodman (1987a) clearly states that, model and data shortcomings aside, it is his judgment that the available information is sufficient to warrant listing the subspecies as threatened at this time, based on five factors: (1) current small population size; (2) very low reproductive rates; (3) extremely variable reproductive rates; (4) restriction to a particular habitat type; and (5) dietary dependence on the types of species (rodents) whose populations fluctuate substantially.

Both Boyce (explicitly) and Goodman (implicitly) stressed the importance of developing a PVA model or analysis with geographic structure as an absolute prerequisite for making adequate projections of population viability. They also stressed the importance of better estimates of the basic demographic parameters of survival and reproduction, the variances of these parameters, and the confidence intervals of the estimates.

3. <u>Genetic Considerations</u>

Lande's (1987a, 1988a) PVA does not deal with genetic issues in an explicit, quantitative manner. The Forest Service PVA attempts to do so, however, the treatment of genetic effects in the FSEIS is inappropriate for the five reasons discussed below.

(1). The isolation-by-distance correction for effective population size (N_e) is not an appropriate adjustment to N_e for the purposes of determining inbreeding coefficients and rate of loss of overall genetic variability of the population. Because detrimental genetic effects are inversely proportional to N_e, correct calculation of N_e is essential for predicting genetic effects (see Appendix A for definition of N_e).

(2). Inbreeding effects are more appropriately predicted by the magnitude of the per-generation increase in inbreeding coefficients, and not by the cumulative inbreeding coefficients (F) alone that are presented in Table B-21 of the FSEIS (USDA 1988).

(3). The criterion for genetic effects is based on the short-term viability concern about the immediate effects of inbreeding depression. The long-term genetic viability criterion for population sizes required to maintain sufficient genetic variation for continuing adaptation was not considered (see Appendix A, and Franklin 1980, Soule 1980). The long-term persistence and adaptability of populations of the owl is not addressed by the short-term criterion applied in the FSEIS.

(4). As discussed above, the demographic simulations did not incorporate any interactions with genetic factors, yet it is the generally reduced survival and reproduction of highly inbred organisms that is the basis for concern over this factor.

(5). Although Lande's (1987a, 1988a) PVA was a metapopulation model, the genetic effects of a fragmented population were not considered. With the continued fragmentation of habitat expected under proposed management alternatives, the importance of a metapopulation structure will become evident.

In our view, both the Forest Service PVA and Lande's analysis demonstrate a plausible risk of extinction for the northern spotted owl in the foreseeable future under current plans, at least in significant portions of its range. Our major concerns with these PVAs relate to certain simplistic assumptions in their structures and the accuracy of the data they employ. We feel that appropriate modifications to the PVAs to enhance their realism probably will result in lower estimates of population viability for any given dataset. We cannot predict the effect of further data, but we do note and wish to underscore that the current database is the product of numerous studies of the subspecies in various portions of its range conducted by a number of investigators over the past 10 to 15 years. Although sample sizes are often small, we find few inconsistencies in the data and results from one study to another.

B. Determining Requirements for Viability

Determining the precise amount and distribution of old-growth habitat necessary to confer a high probability of persistence to the spotted owl is a more difficult question than assessing whether or not the subspecies faces a real risk of extinction in the foreseeable future under current or proposed management regimes. However, neither the Forest Service PVA, Lande's analysis, nor the existing database are sufficient to specify both the amount and distribution of old growth necessary to assure, at a high level of probability, the subspecies' survival. This is not surprising in view of the fact that the existing PVAs rely on data generated from spotted owl studies intended to determine general life history parameters and habitat relationships useful in making forest management decisions, not for precise estimates of rangewide population trends or for PVA assessments. Research to date has not been designed or supported to fully characterize a PVA analysis, or even to determine population trend, rangewide.

We believe that an adequate determination of a viable spotted owl habitat network is possible, but will require, at a minimum, the following:

(1). Development of a stochastic PVA simulation model that can evaluate the effects of alternative geographic patterns of SOHA/SOMA number, size, and location on overall viability;

(2). Complete summary and analysis of all existing demographic data, including those contained in agency files and reports. This information could be used for initial testing and characterization of the model described above, which should assist in pinpointing critical information and data needs to be gathered through an intensified and focused research effort; and

(3). An intensified and well-coordinated research program that would provide statistically reliable estimates of the mean and variances of the basic demographic parameters (i.e., survival, reproduction, inter-patch dispersal, etc.) in relation to the variables of SOHA/SOMA number, size, quality, and location (under various management scenarios).

Because determination of some of the information outlined above may well require a certain level of habitat manipulation, there may be opportunities to coordinate and integrate certain timber harvesting activities with the type of research program we believe will be necessary to resolve the issue of habitat requirements for the subspecies. We also note from numerous suggestions in the body of information on this subspecies that the type or pattern of timber harvest may be as important as the volume of timber harvest in determining the fate of the subspecies. Therefore, we view research on the effects of silvicultural options on habitat suitability for the owl as an important component of any research program.

VII. Summary

The preceding sections represent a thorough analysis of the issues and questions that should lead to a better understanding of the northern spotted owl and its habitat. To summarize, our analysis shows that:

(1). Northern spotted owls demonstrate a strong preference for old-growth forests. These preferences have been shown by several measures: (a) at least 90 percent of the occupied sites where spotted owls have been observed contained predominantly old-growth stands; (b) owl densities were higher in old-growth stands than in younger stands; and (c) owls allocate a higher than expected proportion of their time foraging, nesting, and roosting in old-growth forests.

(2). Ecological theory and empirical data support the conclusion that old-growth forests, in the proper amount and juxtaposition, are essential to the continued existence of the northern spotted owl. Continued reduction and fragmentation of old-growth forest will adversely affect owl populations by forcing them to use less suitable habitats. Affected owls will likely have larger home ranges (as may be presently happening on the Olympic Peninsula and Coast Ranges), and modify their activity patterns to meet their energy and nutritional requirements. Such modifications of energy budgets (increase in foraging effort per unit of prey) may result in lower average reproductive rates for individual owls and the overall population of northern spotted owls.

(3). Current timber management policies and practices not only lead to the direct loss of preferred northern spotted owl habitat, but result in fragmentation of the remaining habitat. This is leading to increasingly smaller patches of remaining habitat and may lead to isolation of pairs of owls or local populations under current policies. This direct habitat loss and fragmentation may influence owl density, increase energy expenditure of remaining owls as the result of increased home range size, increase competition and predation, influence the probability of successful dispersal of young owls, and subject local populations to greater risks associated with random demographic, environmental, and genetic events.

(4). The preferred old-growth forest habitat of the northern spotted owl has declined from 70 to 80 percent from historical levels. The present range of the northern spotted owl closely matches the distribution of federally-managed forests, with over 90 percent of the known pairs of owls found within those forests. The subspecies has been effectively extirpated from most of the Puget Trough area, highly settled areas along Puget Sound and the Willamette Valley, and the Coast Ranges of southwestern Washington and northwestern Oregon. Under current plans, about 50 to 60 percent of the remaining preferred habitat will be gone by the middle of the next century (at a rate of about 1 to 2 percent per year). In certain areas, preferred and suitable habitat may be gone in less than 20 to 40 years (Olympic Peninsula and the central Oregon Coast Ranges). Remaining habitat will be fragmented and mostly scattered in reserved areas, parks, management areas (SOHAs/SOMAs), and areas unsuitable for timber management.

(5). Population surveys indicate that there are about 1,500 pairs of northern spotted owls within the present range; over 90 percent are found on federally-managed lands. Small populations and/or potentially isolated pairs of owls are found on the Olympic Peninsula, in the central and northern Oregon Coast Ranges, and in Marin County, California. The present population is predicted to decline by about 50 percent (on Forest Service lands) to 70 percent (BLM lands) from present levels over the next 50 to 60 years under current management plans. These estimates may be conservative, since they do not consider the impact of fragmentation and isolation on remaining pairs. Most remaining pairs will be found in reserved areas, parks, management areas (SOHAs/SOMAs), and areas unsuitable for timber harvest. These latter areas may not be as suitable for spotted owls as many present lands.

(6). Three types of evidence point to declines in northern spotted owl population size over time. Data on habitat changes and projections of future changes (as anticipated under current timber and spotted owl management plans) lead to the expectation of continued declines in spotted owl numbers as preferred habitat declines and is converted to young-age forest. Although precise estimates of rates of population change for specific areas do not exist, biologists studying spotted owls have reported declines in some areas that have been monitored over a number of years. Finally, when the best available estimates of spotted owl survival and reproductive rates are combined to compute asymptotic rates of increase, resulting values point to a declining population.

(7). The Forest Service and BLM both have adopted similar management planning policies to manage habitat for pairs of spotted owls. A network of selected spotted owl habitat or management areas (SOHA or SOMA) is being established by both agencies. However, it is unknown if the number of sites, allocated acreage of habitat per managed site, and juxtaposition of those sites will provide for the long-term population viability of the northern spotted owl. These plans are untested, flexibility in management options is unclear, and little or no allowance is made for long-term catastrophic environmental changes in habitat conditions that may impact small habitat patches.

(8). Two recent population viability analyses indicate that there is a plausible risk of extinction for the northern spotted owl in the foreseeable future, at least in significant portions of its range, under current habitat management planning. More realistic assessments are likely to produce even more pessimistic projections for the subspecies' viability. Weaknesses in the data base employed by both assessments are evident, but it is not clear how better data would affect current projections of viability. It is important to note that the data are the product of a variety of long-term efforts in various portions of the subspecies' range and that the overall results are uniformly suggestive of a current population that is declining.

The question of the usefulness of the data to determine the present and future status of the northern spotted owl was thoroughly reviewed during this process. Recent newspaper articles (Oregonian, Feb. 20, 1989) have speculated on the impact of radio transmitters used on spotted owls to collect research information, and on the validity of research data resulting from those studies. It is unknown if the reproductive rate of transmitter-equipped owls is lower than non-equipped owls; a few accidental deaths of radioed owls have been recorded. Radio transmitters used on spotted owls are within the weight guidelines specified by the Fish and Wildlife Service, and when the overall range of the subspecies is considered, we found no evidence that radio transmitters have caused a significant increase in mortality of juvenile owls. Neither is there any evidence that transmitter-equipped owls behave differently or utilize habitat differently than unmarked birds.

We did note insufficiencies in some of the available data. Most research projects have not been and are not presently structured to gather information specific to determining population trends nor, in most cases, to determining and testing various management strategies. In some cases, data were not reported in a fashion that readily allowed comparison with other data from similar studies. In addition, except for the various attempts at viability analyses, little effort has been made by any involved parties to fully analyze or interpret the considerable amount of data that is available for this species. However, we concluded that these problems did not hamper our ability to carry out an adequate review and analysis of the available information to assess the status of the northern spotted owl at this time. In our opinion, although there is always a need for more information, more is known about the northern spotted owl than many other wildlife species, and certainly more than for most species considered for listing under the Endangered Species Act. In addition, we note that our conclusions are consistent with the interpretations and conclusions presented over the past few years by others knowledgeable with the northern spotted owl and population assessments.

Furthermore, we note that a remarkable feature of the results of various and numerous studies on the owl is their consistency and congruity, not only from year to year but between studies as well. Wildlife researchers often are skeptical of one another's hypotheses, assumptions, methods, and conclusions. However, we note that the unanimity of the community of researchers involved with spotted owl investigation is all the more remarkable because the researchers represent a variety of agencies, universities, and organizations. Methodologies used in spotted owl investigations often incorporate the latest techniques available to wildlife ecologists: e.g., radio-telemetry (ground and aerial); population modeling; population viability analysis; and geographical information system analysis. The interpretation of the status of the northern spotted owl has and will continue to be benefited by the appropriate application of these data acquisition and analysis techniques. In addition, emphasis on habitat mapping and data analyses, using many of these techniques, will greatly assist in determining future habitat and population management techniques, provided these and future studies are directed toward answering these types of questions in a timely manner. We want to emphasize that considerable opportunities may exist within the presently accumulated database to further investigate not only a variety of management options, but also to review the relationship between various timber management practices and spotted owls and their habitat.

VIII. REFERENCES CITED

Allen, H.L. 1988. What's happening to spotted owls in Washington? Why were they listed as endangered? Presentation at Wildlife Commission meeting, State of Washington, Jan. 15, 1988.

Allen, H.L., and L.W. Brewer. 1985. A review of current northern spotted owl (<u>Strix</u> <u>occidentalis</u> <u>caurina</u>) research in Washington State. Pp. 55 to 57. <u>In</u> R.J. Gutierrez and A.B. Carey, tech. eds. Ecology and management of the spotted owl in the pacific Northwest. USDA Forest Service. Gen. Tech. Rept. PNW-185.

Allen, H.L., T. Hamer, and L.W. Brewer. 1985. Range overlap of the spotted owl (<u>Strix</u> <u>occidentalis</u> <u>caurina</u>) and the barred owl (<u>Strix</u> <u>varia</u>) in Washington and implications for the future. <u>In</u> Raptor Research Foundation Symposium on the Management of Birds of Prey, Session 11: The biology, status, and management of owls. November 9 to 10, 1985, Sacramento, CA (Abstr.).

Allen, H.L. and K. Dixon, K.E. Knutsen, and A.E. Potter. 1987. Cooperative administrative study to monitor spotted owl management areas in National Forests in Washington; progress rept. no. 3. Washington Dept. of Wildlife.

Anthony, R.G., D.K. Rosenberg, D. DellaSalla, S.H. Desimone, B.C. Latta, R.S. Lutz. 1988. Patterns of distribution and abundance of small mammals in old- and second-growth forests in the Oregon Cascades. Unpub. rept. Oregon State Univ. Corvallis, OR.

Barrows, C.W. 1981. Summer roost selection by spotted owls: and adaptation to heat stress. Condor 83:302-309.

Barrows, C.W., and K. Barrows. 1978. Roost characteristics and behavioral thermoregulation in the spotted owl. Western Birds 9(1):1-8.

Beuter, J.H., K.N. Johnson, and H.L. Scheurman. 1976. Timber for Oregon's tomorrow, an analysis of reasonably possible occurrences. Res. Bull. 19. Oregon State University. Corvallis, OR.

Bontadelli, P. 1989. California Dept. of Fish and Game. Ltr. dated Feb. 27, 1989, to M. Plenert, Fish and Wildlife Service, Portland, OR. 3p.

Boyce, M.S. 1987. A review of the U.S. Forest Service's viability analysis for the spotted owl report for the National Council of the Paper Industry for Air and Stream Improvement. Unpub. Rept. 50p.

Brown, E. (ed.) 1985. Management of wildlife and fish habitat in forests of Western Oregon and Washington. No. RG-FGWL-192-1985. USDA Forest Service. Portland, Ore. 332p.

Brown, J.H. 1984. On the relationship between abundance and distribution of species. Amer. Natur. 124(2):255-279.

California Dept. of Forestry and Fire Protection. 1988. California's Forests and Rangelands: Growing Conflict over Changing Uses. Calif. Dept. Forestry and Fire Protection. Sacramento, CA. 348p.

Carey, A.B. 1985. A summary of the scientific basis for spotted owl management. Pp. 100-114. In R.J. Gutierrez and A.B. Carey, tech. eds. Ecology and management of the spotted owl in the Pacific Northwest. USDA Forest Service. Gen. Tech. Rept. PNW-185.

Cody, M.L. 1985. An introduction to the habitat selection in birds. Pp. 4-58 In: Cody, M.L. (Ed.), Habitat selection in birds. Academic Press, Inc. New York.

Dawson, W.R., J.D. Ligon, J.R. Murphy, J.P. Myers, D. Simberloff, and J. Berner. 1986. Report of the the advisory panel on the spotted owl. Audubon Conservation Report No. 7. National Audubon Society. New York.

Ewens, W.J. 1989. The effective population sizes in the presence of catastrophes. Pp. 9-25 In M.W. Feldman (ed.), Mathematical Evolutionary Theory. Princeton University Press, Princeton, N.J.

Forsman, E.D. 1976. A preliminary investigation of the spotted owl in Oregon. M.S. Thesis. Oregon State Univ. Corvallis, OR. 127p.

Forsman, E.D. 1980a. Habitat utilization by spotted owls in the west central Cascades of Oregon. PhD. Thesis, Oregon State Univ., Corvalis, OR.

Forsman, E.D. 1980b. Habitat utilization by spotted owls on the Eugene District of the Bureau of Land Management. Unpub. ms.

Forsman, E.D., and E.C. Meslow. 1985. Old-growth forest retention for spotted owls, how much do they need? Pp. 58-59. In R.J. Gutierrez and A.B. Carey, eds. Ecology and management of the spotted owl in the Pacific Northwest. USDA Forest Service. Gen. Tech. Rep. PNW-185.

Forsman, E.D. 1986. Spotted owls in young forests - additional surveys in the northern Coast Range of Oregon. Unpub. rept.

Forsman, E., and E.C. Meslow. 1986. The spotted owl. Pp. 743-761. In A.S. Eno, R.L. DiSilvestro, and W.S. Chandler. Audubon Wildlife Rept. 1986. National Audubon Society, New York, NY, USA.

Forsman, E.D. , E.C. Meslow, and M.J.Strub. 1977. Spotted owl abundance in young versus old-growth forests, Oregon. Wildl. Soc. Bull. 5(2): 43-47.

Forsman, E.D., E.C. Meslow, and H.M. Wight. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monograph No. 87.

Forsman, E,D., C.R. Bruce, M.A. Walter, and E.C. Meslow. 1987. A current assessment of the spotted owl population in Oregon. Murrelet 68:51-54.

Fox, L. 1988. A classification, map, and volume estimate for the coast redwood forest in California. Final Report. Calif. Dept. Forestry and Fire Protection. Sacramento, CA. 42p.

Franklin, A., and R.J. Gutierrez. 1987. Population strategy of the northern spotted owl in northern California: A demographic and empirical analysis. Unpub. progress rept.

Franklin, A.B., and R.J. Gutierrez. 1988. Population ecology of the northern spotted owl in northwest California: preliminary results. 1987 Progress rept. Calif. Dept. Fish and Game. Sacramento, CA. 27p.

Franklin, A., J.P. Ward, and R.J. Gutierrez. 1987. Population ecology of the northern spotted owl (Strix occidentalis caurina) in northern California: preliminary results. 1986 Progress rept. No. W-65-R-3(544). California Dept. Fish and Game, Sacramento, CA. 29p.

Franklin, A.B., J.A. Blakesley, and R.J. Gutierrez. 1989. Population ecology of the northern spotted owl in northwest California: preliminary results. 1988 Progress rept. Calif. Dept. Fish and Game. Sacramento, CA. 30p.

Franklin, I. R. 1980. Evolutionary change in small populations. Pp. 135-149 in M. E. Soule and B. A. Wilcox (Eds.), Conservation Biology; An Evolutionary-Ecological Perspective. Sinauer Assoc., Sunderland, Mass.

Franklin, J.F. and R.T.T. Forman. 1987. Creating landscape patterns by forest cutting: Ecological consequences and principles. Landscape Ecol. 1(1):5-18.

Franklin, J.F., and T.A. Spies. 1984. Characteristics of old-growth Douglas fir forests. Pp. 328-334 In: New forests for a changing world. Soc. of Am. Foresters. Bethesda, Md.

Fretwell, S.D. 1972. Populations in a seasonal environment. Princeton Univ. Press, Princeton.

Fretwell, S.D., and H.L. Lucas, Jr. 1969. On territorial behavior and other factors influencing habitat distribution in birds. I. Theoretical development. Acta Theoretica 19(1):16-36.

Friesen, C.A. and E.C. Meslow. 1988. Home range size and habitat utilization of northern spotted owls in the Eugene BLM District, Oregon. Progress report supplement No. PNW 86-340. Oregon State Univ., Corvallis, OR. 10+p.

Garcia, E.R. 1979. A survey of the spotted owl in Washington. In P.O. Schaeffer and S.M. Ehlers, eds. Owls of the west, their ecology and conservation. National Audubon Soc., Western Education Center, Tiburon, CA. 97p.

Ganey, J.L. 1988. Distribution and habitat ecology of Mexican spotted owls in Arizona. MS thesis. Northern Arizona Univ.

Gilpin, M.E. 1987. Spatial structure and population vulnerability. Pp. 125-141 in M.E. Soule (ed.) Viable Population Conservation. Cambridge Univ.

Press, Cambridge.

Gilpin, M.E. and M. Soule. 1986. Minimum Viable Populations: The process of species extinctions. Pp. 13-34. In M.E. Soule (ed.) Conservation Biology: The Science of scarcity and diversity. Sinauer Associates, Sunderland, Mass.

Goodman, D. 1987a. Comments on the viability analyses for the spotted owl. Commissioned review for U.S. Fish and Wildlife Service. 11p.

Goodman, D. 1987b. The demography of chance extinction. Pp. 11-35. In M.E. Soule (ed.) Viable Populations for Conservation. Cambridge Univ. Press, Cambridge.

Gould, G.I., Jr. 1974. The status of the spotted owl in California. California Dept. Fish and Game, Sacramento, CA Rept. No. 74-6. 56p.

Gould, G.I., Jr. 1975. Habitat requirements of the spotted owl in California. California/Nevada Wildlife Trans. 102-117.

Gould, G.I., Jr. 1977. Distribution of the spotted owl in California. Western Birds 8:131-146.

Gould, G.I., Jr. 1979. Status and management of elf and spotted owls in California. Pp. 86-97. In P.P. Schaeffer and S.M. Ehlers, eds. Symposium on owls of the west, their ecology and conservation. National Audubon Soc., Western Education Center, Tiburon, CA. 97p.

Gould, G.T. 1985. Management of spotted owls by The California Dept. of Fish and Game. Pp. 21-26. In R.J. Gutierrez and A.B. Carey (eds.) Ecology and Management of the Spotted Owl in the Pacific NW. Gen. Tech. Rept. PNW-185. USDA Forest Service, Portland, OR

Green, K. 1985. The old growth redwood resources an historical overview of harvesting and preservation. Unpub. rept. prepared for U.S. Dept. Justice, Wash., D.C. 32p.

Greene, S. 1988. Research natural areas and protecting old-growth forests on federal lands in western Oregon and Washington. Nat. Areas J. 8(1):25-30.

Gutierrez, R., D.M. Solis, and C. Sisco. 1984. Habitat ecology of the spotted owl in northwestern California: implications for management. In New Forests for a Changing World, Proc. of 1983 Soc. Amer. For. Nat. Conv., Portland, OR.

Gutierrez, R., A.B. Franklin, W. Lahaye, V.J. Meretsky, J.P. Ward. 1985. Juvenile spotted owl dispersal in northwestern California: preliminary results. Pp. 60-65. In R.J. Gutierrez and A.B. Carey, tech. eds. Ecology and management of the spotted owl in the Pacific Northwest. USDA Forest Service Gen. Tech. Rept. PNW-185.

Gutierrez, R. and D. Call. 1988. Home-range size and use by California spotted owls on the Tahoe National Forest. Final rept. Humboldt State

Univ. Arcata, CA. 26p.

Hamer, T.E. 1988. Home range size of the northern barred owl and northern spotted owl in western Washington. MS thesis. Western Washington Univ.

Hamer, T.E. 1989. USDA Forest Service. Ltr. to B. Mulder, Fish and Wildlife Service, Portland, 7p.

Hamer, T.E. and F.B. Samson. 1987. Interspecific competition between barred owls and spotted owls in western Washington. Presented at Raptor Res. Symp. Intern. Meeting. Oct. 28-31, 1987. Boise, ID.

Harris, L.D. 1984. The Fragmented Forest. Univ. of Chicago Press. 211p.

Harris, L.D., C. Maser, and A. McKee. 1982. Patterns of old growth harvest and implications for Cascades wildlife. Trans. N. Am. Wildl. Nat. Res. Conf. 47:374-92.

Haynes, R.W. 1986. Inventory and value of old-growth in the Douglas-fir region. USDA Forest Service. Pac. NW Res. Stat. Res. Note PNW-437. Portland, OR.

Heinrichs, J. 1983. The winged snail darter. J. Forestry 81(4):212-215.

Irwin, L. 1986. Ecology of the Spotted Owl in Oregon and Washington. Technical Bulletin No. 509. National Council of the Paper Industry for Air and Stream Improvement (NCASI). 58p.

Irwin, L. 1987. Information for consideration by U.S. Fish and Wildlife Service for status review. Unpub. rept. for NCASI. Corvallis, OR.

Irwin, L., T.L. Fleming, and S.M. Speich. 1988. Spotted owl presence and habitat components in younger forests of southwestern Washington. Unpub. rept. for NCASI. Corvallis, OR.

Irwin, L., T.L. Fleming, S.M. Speich, and J. Buchanan. 1989a. Spotted Owl Presence in Managed Forests of Washington. Unpub. rept. for NCASI, Corvallis, OR. 14p.

Irwin, L., J. Buchanan, E. McCutcheon, and C. Phillips. 1989b. Characteristics of spotted owl nest sites in the Wenatchee National Forest. Unpub. rept. for NCASI. Corvallis, OR.

Juelson, T. 1985. Managing northern spotted owls in Washington: the position of the Washington Dept. of Game. Pp. 31-33. In R.J. Gutierrez and A.B. Carey (ed.s) Ecology and management of the spotted owl in the Pacific Northwest. USDA Forest Service. Gen. Tech. Rep. PNW-185.

Juelson, T. 1989. Washington Dept. of Wildlife. Ltr. dated Feb. 28, 1989, to B. Mulder, Fish and Wildlife Service. 1+p.

Kerns, S.J. 1988. Observations of wildlife diversity on lands of the Pacific Lumber Company. Prel. draft rept. for Pacific Lumber Co. Scotia, CA.

Lande, R. 1987a. Demographic models of the northern spotted owl. The University of Chicago, Dept. of Biology, Chicago, IL. Unpub. rept.

Lande, R. 1987b. Extinction thresholds in demographic models of territorial populations. American Naturalist 130:624-635.

Lande, R. 1988a. Demographic models of the northern spotted owl (Strix occidentalis caurina). Oecologia 75:601-607.

Lande, R. 1988b. Genetics and demography in biological conservation. Science 241:1455-1460.

Lande, R. and G.F. Barrowclough. 1987. Pp. 86-123. In M.E. Soule (ed.), Viable Populations for Conservation. Cambridge Univ. Press, Cambridge.

Laudenslayer. W.F. 1985. Candidate old growth on national forest system administered lands in California since the initiation of National Forest Management. Unpub. Rept. USDA Forest Service. 16p.

Laymon, S.A., H. Salwasser, and R.H. Barrett. 1985. Habitat suitability Index Models: Spotted Owls. Bio. Rept. 82(10:113). U.S. Fish and Wildlife Service.

Lidicker, W.Z. 1975. The role of dispersal in the demography of small mammals. Pp. 103-128. In: Golley, F.B., K. Petusewicz, and L. Ryszkowski (eds.), Small mammals: Their productivity and population dynamics. Cambridge Univ. Press, New York.

Lundberg, A., R.V. Alatalo, A. Carlson, and S. Ulfstrand. 1981. Biometry, habitat distribution and breeding success in the pied flycatcher (Ficedula hypoleuca). Ornis Scand. 12:68-79.

Marcot, B.G. 1987. Data used to compute home range sizes. USDA Forest Service. Portland, OR.

Marcot, B.G. 1988a. Documentation of Procedure for estimating capability of habitat to support breeding pairs of spotted owls. Unpub. draft rept. USDA Forest Service, Portland, OR. 16p.

Marcot, B.G. 1988b. USDA Forest Service. Memo dated July 27, 1988, to H. Black. USDA Forest Service. Portland. 8p.

Marcot, B.G. 1988c. Documentation of distribution of suitable spotted owl habitat in key locations in Region 6. Unpub. draft rept. USDA Forest Service. Portland, OR.

Marcot, B.G., and J. Gardetto. 1980. Status of the spotted owl in Six Rivers National Forest, California. Western Birds 11(2):79-87.

Marcot, B.G., and R, Holthausen. 1987. Analyzing population viability of the spotted owl in the Pacific northwest. Trans. Fifty Second N.Am. Wild. and Nat. Res. Conf.

Maruyama, T., and M. Kimura. 1980. Genetic variability and effective population size when local extinction and recolonization of subpopulations are frequent. Proc. Natl. Acad. Sci. U.S.A. 77:6710-6714.

Meslow, E.C., C. Maser, and J. Verner. 1981. Old-growth forests as wildlife habitat. Trans. N. Am. Wildl. Nat. Res. Conf. 46:329-334.

Meslow, E.C., K. Nickell, and R. Hause. 1986. Spotted owls on harvested areas: adult monitoring program. Unpub. ms. for Bureau of Land Management.

Miller, G.S. 1989. Dispersal of juvenile northern spotted owls in western Oregon. MS thesis. Oregon State Univ., Corvallis, OR.

Miller, G.S. and E.C. Meslow. 1986. Dispersal of juvenile northern spotted owls in the Pacific Northwest Douglas-fir Region. Unpub. progress rept. (1982-1985). 45p.

Miller, G.S., and E.C. Meslow. 1988. The ecology of spotted owls in the central Cascades, western Oregon. Ann. Rept. Oregon State Univ., Corvallis, OR. 45p.

Moller, A.P. 1982. Characteristics of magpie (Pica pica) territories of varying duration. Ornis Scand. 13:94-100.

Morrison, P.H. 1988. Old Growth in the Pacific Northwest: A Status Report. The Wilderness Society. Washington, D.C. 46 p.

Morrison, P.H. 1989. An analysis of northern spotted owl habitat in six National Forests of the Pacific Northwest. Unpub. Rept. Wilderness Sec., Seattle, WA. 9p.

Neal, D.L, J. Verner, G.N. Steger, and G.P. Eberlein. A study of spotted owl home range size and composition in the Sierra National Forest. Ann. Prog. Rept. USDA Forest Service. Pac. SW Forest and Range Exp. Stat., Fresno, CA. 9+p.

Nichols, J. 1987. Fish and Wildlife Service, Memo of Nov. 3, 1987 to M. Shaffer, Fish and Wildlife Service. Washington, DC

Nilsson, S.G. 1976. Habitat, territory size, and reproductive success in the nuthatch (Sitta europaea). Ornis Scand. 7:179-184.

Noon, B.R. and C.M. Biles. (in review) The Mathematical demography of the spotted owl in the Pacific Northwest. Ms. submitted to J. Wildl. Man. 38+p.

Norse, E.A. 1988. Sustaining biological diversity and timber production in a changing world. Unpub. draft. rept. Wilderness Society. Washington, DC. 8p.

O'Connor, R.J. 1986. Dynamical aspects of avian habitat use. Pp. 235-240 in J. Verner, ed. Wildlife 2000: Modeling habitat relationships of terrestrial vertebrates.

Old-Growth Definition Task Group. 1986. Interim definitions for old-growth. Douglas-Fir and mixed-conifer forests in the Pacific Northwest and California. Pac. NW Res. Stat.. Res. Note PNW-447. Portland, OR. 7p.

Oregonian. 1989. Article titled: Radio transmitters on spotted owls may kill them, say some researchers. Feb. 20, 1989. Portland, OR.

Palmer, C. 1989. Yakima Indian Nation, Ltr. dated Feb. 27, 1989 to B. Mulder, Fish and Wildlife Service. Washington. 8p.

Postovit, H.R. 1977. A survey of the spotted owl in northwest Washington. National Forest Products Association, Washington, DC. Unpub. rept.

Pulliam, H.R. 1989. Sources, sinks, and population regulation. Unpub. ms. Department of Zoology and Institute of Ecology, University of Georgia, Athens, GA.

Reid, J., S. Horton, and A. Carey. 1987. Old-growth forests wildlife research in the Coast Range: Spotted owl habitat use in the Oregon Coast Range. Prog. Rept. 1987. USDA Forest Service, Pac. NW Res. Stat.

Robertson, F.D. 1989. USDA Forest Service. Ltr. dated Feb. 27, 1989 to M. Plenert, Fish and Wildlife Service. Portland, OR. 3+p.

Robertson, R.J. 1972. Optimal niche space of the red-winged blackbird (Agebius phoenicius). I. Nesting success in marsh and upland habitat. Can. J. Zoology 50:247-263.

Rosenberg, D. and R.G. Anthony. 1989. Oregon State Univ. Ltr. dated Feb. 20, 1989 to B. Mulder, Fish and Wildlife Service. 1p.

Ruediger, W.C. 1985. Implementing a spotted owl management plan: the Gifford Pinchot National Forest experience. Pp. 10-13. In R.J. Gutierrez and A.B. Carey, tech. eds. Ecology and management of the spotted owl in the pacific Northwest. USDA Forest Service. Gen. Tech. Rep. PNW-185.

Ruggiero, L.F., R.S. Holthausen, B.G. Marcot, K.B. Aubry, J.W. Thomas, and E. C. Meslow. 1988. Ecological dependency: The concept and its implications for research and management. Trans. 53rd N.A. Wildl. and Nat. Res. Conf.

Shaffer, M.L. 1981. Minimum population sizes for species conservation. Bioscience 31:131-4.

Shaffer, M.L. 1985. The metapopulation and species conservation: the special care of the northern spotted owl. Pp. 86-99. In R. J. Gutierrez and A.B. Carey (eds.) Ecology and Management of the Spotted Owl in the Pacific Northwest. Gen. Tech. Rep. PNW-185. USDA Forest Service, Portland, OR.

Shaffer, M.L. 1987a. Assessment of population viability projections for the northern spotted owl. Unpub. rept. for the U.S. Fish and Wildlife Service, Portland, OR. 29p.

Shaffer, M.L. 1987b. Minimum viable population: Coping with uncertainty. Pp. 69-87. In M.E. Soule (ed.) Viable Populations for Conservation. Cambridge Univ. Press, Cambridge.

Simberloff, D. 1987. The spotted owl fracas: mixing academic, applied, and political ecology. Ecology 68:766-772.

Sisco, C. and R. Gutierrez. 1984. Winter ecology of radio-tagged spotted owls on Six Rivers National Forest. Humboldt County, Calif. USDA Forest Service, Six Rivers National Forest, Eureka, CA. 139p. (unpub. rept.)

Society of American Foresters Task Force. 1983. Report of the SAF Task Force on scheduling the harvest of old-growth timber, Am. Foresters. 38p.

Solis, D.M. 1983. Summer habitat ecology of spotted owls in northwestern Washington. M.S. Thesis. Humboldt State Univ., Arcata, CA.

Solis, D.M., and R.J. Gutierrez. 1982. Spotted owl habitat use on Six Rivers National Forest, Humboldt County, California. USDA Forest Service, Six Rivers National Forest, Eureka, CA. 230p. (Unpub. rept.)

Soule, M. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pp. 151-169. In M. E. Soule and B. A. Wilcox (eds.), Conservation Biology: An Evolutionary-Ecological Perspective. Sinauer Assoc., Sunderland, MA.

Soule, M. 1987. Univ. of Michigan. Ltr. of Nov. 1, 1987 to M. Shaffer, Fish and Wildlife Service.

Spies, T.A., and J.F. Franklin. 1988. Old-growth and forest dynamics in the Douglas-fir region of western Oregon and Washington. Nat. Areas. J. 8(3):190-201.

Spotted Owl Subcommittee of the Oregon/Washington Interagency Wildlife Committee. 1988. Interagency management guidelines for the northern spotted owl in Washington, Oregon, and California. Unpub. draft rept. 16+p.

Stjernberg, T. 1979. Breeding biology and population dynamics of the scarlet redfinch (Carpodacas erythrinus). Acta. Zool. Fenn. 15:71-88.

Tilghman, N.G. and P.W.C. Paton. 1988. Examination of home range size and habitat use of the spotted owl in the Klamath Province. Prog. Rept. USDA Forest Service. Pac. SW Forest and Range Exp. Station. Arcata, CA. 31+p.

Thomas, J.W., L.R. Ruggiero, R.W. Mannon, J.W. Schoen, and R.A. Lanca. 1988. Management and conservation of old-growth forests in the United States. Wildl. Soc. Bull. 16:252-262.

U.S. Department of Agriculture. 1986. Draft supplement to the environmental impact statement for an amendment to the Pacific Northwest Regional Guide. Vols. 1 and 2. USDA Forest Service, Portland, OR.

U.S. Department of Agriculture. 1988. Final supplement to the environmental impact statement for an amendment to the Pacific Northwest Regional Guide. Vols. 1 and 2. USDA Forest Service, Portland, OR.

U.S. Department of Interior. 1984. Timber management for the 1980's. Bureau of Land Management. 24p.

U.S. Department of the Interior. 1987a. The northern spotted owl status review. Fish and Wildlife Service. Portland, OR. 47p.

U.S. Department of Interior. 1987b. 12-month petition finding. Memo dated Dec. 17, 1987 from Regional Director, Region 1, to Director, Fish and Wildlife Service. 5p.

U.S. Department of Interior. 1987c. Northern spotted owl analysis (draft rept.). Bureau of Land Management. Portland, OR.

U.S. Department of Interior. 1987d. Spotted owl Environmental Assessment. Bureau of Land Management, Portland, OR.

U.S. Department of the Interior. 1988. Interagency agreement dated Aug. 12, 1988 between Fish and Wildlife Service, Forest Service, Bureau of Land Management, and National Park Service. 3p.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. J. Wildl. Manage. 47(4):893-901.

Vetterick, P.W. 1989. Bureau of Land Management. Ltr. dated Feb. 28, 1989 to M. Plenert, Fish and Wildlife Service. Portland, OR. 2+p.

Wagner, F.F., and E.C. Meslow. 1988. Spotted owl monitoring: Medford segment, Miller Mountain study area. Prog. Rept. PNW-86-390. Pac. NW Res. Stat., Corvallis, OR.

Ward, J.P., and R.J. Gutierrez. 1989. Spotted owl reproduction and prey abundance in northwest California: Pilot study, 1987. Unpub. rept. Dept. Wildlife, Humboldt State Univ., Arcata, CA.

Washington Dept. of Wildlife. 1988. Olympic Peninsula Overview. Unpub. rept. 11p.

Wilcox, B. 1987. Stanford Univ. Ltr. of Nov. 23, 1987 to M. Shaffer.

Wilderness Society. 1988. End of the ancient forests: Special report on National Forest plans in the Pacific Northwest. Wilderness Society, Washington, DC. 57+p.

Personal Communications Cited:

Bonn, D. Bureau of Land Management. Medford, OR
Bruce, C. OR Dept. of Fish and Wildlife, Corvallis, OR
Carey, A. USDA Forest Service, Pac. NW Res. Stat., Olympia, WA
Decker, J. Bureau of Land Management, Arcata, CA
Foisy, B., Bureau of Land Management, Coos Bay, OR
Forsman, E. USDA Forest Service, Pac. NW Res. Stat., Olympia, WA
Franklin, A. Humboldt State Univ., Arcata, CA
Gould, G. Calif. Dept. Fish and Game, Sacramento, CA
Gunderson, G., USDA Forest Service, Portland, OR
Hamer, T. USDA Forest Service, Mt. Baker-Snoqualmie National Forest, WA
Larson, J. Nat. Park Service, Seattle, WA
Lint, J. Bureau of Land Management, Roseburg. OR
Logan, W. Bureau of Land Management, Salem, OR
Mays, K. USDA Forest Service, Portland, OR
Meslow, E.C. Fish and Wildlife Service, Oregon State Univ., Corvallis, OR
Moorhead, B. Nat. Park Service, Olympic National Park, WA
Neitro, B. Bureau of Land Management, Portland, OR
O'Halloran, K. USDA Forest Service, Portland, OR
Potter, A. WA Dept. of Wildlife, Olympia, WA
Simon-Jackson, T. USDA Forest Service, San Francisco, CA
Smithey, D. Bureau of Land Management, Coos Bay, OR
Thomas, C. Bureau of Land Management, Eugene, OR
Winson, E., Bureau of Indian Affairs, CA

IX. APPENDIX A: Genetics of Isolated and Fragmented Populations

When the overall range of a species becomes effectively subdivided by barriers to dispersal, it is more appropriate to assess the genetic and demographic viability of each individual population separately, rather than use the total size of the combined populations to assess genetic viability. Although it is recognized that demographic consequences of demographic and environmental variability are usually of more immediate concern than genetic factors (Dawson, et al. 1986, Lande, 1988b), the current sizes of some potentially isolated populations of the northern spotted owl are probably small enough for genetic effects to be of concern.

The Olympic Peninsula population of the spotted owl may already be genetically isolated from other populations. In addition, the other barriers to genetic exchange recognized in the FSEIS and in this report have the potential to effectively isolate other portions of the northern spotted owl's range. Provisions to link the potentially isolated populations will provide, at best, only very tenuous connections, so that isolation and the loss of genetic viability of the isolated populations must be considered at least a potential threat.

If the Columbia River corridor and the Interstate 5 corridor near Medford, Oregon, are or were to become effective barriers to genetic continuity, then owl populations in each physiographic province in Washington and Oregon would became genetically isolated. The Washington Cascades and the Oregon Cascades each have the potential to be subdivided by the Snoqualmie Pass and the Santiam Pass corridors, respectively. Great caution must be used when inferring from measured dispersal distances of spotted owls the ability of owls to genetically bridge these gaps. Owls must not only disperse across a gap, but must subsequently breed and rear viable offspring for the gap to have been successfully bridged in genetic terms. Average dispersal distances resulting in actual gene flow may, therefore, be somewhat less than current averages of measured dispersal distances.

The present numbers of owl pairs in the Olympic, Washington Cascade, and Oregon Coastal populations, if each is treated as an isolated population, are already low enough for concern about their long-term genetic viability. Population sizes of the Oregon Cascades and Klamath Mountains (Oregon and California portions combined) approach the several hundreds of individuals desired for genetic viability (Lande and Barrowclough 1987), although genetic viability of the Oregon Cascade population may be dependent on continued gene flow across the Santiam Pass corridor, which is a potential barrier. There is still reason for some concern about population sizes in each of the last three provinces, even if they remain at about their present levels.

The above discussion is intended to describe the actual and potential threats of isolation to long-term genetic viability. The population levels desirable to maintain genetic viability are probably much lower than those required for overall population viability because: (1) the relationship of field-measured population sizes to effective population sizes (N_e)[1] is uncertain, and present estimates of that relationship are likely to result in overestimates of current and future effective population sizes; (2) viable population sizes

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[1] The effective population size (N_e) is the size of an ideal population that has the same rate increase in inbreeding through genetic drift as some real population under consideration (Lande and Barrowclough 1987). N_e can be estimated for a population from the census number of breeding adults by using corrections based on sex ratio, fluctuations in population size over time, and variation in individual reproductive contributions. The effective population size is extremely important because it permits the estimation of the rate at which genetic variability is lost from a population.

that account for environmental and demographic variability are larger than those required for genetic viability alone; and (3) other threats, such as those presented by habitat occupancy patterns (Lande 1988a), are not considered.

Such effects are difficult to model for a given species because of: (1) the highly variable susceptibility of different species to inbreeding depression; (2) the precise relationship between levels or rates of inbreeding and fitness is not known; and (3) because of the difficulty in predicting the effects of selection. The northern spotted owl was probably, before significant fragmentation of its range, a widespread, outbreeding species with little history of inbreeding. Such species have been found to be more likely than others to experience inbreeding effects when forced by isolation and small population sizes to inbreed. Evaluation of possible inbreeding effects is essential in such species. Although models that integrate genetics with demography present difficulties that require further research, it must be recognized that demographic simulations and projections that do not take genetic influences into account will be optimistic, especially as population sizes become smaller.

Fragmentation can also have harmful genetic consequences through its effect on the effective population size (N_e). A population comprised of discrete habitat patches, such as those that result from fragmentation, is termed a "metapopulation," and the processes of extinction and re-colonization of individual patches can have deleterious genetic effects that might not be predicted by models that do not consider metapopulation structure (Maruyana and Kimura 1980, Ewens 1989).

A small subpopulation occupying a patch has a finite probability of extinction. If such a population were to become extirpated, there is likely to be a lag period between the time of this local extinction to the time colonizing individuals from other patches disperse to and re-establish a breeding population on that patch, if those patches still exist and can be located. When subpopulation extinction and recolonization of patches are frequent, the effective population size for the overall population is usually reduced compared to that expected when a population comprises individuals that are assumed to be mating at random and is continuously distributed (Maruyama and Kimura 1980, Ewens 1989). As a consequence of a reduction in effective population size, metapopulation structure is likely to accelerate the expected rate of loss of genetic variation from the total population.

Given the inescapable fragmentation of owl population into subpopulations, the effect of the "metapopulation" structure on overall (N_e) and genetic variability must be considered. If blocks of SOHAs/SOMAs become isolated from one another so that metapopulation effects become significant, the outlook for maintaining genetic viability would be less optimistic than presented in this paper or the FSEIS.

APPENDIX B: <u>Errata Sheet for 1987 Status Review</u>

1. p. 5, para. 1, line 6: change "range 40 to 68" to "range 49 to 67"

2. p. 5, para. 1, line 11: change "1985" to "1986"

3. p. 7, para. 1, line 4: delete "clutch or"

4. p. 7, para. 3, line 3: change "individuals" to "pairs"

5. p. 7, para. 3, line 3: change "es" to "where the female was"

6. p. 7, para. 3, line 4" change "1986" to 1987"*

7. p. 7, para. 3, line 5: change "subadult/adult pairs" to "paired subadult/female"

8. p. 7, para. 3, line 6: change "adult pairs" to "paired adult females"

9. p. 7, para. 3, line 7: change "adult pairs" to "females"

10. p. 7, para. 3, line 8: change "adults" to "adult females"

11. p. 8, para. 1, line 3: change "estimated longevity" to "an estimated longevity of 25 years"

12. p. 8, para. 2, line 11: change "is age dependent" to "may be age dependent"

13. p. 8, para. 3, line 5: change "males" to "males versus females"

14. p. 9, para. 5, line 8: change "only 3" to "only 7"

15. p. 9, para. 5, line 8: change "6 were" to "4 were"

16. p. 9, para. 5, line 9: change "Meslow and Miller" to "Miller and Meslow"

17. p. 13, para. 4, line 3: delete "Irwin pers. comm"

18. p. 18, para. 4, line 3: delete (the first) "1987"

19. p. 20, para. 5, line 1: change "eight spotted owls at six locations" to "nine spotted owls at three locations"

20. p. 20, para. 5, line 2: delete "and three subadults"

21. p. 23, para. 3, line 6: change "65" to "68" and change "2" to "3"

22. p. 24, para. 3, line 8: add "under the Forest Service's preferred alternative." to sentence ending in "...extinct."

23. p. 27, para. 3, line 2: change "during 1984" to "during the period from 1973 through 1984"

24. p. 30, para. 3, line 2: change "80" to "70"

25. p. 31, para. 2, line 3: change "habitat" to "habitat areas"

26. p. 34, para. 8, line 2: change "and its habitat. Implementation..." to "and/or its habitat. Generally, State Laws do not protect the owls owls' habitat. Implementation..."

27. p. 35, para. 4, line 2: change "289" to "400"

APPENDIX C: Biographical Sketches

- Jim A. Bottorff

  Education: B.S. Wildlife Sciences, Purdue University; M.S. Wildlife Biology, West Virginia University

  Current Position: Endangered Species Specialist, U.S. Fish and Wildlife Service, Portland, Oregon

  Professional: Extensive experience with endangered species in the Pacific Northwest, research on migratory birds (Bald eagles, Canada geese); consultant on endangered species issues

- Steven M. Chambers

  Education: B.A. and M.A. Biology, University of California, Riverside; Ph.D. Zoology, University of Florida

  Current Position: Chief, Division of Endangered Species, U.S. Fish and Wildlife Service, Region 2, Albuquerque, New Mexico

  Professional: Experience with endangered species recovery and listing; visiting professor of zoology, Univ. of Florida; interested in management implication of conservation biology and population genetics

- Joseph J. Dowhan

  Education: B.S. Biology, Delaware Valley College; M.S. Ecology, University of Connecticut; graduate work in Coastal Ecology, University of Massachusetts

  Current Position: Coordinator of the California Condor Recovery Program, U.S. Fish and Wildlife Service, Endangered Species Office, Ventura, California

  Professional: Wildlife biologist with national and international experience with endangered species

- Adrian Farmer

  Education: B.S. Mech. Engineering, University of South Carolina; M.S. Zoology, North Carolina State University

  Current Position: Section Leader, Resource Evaluation and Modeling Section, National Ecology Research Center, Ft. Collins, CO

  Professional: Wildlife biologist with experience in habitat management, designing and conducting environmental impact studies on major federal projects, and research on habitat requirements and development of habitat assessment methodologies

- Kathleen Franzreb

  Education: B.A. and M.A. Zoology, U.C.L.A.; Ph.D. Zoology, Arizona State University

  Current Position: Endangered Species Biologist (Listing and Recovery Coordinator), U.S. Fish and Wildlife Service, Sacramento, California

  Professional: Certified Wildlife Biologist; research addressing the impacts of habitat modification on the avian community, intersexual and intersexual habitat partitioning, and avian foraging behavior

- James (Jay) F. Gore

  Education: B.S. Wildlife Management, South Dakota State University; M.S. Wildlife Management, University of Maine

  Current Position: Assistant Field Supervisor, Boise Field Office, U.S. Fish and Wildlife Service

  Professional: Certified Wildlife Biologist, The Wildlife Society; President of the Illinois and Idaho Chapters of The Wildlife Society; Recipient of the 1989 Professional Wildlife Award, Idaho Chapter, The Wildlife Society

- E. Charles Meslow

  Education: B.S. Wildlife Management, University of Minnesota; M.S. Wildlife Management, University of Minnesota; Ph.D. Wildlife Ecology/Zoology, University of Wisconsin

  Current Position: Professor of Wildlife Ecology and Leader, Oregon Cooperative Wildlife Research Unit, Oregon State University

  Professional: Certified wildlife biologist; Research addressing wildlife issues in the Northwest; primary research areas: forest wildlife management especially old growth relationships and "sensitive" species management

- Barry S. Mulder

  Education: B.S. Zoology, M.S. Ecology and Animal Behavior, University of Michigan

  Current Position: Coordinator for Spotted Owl Program, Region 1, Portland, OR

  Professional: Wildlife biologist with 10 years experience with endangered species recovery impact assessments and conflict resolutions; interests in small mammal and bird population biology and management

- James D. Nichols

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  Professional: Member of New Board of Governors, Society for Conservation Biology; member of the Wildlife Society; former Advisor on Biological Diversity to the Agency for International Development; primary research interests: population viability assessment and conservation biology

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APPENDIX D: Acknowledgements

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