Appendix J3
Additional Analysis and Discussion

Appendix J3 of the Final SEIS
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Further Explanation of Assumptions Concerning Nonfederal Lands Effects

This portion of Appendix J3 clarifies the role that effects of the management of nonfederal lands play in the cumulative effects analysis in this SEIS. Generally, such effects are addressed in two ways in the analysis of effects on individual species or species groups in the SEIS.

First, this SEIS reports the results of the assessment conducted by the Assessment Team. These results reflect a specific focus on the likelihood that the alternatives would provide species' habitat in varying amounts and distributions on federal lands (FEMAT Report, pp. IV-42, IV-44, IV-47). For the purposes of assigning likelihood ratings, FEMAT panelists were asked to focus their assessment on three major factors: habitat conditions on federal lands; life history characteristics of the species; and any bottlenecks in habitat (and population) that would occur under the alternatives (FEMAT Report, p. IV-44). This focus was chosen to provide more usable information regarding the efficacy of the alternatives to provide habitat on federal lands to support species viability and biodiversity under the National Forest Management Act.

Thus, in an effort to keep the focus of the FEMAT assessment panel ratings on federal lands, the panels were instructed as follows:

> **Assume that conditions other than habitat on federal land are adequate to provide for well-distributed, stabilized populations. These factors include environmental conditions other than habitat condition (e.g., ocean pollution); habitat conditions on nonfederal land; land ownership patterns; and the amount of overlap between the species range and the range of the spotted owl. These factors will be brought back into the assessment in a later step, but should not influence the initial rating. For example, the overall likelihood of supporting viable populations of marbled murrelets will be strongly influenced by ocean conditions and by habitat conditions on nonfederal lands. However, in the initial rating we are asking the panelists to only assess the likelihood that nesting habitat on federal land will be adequate to support well-distributed populations of murrelets on federal land. In a subsequent step, we will ask panelists to describe the likely effects of other factors. (FEMAT written instructions to panelists).**

The intent of this direction was not to ignore possible problems resulting from cumulative effects, or to make the assumption that viable populations of species could be supported by nonfederal lands alone. Rather, it was designed to cause panelists to initially think mainly about the degree to which federal habitat itself could be expected to support stable, well distributed populations respective of the management of nonfederal lands. Thus, except as otherwise explicitly noted, this assumption had the practical effect of marginalizing or rendering essentially immaterial the degree and nature of a contribution of nonfederal lands to panel ratings. If the assessment ratings instead had been designed to evaluate habitat on all lands regardless of ownership, it would have been difficult, if not impossible, to determine the benefit expected to accrue to some species or species group from habitat provided on federal lands under each of the alternatives.

The Assessment Team acknowledged during the assessment that because this approach to panel ratings focused on the adequacy of habitat on federal lands, it did not address cumulative effects. Therefore, after the panel ratings were completed, panelists were asked to address the degree to which factors other than those explicitly considered in the ratings would affect the species or species groups under consideration (FEMAT Report, pp. IV-45, IV-47). Specifically, panels were asked to describe the actual influence on the species or species group of land ownership patterns and habitat conditions on nonfederal lands, habitat conditions outside the range of the northern spotted owl, and other environmental conditions caused by activities off federal lands (FEMAT Report, pp. IV-44, IV-47). This information was recorded in panel notes and summarized in sections of the FEMAT Report. In the case of marbled murrelets, a second assessment was completed on overall population viability that explicitly took into account cumulative effects (FEMAT Report, p. IV-152).

Second, after publication of the FEMAT Report and the Draft SEIS, additional steps were taken to analyze cumulative effects. As part of the additional species analysis, all of the species or species groups that had been assessed by the Assessment Team were subsequently screened to see if additional analysis would prove useful under a variety of criteria. One screen focused on the viability of a species or species group that may be affected by factors other than management of federal lands (see Process for Additional Species Analysis in Chapter 3&4 and the documentation generated by the analysis in Appendix J2). Where cumulative effects on a species or species group could be significant, additional analysis was completed and mitigation measures were proposed, where appropriate. In some cases, proposed mitigation would increase the contribution of federal lands to offset the likely impacts from nonfederal lands or other factors.

The analysis of effects on the northern spotted owl generally has followed the process outlined above. The FEMAT assessment panel ratings for the spotted owl depended specifically on the likelihood that the respective alternatives would provide adequate habitat conditions for spotted owl populations to stabilize across federal lands. These ratings did not reflect an assessment of the contribution of habitat on nonfederal lands to the northern spotted owl (FEMAT Report, p. IV-150). However, after the panel assigned its likelihood ratings, FEMAT did address the role of nonfederal lands in achieving recovery of the owl (FEMAT Report, pp. II-32—II-33, IV-150). The Assessment Team noted that nonfederal lands are critical to the conservation of the owl in certain areas, often where federal lands are uncommon (FEMAT Report, p. IV-150).

As noted in Chapter 3&4, since completion of the FEMAT Report, the Department of the Interior has published a Notice of Intent to prepare an EIS analyzing the adoption of a special rule pursuant to Section 4(d) of the Endangered Species Act concerning the northern spotted owl (Federal Register, Dec. 29, 1993; 58 FR 69132—69149). The notice provides a general overview of the proposal to adopt such a rule, which would remove or revise the incidental take prohibition for the owl on some nonfederal lands, while retaining the prohibition on nonfederal lands which have previously been noted as being complementary to the federal conservation strategy (58 FR 69133, and p. 3&4-8 in the Final SEIS), and where federal lands may not be adequate to provide for owl conservation (Final SEIS, p. G-37).

The discussion in the SEIS generally recognizes the importance of contributions of some nonfederal lands to the northern spotted owl (see p. 3&4-244). It also considers the proposal

to adopt a 4(d) rule, and notes that the rule is intended to complement the alternatives in the SEIS with respect to the owl's recovery (see pp. 3&4-244—3&4-245). In terms of the actual contribution that can be expected from nonfederal lands, the SEIS generally assumes that management of nonfederal lands will comply with the Endangered Species Act.

In light of the proposal to adopt a 4(d) rule that would authorize the incidental take of some spotted owls on nonfederal lands, consideration of effects on the owl from management of nonfederal lands must be contingent. This means that the SEIS assumes that, for the present and short term, the Endangered Species Act will continue to be implemented consistent with current direction relating to take of owls and, therefore, that all owls on nonfederal lands will be protected from take under Section 9, unless and until a 4(d) rule is adopted (see p. 3&4-245). Given the possibility that such a rule may be adopted, it is recognized that some owls currently on nonfederal lands may be incidentally taken unless they occur in certain "Special Emphasis Areas" which would be chosen to facilitate the achievement of the conservation goals for the spotted owl. Based on the proposal in the 4(d) rule EIS notice and on the express intent that any area designated as a "Special Emphasis Area" under the proposed 4(d) rule would complement the alternatives in this SEIS, it is not expected that adoption of such a rule would significantly change any projected contribution of nonfederal lands to the owl, especially at the programmatic level of this SEIS. It also should be noted that factors relevant to cumulative effects also are addressed in the materials the SEIS incorporates by reference and the NEPA documents to which the SEIS is a supplement.

Expanded Discussion of Cumulative Effects on the Population Viability of the Marbled Murrelet

Chapter 3&4 of this SEIS contains a general statement regarding the cumulative effects of the proposed action and those associated with the other major factors affecting the marbled murrelet, including management of nonfederal lands (see p. 3&4-249). However, the main focus of that discussion focuses on those effects expected to result from modification of habitat on federal lands, given that the proposed action would revise management direction for such lands. Factors other than the amount and distribution of habitat on federal lands that are thought to affect murrelet viability include vital population rates, prey availability, predation, nesting habitat on nonfederal lands, and direct mortality from net fisheries and oil spills. There are few data, if any, addressing most of these factors. Nevertheless, because of the potential significance of the factors on the overall population viability of the murrelet, the FEMAT assessment panel sought in one of its assessments to consider factors other than the expected habitat conditions on federal lands (FEMAT Report, p. IV-152).

This discussion of each of the major factors (other than alteration of habitat on federal lands) is presented to describe the issues thought to most significantly affect population viability of the murrelet. For a fuller discussion of each factor, see the Biological Report of the Fish and Wildlife Service (Marshall 1988); the final rule listing the murrelet population in Oregon, California, and Washington as a threatened species; and the proposed rule designating critical habitat for that population (57 Federal Register 45328—45337 (Oct. 1, 1992); 59 Federal Register 3811—3824 (Jan. 27, 1994)). Each of these documents is incorporated by reference into this appendix. In addition, the Federal Government will address the marbled murrelet in more detail in its ongoing Conservation Assessment and the Draft Marbled Murrelet

Recovery Plan, which is expected to be released later this year.

Vital Rates

With fewer than 70 nests found to date, data are not available for most aspects of the species' breeding biology. Out of necessity, certain inferences are drawn from other members of the Alcidae family, of which the murrelet is a member. Alcids typically have a variable reproductive rate, in that not all adults may nest every year; marbled murrelets seem to follow this pattern. They also have a relatively low reproductive rate (producing one chick per year, maximum), and thus, must rely upon being relatively long-lived and breeding several times to produce enough young to replace themselves (Hudson 1985). The average annual adult survival known for stable populations of several other alcid species is approximately 90 percent survival per year, meaning that in any one year, approximately 10 percent of the breeding-age individuals in a given population die (Hudson 1985). The average known post-fledgling survival to breeding age for alcids has been estimated to be 29 percent (i.e., that proportion of the young from any one year that will actually survive to the age of first reproduction) (Hudson 1985). Murrelets lay one egg per nest and are estimated to live an average of 10 years, based on the longevity of other alcids (Hudson 1985). If these estimates that the murrelet is a relatively long-lived species are generally sound, then recruitment rates likely would be a more accurate indicator of the murrelet's population dynamics than would direct population counts.

Murrelets are currently documented to be experiencing low recruitment rates. Juvenile to adult ratios of murrelets have been estimated to be between 0.012 and 0.035, meaning that there are between approximately 1 and 4 juveniles of a particular year observed for every 100 adults observed (Strong et al. 1993). Juvenile/adult ratios from counts taken along the central Oregon coast from 1988 through 1992 yielded similar average juvenile recruitment rates of between 1 and 4.5 percent (Nelson and Hardin, in prep.). Surveys conducted in California have produced ratios within this range since 1989. Among other possible factors, these low estimated recruitment rates may be at least partially the result of losses of nesting opportunities, or mortality of juveniles as they leave inland nest sites and attempt to reach the ocean. To the extent the rates reflect the loss of nesting opportunities on federal lands, the SEIS alternatives that protect more nesting habitat should be expected to have more beneficial effects on recruitment. To the extent the rates reflect the mortality of juveniles produced on federal lands, one plausible cause of such juvenile mortality is predation, which is discussed separately below. To the extent the rates reflect either of these factors on nonfederal lands, there should be no direct effect of any SEIS alternative on recruitment because the proposed action provides management direction for federal lands only.

Prey Availability

Marbled murrelets generally forage in near-shore marine waters. They have been reported to feed on a variety of small fish and invertebrates, including Pacific herring (*Clupea harengus*), Pacific sandlance (*Ammodytes hexapterus*), northern anchovy (*Engraulis mordax*), capelin (*Mallotus villosus*), smelt, euphids (*Eupahsia pacifica, Thysanoessa spinifera*), and mysids (Carter and Sealy 1987, Sanger 1987, Sealy 1975, Strong et al. 1993). Thus, marine systems producing these kinds of species comprise important foraging habitat for the species. Because the proposed action addresses management of federal forest lands only, foraging habitat will not

be affected by selection of any of the SEIS alternatives.

Predation

Great horned owls (*Bubo virginianus*), Stellar's jays (*Cyanocitta stelleri*), ravens (*Corvus corax*), sharp-skinned hawks (*Accipiter striatus*) and common crows (*Corvus brachyrhynchos*) are known predators of the marbled murrelet. Gray jays (*Perisoreus canadensis*) are also suspected predators. From 1974 through 1991, approximately 71 percent of all known murrelet nests in the Pacific Northest failed, with 70 percent of those failures due to predation (Nelson 1992). A 1992 study indicated that, of 25 murrelet tree nests located, 10 failed because of predation. Three others failed from other factors, 10 were successful, and the status of the remaining 2 nests was indeterminable (Nelson 1992).

Although supporting data showing cause-and-effect and magnitude generally are lacking, it is believed that forest fragmentation increases the risk of predation on bird nests (eggs and chicks), especially the risk from corvid predators. This hypothesis is thought similarly to apply to the murrelet. One of the fundamental purposes of each of the alternatives in this SEIS is to create large reserves of late-successional and old-growth habitat that will, among other things, help to avoid adverse effects of fragmentation. Generally speaking then, the larger the acreage of reserves in the marbled murrelet's range called for in an SEIS alternative, the less fragmentation that will occur from timber harvest on federal lands, and the greater the benefits to marbled murrelet populations.

Forest canopy closure over the nest site also is believed to provide camouflage protection from predation for the murrelet. All of the SEIS alternatives, except for Alternatives 7 and 8, provide for protection of occupied murrelet sites, both those currently known and those discovered during requisite surveys. Thus, Alternatives 1 through 6, 9, and 10 generally should at least maintain protection from predation provided by the existing canopy closure at all known and discovered occupied sites. Because the proposed action addresses management of federal lands only, any further fragmentation or loss of canopy cover near nest sites on nonfederal lands will not be directly affected by selection of any of the SEIS alternatives.

Nonfederal Habitat Conditions

Approximately 40 to 50 percent of the marbled murrelet's range within Washington, Oregon, and California occurs on nonfederal lands. Several areas on nonfederal lands, especially in California, currently contain substantial numbers of marbled murrelets. Most remaining suitable nesting habitat for the murrelet within Washington, Oregon, and California is on federal lands, although there are valuable areas of habitat within the murrelet's range that contain little or no federal lands (e.g., southwest Washington and Humboldt and Santa Cruz/San Mateo Counties in California). Moreover, there are approximately 189 known occupied murrelet sites on nonfederal lands, which comprises approximately 20 percent of the currently known total (FEMAT Report). Most of the nesting habitat that historically existed on private lands within this tri-state region has been eliminated, due in large measure to timber harvest (Green 1985, Norse 1988, Thomas et al. 1990). Remaining tracts of potentially suitable habitat on private lands in this tri-state area is subject to harvest, although any such harvest would need to comply with Section 9 of the Endangered Species

Act, given the threatened status of the species under that statute. Under state law, the murrelet is currently listed as endangered in California, as sensitive in Oregon, and threatened in Washington. In addition, much of the known marbled murrelet habitat in California is located in State or National Parks that are generally protected from timber harvesting.

As noted in the Final SEIS's discussion of effects from nonfederal land management (pp. 3&4-8—3&4-10, p. 3&4-244, and p. G-37), the Department of the Interior has issued a Notice of Intent to prepare an EIS analyzing the adoption of a special rule pursuant to Section 4(d) of the Endangered Species Act concerning the northern spotted owl (Federal Register, Dec. 29, 1993; 58 FR 69132—69149). The notice sets forth a general overview of the proposal to adopt such a rule. The proposal is to remove or revise the incidental take prohibition for the owl on some nonfederal lands.

The spotted owl 4(d) proposal bears mentioning in the context of this discussion of the effects of nonfederal land management on the marbled murrelet because, were it to be adopted, it would affect the management of late-successional and old-growth forest stands on some of the nonfederal lands within the murrelet's range. Adoption of the proposal should have no marked effect on the enforcement of Section 9 relative to murrelets, however, because the removal of incidental take protection for the northern spotted owl on certain nonfederal lands would not affect the "take" prohibition concerning the marbled murrelet on those same lands. Thus, any harvest of owl habitat that would result in the incidental take of an owl on nonfederal lands made permissible by adoption of a 4(d) rule for the owl would not be allowed if it would result in the take of a murrelet under the ESA. The notice also discussed the possibility of providing further guidance to avoid incidental take of the marbled murrelet in the 4(d) rule for the owl, but no firm proposal along these lines has yet emerged.

Oil Spills

Marbled murrelets are susceptible to mortality from oil spills because they tend to spend most of their time in local concentrations at sea, swimming on the ocean surface and feeding close to shore. Oil spills are not possible to predict but, depending on their location, extent, and time of occurrence, could have significant adverse effects on local or regional populations of murrelets, even possibly resulting in local extirpations. Murrelets have been affected adversely or killed as a result of past oil spills in both Washington and California. Because the proposed action provides management direction for federal forest lands only, selection of any of the SEIS alternatives would have no effect on issues of murrelet viability associated with oil spills.

Gill-Net Fishing

tudies have shown that the marbled murrelet suffers mortality from gill-net fishing (Carter and Sealy 1982, Kuletz 1992). Oregon and California no longer allow gill-net operations that would affect marbled murrelets. Washington, however, issues approximately 1200 gill-net licenses a year (Marshall 1988). Gill-net fisheries occur in areas of murrelet concentrations in Washington (e.g., the Puget Sound), but the mortality rate is uncertain and data is beginning to be collected on these impacts to murrelet populations. Because the proposed action addresses only federal forest management, selection of any of the SEIS alternatives would not

affect mortality associated with gill-net fishing.

Spotted Owl Population Viability and the Use of Models

Concern about northern spotted owls and the continued harvest of their habitat extends back to the early 1970's, shortly after research on the species had begun in Oregon (Thomas et al. 1993). Since that time, both the knowledge of owls and the sophistication of scientific arguments surrounding them have increased dramatically. At least a half dozen major federal forest plans have focused on spotted owls and/or their habitat, and information and analyses have been contributed by both federal and nonfederal scientists.

Much of the controversy surrounding northern spotted owls and federal forest plans has focused on whether the population of owls would remain viable, or gradually trend toward extinction upon a plan's implementation. Demographic analyses provide useful insight into how population parameters for the owl likely have changed in the past. The most recent analysis of owl demographic data was issued in early January 1994; it appears in the Final SEIS as Appendix J1 and is discussed at some length on pages 3&4-212 and 3&4-229. A recent investigation of the models used to analyze such demographic data (Goldwasser et al. 1993) suggested that there could be considerable error in estimating the rate of population growth, especially if environmental fluctuation is a strong influence on the population. The same investigation concluded that the model's assessment of trends in survival rates was generally accurate.

The use of such demographic analyses in the assessment of population viability is limited because the results of the analyses pertain only to the period of data collection. They do not provide information on expected future changes in owl populations or on the relationship between habitat and population dynamics. Therefore, other tools have been developed to address these questions in analyses of population viability.

While the controversy over owls has continued, there has been significant evolution in scientific concepts related to population viability and the procedures used to assess viability (Marcot 1994 unpub.). Much of the early thinking on population viability focused strongly on the maintenance of genetic diversity and on the determination of minimum viable population sizes (Soule 1980). As the discussion of population viability continued, thinking expanded to encompass other factors that could influence long-term viability (Shaffer 1983). For spotted owls, these factors can be separated into: (1) those that are internal to populations, such as random demographic events, genetic drift and inbreeding, and change in social behavior; and (2) those external to the population, such as chronic habitat change, interspecific competition, and large-scale environmental disturbances that are catastrophic to the population (Salwasser et al. 1984). Introducing these additional complexities into viability assessments has reduced the likelihood that a simple, single minimum viable population level could be identified for the spotted owl.

Over the last 50 years, the most significant influence on northern spotted owl populations has

been the chronic loss of habitat through timber harvest (Murphy and Noon 1992, USDI FWS 1990). The effects of habitat loss might be expressed in the spotted owl population in a number of different short and long-term ways, including changes in demographic attributes, decreases in genetic variation, changes in behavior, and changing susceptibility to predation, diseases, pathogens, and other environmental factors. Assessments of northern spotted owl viability have attempted to synthesize at least some of these risk factors (Dawson et al. 1987, Thomas et al. 1990, USDA FS 1986, USDA FS 1988, USDA FS 1992, USDI 1992 unpub). The Final Draft Recovery Plan for the Northern Spotted Owl (USDI 1992 unpub.) summarized risks to the owl population as follows:

Habitat factors
- **Systematic habitat loss**
- **Habitat fragmentation**
- **Habitat gaps**

Population dynamics
- **Demographic variation**
- **Decline in population size (Allee effect)**
- **Low success of juvenile dispersal**
- **Loss of genetic variation**

Environmental factors
- **Variation in environmental conditions**
- **Catastrophic events**
- **Species interactions**
- **Lack of coordinated conservation measures**

The risk discussion in the Final Draft Spotted Owl Recovery Plan noted the general features of the plan that were designed to deal with these risks. The broad outlines of these features are shared in common across all the alternatives presented in this SEIS. Large reserve size was noted as a direct response to the risks from systematic habitat loss, habitat fragmentation, and unfavorable species interactions. While some habitat loss would continue in matrix forests, the loss and fragmentation of forests due to logging within the Late-Successional Reserves would essentially stop. Habitat conditions for owls within the reserves would generally improve over time as currently younger forests grow to a condition where they would begin to provide greater benefit for owls. Thus, threats associated with fragmentation would decline within the reserves over time. Reduction of these threats will provide greater security for the owl population in as little as 50 years (the time when current young forests would begin providing the canopy characteristics of owl habitat).

Both the size and the design of the Late-Successional Reserve networks are intended to reduce risks associated with demographic variation, the Allee effect, potential low success of juvenile dispersal, loss of genetic variation, risk of catastrophic events, and variation in environmental conditions. Size of the Late-Successional Reserves is designed to provide for subpopulations large enough for at least short-term (next 50 years) stability and the reserves are located to allow spotted owls from one location to potentially recolonize other areas if local populations fail. This reduces risks from both demographic variation and the Allee effect. Potential risks from failure of juvenile dispersal are reduced by establishing reserves so that the distances between them are within the dispersal capability of young owls, and managing the intervening matrix forest for conditions that would facilitate dispersal.

Similarly, any potential risk of loss of genetic variation would be reduced by the movement of owls among reserves, facilitated by the placement of reserves and management of intervening areas for dispersal habitat. There is general agreement that, in light of current known and estimated population numbers, the level of risk to northern spotted owls from genetic causes is low (Barrowclough and Coats 1985). Risks from catastrophic events are reduced by the size of individual reserves, the design of the network which places every reserve within the dispersal capability of two or more other reserves, and the management of reserves to reduce such risks. Finally, risks from environmental variation are reduced by making reserves large and establishing them throughout the range of environmental variation within the range of the owl.

A number of the planning efforts for northern spotted owl populations have relied primarily or exclusively on qualitative, professional judgments for assessment of risk to the owl's population viability (Thomas et al. 1993, USDA FS 1992, USDI 1992 unpub.). Other plans and assessments have included modeling efforts that were used either in the development of plans or in the assessment of their risks. One of the first efforts included that for the *Draft Supplement to the Environmental Impact Statement for an Amendment to the Pacific Northwest Regional Guide* (USDA FS 1986). The analysis in the 1986 Draft SEIS included the use of a modified Leslie matrix model (Leslie 1945, 1948) that incorporated stochastic effects. A separate spatially-explicit simulation model was also used in the Draft SEIS. This later model simulated movements of both juvenile and adult owls as well as variable birth and death rates. Both models were used as components of a risk assessment rule set for evaluation of the alternatives presented in the 1986 Draft SEIS. *The Final Supplement to the Environmental Impact Statement for an Amendment to the Pacific Northwest Regional Guide* (USDA FS 1988) continued the use of the modified Leslie matrix model, but dropped the spatially-explicit simulation because model behavior was dependent on parameters for which there was no empirical data.

Concurrent with these efforts, Lande (1987, 1988) published results of a mathematical, nonspatial model of dispersal and territory occupancy which extended analysis done by Levins (1969, 1970). This model was used to estimate the minimum proportion of habitat needed to sustain a population of northern spotted owls in a broad region. Based on the results of the model, Lande concluded that reduction of spotted owl habitat to a proportion less than 21 percent of the total landscape (federal and nonfederal), would eventually result in extinction. He also found that Forest Service demographic analysis (USDA FS 1986, 1988) had underestimated population growth rates due to truncation of the life table that was used in the analysis.

Boyce (1987) also criticized the Forest Service analysis in the 1986 Draft SEIS, primarily for failure to incorporate density dependence and spatial effects. He developed a stage-structured, single-sex, Leslie model in which he made the parameters of survival and fecundity dependent on population density. He used this model largely to support his contention that the likelihood of extinction of northern spotted owls could not be appropriately evaluated by the models the Forest Service had used to that point in time.

Doak (1989) developed a model of the female owl population in which he introduced a spatial structure by simulating dispersal between and within clusters of territories. Different possible management alternatives could be simulated by varying the total number of

territories, the number of clusters, and the number of territories per cluster. The dispersal process was two stage, with dispersal attempts within the cluster followed by dispersal attempts to other clusters. Doak reached three major conclusions based on this analysis. First, he noted high sensitivity to dispersal parameters, and suggested that managing the landscape to facilitate dispersal would help sustain populations. Second, he found that increasing the number of territories within clusters would improve the success of dispersing owls. Finally, he concluded that spotted owl populations would continue to decline even if all habitat alteration were stopped, but that some portion of the population would likely persist for a long period. He suggested that this long-term persistence could allow time for both habitat and populations to make a significant recovery.

Thomas et al. (1990) reported results from two models that shared some characteristics with the Doak model. These models were based on unpublished work by Lamberson et al. (1989). The first was a two-sex model with individual territories distributed across the landscape which was used to examine interactions between suitable habitat loss and dispersal capabilities. They drew two major conclusions from the analysis using the first model. First, that extinction could result from either habitat or population density reaching a critically low threshold. This supported the possibility of the Allee effect--extinction of a population even in the presence of suitable habitat. The second major conclusion was that occupancy rates of suitable habitat might be abnormally high during periods of habitat decline, and that the population might subsequently decline very rapidly. The second (Lamberson et al. 1989) model was a single-sex model used to investigate the relative advantages of various sizes of territory clusters. The major conclusion drawn from this model was that increasing cluster size has positive effects on owl populations. The mean occupancy of suitable territories was observed to increase when cluster sizes increased from 5 to 10 territories and again when they increased from 10 to 20 territories. The major conclusions of these two modeling efforts were used in the design of the Conservation Strategy for the Northern Spotted Owl (Thomas et al. 1990). Further discussion of these models was provided in Lamberson et al. (1992) and McKelvey et al. (1992).

Carroll and Lamberson (1993) developed a difference equation model for territorial species. They provided two different models of dispersal. One model assumes that suitable habitat is uniformly or randomly distributed through the range of the population. The other assumes that home ranges are concentrated in clusters of suitable habitat. They cautioned that the model was too general to be applied to any particular species, but noted that it supported two general conclusions that had been reached in other modeling efforts. The first conclusion was that a threshold exists in the amount of suitable habitat, and that the population trends toward zero when that threshold is passed. The second was that the equilibrium population density associated with a system of reserves will be higher when reserves are larger, even though the larger reserves are further apart. They concluded that an optimal conservation strategy would be similar to the strategy of Thomas et al. (1990) with many moderately large reserves broadly distributed throughout the range of the species.

In a recent development, the California Forestry Association produced a model termed the California Owl Population Simulator (COPS) (California Forestry Association 1993). COPS is based on the spatially-explicit simulator of McKelvey et al. (1992), but differs from it in several ways. Perhaps most significant is a different model structure for delineating owl territories. In McKelvey et al. (1992), territories are defined by a grid of hexagons of fixed

size. COPS replaces this structure with logic that individually defines the size of each owl territory. The model was used in an analysis of the northern spotted owl population in the Klamath Province of California, with results indicating that the population would reach equilibrium in this area. The result was not specific to a management alternative. The authors note that the model structure needs sensitivity testing, particularly in regard to eight parameters for which little or no empirical data is available.

McKelvey et al. (1992) also described the structure of a spatially-explicit life history simulator for northern spotted owls. This landscape model builds on much of the previous modeling work. The model accepts input on the habitat conditions in a landscape from a Geographic Information System (GIS) data base. The landscape is divided into hexagons that roughly approximate the size of annual home ranges of owl pairs. The habitat quality of the hexagons is then linked to the likelihood of owls settling on the site and the survival and fecundity of owls that become territorial on the site. Nonterritorial owls move through the landscape according to rules that can be varied within the model. The model is stochastic, (that is, it offers dynamics controlled by the generation of pseudo-random numbers). As the simulation proceeds through time, the model can accept information on changes to habitat conditions in the landscape. Thus, it can simulate the response of owl populations to habitat change caused by timber harvest or other factors. This model was used in analysis of Draft Land and Resource Management Plans for BLM Districts (USDI BLM 1992a-f). Also, results of this model for three of the SEIS alternatives are presented later in this appendix, reflecting the general effects of the patterns of timber harvest allowed under each alternative.

In summary, discussion of viability of northern spotted owls, and other species, have evolved from the consideration of single factors and minimum viable populations to more comprehensive considerations of the variety of factors that could influence population persistence. A number of modeling efforts have been developed to support analyses of population viability for owls. These include both mathematical and simulation models. Despite the differences in approach and detail among the models, they tend to support several general conclusions. One conclusion is that there exists at least a theoretical lower threshold of suitable habitat in the landscape below which the population would trend inevitably toward extinction. Another is that arranging suitable habitat to support clusters of territories rather than single territories tends to reduce risks of demographic stochasticity and increase the stability of populations.

As models have evolved, there has also been considerable discussion about the value of using models in making management decisions. This subject has received considerable attention in several recent planning documents (FEMAT Report, Thomas et al. 1993, USDI 1992 unpub.). There seems to be general agreement that models can provide valuable input to management decisions, provide for well-structured investigations of hypotheses, and allow consistent evaluation of various options. There also seems to be general agreement that the models should not be viewed as reality, and their outputs should not be regarded as actual predictions of the fate of populations. Rather, they provide valuable insights into the projected behavior of populations and can contribute to informed decision making. Despite the value of models, they are only one tool in evaluating wildlife populations and habitat, and do not replace sound professional judgment in decision making.

References

Barrowclough, G.F.; Coats, S.L. 1985. The demography and population genetics of owls with special reference to the conservation of the spotted owl (*Strix occidentalis*). Pages 74-85 in: Gutierrez, R.J.; Carey, A.B., eds. Ecology and management of the spotted owl in the Pacific Northwest. Gen. Tech. Rep. PNW-185. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Boyce, M.S. 1987. A review of the U.S. Forest Service's viability analysis for the spotted owl. Corvallis, OR: National Council of the Paper Industry for Air and Stream Improvement, Inc. 50 p. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

California Forestry Association. 1993. Appendix F in: A petition to remove the northern spotted owl in California from the list of threatened species. Sacramento, CA: California Forestry Association. 24 p.

Carroll, J.F.; Lamberson, R.H. 1993. The owl's odyssey; a continuous model for the dispersal of territorial species. SIAM Journal on Applied Mathematics 53(1):205-218.

Carter, H.R.; Sealy, S.G. 1982. Marbled murrelet mortality due to gillnet fishery in Barkley Sound, British Columbia. In: Nettleship, D.N.; Sanger, G.A.; Springer, P.F., eds. Marine birds: their feeding ecology and commercial fisheries relationships. Proceedings of the Pacific Seabird Group Symposium; 1982 January 6-8; Seattle, WA. Canadian Wildlife Service Special Publication.

Carter, H.R.; Sealy, S.G. 1987. Inland records of downy young and fledgling marbled murrelets in North America. Murrelet 68:58-63.

Dawson, W.R.; Ligon, J.D.; Murphy, J.R., [and others]. 1987. Report of the scientific advisory panel on the spotted owl. Condor. 89:205-229.

Doak, D. 1989. Spotted owls and old-growth logging in the Pacific Northwest. Conservation Biology. 3:389-396.

Goldwasser, L.; Groom, M.; Kareiva, P. 1993. The effects of model structures and annual variability on population viability analyses of the northern spotted owl (Strix occidentalis caurina). Seattle, WA: University of Washington, Department of Zoology, NJ-15. 60 p.

Green, K. 1985. The old growth redwood resources: an historical overview of harvesting and preservation. Unpublished report. Washington, DC: U.S. Department of Justice. 32 p.

Hudson, P.J. 1985. Population parameters for the Atlantic alcidae. Pages 233-261 in: Nettleship, D.N.; Birkhead, T.R., eds. The Atlantic alcidae: the evolution, distribution and biology of the auks inhabiting the Atlantic ocean and adjacent water areas. London: Academic Press.

Kuletz, K. 1992. Assessment of injury to marbled murrelets from the Exxon Valdez oil spill. Draft report. Anchorage, AK: U.S. Department of the Interior, Fish and Wildlife Service. 59 p.

Lamberson, R.H.; McKelvey, R.; Noon, B.R.; Voss, C. 1989. The effects of varying dispersal capabilities on the population dynamics of the northern spotted owl: preliminary results. Unpublished manuscript. On file with: Interagency SEIS Team, P.O. Box 3623, Portland, OR 97208-3623.

Lamberson, R.H.; McKelvey, R.; Noon, B.R.; Voss, C. 1992. A dynamic analysis of northern spotted owl viability in a fragmented forest landscape. Conservation Biology. 6:505-512.

Lande, R. 1987. Extinction thresholds in demographic models of territorial populations. Amer. Nat. 130:624-635.

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

Leslie, P.H. 1945. On the use of matrices in certain population mathematics. Biometrika. 33:183-212.

Leslie, P.H. 1948. Some further notes on the use of matrices in population mathematics. Biometrika. 35:213-245.

Levins, R. 1969. Some demographic and genetic consequences of environmental heterogeneity for biological control. Bull. Entomol. Soc. Am. 15:237-240.

Levins, R. 1970. Extinction. Pages 75-107 in: Gerstenhaber, M.L. ed. Some mathematical questions in biology. Lect. Math Life Science, Vol 2. Providence, RI: Am. Math Soc.

Marcot, B.G. 1994. Population viability assessment and management --a brief history. 30 p. Unpublished, unreviewed manuscript. On file with: Interagency SEIS Team, P.O. Box 3623, Portland, OR 97208-3623.

Marshall, D.B. 1988. Status of the marbled murrelet in North America: with special emphasis on populations in California, Oregon and Washington. Portland, OR: Audubon Society of Portland. 42 p.

McKelvey, K.; Noon, B.R.; Lamberson, R.H. 1992. Conservation planning for species occupying fragmented landscapes: the case of the northern spotted owl. Pages 424-450 in: Kareiva, P.; Kingsolver, J.J.; Huey, R.B., eds. Biotic interactions and global change. Sunderland, MA: Sinauer and Associates, Inc.

Murphy, D.D.; Noon, B.R. 1992. Integrating scientific methods with habitat conservation planning: reserve design for northern spotted owls. Ecological Applications 2(1):3-17.

Nelson, K.; Hardin, J.G. [in prep.] Counts of marbled murrelets at sea from shore-based stations along the Oregon coast, 1988-1992. Pacific Seabird Group.

Nelson, K. 1992. Later dated February 29 to the U.S. Fish and Wildlife Service.

Norse, E.A. 1988. Sustaining biological diversity and timber production in a changing world. Unpublished draft report. Washington, DC: The Wilderness Society. 8 p.

Salwasser, H.; Mealey, S.P.; Johnson, K. 1984. Wildlife population viability--a question of risk. No. Amer. Wildlife Nat. Res. Conf. 49.

Sanger, G.A. 1987. Winter diets of common murres and marbled murrelets in Kachemak Bay, Alaska. Condor 89:426-430.

Sealy, S.G. 1975. Feeding ecology of the ancient and marbled murrelets near Langara Island, British Columbia. Can. J. Zool. 53:418-433.

Shaffer, M.L. 1983. Determining minimum viable population sizes for the grizzly bear. Int. Conf. Bear Res. and Manage. 5:133-139.

Soule, M.E. 1980. Thresholds for survival: maintaining fitness and evolutionary potential. Pages 151-170 in: Soule, M.E.; Wilcox, B.A., ed. Conservation biology: an evolutionary-ecological perspective. Sunderland, MA: Sinauer Associates.

Strong,C.S.; Gilardi, J.R.; Gaffney, J.; Cruz, J. 1993. Abundance and distribution of marbled murrelets at sea on the Oregon coast in 1992. Final report. Salem, OR: Oregon Department of Fish and Wildlife. 29 p.

Thomas, J.W.; Forsman, E.D.; Lint, J.B., [and others]. 1990. A conservation strategy for the northern spotted owl: a report of the Interagency Scientific Committee to address the conservation of the northern spotted owl. Portland, OR: U.S. Department of Agriculture, Forest Service; U.S. Department of the Interior, Bureau of Land Management, Fish and Wildlife Service, and National Park Service. 427 p.

Thomas, J.W.; Raphael, M.G.; Anthony, R.G., [and others]. 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest. The Report of the Scientific Analysis Team. Portland, OR: USDA Forest Service, National Forest System, Forest Service Research. 530 p.

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

USDA Forest Service. 1988. Final supplement to the environmental impact statement for an amendment to the Pacific Northwest Regional Guide. Spotted owl guidelines. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 2 vols.

USDA Forest Service. 1992. Final environmental impact statement on management for the northern spotted owl in the National Forests. Portland, OR: U.S. Department of Agriculture, Forest Service, National Forest System. 2 vols., 12 maps, 6 page errata sheet.

USDI. 1992 [unpublished]. Final draft recovery plan for the northern spotted owl. Portland, OR: U.S. Department of the Interior. 2 vols. On file with: Interagency SEIS Team, P.O. Box 3623, Portland, OR 97208-3623.

USDI Bureau of Land Management. 1992a. Draft Coos Bay District resource management plan and EIS. Coos Bay, OR: U.S. Department of the Interior, Bureau of Land Management. 2 vols.

USDI Bureau of Land Management. 1992b. Draft Eugene District resource management plan and EIS. Eugene, OR: U.S. Department of the Interior, Bureau of Land Management. 2 vols.

USDI Bureau of Land Management. 1992c. Draft Klamath Falls District resource management plan and EIS. Klamath Falls, OR: U.S. Department of the Interior, Bureau of Land Management. 2 vols.

USDI Bureau of Land Management. 1992d. Draft Medford District resource management plan and EIS. Medford, OR: U.S. Department of the Interior, Bureau of Land Management. 2 vols.

USDI Bureau of Land Management. 1992e. Draft Roseburg District resource management plan and EIS. Roseburg, OR: U.S. Department of the Interior, Bureau of Land Management. 2 vols.

USDI Bureau of Land Management. 1992f. Draft Salem District resource management plan and EIS. Salem, OR: U.S. Department of the Interior, Bureau of Land Management. 2 vols.

USDI. Fish and Wildlife Service. 1990. 1990 status review: northern spotted owl. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service. 94 p.