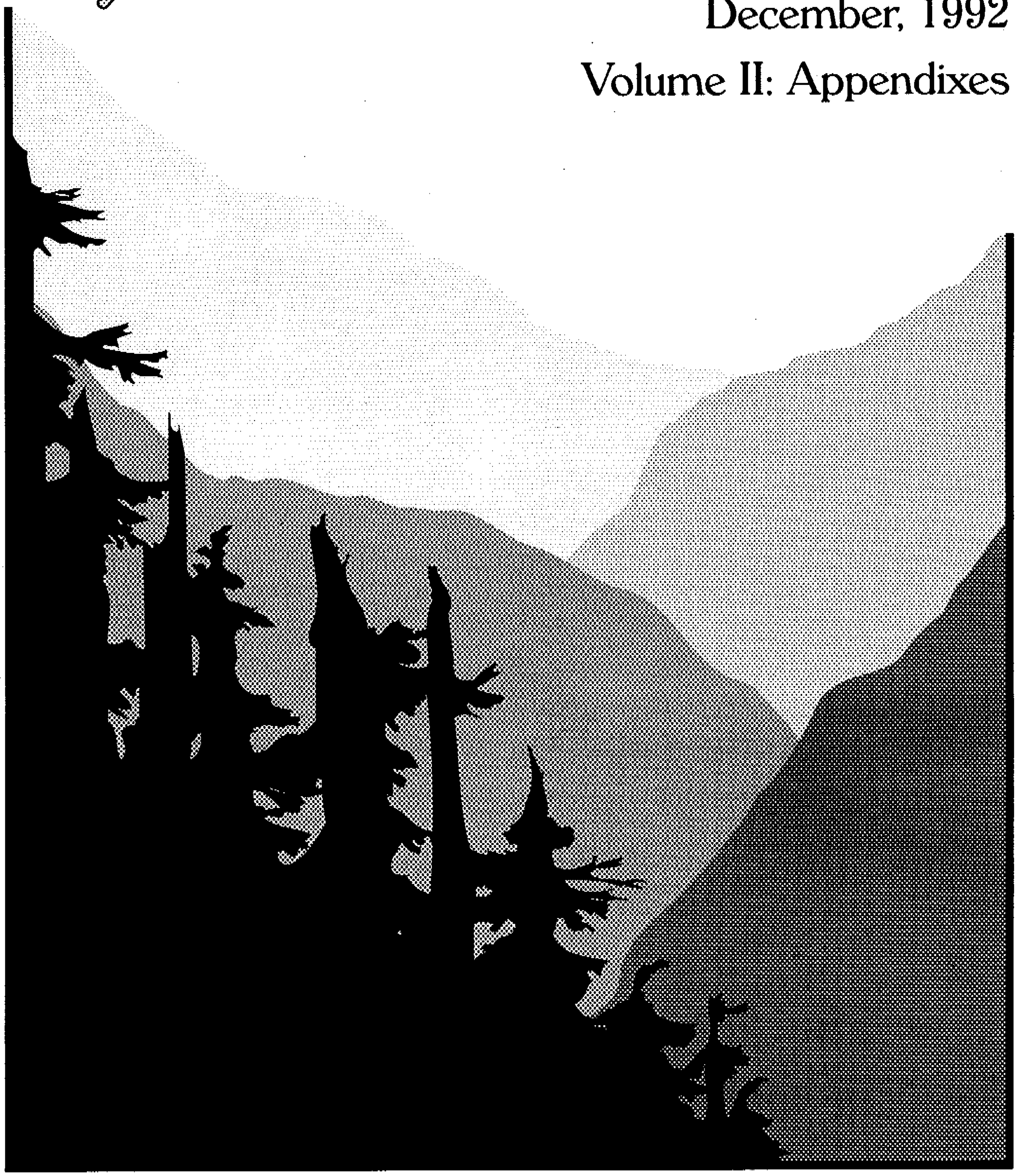
FINAL DRAFT

Recovery Plan for the Northern Spotted Owl

December, 1992

Volume II: Appendixes



[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

[illegible]

Contents: Volume II

Appendixes to the Recovery Plan for the Northern Spotted Owl

Contents

The average annual change (with n pairs of years) is thus

$$\frac{1}{n}\sum\frac{N_{t+1}}{N_t} = \frac{1}{n}\sum(s_{at}+f_t s_{jt}) \tag{2}$$
$$= \bar{s}_a + \frac{1}{n}\sum f_t s_{jt}$$

Now, if f_t and s_{jt} are uncorrelated (which will be true if they vary independently of each other), then

$$\frac{1}{n}\sum f_t s_{jt} = \bar{f}\bar{s}_j \tag{3}$$

in which case

$$ave.\ \frac{N_{t+1}}{N_t} = \bar{s}_a + \bar{f}\bar{s}_j \tag{4}$$

so if we measured s_a, f, and s_j for several years (and if the correlation between f_t and s_{jt} was sufficiently close to zero) then the average change among years (λ), could be calculated as in equation (4).

Several practical problems arise in estimating the average change among years (λ) for owls from demographic rates. Most of these problems are related to the fact that floaters, and a few territorial owls, usually are missed during the surveys at the start of each year. Survival rates can be estimated from telemetry data but obtaining data from several areas and years would be extremely expensive. As a result, capture-recapture methods must be used to estimate the survival rates.

Three common problems encountered in estimating population trends from demographic rates are described here. We discuss them with reference to the simple equation for λ, previously described, but note that in reality more complex equations generally must be used. Equation (4), however, will suffice for illustrating the problems and providing a general indication of how much error these problems may cause in estimating λ. Before discussing the three problems, it may be helpful to define the terms in more detail. We define these terms using all owls (i.e., males and females) whereas demographic analyses are usually based solely on females.

$$f_t = \frac{\text{number of fledglings produced in year } t}{N_t}$$

$$s_{at} = \frac{\text{number of the } N_t \text{ still alive at the start of year } t+1}{N_t}$$

$$s_{jt} = \frac{\text{number of the } f_t \text{ still alive at the start of year } t+1}{f_t}$$

1. Overestimation of $\overline{f}$.

N_t includes all owls alive at the start of year t, but the number of fledglings per pair usually is estimated solely from territorial owls. Thus, N_t is underestimated and f_t is usually overestimated unless there are no floaters. One way to investigate this problem is by replacing $\overline{f}$ with $\overline{f}_g\overline{p}_g$ where $\overline{p}_g$ is the proportion of owls alive at the start of the year that are territorial and $\overline{f}_g$ is the average number of fledglings per territorial owl. Omitting $\overline{p}_g$ is equivalent to assuming that it equals 1.0. If it is less than 1.0, but is omitted, then population change is overestimated by the quantity $\overline{fs_j}(1 - \overline{p}_g)$. For example, with $\overline{f} = \overline{s}_j = 0.3$ and $\overline{p}_g = 0.7$, the error would be 0.027, so if population change was actually 0.975, the estimate (using the simple equation above and ignoring sampling error) would be 1.002. No one knows the true value for $\overline{p}_g$ but 0.7 is a possible value and serves to indicate the potential seriousness of this source of error.

2. Underestimation of $\overline{s}_j$.

Some owls born in year t, leave the study area but survive until the start of year t+1. They are counted as having died, unless they reappear in later years, which causes s_{jt} to be underestimated. The significance of this problem depends on how many juveniles emigrate (and survive), which in turn depends on the size of the study area, intensity of searches outside the study area, and dispersal distances. If a proportion of the juveniles, p_{je}, emigrates from the study area but survives at the same rate as those juveniles that remain in the study area, then $\overline{s}_j$ is underestimated (aside from sampling error) by p_{je}, and λ is underestimated by $\overline{fs_j}p_{je}$. For example, if 20 percent of the juveniles leave the study area ($p_{je} = 0.2$) and $\overline{f} = \overline{s}_j = 0.3$, then the error is 0.018. If the true λ was 1.00, the estimate (aside from sampling error) would be 0.982. Detailed studies that would permit estimation of p_{je} for real study areas have not yet been carried out.

3. Temporary emigration.

Because floaters are seldom detected, young owls typically "disappear" for a few years and then reappear when they gain territories. The capture probabilities vary in exactly the way they would if the owls temporarily left the study area and then returned to it as adults. Such behavior violates the assumptions of capture-recapture models, and is known in capture-recapture literature as the problem of "temporary emigration." The problem is complex because its effects on the capture-recapture estimates are difficult to assess.

Due to these possible problems, measurement of demographic rates and calculation of trends from them must be used with caution (see Appendix C). On the other hand, these methods may offer the only way to assess population trends in the entire population - as opposed to the territorial segment of it - and these methods should therefore be subjected to additional study and investigation. In particular, a detailed evaluation of the possible biases should be carried out before these estimates are used to make management decisions.

Use of these methods is illustrated in Appendix C which describes analyses of data from five demographic study areas. The studies provided data from 5 to 7 years and from approximately 300 to 700 owls. The confidence intervals for the estimate of λ varied from approximately 0.04 to 0.09. These levels of precision were sufficient to show that the populations studied were declining, however considerably more data would be required to detect trends of 2 to 4 percent per year. See Appendix C for further discussion of interpretation of these results.

Population Models

Various difficulties with the direct counts and demographic analyses as a means of estimating population trends are discussed in the preceding section. One additional problem with those methods is that they apply only to the area and period of time actually monitored. No rigorous basis is provided for predicting trends in the future or trends that would occur in hypothetical situations (e.g., under a proposed management plan). Population models provide a way to make such predictions. The models contain information about the environment, including the initial location of owls, and a series of rules governing births, deaths, and movements. These rules are used in a stochastic simulation of births, deaths, and movements during a year. At the end of the year, the locations of all owls are again recorded, and then they are used for the second year of the simulation. This process is repeated for as long a period as the user desires. The model permits up to six cell types, three age classes, and two sexes, with possibly different demographic rates. The rules for movements by juveniles and adults are flexible and permit simulation of a wide variety of behaviors. Additional details are in McKelvey (1991).

The Recovery Team convened an advisory committee of biologists to provide recommendations for the use of the landscape model. The committee compiled data of value in determining the parameters required by the model and made recommendations for certain structural changes. The advisory committee has not finalized recommendations, but intends to do so during the coming few months. Preliminary recommendations have been developed for habitat-specific productivity, juvenile survival rates, and adult survival rates for Washington and Oregon west of the Cascade crest and north of the Oregon Klamath and California Klamath provinces. The model appears powerful and flexible, and may be capable of producing realistic simulations. Considerable work is needed, however, to make the model operational. The following information is of particular importance:

1. Habitat specific productivity and survival.

   Preliminary estimates are available for portions of the owl's range, but in other portions we do not have definitions for cell types. The needed information could be collected using two general approaches. First, home ranges of owls being monitored for productivity and adult survival should be assigned to cell types so that a sample for each type could be obtained. Second, intensive studies of radio-transmittered owls should be made to improve our understanding of habitat types that are used and avoided. Study should also be made of the particular values to owls provided by each stand type. Much work of this sort has been done in western Oregon and Washington, but similar studies are needed (and in some cases are in progress) in environments east of the Cascade crest, in California, and in the Oregon Klamath province. Habitats of particular interest should be selected for these studies.

2. Effects of habitat on movements by dispersing juveniles.

   This topic has received little study but is critical for the evaluation of the recommended recovery program. Intensive monitoring of dispersing juveniles is needed to reveal how their movements and survivorship are affected by the configuration of habitat in the landscape they pass through, how widely they search for territories during dispersal, whether they settle in the first available place, and how far they travel if vacancies are not available. Close monitoring of a relatively small number of owls (rather than occasional location of a larger sample) is needed. Monitoring such a sample of dispersing owls, and analysis of the habitats and resident owls in their path, would provide a far better basis than we have at present for deciding on the values of the movement parameters in the landscape model. They would also provide a better evaluation of the 50-11-40 rule. Such studies might be carried out in the density areas where the locations of other owls are already well known.

3. Behavior of floaters.

   Floaters may buffer the population against loss of breeding adults if the floaters rapidly fill vacancies (Franklin In Press). At present, however, we know little about the behavior of these floaters, so determining their importance in maintaining stable populations is difficult. Monitoring a small sample of owls, perhaps followed continuously after being banded as fledglings, could provide much of the needed information. The critical question is how widely and continuously they search for vacancies in territories. Other issues, such as how their survival rates compare to territorial adults, should also be investigated.

As this information is obtained, it will be important to challenge the model with tests to reveal the reliability of its predictions. For example, predictions by the model of how dispersing juveniles will move throughout real landscapes can be compared with actual movements by radio-transmittered owls. The environment in 1950, when public lands were largely covered by old-growth and presumably had rather continuous populations of owls, can be reproduced in the computer and then altered during a 40-year simulation to resemble its current state. Distribution of owls at the end of the simulation then can be compared to actual distribution. Other tests of this sort can be carried out, to increase our knowledge of what the model can, and cannot, reveal about owl trends. Three broad outcomes of this work might be distinguished: the model may not make any reliable predictions, it may permit an "ordering" of trends under different proposals, or it may permit estimates of trends of sufficient accuracy to be useful. It is too early for confidence about how well the landscape model will perform, but it appears to have a better chance of predicting order, and perhaps absolute trends, than any other approach for modeling population dynamics of spotted owls.

Early Warning Methods

Two other methods for making inferences about population trends warrant consideration. Neither will provide reliable estimates of trends, but both may provide an "early warning" that population declines are imminent.

The first method is monitoring the age of first-time territory holders. The rationale of the method is that if the floaters comprise a large proportion of the population, then many of the first-time territory holders probably will not be young (1- or 2-year-old) owls. However, if all adults hold territories then all first-time territory holders must be young owls (unless adults move after establishing a territory, which is thought to be uncommon). These facts suggest that as the population of floaters declines, the proportion of first-time territory holders that are young owls eventually must increase to 1.0. Accordingly, monitoring this proportion might provide a basis for crude inferences about the size of the floater population. If the ratio was 1.0 in one population and 0.3 in another, we might reasonably infer that the first population had more floaters, and if the proportion began increasing, we might suspect that the overall population was declining even if the number of territorial owls remained stable.

The exact relationship between the proportion of first-time territory holders that are young and either the size of the floater population or the rate of population change appears complex and difficult to model. Computer simulations, however, can be used to indicate general trends. We prepared such a simulation (see Appendix C) and used it to investigate the behavior of this age ratio. If floaters are assumed to have wide "knowledge" of vacancies, and particularly if older owls are assumed to have a competitive advantage in filling vacancies, then the age ratio, in a population undergoing overall decline, remains rather constant until only a year or two before a decline begins in the territorial population. If each floater only fills vacancies occurring in a small area then the proportion drifts upwards much more slowly as population size declines. In the former case, the age ratio would be of little value as an early warning sign, whereas in the latter case it could be of significant help.

Ages of first-time breeders should be obtained for a series of populations, and the behavior of floaters should be studied so that computer simulations can be made more realistic. Age ratios usually are obtained in the course of monitoring adult survival rates so this information can be obtained with little or no extra cost.

The second early warning method is the time that vacancies in the territorial population remain unfilled. Much the same argument as was made earlier can be applied to this variable. If a large floater population exists, then one would expect replacement times to be short, whereas eventually, as the population declines, some vacancies will not be filled at all. Thus, the replacement time should increase gradually as a population declines. Also, if floaters search widely for vacancies, then the upward trend in replacement time might not begin until nearly all floaters had disappeared, whereas if they search only locally, the upward trend might begin much sooner. This issue could be investigated to some extent by recording replacement times and tracking the change in their average value as a population changes in size. Empirical information about the behavior of floaters, however, also would be of great value in understanding this variable and using its behavior to make inferences about population trends. This method would probably only work when some vacancies remain unfilled for at least a year.

A Comprehensive Monitoring Program

This section contains preliminary recommendations for a comprehensive monitoring program. The suggestions will need review and refinement, but enough information exists to develop the general outlines for the program. Considerable overlap exists in the information needed by the various approaches described previously (see Table A.1). Most components of the comprehensive program already exist, but they need to be integrated with each other, coordination between the principal investigators is needed, and appropriate levels of standardization and reporting need to be identified and implemented.

Estimating or predicting population trends is the main objective of these monitoring programs, but the information they provide also could be useful in other aspects of the recovery program. For example, counts of territorial owls could provide indications of relative abundance in young landscapes with and without remnant old-growth stands or individual trees. This information could be useful to silviculturists studying ways to accelerate development of suitable habitat. In the following discussion, we attempt to identify some of these objectives and suggest how the monitoring program can be designed to help achieve them as well as achieve the primary goal of estimating or predicting population trends.

Table A-1. Summary of information needed for different approaches to estimating or predicting population trends.

1. Direct counts (information needed rangewide)
   a. Responses per station on roadside surveys
   b. Actual density in several areas
   c. Responses on rapid survey in censused areas

2. Demographic analyses (information needed rangewide)
   a. Productivity
   b. Juvenile survivorship
   c. Adult survivorship

3. Population projections (information needed from selected areas)
   a. Productivity in relationship to habitat types
   b. Detailed data about juvenile dispersal
   c. Juvenile survivorship in relationship to landscape types
   d. Adult survivorship in relationship to habitat type
   e. Information about behavior of nonterritorial adults

4. Early warning methods (information needed rangewide)
   a. Ages of first-time territory holders
   b. Replacement times
   c. Information about behavior of nonterritorial adults

Density and Regional Study Areas

The density and regional studies will play an essential role in the monitoring effort as well as providing other critical information not directly related to monitoring. They will probably provide the most precise estimates of change in size of the territorial population, they will provide data for demographic analyses and population models, and they will probably provide the best information about how demographic rates and other behavior vary with habitat condition. They might be excellent sites for transmitter studies (see the following sections) and they will also provide the data needed to "calibrate" the roadside survey and prevent biases due to changing detection rates (see the following sections). We strongly recommend that these studies be continued and in some cases expanded. Consideration should be given to transforming them from owl studies into ecosystem studies.

Field methods for finding owls and recording survivorship and reproductive success in the density studies are already well developed (e.g., Forsman et al. 1984, Gutiérrez and Carey 1985) and will not be reviewed here. Methods for selection and sampling of owl sites in the regional study areas, however, may warrant more attention. The issues are described later in the appendix and preliminary recommendations are provided.

One of the most troublesome problems in the demographic analyses is that many juvenile owls and some subadults and adults probably leave the study areas and breed outside them. As a result, capture-recapture methods tend to underestimate survival rates and population trends. Another problem with the overall monitoring effort at present is that virtually no information about productivity or survival comes from many parts of the owl's range, or if information is available, uncertainty may exist about the methods used to collect the data.

Both of these problems might be reduced by expanding the regional study areas to cover the entire range of the owl. The expanded regional areas could be subdivided, and some parts of each regional study area might be surveyed much more intensively than other parts. The overall cost might be comparable to current costs of the density studies. But if a well-defined probability sample could be selected in all (or at least most) areas, then a) an improved basis for estimating emigration rates and population trends would be provided, and b) at least limited information about productivity and survival rates would be provided from all parts of the owl's range. The national forests, U.S. Bureau of Land Management districts, and private landowners might carry out much of the sampling, especially in areas from any existing regional study area.

Single Visit Surveys

Neither the density study areas nor the regional study areas are likely to provide the ***regionwide*** information about trends called for in the delisting criteria. Large portions of the owl's range do not, and never will, have density areas. The regional studies do not sample all existing nest or activity sites each year; instead, they involve selecting a sample of sites and then following these for several years. A decline in occupancy at these sites does not indicate an overall decline in population size (of territorial owls) because disappearances at some sites may be balanced, or more than balanced, by new sites becoming occupied. The regional study methods would only provide trend estimates if a random sample of areas was thoroughly searched each year to detect new sites. This would be expensive due to the rigorous field procedures involved (e.g., minimum of six visits before assuming owls are absent).

In view of these problems, consideration should be given to establishing call-count routes which are visited a single time to detect trends in the territorial population. This type of "one-time" survey is widely used to monitor wildlife populations. Indeed, the great majority of species has been monitored with this kind of survey for decades and the approach has proven capable of detecting major changes in abundance for numerous species (e.g., Robbins et al. 1986). One-visit surveys, conducted along roadsides, would be far less expensive than density or regional studies which include multiple visits to unoccupied sites and detailed walk-in visits to search for, and then monitor, nests.

Sample size requirements for these surveys have been discussed by Bart and Robson (In Prep.). Sample size includes the number of stations (or routes) monitored per year and the number of years during which monitoring continues. Two analyses were carried out. The first was based on a series of computer simulations in which statistical methods were used to create data sets with known underlying trends. Estimates of these trends then were calculated and compared to the known, true values. The process was repeated with different parameter sets to investigate sample size requirements and identify factors that affect them. This analysis permitted a detailed investigation of sample size requirements but required an assumption that the computer model was realistic. For the second analysis, data were obtained from the FWS Breeding Bird Survey on population trends in several species of hawks and owls. Long-term trends were calculated and the number of years required to obtain reliable estimates of these trends were calculated. This analysis provided much less detailed results but involved real, rather than simulated, data. Each analysis provided useful information, but even in combination they provided only preliminary estimates of the sample sizes that will be necessary to obtain reliable estimates of long-term trends in spotted owl populations. The results of both analyses were that a minimum of 8 years will probably be required to obtain reliable estimates of population trends. With shorter time periods, short-term fluctuations tended to mask the true long-term trend. See Bart and Robson (In Prep.) for details of the analyses.

Coordination

A clear need exists for coordination and integration of the results from these surveys and analyses. If different survey methods, different sampling techniques, and different ways of describing habitat are employed by field workers, then the overall recovery effort will be far less efficient in providing the information needed to refine the recovery plan and eventually delist the subspecies. The coordination effort must ensure that methods are standardized and that rangewide sampling plans are followed. However, it must be recognized that different investigators have different objectives, and these may require different field methods and analyses. A few specific tasks, designed to accomplish this coordination, while not conflicting with the separate objectives of individual investigators, are identified next.

1. Obtain commitments to carry out the proposed surveys.

   The monitoring program proposed here can succeed only if the major federal and state agencies, and some of the major private landowners, agree to participate. The Recovery Team has convened a committee of agency and private biologists to develop the monitoring effort. Representatives to this committee should be formally appointed and authorized to represent their agencies and companies in making commitments to the monitoring program. Long-term commitments will be particularly important.

2. Organize a centralized system for obtaining and analyzing the survey results.

   Coordination of the monitoring effort will require numerous logistic efforts such as preparing data forms and mailing lists, entering data, preparing and running analytic programs, filling data requests, and preparing reports. The Recovery Team should take initial responsibility for this coordination and should sponsor a study to determine how long-term assurance of effective coordination can best be assured.

3. Assess the role of the GIS in the monitoring program.

   Many examples of contributions that the geographical information system (GIS) could make to the monitoring program have been described. Obtaining GIS products, however, has often been difficult. The problems should be studied and resolved to the extent practical. The Recovery Team has arranged for assistance from the U.S. Geological Survey in assessing GIS needs and capabilities, and additional efforts of this type should be made.

Literature Cited

Forsman, E.D.; Meslow, E.C.; and Wight, H.M. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monographs 87:1-64.

Franklin, A. B. In Press. Population regulation in northern spotted owls: theoretical implications for management. In McCullough, D.; Barrett, R. ed. Wildlife 2001: Populations. Essex, England: Elsevier Press.

Gutiérrez, R.J.; Carey, A.B. eds. 1985. Ecology and management of the spotted owl in the Pacific Northwest. General Technical Report PNW-185. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experimental Station. 119 p.

McKelvey, K. 1991. A spatially explicit life-history simulator for the northern spotted owl. Berkeley, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Forest and Range Experiment Station. 26 p.

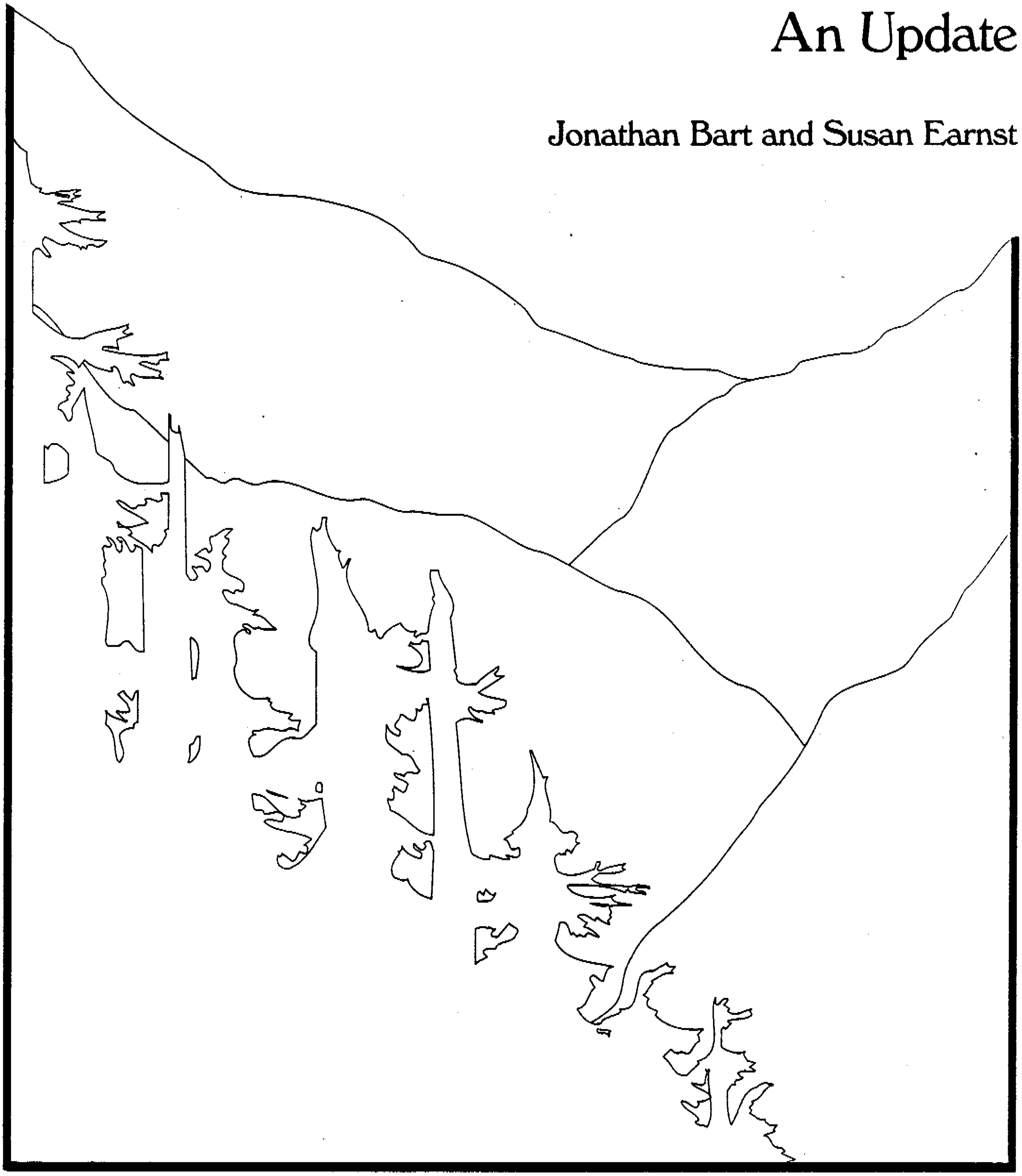
Robbins, C.S.; Bystrak, D.; Geissler, P.H. 1986. The breeding bird survey: its first fifteen years, 1965-1979. Washington, D.C.: U.S. Department of the Interior, Fish and Wildlife Service, Resource Publication 157. 196 p.

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, B.R.; Verner, J. 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.

Appendix B

Suitable Habitat for Northern Spotted Owls: An Update

Jonathan Bart and Susan Earnst



Contents

Abstract

This appendix discusses the use of information about habitat suitability in the recovery program. Information about habitat suitability is divided into six categories: structural features of sites used by owls, amount of habitat in home ranges, habitat selection for roosting and foraging, abundance of owls in different habitats, demographic rates in different habits, and functional studies of resources needed by owls. Our current knowledge about each of these areas is summarized, emphasizing knowledge obtained since the review by Thomas et al. (1990). New information provides a clearer description of habitats used by owls and suggests that, as predicted by Thomas et al. (1990), a wider range of habitats may be suitable for owls in California than in Oregon and Washington west of the Cascade crest. New evidence also suggests that adult survival rates decline with decreasing amount of old-growth near to the nest. This finding is important because of the extreme sensitivity of population viability to adult survival rates. Recommendations for future work include standardizing habitat measurements, preparing habitat maps for the demographic study areas, and emphasizing new research in several specific areas or habitats.

This appendix summarizes information from habitat studies about northern spotted owls. Thomas et al. (1990) should be consulted for a comprehensive review of this topic; this appendix emphasizes studies which have appeared since Thomas et al. (1990). We discuss how habitat information will be used in the recovery program, review the state of our knowledge about suitable habitat for northern spotted owls, and offer tentative suggestions about priorities for future research on habitat requirements of owls.

We were assisted in the preparation of this appendix by Gary Benson, Randy Dettmers, Jeff Grenier, David Johnson, Jo Ellen Richards, Kristin Schmidt, and David Solis, each of whom analyzed studies and data bases describing habitat relationships of spotted owls in a portion of the owl's range. Reports by Benson (1991a, 1991b) and Grenier (1991) are included in the recovery plan's administrative record. Bruce Bingham, Mark Boyce, Jennifer Blakesley, Charlie Brown, Joe Buchanan, Lowell Diller, Lee Folliard, Eric Forsman, Alan Franklin, Rocky Gutiérrez, Tom Hamer, Larry Irwin, Steve Kerns, Kevin McKelvey, Joe Meyer, Barry Noon, Malcolm Pious, Steve Self, and Cindy Zabel provided us original summaries and analyses of their data or pre-publication manuscripts. Previous drafts of the appendix were reviewed by Bob Anthony, Edie Asrow, Gary Benson, Bruce Bingham, Lowell Diller, Alan Franklin, Rocky Gutiérrez, Richard Holthausen, Bruce Marcot, and Steve Self.

Studies of Habitat Suitability

Habitat suitability might be defined qualitatively as the degree to which a given habitat provides the resources northern spotted owls need to survive, reproduce, and disperse successfully. No single definition captures all of the ways of measuring habitat suitability. For example, consider a study to determine the suitability of a particular habitat for foraging. Suitability might be assessed as the amount that foraging owls use the habitat, by capture rates per unit of time spent hunting in the habitat, by susceptibility to predators of owls foraging in the habitat, or by time required for the prey population to rebound after being depleted. Each of these measures would provide useful information and could legitimately be considered an aspect of habitat suitability. Habitat suitability is thus best considered an area of study, rather than a specific parameter. In a specific context, however, more precise definitions of habitat suitability may be reasonable. Furthermore, it is certainly possible to measure habitat features or attributes that have little or no relationship to the habitat's suitability for owls. Consequently, the issue of whether a study has used good measures of suitability is important, even though we usually cannot provide a precise, quantitative definition of suitability.

Information from studies of habitat suitability will be useful in many parts of the recovery program. For example, habitats supporting self-sustaining owl populations should be identified and described, proposed conservation programs must be evaluated, models of owl population dynamics must have realistic descriptions of habitat relationships, and the structure of habitats that land managers will attempt to develop and maintain must be described. In this section, we discuss the types of information needed for these assessments and predictions, and provide a brief evaluation of the ways in which each kind of information will be most useful in the recovery program.

Types of information collected

Studies of habitat suitability for owls may be divided into six broad categories:

1. Structural features of utilized habitats.
2. Amount and distribution of suitable habitat in home ranges.
3. Habitat selection for roosting and foraging.
4. Abundance of owls in different habitats.
5. Demographic rates of owls in different habitats.
6. Studies of specific resources needed by owls.

Studies describing structural features of utilized habitats present quantitative measurements of the habitats used by spotted owls for roosting and foraging. Variables reported frequently include dbh, canopy cover, and tree species composition. These variables, and others, may be reported for all trees or for overstory and understory. Separate analyses may be carried out for different activities such as nesting, roosting, and foraging, or for different periods such as breeding and nonbreeding. Measures of central tendency (e.g., mean, median), variability (e.g., range, standard deviation), and precision (e.g., standard error, coefficient of variation) usually are presented for each variable measured.

Studies estimating the amount of habitat in home ranges generally have employed telemetry methods and the "minimum convex polygon" approach to delineate home ranges (Thomas et al. 1990:193). A few studies have calculated the amount of habitat within some distance (e.g., 1.3 or 2.1 miles) of the nest. Lehmkuhl and Raphael (In Press) investigated the use of this method on the Olympic Peninsula and found that it gave generally satisfactory results for habitat assessment. The habitats usually have been defined using size classes (e.g., old-growth, mature, pole, etc.) or age classes (e.g., more than 200 years, 120 to 200 years, etc.). Combinations of variables (e.g., mean dbh more than 21 inches and canopy cover more than 70 percent) have been used to define categories in a few studies.

Habitat selection for roosting and foraging has been assessed using telemetry methods to define home range borders and identify specific sites used by foraging or roosting owls. Investigators then compare the proportion of the locations in a habitat with the proportion of the home range covered by the habitat. Statistical analyses usually have been employed to determine which habitats (if any) were used significantly more often than would be expected if locations were distributed randomly with respect to the habitat types. Habitats used significantly more often than expected often are referred to as "preferred" and habitats used significantly less often than expected under the random distribution hypothesis often are referred to as "avoided." There is no implication of a state of mind, as is usually true when these words are used to describe human actions. Furthermore, results of the "use-availability" analysis provide no evidence that the features used to categorize habitats had any direct influence on owls; the features may have been correlates, rather than causes, of the preferences. White and Garrott (1990) provide a good discussion of use-availability analyses.

Studies of owl abundance in different habitats usually have employed index methods or intensive surveys to estimate relative or absolute abundance in two or more habitats. Few nonterritorial owls are detected during these surveys, so "abundance" means abundance of territorial owls, not all owls. This issue is discussed in more detail in Appendix A. The sample units in these studies generally have been survey stations, circles, or landscapes. Survey stations are assigned to the habitat category in which the station is located. Circles and landscapes generally are assigned to habitat categories based on the proportion of the sample unit covered by a particular habitat. For example, the habitat categories might be defined using proportion of the sample unit covered by "older forest" (e.g., stands more than 80 years old). The categories might be 0 to 20 percent, 21 to 40 percent, 41 to 60 percent, and more than 60 percent. Alternatively, the habitat type may be regarded as a continuous variable (e.g., percent older forest). In either case, the investigation would provide information about the relationship between the proportion of older forest and owl abundance.

Studies of owl demographic rates in different habitats generally have measured one or more of the following variables: proportion of territories with pairs, number of young fledged per pair-year, turnover rates of territorial adults, survival rates of adults, survival rates of juveniles. Turnover rates are defined as the proportion of adults disappearing from territories each year. Most of these analyses have been similar to studies of abundance except that the sample units have been pairs or territories (rather than plots) and demographic rates rather than abundance have been measured for each sample unit. The definition of habitat categories has followed the same process as in studies of abundance. A few studies (see Appendix C) have used estimates of birth and death rates, as well as rates of immigration and emigration, to calculate the rate at which population size changed during the study.

Studies of the specific resources needed by owls have investigated diet, prey base, nest sites, and home range size and composition. The objective in these studies was to identify the resources needed by owls for specific activities and to understand the processes that determine how well a particular habitat supplies these resources. These studies provide insights about the causes, rather than just correlates, of habitat suitability. The studies are reviewed in section II.A. of the recovery plan and are not reviewed in this appendix.

It may be useful to recognize that the studies just mentioned provide descriptive, correlational, and functional information about habitat relationships of spotted owls. Measurements of structural features and amounts of habitat provide descriptive information about the environments where owls are found. Studies of habitat selection, density, and demographic rates provide correlations between habitat features or categories and measures of suitability (e.g., use, density, or demographic rates). These studies do not necessarily identify the features of importance to owls, so extrapolation to other environments may not be warranted. Studies of the specific resources needed by owls, however, help supply this understanding of causal relationships between habitat features and owl viability and thus greatly improve the reliability of assessments and predictions.

Use of the information

Assessments and predictions about the suitability of habitats for owls generally involve three steps:

1. Define habitats and habitat categories.
2. Determine suitability of each habitat category.
3. Evaluate basis for extrapolating findings to other populations.

The six types of information identified earlier play different roles in these three steps (Table B.1). Descriptive information about the structure of utilized sites and amounts and configuration of habitat within home ranges is particularly helpful in defining habitat

Table B.1. Roles and relative importance of different kinds of information about habitat suitability in making assessments and predictions about owl viability[a].

	Step in Making Assessments or Predictions		
Measure of Habitat Suitability	**Define Habitat Categories**	**Measure Habitat Suitability**	**Evaluate Basis for Extrapolation**
Structural Features of Utilized Habitats	XXX	X	*
Amounts of Habitat in Home Ranges	X	XX	*
Preference for Roosting and Foraging	*	XX	X
Abundance of Owls in Different Habitats	*	XX	X
Demographic Rates in Different Habitats	*	XXX	XX
Studies of Specific Resources	XXX	XX	XXX

[a] XXX = most important
* = least important

categories. Knowing the amount of habitat present in home ranges also provides some indication of which landscapes provide suitable conditions. Correlational information provided by studies of which habitats are preferred for roosting and foraging, and by studies of density and demographic rates, are most useful in measuring the suitability of existing habitats. Correlational studies also provide some assistance in defining new habitats and deciding how much the results can be extrapolated to other populations of interest. Functional studies, in which causes are identified and distinguished from correlates, provide a good basis for measuring suitability and an excellent basis both for defining new habitat categories and for evaluating whether, or how well, the results of studies can be extrapolated to other populations. A few examples illustrating these generalizations and showing how studies of habitat suitability complement and reinforce each other are given later. More detailed discussions of how each type of information can be used in the recovery program are provided in subsequent sections.

Early surveys for owls revealed that density was high in areas with plentiful old-growth and low elsewhere. These descriptive and correlational results were supplemented by functional studies that sought to identify the specific resources needed by owls that were present in old-growth and absent in other areas. The results of the correlative and functional studies convinced most investigators that owl densities would remain low outside of old-growth. Since old-growth was expected to decline in abundance, this led to the prediction that overall owl populations would decline. In this example, the parameter indicating habitat suitability was abundance, and the habitat categories were old-growth and other. The critical assumption on which the prediction was based was that density would remain low outside of old-growth areas.

The landscape model discussed in Appendix A permits the definition of up to six habitat types, and the specification of various "rules" that define behavior and success of owls within each type. These rules are assumed to remain the same within each type through time. The parameters are thus the demographic rates and other rules followed by the model, and the habitats are defined by the investigator. Both correlative and functional studies are needed to define the habitat types, estimate parameter values within them, and evaluate the assumption that parameter values will be similar in study areas and areas about which inferences are made using the landscape model.

Owls are sometimes present in areas where most of the trees are fairly young (e.g., 50 to 80 years old), but some older and larger trees are present (e.g., Thomas 1990:184). This leads to the hypothesis that if some large trees were left during harvest, density of owls might increase substantially when the regenerating stand reached an age of 50 to 80 years. In this prediction the habitat is 50- to 80-year-old stands with remnant large trees, the parameter indicating suitability is density, and the primary assumption is that density in future habitats of this type will be similar to the existing habitats that have been studied. Descriptive and correlational studies were useful in developing the hypothesis that retaining large trees creates suitable habitats. Functional studies are needed, however, to reveal whether large trees cause the high density of owls (compared to existing stands without large trees) or whether the large trees are simply correlates of some other feature that occurs in the existing habitats but might not occur as a result of the silvicultural manipulation.

Much of the effort in the recovery program will be devoted to identifying habitats that are "suitable" for owls at the stand, territory, and landscape level. All types of habitat study have contributions to make in this effort. Suppose, for example, that we have defined a habitat, call it Type A, that we believe might provide all of the resources needed by owls to maintain viable populations. We would first define the habitat using structural measures such as average dbh, canopy cover, and presence of a hardwood understory. We would then use several types of information to evaluate the hypothesis that Type A habitat was suitable for owls.

We might begin by examining the data from utilized habitats. Finding that utilized habitats frequently met our definition of Type A habitat, and that home ranges consistently contained large amounts of Type A habitat, would support the hypothesis. We would also examine data from correlational analyses. The habitat categories would be Type A and other. Strong preference for Type A stands would tend to support our hypothesis, as would a finding that density and demographic rates were higher in circles, landscapes, and territories with large amounts of Type A habitat. Results from functional studies would be useful in determining whether the specific features of importance to owls were highly correlated with the elements in our definition of Type A habitat and if they were, whether this was likely to be true in other environments to which we might wish to extrapolate our findings. We would not expect that all these tests and analyses to support the predictions, but if few of them did, then we probably would discard or substantially modify the definition of Type A habitat and start again. If most of the predictions were verified, then we would tend to feel that a good definition of suitable habitat had been developed.

A process much like that just described has been carried out in evaluating the hypothesis that older (i.e., mature and old-growth) forests provide suitable habitat for owls. Descriptions of utilized habitat have shown that nesting, roosting, and foraging owls usually are found in older stands and the structural features of these stands have been described in quantitative terms. Comparisons of stands have shown that owls exhibit a strong preference for older stands for roosting and foraging. Reproductive success has been shown to be higher for pairs having more older forest in or near their home ranges. Density and adult turnover rates also have been shown to be positively correlated with the amount of older forest in the landscape. Several hypotheses about the possible functions of older forest in supporting owls have been generated, and evidence supporting some of them has been reported. Thus, while no one piece of evidence would (or should) provide a high level of confidence that older forests provide suitable habitat for owl populations, taken together these studies do provide such confidence. This of course does not mean that older forest is the only habitat that provides suitable habitat, but hypotheses predicting that other habitats also provide suitable habitat must be evaluated in the same comprehensive way that the hypothesis about older forest has been evaluated.

As the previous examples indicate, the results from descriptive, correlational, and functional studies are best used in combination, rather than in isolation. Descriptive information is most useful for defining habitat categories; correlational information at the stand, home range, and landscape level is most useful for measuring suitability of specific habitats; functional information is particularly useful for identifying the specific resources of value to owls and thus providing insights about how widely results can be extrapolated to other populations. Information from any single type of study would provide a poor basis for assessments or predictions about habitat suitability; taken together, however, they provide an excellent basis for such analyses. Subsequent sections explore in more detail the ways that each type of information contributes to analyses of habitat suitability.

Recent Literature

Thomas et al. (1990) provided a thorough review of the literature, including many pre-publication reports, available at the time of their report. Our discussion of habitat suitability is based largely on their review. Several studies have been published since the Thomas et al., and we have conducted new analyses of a few topics. The new studies, or studies from which we have extracted original data, are described briefly in the following section.

California

Asrow (1983) sampled the vegetation of four occupied spotted owl management areas (SOMAs) in old-growth Douglas-fir/white fir forests on the Scott River Ranger District of the Klamath National Forest. Owl presence was documented using a combination of night and day surveys during the 1983 breeding season. Vegetation was sampled on six variable-radius plots in each SOMA. One plot was centered on the location of the owl; other plots were placed 132 feet from the central plot and equal distances from each other.

Bingham (1991) described stands used by 20 radio-transmittered owls for roosting and foraging in Douglas-fir/tanoak/madrone forests on the Mad River Ranger District (Six Rivers National Forest) in the California Klamath physiographic province. Utilized stands were defined as those with more than three telemetry locations. Data were summarized separately for roosting stands (based on daytime locations) and foraging stands (based on nighttime locations) in the breeding and nonbreeding season. Vegetation was sampled on three to eight 0.25-acre plots per stand. The author presented the data as means for each of three vegetation classes (defined on the basis of a cluster analysis); the data presented in this appendix are the means of these three classes, weighted by sample sizes.

Blakesley et al. (1992) recorded 421 owl locations, including 79 nest sites, during the breeding seasons of 1985 to 1989 in the Willow Creek study area in northwestern California. Stand types were defined by dominant vegetation (conifers, hardwoods, unvegetated), mean dbh, elevation, aspect, position (lower, middle, or upper third), and slope.

Chávez-León (1989) measured habitat structure in 14 stands used by owls during 1987 and 1988 in the California Klamath province (Humboldt and Mendocino Counties) in northwestern California. Pairs occupied nine and 10 sites in 1987 and 1988, respectively; nesting pairs occupied five and three sites in 1987 and 1988, respectively. Twelve of the 14 sites were in typical Douglas-fir/tanoak/madrone forests, and two were in redwood forests. The landscape was highly fragmented; stands used by owls sometimes were fragmented and varied in size from 49 to 642 acres. Habitat structure was measured on five or more variable-radius plots randomly placed within each stand. Chávez-León excluded some plots in calculating mean densities and basal areas, but we used all plots for our analysis. Folliard and Reese (1991) measured 30 nest sites and nest stands during 1990 in second-growth redwood/Douglas-fir forests in the California Coast province (Humboldt and Del Norte Counties). Plots were circular and covered 0.18 acres (radius = 50 feet). Nest-site plots were centered on the nest but did not include the nest tree in measures of density and basal area. Four or five plots were distributed randomly within 0.5 miles of the nest and in the nest stand.

Jimerson et al. (1991a) quantified the structure of old-growth Douglas-fir/tanoak/madrone stands in SAF 234 (i.e., Society of American Foresters forest type 234) in the California Klamath province. Data were collected on the Six Rivers, Siskiyou, and Klamath (western half) National Forests, and the Northern California Coast Range Preserve. Vegetation was sampled on three variable-radius plots in each old-growth stand. Bingham and Sawyer (1991) presented a summary of this information.

Jimerson et al. (1991b) quantified the structure of old-growth Pacific Douglas-fir forests stands in SAF 229 in the California Klamath province. Data were collected on the western half of the Klamath and Six Rivers National Forests. Vegetation was sampled on three variable-radius plots in each old-growth stand.

Kerns (1989) measured habitat structure at one roost site in each of 10 home ranges in redwood forests of the California Coast province (Humboldt County). The roost stands were in second-growth with few snags or old-growth trees remaining. Roost stands were considered "used" if an owl was present on more than one daytime visit; owls were present in most used stands during two or three daytime visits. Owl use was documented in 1988, and vegetation was sampled in 1989. One 0.5-acre vegetation plot was centered on the roost tree or, for smaller stands, in the stand (Kerns pers. comm.).

LaHaye (1988) measured habitat structure at six nest sites and stands in redwood forests of the California Coast province and in 38 nest sites and stands in the California Klamath province (32 in Douglas-fir/tanoak/madrone forests, and six in mixed-conifer forests of incense cedar/sugar pine/black oak). The nests were widely distributed throughout the owl's geographic range in California. Nest stands contained patches of remnant older trees that had escaped fires and other natural catastrophes, and in which the nests were usually located. The nest site was characterized by one plot centered at the nest tree and four plots located 75 feet from the nest tree and at equal distances from each other. Nest stands were characterized by plots at several distances from the nest. We used the data from four plots 450 feet from the nest tree and four plots 600 to 4,500 feet from the nest. All plots were of variable radius.

Pious (1989) measured habitat structure at seven nest sites and 22 roost sites in coastal redwood forests of the California Coast province in Mendocino County. The sites were in second-growth stands in a landscape lacking any extensive, unharvested stands more than 200 years old. The location of roost sites was determined April-July 1989 through a series of nighttime calling surveys and daytime visits; the roosts were in 22 home ranges (Pious pers. comm.). Nest sites were described using two 0.17-acre strips placed perpendicular to one another and each centered at the nest. Nest stands and roost stands were described using two or three plots; each plot was a 0.25-acre strip, randomly placed within each stand.

Self and Brown (pers. comm.) described habitat structure at 21 nest sites in the California Klamath province, in northcentral California. Most of the sites were located during the preparation of timber sales, and thus the surveys were concentrated in dense stands with large trees, rather than being fully representative of the landscape. The nests were in second-growth stands of Douglas-fir or Klamath mixed-conifers (white fir, Douglas-fir, ponderosa pine, incense cedar, and sugar pine). Most areas were under even-aged management regimes composed of a mixture of partial harvest techniques (selective, seed tree, shelterwood, thinning). All but one of the areas studied had some clear-cut regeneration harvests during the previous 10 years. Within-stand diversity was generally high due to the history of partial harvesting. Nest sites were described using two 0.17-acre strips centered on the nest tree.

Simpson Timber Company (1991) published a draft habitat conservation plan containing results of its owl monitoring and research program. Surveys to determine owl abundance, distribution, and reproductive success have been carried out annually on Simpson's land in the California Coast province since 1989.

Sisco and Gutiérrez (1984) and Sisco (1990) characterized the winter (October-February) roosting and foraging sites of five radio-transmittered owls during fall 1982 and winter 1983 in the Six Rivers National Forest (Humboldt County, California) in the California Klamath province. Most home ranges were in Douglas-fir/tanoak/madrone forests, although parts of some home ranges at higher elevations were in montane forest (white fir, ponderosa pine, sugar pine, and incense cedar). Most roosting and foraging stands were unmanaged, although the landscape and home ranges contained some stands under even-aged management. Roosting sites were visually located; sites with more than five nighttime telemetry locations were considered intensively used foraging sites. Twenty-seven roost sites and 200 foraging sites were characterized. Vegetation was sampled within a circular 0.1-acre plot centered on the roost tree or foraging location.

Solis (1983) and Solis and Gutiérrez (1990) characterized roosting and foraging sites of 10 radio-transmittered owls during the breeding seasons (February to September) of 1980 and 1981 on the Six Rivers National Forest (Humboldt County, California) in the California Klamath province. Six of the owls were also studied by Sisco (1990). Fifty visually-located roost sites and 398 foraging sites were characterized. The habitat and sampling methods were identical to those of Sisco (1990).

Zabel et al. (1991) studied habitat use by spotted owls during the breeding and nonbreeding seasons in the Six Rivers and Klamath National Forests. Stand types were defined by dominant vegetation (conifers, hardwoods, nonvegetated), mean dbh, elevation, aspect, position (lower, middle, or upper third), and slope.

Oregon and Washington

Allen et al. (1989) described stands used by 18 radio-transmittered owls in nine SOMAs in the Gifford-Pinchot, Mt. Baker-Snoqualmie, and Olympic National Forests. Douglas-fir, western hemlock, and Pacific silver fir were the major overstory trees. Vegetation was sampled at 436 intensively used sites (i.e., sites with clusters of locations). At each site, 25 measurements were recorded using the point-center-quarter method. Most of the sites were in small stands of old-growth.

Benson (1991b) described stands used by six radio-transmittered owls in mixed-conifer forests in the Wenatchee National Forest (Cle Elum Ranger District). Intensively used stands (those with three or more telemetry locations) within 0.5 miles of the nest were sampled with three to nine plots distributed uniformly in the stand. Each plot contained a variable-radius plot, a 0.20-acre circular plot, a 0.5-acre rectangular plot, and a line transect.

Buchanan (1991) characterized 62 nest sites and surrounding nest stands throughout the eastern Washington Cascades province. Most of the nests were in the Wenatchee and Okanogan National Forests; a few were on private lands. The forests were dominated by Douglas-fir and grand fir, with some ponderosa pine, western larch, western red cedar, and western hemlock, and with little hardwood understory. Median nest stand age was 130 years. Most young and mature stands contained remnant old-growth trees. Young had fledged at most of the nests within the previous 4 years, and only four nests had no record of successful nesting. Nest sites were described using a single 0.25-acre plot, and four 0.1-acre plots, located within 110 feet of the nest tree. Nest stands were described using a single plot randomly placed within 1,300 feet of the nest tree.

Carey et al. (1991) conducted surveys for spotted owls (and other species) in eight young stands (40 to 72 years), 10 mature stands (80 to 120 years), and 29 old-growth stands (200 to 525 years) in the southern Oregon Coast Range province. Surveys were conducted during April, May, or June in 1985 and 1986. The stands were visited approximately seven times in each year. Average stand size was about 70 acres.

Hamer (pers. comm.) described 11 nest sites in the Mt. Baker-Snoqualmie National Forest. Nest sites were described using a circular, 0.5-acre plot centered on the nest tree.

Meyer et al. (1992) studied relationships between habitat quality and various demographic measures on BLM lands in southern Oregon and the border between the Oregon Klamath and Oregon Coast Range provinces. They selected 50 nest sites that each had been visited at least four times in each of 5 years. Habitats were defined using age and other features. Amounts of each habitat within 2.1 miles of the nest were measured. Several other variables (e.g., elevation, fragmentation indices) were also recorded.

Spies et al. (1988) quantified the stand structure in 85 old-growth Douglas-fir stands in the western Washington Cascades, western Oregon Cascades, and Oregon Coast Range provinces. Most study sites were in the Western Hemlock Zone and the lower elevation of the Pacific Silver Fir Zone; some sites were in the Mixed-conifer Zone and the Sitka Spruce Zone. Douglas-fir was the dominant species in all stands, although western hemlock was codominant in some stands. During 1983-1984, vegetation was sampled in five nested circular plots per stand, spaced 325 feet or 490 feet apart depending on stand size (range 10 to 50 acres). Nested plots included 0.1-acre, 0.25-acre, and 0.5-acre plots.

Structural Features of Sites Used by Owls

Relatively few descriptions of stand structure at owl sites were reported by Thomas et al. (1990). In the past 2 years, however, several new studies have appeared. We tabulated the information from studies in Thomas et al. (1990) and information from the more recent studies. Most studies recorded measurements at specific sites, as determined by radio-telemetry methods or by visually locating the owl. A few studies also recorded measurements from locations placed randomly with the stand. We refer to the latter as stand measurements; all other data in the tables are from specific sites used by owls.

We report average values from each study for abundance of trees by size class (all trees and hardwood understory), canopy cover, and abundance of snags. Where possible, results are presented separately for nesting, roosting, and foraging and for breeding and nonbreeding seasons. We emphasize that the range in values in our tables is not the range of average values in individual territories. Owls occurred in a much broader range of conditions than the range of values in our tables.

Many of the studies reported indicators of variability (e.g., ranges, standard deviations), but in most cases they were difficult to interpret because they depend strongly on plot sizes and sample sizes. The range (or standard deviation) of values from small plots generally will be larger than the range (or standard deviation) from large plots in the same area. Furthermore, many investigators combined plots across home ranges in calculating their measures of variability. The parameter (i.e., quantity of interest), in this case is difficult to describe in biological terms. We report only the average values from each study, while recognizing that information about variability also would be of value.

Results

California Klamath and California Coast provinces: Average canopy cover was 80 percent or more in all studies (Table B.2). The average number of trees/acre, by size class, also was quite consistent except for large (more than 36 inches dbh) trees that varied in density from 4 to 14 per acre (Table B.2). No major differences were apparent between sites used for nests and sites used for roosting or foraging. Old-growth stands may have had slightly smaller average canopy cover than stands used by owls, however more detailed studies are necessary to reach firm conclusions.

Table B.2. Habitats used by northern spotted owls in the California Klamath and California Coast provinces (values are the means from each study).

Feature	Value	Nest Sites		Roosting		Roosting and Foraging		Nesting, Roosting, Foraging		Old-growth
Canopy		81[a]	86[b]			84[b]				
Closure	%	92[c]	93[d]	84[e]	80[f]	91[g]	80[h]	95[i]	84[j]	65-80[l]
Trees/acre	5-10"	81[c]	69[d]	87[e]	92[f]	95[g]	124[h]	100[i]	75[k]	•
by dbh	11-20"	51	65	37	39	36	42	60	•	•
Class	21-25"	23	19	17	18	15	14	14	*	*
	>35"	7	4	8	7	14	11	5	13	•

[a]LaHaye (1988) (average of values for Klamath and California Coast provinces)
[b]Pious (1989)
[c]Folliard and Reese (1991), Diller and Folliard (pers. comm.)
[d]Self (pers. comm.)
[e]Bingham (1991) (Non-breeding season)
[f]Solis (1983)
[h]Sisco (1990)
[i]Chávez-León (1989)
[j]Asrow (1983)
[k]Kerns (1989) (Categories provided were 4-9" and "old-growth." Most of the old-growth trees were >36" dbh.)
[l]Bingham and Sawyer (1991)
* = data not available

Hardwoods comprised a large proportion of the trees less than 21 inches in dbh and a smaller proportion of the larger trees (Table B.3). Snags were rare in the studies in managed forests in the California Coast province (Folliard and Reese 1991, Pious 1989, Kerns 1989) (Table B.4). In the California Klamath province, snags in stands used by owls occurred at average densities similar to densities in old-growth stands. The average density of down logs appeared to be similar in the California Coast and California Klamath provinces.

Three studies compared habitats used by roosting and foraging northern spotted owls (Table B.5). The studies provided data about canopy cover, size class distributions of live trees, canopy closure, and numbers of snags. No differences in the habitats used for roosting and foraging were detectable in these structural features. One study (Pious 1989) provided habitat data for both nesting and roosting/foraging (Table B.6), and no differences were detectable in the average number of large trees, canopy closure, or density of down logs. More small trees were present at roosting sites than at nesting sites.

LaHaye (1988), Folliard and Reese (1991), and Pious (1989) compared measurements from nest sites and from throughout the nest stand (Table B.7). Average canopy closure, percentage of hardwood trees and the densities of small and medium-sized trees were about the same in the nest stand and at nest sites. In the first two studies, fewer large trees were present, on average, in the stands than at nest sites. These data suggest that the owls in these studies selected average sites within stands except that utilized sites had more large (more than 36 inches dbh) trees.

Other provinces: Fewer studies providing quantitative descriptions of utilized habitat are available from other provinces. Studies in the western Washington Cascades, Oregon Coast Range, and Olympic Peninsula provinces revealed approximately similar results for nest

Table B.3. Percent hardwoods in the understory (based on density) by dbh class at sites used by northern spotted owls in California.

Province	dbh (inches)	Nest Site	Roosting		Roosting/ Foraging	Foraging	
California Coast	5-10	63[a]	*		*	*	
	11-20	50	*		*	*	
	20-35	18	*		*	*	
	35	0	*		*	*	
	11-24	51[b]	*		*	*	
	24-36	6					
	36	0	*		*	*	
	5-16	78[c]	68[c]		*	*	
	16	13	17				
	5-16	*	43[d]		*	*	
	16	*	13		*	*	
California Klamath	5-10	31[e]	86[f]	73[g]	92[h]	68[f]	61[g]
	11-20	32	70	66	83	49	44
	21-35	19	22	43	44	17	27
	35	17	0	8	4	6	4
	5-10	*	58[i]	62[i]	9[j]	56[i]	62[i]
	11-20	77[b]	30	30	8	28	31
	21-35	30	10	9	2	8	9
	35	0	3	4	0	3	4

[a]Folliard and Reese (1991); Diller and Folliard (pers. comm.)
[b]LaHaye (1988) (intervals were 11-24", 25-36", and 36")
[c]Pious (1989)
[d]Kerns (1989)
[e]Self (pers. comm.)
[f]Solis (1983)
[g]Sisco and Guitérrez (1984); Sisco (1990)
[h]Chavez-Leon (1989)
[i]Bingham et al. (1991)
[j]Asrow (1983) (intervals were 1-10", 11-17", 18-29" and 30")
* = data not available

Table B.4. Abundance of snags and logs in habitats used by northern spotted owls in the Klamath and California Coast provinces.

Feature	Province	Inches	Nest Site	Nest Stand	Roost		Roost/ Forage		Forage		Old-Growth	
Snags: Number/Acre by dbh class	California Coast	>5	0[a] ~0[k]	0[a] ~0[k]	1[b]	3[a]	*	*	*	*	*	*
	Klamath	>5	22[c]	*	16[d] 30[f]	19[e] 33[f]	16[g]		19[d] 34[f]	18[e] 35[f]	17[h]	21[i]
		>20	*	*	5[d] 2[f]	2[f]	1[g]		3[d] 2[f]	3[f]	2[h]	4[i]
		0-10	*	*	*		20[j]		*	*	*	*
		11-18	*	*	*		2		*	*	*	*
		>18	*	*	*		4		*	*	*	*
Logs: Number/Acre	California Coast	>10	59[a]	45[a]	53[a]	47[b]	*		*	*	*	*
by Diameter	Klamath	>10	55[c]	*	29[f]	31[f]	32[f]	35[f]	*	*	*	*
at Large End		>20	*	*	10	8	10	8	12[h]	23[i]	*	*

[a]Pious (1989)
[b]Kerns (1989)
[c]Self (pers. comm.)
[d]Solis (1983)
[e]Sisco and Guitérrez (1984)
[f]Bingham et al. (1991)
[g]Chávez-León (1989)
[h]Jimerson et al. (1991a)
[i]Jimerson et al. (1991b)
[j]Asrow (1983)
[k]Diller and Folliard, (pers. comm.)
* = data not available

sites, roosting or foraging sites, and sites in old-growth stands, except that more large trees were found in the Olympic Peninsula province than in the other provinces studied (Table B.8). In the eastern Washington Cascades province, fewer large and medium-sized trees occurred at nest sites, nest stands, and foraging sites than in the other provinces.

Maximum tree height was 103 feet in plots used for roosting and foraging in the eastern Washington Cascades province (Benson 1991b). Spies et al. (1988) reported maximum tree heights in old-growth stands of 198 feet in the Oregon Coast Range province, 184 feet in the western Oregon Cascades province, and 168 feet in the western Washington Cascades province. Maximum tree heights have not been reported for stands used by owls in these provinces.

Total canopy closure averaged 83 percent for 11 nest sites in the western Washington Cascades province (Hamer 1988). In the eastern Washington Cascades province, total canopy cover averaged 75 percent at 62 nest sites and 72 percent in the stands within which the nests were found (Buchanan 1991). In the same province, total canopy cover at roosting and foraging sites averaged 47 percent in six home ranges (Benson 1991b).

Table B.5. Comparison of habitats used by northern spotted owls for roosting and foraging in the California Klamath province.

Structural Feature	Value	Solis (1983)		Sisco & Guitérrez (1984)		Bingham et al. (1991)			
		Roosting	Foraging	Roosting	Foraging	Roosting[a]		Foraging[a]	
Trees/Acre by dbh Class	5-20"	128	133	196	135	124	131	124	128
	20-35"	15	15	13	14	17	18	18	17
	>35"	16	12	10	11	8	7	8	7
Canopy Closure	%	93	88	*	*	83	85	84	80
Snags/Acre by dbh Class	>5"	16	19	19	18	30	33	34	35
	>20"	5	3	*	*				

[a]First column is for breeding seasons; second column is for nonbreeding season.
* = data not available.

Table B.6. Comparison of habitats used by northern spotted owls for nesting and roosting in the California Coast Province.

Structural feature	Value	Nesting	Roosting
Trees/Acre by dbh Class	4-16"	140	229
	>16"	61	52
Canopy Closure	Percent	86	84
Logs/Acre	>10" at large end	59	53

Source: Pious (1989).

Table B.7. Comparison of structural features at nest sites and throughout nest stands used by northern spotted owls.

A. California Klamath and California Coast provinces (data from LaHaye 1988).

Sturctural Feature	Value	Nest Site	Nest Stand
Canopy Closure	%	81	74
Trees/Acre by dbh Class	11-24"	63	42
	25-36"	17	3
	>36"	6	1
Basal Area[a] of Snags by dbh	>15"	23	14

[a] ft^2/ac

B. California Coast province (data from Folliard and Reese 1991, Diller and Folliard pers. comm.).

Structural feature	Value	Nest site	Nest stand
Canopy Closure	%	92	94
Trees per Acre by dbh Class	5-10"	81	136
	11-20"	51	57
	21-36"	23	18
	>36"	7	2

B. *continued–*

Structural Feature	Value	Nest Site	Nest Stand
% of Live Trees that were Hardwoods	<10"	63	75
	11-20"	50	39
	21-36"	18	15
	>36"	0	0
Log Volume by dbh Class	15"	3208	2377

C. California Coast province (data from Pious 1989)

Structural Feature	Value	Nest Site	Nest Stand
Canopy Closure	%	86	87
Trees/Acre by dbh Class	5-16"	140	193
	16"	61	64
% of Live Trees that were Hardwoods	5-16"	78	58
	>16"	13	7
No. of Snags per Acre	>5"	0	0

Only a few studies have reported snag densities (Table B.9) but densities appeared to be approximately similar at nest sites and foraging and roosting sites, and in nest stands at old-growth stands, except that fewer medium and large snags were present in the eastern Washington Cascades province.

Down log densities were similar at nest sites and old-growth sites in the western Washington Cascades province (Hamer pers. comm., Spies et al. 1988).

Hardwoods were rare or absent at utilized sites in the western Washington Cascades, Olympic Peninsula, and eastern Washington Cascades provinces (Allen et al. 1989, Forsman and Benson pers. comm., Hamer pers. comm.).

Table B.8. Tree density (number of trees per acre) by dbh class in Oregon and Washington provinces.

Province	dbh (inches)	Nest Site	Nest Stand	Roost/ Forage	Forage	Old-growth
Oregon	3-9					54[a]
Coast	10-19	*	*	*	*	25
Range	20-39					17
	≥40					12
Western	3-9					62[a]
Oregon	10-19	*	*	*	*	33
Cascades	20-39					21
	≥40					12
Western	4-12	58[b]		94[c]	115[d]	
Washington	12-20	31		52	60	
Cascades	20-35	23		41	42	
	>35	10		23	14	
	3-9					64[a]
	10-19	*	*	*	*	34
	20-39					27
	>39					10
Olympic	4-12			89[e]		
Peninsula	12-20	*	*	33	*	*
	20-35			36		
	>35			33		
Eastern	4-13	129[f]	117[f]	*	*	*
Washington	13-23	35	29			
Cascades	23-33	16	10			
	>33	2	3			
	6- 9				59[g]	*
	9-21	*	*	*	59	
	21-32				3	
	>32				3	

[a] Spies (1991)
[b] Hamer (1988) (dbh class definitions differed slightly those given; second size class was 11-20")
[c] Allen et al. (1989) (Mt. Baker-Snoqualmie National Forest)
[d] Allen et al. (1989) (Gifford-Pinchot National Forest)
[e] Allen et al. (1989) (Olympic National Forest)
[f] Buchanan (1991) and (pers. comm.)
[g] Benson (1991b)
* = data not available.

Table B.9. Snag density (number of snags per acre) by dbh class in Oregon and Washington provinces.

Province	dbh (inches)	Nest Site	Nest Stand	Roost/ Forage	Old-Growth
Oregon Coast	>0	*	*	*	16a
Range	>20	*	*	*	7
Western Oregon	>0	*	*	*	25[a]
Cascades	>20	*	*	*	11
Western	>0	*	*	*	30[a]
Washington	>4	42[b]	*	33[c] 41[d]	*
Cascades	>20	18	*	7 7	15
Olympic	>4	*	*	25[e]	*
Peninsula	>20			10	*
Eastern	4-13	19[f]	13[f]	*	*
Washington	14-23	4	6	*	*
Cascades	>23	2	2	*	*
	>10	*	*	5[g]	*
	>20	*	*	1	*

[a] Spies et al. (1988)
[b] Hamer (1988)
[c] Allen et al. (1988) (Mt. Baker-Snoqualmie National Forest)
[d] Allen et al. (1989) (Gifford-Pinchot National Forest)
[e] Allen et al. (1989) (Olympic National Forest)
[f] Buchanan (1991)
[g] Benson (1991b)
* = data not available.

Discussion

The main results of this analysis were as follows. Average canopy cover was high (more than 80 percent) in all studies except those in the eastern Washington Cascades province where average canopy cover was lower at nest sites and much lower at roosting and foraging sites. The average number of trees/acre by dbh class was fairly consistent among studies, except that fewer large trees occurred in the eastern Washington Cascades province and in the eastern part of the California Cascades province and in the western part of the California Klamath province. In all studies, the average number of trees decreased as diameter increased (i.e., in the "reversed J" pattern discussed in Appendix F). The hardwood understory was well-developed in utilized sites in California but was essentially absent in utilized sites elsewhere. Average snag density in utilized sites was similar to average snag density in old-growth sites except in the California Coast province where few snags occurred at utilized sites. Average values were similar for nesting, roosting, and foraging sites. No major differences were apparent between average values for sites and for stands containing the sites.

Review of Tables B.2 through B.9 indicates that information from California is much more complete than information from Oregon and Washington. The work by Allen et al. (1989) on roosting and foraging sites in the Olympic Peninsula and western Washington Cascades provinces and by Buchanan (1991) on nest sites in the eastern Washington Cascades province are the only extensive studies yet reported. Additional information for Oregon and Washington will be available soon from studies currently in progress. Studies in the Oregon Klamath, Oregon Coast Range, and eastern Oregon Cascades provinces also would be valuable.

This type of information is particularly useful in defining habitat categories. These efforts, however, must proceed with caution. For example, the results suggest that utilized sites studied to date tend to have trees of several different diameters (including some large trees), high canopy cover, and dominance by conifers, and that a hardwood understory is usually present in California but is not present in Washington and most of Oregon. As we have stressed, however, these generalizations describe average values in the study; they do not necessarily describe the features present at each site. Thus, owls might use some sites with a few large trees and few other trees but use other sites with no large trees but many smaller trees. This differential use might occur within or between home ranges. In either case, the study-wide averages would be as reported earlier. Bingham (pers. comm.) has suggested that the values in Table B.10 may characterize utilized sites in mature stands but may not characterize utilized sites in old-growth stands very well. This suggestion could be investigated by comparing results for home ranges dominated by old-growth stands with home ranges dominated by mature stands.

Improved descriptions of utilized sites might be obtained by defining a habitat category using several habitat variables. For example, we might examine the study-wide averages reported in Tables B.2 through B.9 and then define a habitat category as including stands with canopy cover exceeding 80 percent and numbers of trees, and proportion of them that were hardwoods, as shown in Table B.10. We could then determine which proportion of the utilized sites in each study were in this category.

In analyses of this sort, the parameter of interest must be specified with care, and the estimation procedure must take proper account of the field methods used to collect the data. The definition of "site" could have a substantial effect on the outcome of the study. Suppose, for example, that the acre centered on utilized sites always conformed to the description in Table B.10. If a few small plots were placed within the acre surrounding

Table B.10. Average values for characteristics of sites used by northern spotted owls in the California Coast and California Klamath provinces.

dbh (inches)	Number of Trees per Acre	Percent of Understory Trees That are Hardwoods
5.0 - 10.9	≥70	60-80
11.0 - 20.9	≥40	45-65
21.0 - 35.9	≥15	10-40
≥36	≥2	0-10

each site and means per plot were calculated, then many sample values would not conform to the descriptions in Table B.10 due solely to sampling error. This is a nontrivial problem (i.e., the errors could be quite substantial), and obtaining unbiased estimates of the proportion of acres meeting the definition would be a difficult statistical task. The analysis would be much simpler if plots and sites were defined to be the same size. Different studies, however, have used different numbers and sizes of plots so such an analysis cannot be performed using existing data.

Information about the structure of utilized sites also will be of value in guiding silvicultural efforts to develop or maintain suitable habitat and in minimizing adverse effects of harvest in the matrix. All of the cautions discussed earlier apply to such efforts, and it must be remembered that these structural measurements provide little information about whether the sites provide suitable habitat because they do not relate structure to reproductive success of the owls. Even less basis is provided by these data for deciding whether other environments sharing some of the structural features might be suitable. Nonetheless, data about structure of utilized stands are an important first step in designing silvicultural programs that will be effective in helping to protect owls.

Amount of Habitat in Home Ranges

Thomas et al. (1990) reviewed studies reporting territory or home range size, and amount of older forest within home ranges. This information is presented in section II of the recovery plan (Tables 2.1 and 2.2) and will not be repeated here, but results from a few other recent studies are presented.

Results

Several recent studies in California provide additional information about the amount of one or more types of habitat within home ranges or circles centered on the nest or activity sites. These studies report the acreage within territories covered by stands with large (more than 21 inches dbh) trees. Solis and Gutiérrez (1990) found that eight summer home ranges in the Willow Creek study area (Six Rivers National Forest) contained a mean of 481 acres (range: 208 to 979 acres) of this habitat. Zabel et al. (1991) reported that annual home ranges contained an average of approximately 900 acres of this habitat in the Six Rivers National Forest (Mad River District, 10 owls), 1,400 acres of this habitat in the Klamath National Forest (Ukonom District, nine owls), and 1,600 acres of this habitat in the Siskiyou National Forest (Chetco District, two owls). Self and Brown (pers. comm.) reported that 21 pairs of owls had a mean of 503 acres of stands in which the mean dbh was more than 24 inches within 1.3 miles of their nests. Home ranges were not mapped by Self and Brown, but the home ranges studied by Solis and Gutiérrez (1990) were almost entirely within 1.3 miles of the nests, so the home ranges studied by Self and Brown probably had less than 503 acres. Not all nests studied by Self and Brown were in stands with a mean dbh of more than 24 inches, and some home ranges contained no stands of this type.

Discussion

Studies summarized in Thomas et al. (1990:195) show that considerable variation exists within provinces in the amount of older forest in annual home ranges. The ratio maximum:minimum amount was 15.4 in California Klamath province, 3.5 in the Oregon Klamath province, 5.7 in the Oregon Coast Range province, 10.7 in the western Washington Cascades province, and 3.0 in the Olympic Peninsula province. In California, some of the nests studied by Self and Brown (pers. comm.) had virtually no stands with mean dbh more than 24 inches.

Several explanations for the large variation in amount of older forest within home ranges are possible, and they have different implications for the recovery program. In general, the variation does not cause too much concern about how well designated conservation areas (DCAs) will function, but does cause considerable concern about guidelines for avoiding "take" that suggest preserving amounts of habitat around individual pairs that equal the median amounts that have been recorded in home ranges. This point is illustrated by the following hypotheses to explain the high degree of variation observed in amount of habitat within home ranges.

1. Owls with more older forest had higher fitness.

   Under this hypothesis, owl fitness is a function of the quantity of habitat. It is possible that only those owls with the most older forest reproduce and survive at replacement rates (or higher). In such a case, preserving the median amount of older forest around single pairs might not permit any of the pairs to survive and reproduce at replacement rates. In contrast, using the median amount to decide how large a DCA should be would be appropriate. Some home ranges would be larger than the median, some would be smaller, but the cluster as a whole reasonably could be expected to sustain itself.

2. Quality of the older forest varies (e.g., in density of prey and growth rate of prey populations).

   Under this hypothesis, the amount of habitat needed to support a pair of owls varies among home ranges. In some areas, 1,000 acres of older forest might be needed for owls to survive and reproduce at replacement levels; in other areas, 2,000 acres might be needed. If owls actually use the amount they need, and we preserve the median amount around individual pairs, then only half the pairs will be provided with the amount of habitat they need for replacement levels of productivity and survival. As in the first hypothesis, this is not too serious in designing DCAs because the owls will delineate home ranges to take into account the variability in habitat quality.

3. The definition of older forest includes unsuitable habitat and/or excludes suitable habitat.

   Under this hypothesis, the definition of suitable habitat is a poor predictor of real habitat suitability. For example, fragmentation or number of canopy layers might affect quality of habitat but might not be parts of the definition of suitable habitat. In this case, defining older forest as any mature or old-growth stand might lead to preserving either more or less than the amount of habitat needed by owls to survive and reproduce at replacement levels. If DCAs are placed where owls are present and viable, then the poor knowledge of what actually constitutes suitable habitat would be much less serious.

These examples are intended to emphasize that the large variation in amount of older forest within home ranges raises concerns about our current ability to decide which habitat, and how much of it, should be protected around individual pairs to ensure that they can survive and reproduce at replacement levels. The uncertainty is less serious for construction of the DCAs, particularly because they are generally constructed around known pairs. As noted by the U.S. Forest Service in comments about an earlier draft of this appendix, some of the variation may be due to different amounts of time during which owls were tracked. This issue deserves additional attention.

Considering the large variation in amount of habitat within home ranges, there is some question about the value of additional studies that report this figure unless these studies also provide information about how the habitat is used or the success of owls in the home ranges. Future work should probably combine estimates of home range size and amounts of older forest present with more detailed stand descriptions, measures of viability, and functional studies to examine how different stands are used.

Habitat Selection for Roosting and Foraging

Thomas et al. (1990:143-170) reviewed the literature about use of habitats, categorized by successional stage, for roosting and foraging. In Oregon and Washington, west of the Cascade crest, old-growth stands were consistently preferred for both activities. Results were mixed for mature stands. Young stands, pole stands, and other stands were consistently avoided. Old-growth stands were defined as being more than 200 years old in most studies. Mature stands in most of the studies were 80 to 200 years old and even-aged (or had "few canopy layers"), and had mean diameters of approximately 21 to 39 inches. More recent work is summarized in the following sections.

Results

Several recent studies in California have analyzed habitats defined by mean dbh of the stand. Some of these studies have used the following definitions: seedlings and saplings: less than 5 inches; pole timber: 5 to 10.9 inches; small timber: 11 to 21 inches; mature and old-growth timber: more than 21 inches. Other studies have combined the two middle categories and have defined the following categories, referred to as seral stages: early successional (less than 5 inches), mid successional (5 to 21 inches), and late successional (more than 21 inches).

Solis and Gutiérrez (1990) and Blakesley et al. (1992) studied habitat use by owls during the breeding season at the Willow Creek study area. The seven owls studied by Solis and Gutiérrez showed a clear preference for mature and old-growth stands (Table B.11); 84 percent of the locations were in large-diameter (more than 21 inches dbh) stands and small-diameter (less than 5 inches) stands were almost never used. Blakesley et al. (1992) found that virtually all roost locations were in the 11- to 21-inch dbh and more than 21-inch dbh categories, and the number of locations per acre of habitat was nearly twice as high in the more than 21-inch stands as in the smaller stands.

During the nonbreeding season, the situation was more complex. Sisco (1990) found little or no preference for particular stands (Table B.11). Only 56 percent of the observations were in mature and old-growth stands, and small diameter stands were used roughly in proportion to their abundance. As shown in Tables B.2 through B.5, however, the average structural features of sites used by these owls were similar in the breeding and nonbreeding seasons. It appears that during the nonbreeding season, the owls used stands roughly in proportion to their availability but they selected sites within these stands that had larger-diameter trees. Blakesley et al. (1992) noted that the 11- to 21-inch dbh stands in this study area have resulted from natural processes and are more variable than plantations of the same mean diameter. This study should not be taken as indicating that 11- to 21-inch dbh plantations in this study area would provide adequate habitat for owls during the nonbreeding season.

Solis (1983) and Solis and Gutiérrez (1990) also presented data about the use of habitats categorized by overstory and understory canopy coverage. Stands in which both the overstory and understory canopy cover exceeded 70 percent had more use than stands with a less well-developed overstory and much more use than stands with a poorly developed overstory and understory (Table B.12). Owls in this study concentrated their activities in stands with high canopy coverage in the overstory and understory.

Zabel et al. (1991), working on the Six Rivers and Klamath National Forests, found only slight tendencies by owls on either forest to select particular stand types, categorized by either mean dbh or canopy cover (Table B.13). Only half the owls showed significant selection for any habitat (i.e., chi-square analysis rejected the hypothesis of random

Table B.11. Relative use of stands with different tree sizes by transmittered northern spotted owls in the California Klamath province[a].

Season	Averages per Owl	Average dbh >21"	5-21"	<5"	Open
Breeding (Mar-Sept)	% of territory	42	31	27	*
	% of locations	84	14	2	*
	% of locations/acre[b]	30	6	0.4	*
Nonbreeding (Oct-Feb)	% of territory	45	30	11	2
	% of locations	56	30	11	2
	% of location/acre[b]	16	8	8	8

[a]Data from Solis (1983) and Sisco and Guiterrez (1984).
[b](% of locations)/(number of acres)
* = data not available.

distribution), and patterns of use varied between owls. In the Klamath National Forest, owls showed slight preference for 21- to 36-inch dbh trees, but no preference for trees more than 36 inches dbh. In the Six Rivers National Forest owls showed no preference for 21- to 36-inch dbh trees and slight preference for trees more than 36 inches dbh. Stands were also divided into those that did and those that did not meet the Forest Service definition of suitable habitat for that region (more than 21 inches dbh, more than 20 percent dominant canopy cover, and more than 70 percent total canopy cover). A use-availability analysis showed that 69 percent of the owls showed significant preference for suitable habitat during the breeding season and 39 percent did so during the nonbreeding season. The authors concluded that habitat preferences were exhibited for stands with large trees and high canopy cover, but that the preferences were weaker in this study than in other studies.

Table B.12. Relative use by northern spotted owls of stands with different overstory and understory canopy coverage.[a]

Canopy cover		No. of Observations	No. of Acres	No. Observations per 100 Acres
Overstory	Understory			
41-70%	41-70%	314	1,568	20.0
0-40%	41-70%	88	1,363	6.5
0-40%	0-40%	89	31,91	2.8

[a]Data from Solis (1983).

Table B.13. Habitat selection by spotted owls in the Klamath and Six Rivers National Forests (source: Zabel et al. 1991).

		Klamath National Forest (Ukonum District)[a]		Six Rivers National Forest (Mad River District)[b]	
Variable	Value	% of Study Area	% of Locations	% of Study Area	% of Locations
Mean dbh	<5"	13	7	7	4
	5-10.9"	13	9	8	6
	11-20.9"	10	10	10	8
	21-35.9"	40	51	45	43
	>36"	24	23	31	39
Canopy Cover	<10%	5	2	7	3
	10-19%	7	5	25	20
	20-39%	23	21	27	29
	40-69%	46	54	29	33
	70-100%	18	18	12	15

[a] Means based on 9 owls and 609 locations during the breeding season and 15 owls and 842 locations during the nonbreeding season.
[b] Means based on 10 owls and 616 locations during the breeding season and 20 owls and 1,436 locations during the nonbreeding season.

Two explanations for this decreased preference were suggested by the Forest Service representative in their comments on this appendix in the draft recovery plan. The stands in Zabel et al.'s (1991) study had generally larger trees than stands in similar studies north of the Oregon Klamath province. Mean percentages of owl home ranges covered by stands with medium and large trees were 64 and 77 at the two study areas in the California Klamath province (Table B.13). In contrast, 20 to 66 percent of the owl home ranges were mature and old-growth forest in the Oregon Coast Range province and in the Cascades. It is possible that owls would have showed more pronounced habitat selection had large trees been less common. A second possible explanation for the low degree of preference exhibited in Zabel et al.'s study is that the adaptive kernel home range estimator was used to define availability of habitat types within home ranges. Past studies have used the minimum convex polygon home range estimator. In general, the more widely defined the available sampling frame, the greater the likelihood of demonstrating selection. By using the adaptive kernel estimator to define the available sampling frame for each home range, Zabel et al. (1991) may have decreased the likelihood of demonstrating selection relative to a restrictive definition of availability based on the minimum convex polygon, as was reported in earlier studies.

An example in which owls may *not* have avoided more open areas is provided by Kerns (1989) who studied radio-transmittered owls in managed stands in the California Coast province. Kerns monitored three owls during the breeding season, obtaining 94, 95, and 151 locations. Many of these locations were recorded in the same night, raising questions about the reliability of Kern's results. Habitat in the area used by each owl varied considerably in canopy closure. The density of locations for one owl ("Bill") was higher in areas with higher canopy closure; one owl ("Luke") did not appear to discriminate on the basis of canopy cover; and the third owl ("Betsy") used thinned, open stands more than unthinned, closed stands. Kerns (1989) reported that brush rabbits comprised 33 percent of the prey (by biomass) of the owls he studied. (By contrast, this species comprised less than 1 percent of the biomass in the diet of the owls studied by Solis 1983.) Possibly, owls feeding heavily on brush rabbits do not show a strong preference for stands with dense canopies, but more data are needed to resolve this question.

A few studies have investigated preferences for other habitat features. Blakesley et al. (1992) found that roosting occurred more often at elevations of 1,000 to 3,000 feet than would be expected if sites were distributed randomly with respect to elevation. In contrast, Zabel et al. (1991) found that low elevations were preferred in both of the forests they studied during both seasons. Blakesley et al. (1992) found that owls avoided gentle slopes but other slopes were used in proportion to their availability. Zabel et al. (1991) found no preferences for slope. Blakesley et al. (1992) did not detect any preferences by owls for a particular aspect, and detected a preference for roosting on the lower third of slopes. Thus, in general, preferences for these features were either weak or inconsistent among sites.

Discussion

Recent results indicate that the pattern of habitat selection in California is less clear than in Oregon and Washington north of the Oregon Klamath province and west of the Cascade crest. The 11 to 21-inch diameter category used in these stands corresponds roughly to the "young" category in Thomas et al. (1990). In the studies Thomas et al. (1990) reviewed, this size class was avoided by 55 percent of 130 owls and only preferred by 3 percent of them. Solis and Gutiérrez (1990) found similar patterns, but Blakesley et al. (1992) and Zabel et al. (1991) found little or no tendency to avoid this size class. Blakesley et al. (1992), however, did report that preferences for older stands were evident when analyses were restricted to small timber (11 to 21 inches dbh) and mature and old-growth cover types. Furthermore, Blakesley et al. noted that the small timber in their study areas was produced from natural "conditions and processes" and that their results may not apply to small timber regenerated after timber harvest because natural stands of small timber have diverse composition and complex structure." Their results should not be taken as indicating that managed stands with 11- to 21-inch dbh trees provide suitable habitat for spotted owls. In this regard, the work of Sisco (1990) is particularly interesting. The owls he studied showed few preferences for habitat defined by mean diameter, but they selected sites for roosting and foraging that were similar to sites in old-growth stands.

As pointed out by the Forest Service in comments about the draft recovery plan, the low degree of preference found in these studies may have been caused by differences in landscape between the studies reviewed here and the studies from north of the Oregon Klamath province reviewed by Thomas et al. (1990). Many of the earlier studies in Oregon were carried out in areas with substantially less suitable habitat. In such cases, preferences were probably stronger and easier to document. The differences between results from the California Klamath and Oregon Klamath provinces and from farther north thus may have been caused by differences in landscape condition rather than by differences in preferences of the owls.

The analyses employing canopy cover as well as tree diameter suggested that both of these variables may be important in determining preferred habitat in California. Results from the work of Solis, (1983) summarized in Table B.12, suggest that both overstory and understory canopy cover were positively correlated with use by owls, as does the report by Zabel et al. (1991) in which owls generally preferred habitats meeting the Forest Service's definition of suitable habitat.

Additional use-availability analyses employing different habitat definitions, and functional studies of the specific resources provided by these habitats, should improve our ability to discern highly preferred and avoided habitats in California. Studies from the California Coast province, the California Cascades province, and the eastside of the Cascades are also needed.

Abundance of Owls in Different Habitats

Thomas et al. (1990) concluded that in most parts of the range of the northern spotted owl density was extremely low in landscapes dominated by stands less than 80 years old and lacking old-growth, and that density increased with the amount of old-growth present in a landscape or study plot. Thomas et al. (1990) also noted that recent studies in California "strongly suggest that suitable and even superior spotted owl habitat can develop faster in coastal forest of redwood and mixed redwood and Douglas-fir" (p. 185) and that "the full range of suitable habitats for spotted owls in California has not yet been determined" (p. 166). Reports published since Thomas et al. (1990) are described in the following section.

Results

Carey et al. (1991) found spotted owls only in old-growth stands during a study in the southern Oregon Coast Range province. Three owls were recorded in 1985, and six were recorded in 1986. The results showed a statistically significant tendency for owl abundance to increase with stand age, but sample sizes were inadequate to test the null hypothesis that abundance is equal in mature and old-growth stands.

Blakesley et al. (1992) found 79 nest sites in stands with trees 11 to 21 inches dbh or more than 21 inches dbh and no nest sites in other habitats. Nest densities per acre were similar in the two habitats. Sites also were characterized by elevation, position, aspect, and slope. Elevations less than 1,000 feet were avoided. Nests were concentrated in the lower third of slopes. No preferences were found for aspect or slope.

Meyer et al. (1992) reported that the amount of mature and old-growth forest in circles at owl sites was higher than the amount in randomly placed sites, a finding that is consistent with previous work. However, when individual successional stages were analyzed, only the amount of old-growth habitat was significantly greater at owl sites than at randomly placed sites.

We analyzed the data provided by Self and Brown (pers. comm.) to investigate relative densities of nests in different habitats. We defined the study area as all the land within 1.3 miles of the nests and recorded the amounts of different habitats in this area, and the number of nests per square mile of each habitat type. This type of analysis should not be used to estimate density of nests (or owls) in a given habitat throughout the entire landscape. For example, if a habitat were highly preferred for nesting and occurred only in scattered patches, then the process discussed previously would substantially underestimate true density. The analysis probably does provide a valid indication of relative preference, however, especially when substantial differences in density occur between habitats. In the data from Self and Brown (pers. comm.) nests were concentrated in the stands with the largest trees and densest canopy (Table B.14). Density was next highest in stands with smaller trees but dense canopies, and was lower in stands with more open canopies and either large or medium-sized trees. Their work also suggested that montane forest types were not as preferred as Douglas-fir or mixed-conifer types. Solis (1983:33, 41) also commented that the owls he studied seemed to avoid montane forest types.

Discussion

The suggestion by Thomas et al. (1990) that more work was needed on habitat suitability in California is supported by the recent results discussed earlier in this appendix. In the studies by Blakesley et al. (1992) and Self and Brown (pers. comm.) nest density was 25 to 50 percent higher in stands with mean tree diameters exceeding 21 inches than in stands with mean tree diameter of 11 to 21 inches. This result provides a sharp contrast to results

Table B.14. Habitat[a] within 1.3 miles of 21 northern spotted owl nests on managed lands in the eastern part of the California Klamath province (Self and Brown pers. comm.).

Average Diameter	Canopy Cover	Area (mi^2)	Number of Nests	Nests per mi^2
>24"	>60%	12.26	10	0.82
11-24"	>60%	4.94	3	0.61
>24"	40-60%	4.23	1	0.24
11-24"	40-60%	36.12	7	0.21

[a] Area covered by stands of Douglas-fir with an understory of tanoak and madrone or by stands of Klamath mixed-conifers (white fir, Douglas-fir, ponderosa pine, incense cedar, and sugar pine with an understory of oak and maple).

from Oregon and Washington in which few nests occurred in stands with mean tree diameters of 11 to 21 inches. It is also noteworthy that in the study by Self and Brown (pers. comm.) density varied much more with canopy cover than it did with tree diameter (Table B.14). The structural features of nest sites in California (Table B.2) show a remarkable similarity to the structure of old-growth sites and nest sites elsewhere in the owl's range. This suggests that owls in California are selecting sites with large trees even when the mean diameter in the stand is well below the mean in old-growth stands. This hypothesis should be investigated carefully because it has important implications for the design of strategies to protect owls in managed forestlands.

The combination of density (and demographic) data and structural features at the nest site and in the nest stand provides a powerful data set for analyzing habitat preferences. Similar information from other parts of California, and from the east side of the Cascades will be particularly useful in the future.

Demographic Rates in Different Habitats

Thomas et al. (1990) reported that proportion of territories with pairs and reproductive success declined as the amount of old-growth declined. This conclusion was based on Forest Service monitoring data and on landscape studies. Results published since Thomas et al. (1990) are described in the next section.

Results

Meyer et al. (1992) did not find any consistent relationships between the number of years that sites were occupied by owls and various measures of forest fragmentation.

We reanalyzed the data from Meyer et al. (1992) to determine whether turnover of adults varied with the amount of older forest (i.e., more than 120 years) present in the circle. Persistence of adults was defined as the probability that an owl present in a circle at the start of a year would be found at the site the next year, given that the site was revisited in the following year. The consensus among spotted owl biologists is that adult owls rarely change breeding sites (Lint pers. comm., Franklin pers. comm., Gutiérrez pers. comm., Miller pers. comm., Wagner pers. comm.). For example, in the Andrews study area in the western Oregon Cascades province, during 305 pair-years, divorce and settlement elsewhere occurred in, at most, four cases and was never established with certainty (Swindle and DeStefano pers. comm.). Persistence, as measured in the preceding statement, probably indicates adult survivorship, although we believe this issue needs further study. We obtained data from the 50 circles studied by Meyer et al. (1992), and Johnson (pers. comm.) supplied us with similar owl and habitat data from 41 sites in the Andrews study area. We did not have individual identification of the owls from the Meyer et al. (1992) study so disappearances that were replaced before the start of the next season would not have been detected. We did have individual identification of the owls in the Andrews Forest and more accurate estimates of turnover rates.

We analyzed the two data sets separately and in combination. In all three analyses, persistence increased with habitat quality. The increase was significant in the data set from the U.S. Bureau of Land Management, not significant in the Andrews Forest data set, and highly significant in the combined data set (Figure B.1, Table B.15). Neither the slopes nor the intercepts in the two data sets differed significantly (or close to significantly). In the combined data set, there was no evidence of nonlinearity. Heteroscedasticity (i.e., unequal variances) was evident but this causes no bias in the estimate of slope.

Simpson Timber Company (1991) reported that 0.72 young per pair were produced by 50 owl pairs in 1990 and that 0.63 young per pair were produced by 92 pairs in 1991; 68 percent of the new recruits in 1991 were adults the turnover rate between 1990 and 1991 was 15 percent; 3 of 19 owls were found elsewhere and had moved rather than died. These values were similar to the values obtained nearby in the Willow Creek study area.

Discussion

The evidence suggesting that adult owl survivorship varies with the amount of older forest in the home range is important because population viability is highly sensitive to adult survival rates. Obtaining more information of this sort should be a high priority for the future.

Results from the Simpson Timber Company suggesting that rates of owl reproduction and adult owl survival are similar on Simpson's land and at the Willow Creek study area are encouraging, though a few more years of data will be needed to evaluate these initial results. The next few years should provide a good indication of how similar long-term reproduction and survival rates are at these two sites and provide a good basis for developing conservation programs on private lands in this area. Identifying the key habitat features and analyzing whether they will remain present in the future should be a high priority in this study.

Table B.15. Regression analysis of occupancy data from the Andrews Experimental Forest and the U.S. Bureau of Land Management (BLM) in Oregon.

Study	Number of Nests	Regression Equation (h = proportion of area covered by suitable habitat)	Standard Error of the Slope	Level of Significance
BLM	50	0.58 + 0.40h	0.18	~0.03
Andrews Experimental Forest	41	0.75 + 0.19h	0.18	~0.30
Combined Data Set	91	0.63 + 0.39h	0.12	~0.005

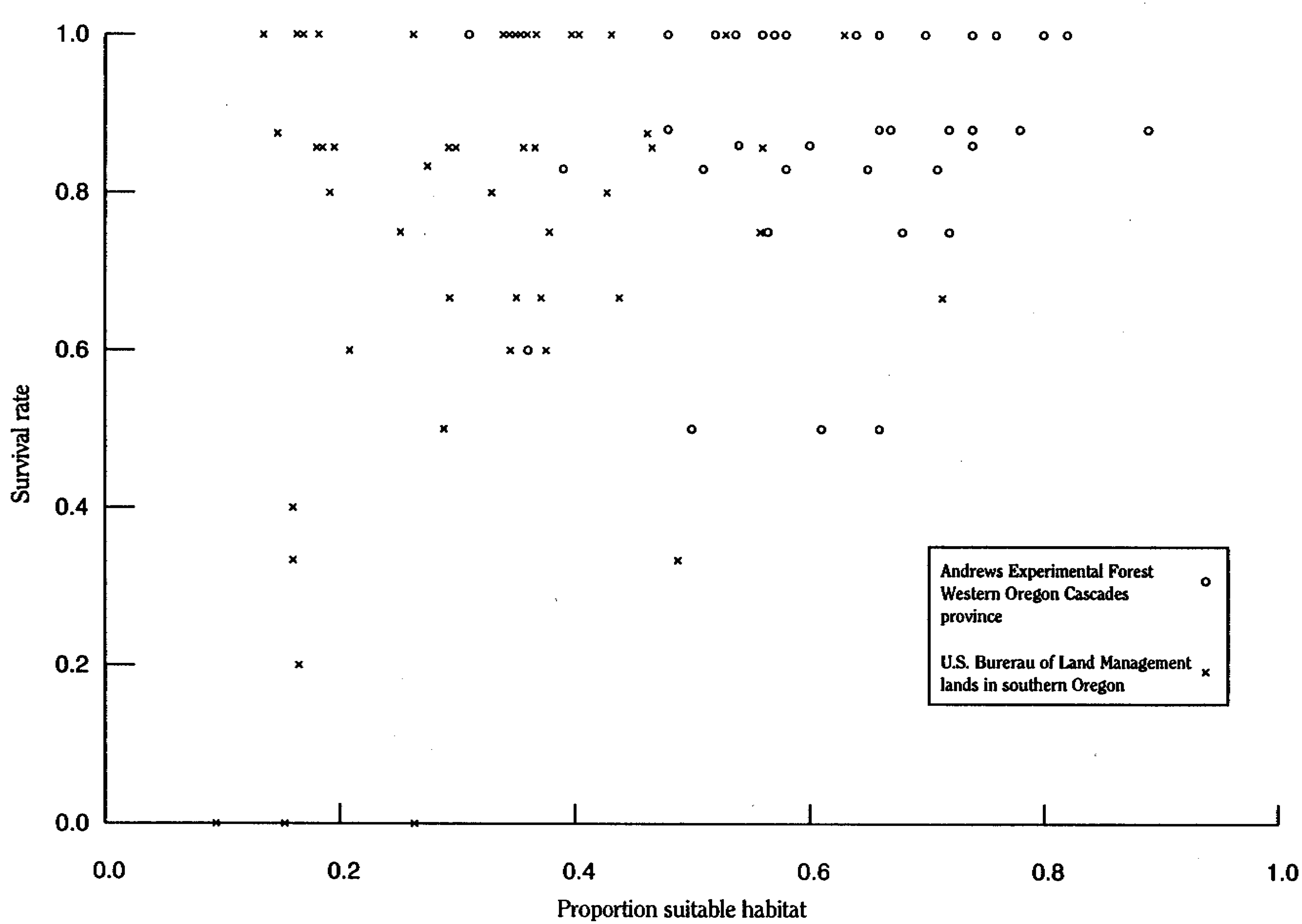


***Figure B.1.** Relationship between annual adult survival rates and proportion of the area within 1.3 miles of the activity center covered by older forest.*

Recommendations for Future Research

We conclude this appendix with brief recommendations about priorities for future research. These suggestions should be discussed in detail by spotted owl biologists and the agencies that will carry out much of the work. The Recovery Team should help facilitate the discussion and ensure that all groups involved in owl conservation participate in developing the research priorities. The following discussion is intended to help meet that objective.

Several suggestions for future research are included in Appendix A, some of which involve studies of habitat suitability (e.g., study of dispersal habitat and the behavior of dispersing juveniles, and development of the landscape model). Those studies are not repeated here.

Standardize habitat measurements

A clear need exists to standardize measurements used to describe habitat at the stand and landscape levels. For example, the information about stand structure at utilized sites (e.g., Tables B.2 through B.5) would be more useful if the same variables had been measured by all investigators. A draft protocol for sampling vegetation in spotted owl habitats developed by Bingham (pers. comm.) might serve as the basis for developing such standards.

Prepare habitat maps for demographic study areas

Detailed habitat maps are not yet available for all demographic study areas. Completing these maps and integrating the habitat and owl data in a geographic information system should be a high priority for the next few years. The resulting information would be of great value in all four types of habitat suitability studies described earlier.

California Coast: As previously noted, preliminary results suggest that owl density is particularly high on parts of Simpson Timber Company lands, suggesting that the California Coast province could be of great value in the owl recovery program. At present, however, we know little of habitat use or suitability in this province. More information about all aspects of habitat suitability is being collected by Simpson Timber Company and other private landowners. These efforts should be encouraged. Particular effort should be made to identify the specific features that determine the suitability of 45- to 55-year-old stands for owls and owl prey. Such information will be critical in determining how to manage these stands in the future so that they will provide suitable habitat for owls.

Eastern California: Presently, little is known about which habitats are used by owls in these areas. Telemetry studies and continued estimation of demographic rates would greatly improve our knowledge of habitat requirements. The work begun by Self and Brown (pers. comm.) should be continued. Banding the owls in these study sites should be a particularly high priority.

East Cascades (Oregon and Washington): Preliminary evidence summarized in Thomas et al. (1990) and Buchanan (1991) indicated that owls in some of this region are abundant and are using a wide variety of habitat types. Research in Washington is continuing and should receive high priority. Use of habitat by radio-transmittered owls and adult owl turnover rates will be of particular interest.

10- to 20-inch dbh plantations with remnant larger trees: As noted in Thomas et al. (1990), many sites are known where owls occur in young stands with remnant large trees. This finding suggests that leaving a few large trees at harvest might cause sites to become suitable for owls much sooner than they would otherwise. With rotation ages of 60 to 80 years, such sites might never be suitable for owls if no trees are left, but might provide some useful habitat for a few decades prior to harvest if large trees had been left at the previous harvest. This possibility is encouraging, but at present we know little about what makes existing sites valuable for owls. It is possible that leaving a few large trees will have little beneficial effect on owls, or that the benefits could be obtained in other, less expensive ways. Studies are needed to identify the specific resources (e.g., owl prey) provided by existing sites with young stands and remnant larger trees.

Stands managed with selective harvest: Many portions of the owl's range are managed with selective harvest regimes. At present we have little information about the suitability of these habitats for owls. Telemetry studies are needed to determine relative use by owls of partially harvested and unharvested old-growth stands. Functional studies evaluating abundance and availability of prey would also be useful to help us understand the current potential value to owls of selectively harvested sites.

Areas where salvage is economically feasible: Little information is available at present to help guide the development of policies about how much salvage should be permitted in DCAs or other owl protection areas. More information is needed about use by owls of such areas for foraging and about the effects of the harvestable snags and logs in accelerating return of the stand to suitable habitat for owls.

Study functions and ways of developing understory

Appendix F discusses silvicultural methods for accelerating the development of suitable habitat, and places particular emphasis on producing stands with the "reversed J" size-class distribution of trees (i.e., the number of trees decreases as the diameter increases). At present, however, we know little about why owls frequent stands with well-developed understories, and we lack detailed silvicultural studies showing how this understory can best be developed in different regions and conditions. Both of these issues should be studied.

Literature Cited

Allen, H.L.; Dixon, K.R.; Knutson, K.L. 1989. Cooperative administrative study to monitor spotted owl management areas in national forests in Washington. Final Report. Washington Department of Natural Resources. 165 p.

Asrow, E. 1983. Scott River Ranger District spotted owl habitat analysis project. Yreka, CA: U.S. Department of Agriculture, Forest Service, Klamath National Forest. 46 p.

Benson, G. 1991a. Characterization of spotted owl habitat in Washington, Oregon, and northern California. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181. 5 p.

Benson, G. 1991b. Stand-level information for spotted owl habitat, Wenatchee National Forest. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181. 5 p.

Bingham, B., Personal Communication, U.S. Department of Agriculture, Forest Service, Arcata, CA.

Bingham, B. 1991. Stand-level characteristics of northern spotted owl habitats on the Mad River District of Six Rivers National Forest. Eureka, CA: U.S. Department of Agriculture, Forest Service, Six Rivers National Forest. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181. 7 p.

Bingham, B.B.; Sawyer, J.O. 1991. Distinctive features and definitions of young, mature, and old-growth Douglas-fir/hardwood forests. Pages 363-377 in: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.M., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Blakesley, J.A.; Franklin, A.B.; Gutiérrez, R.G. 1992. Spotted owl roost and nest site selection in northwestern California. Journal of Wildlife Management. 56:388-392.

Buchanan, J.B. 1991. Spotted owl nest site characteristics in mixed-conifer forests of the eastern Cascade Mountains, Washington. Seattle, WA: University of Washington. 140 p. M.S. thesis.

Carey, A.B.; Hardt, M.M.; Horton, S.P.; Biswell, B.L. 1991. Spring bird communities in the Oregon Coast Range. Pages 122-142 in: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.M., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 533 p.

Chávez-León, G. 1989. Characteristics of fragmented habitats used by the northern spotted owl (*Strix occidentalis caurina*) in northwestern California. Arcata, CA: Humboldt State University. 60 p. M.S. thesis.

Diller, L., Personal Communication, Simpson Timber Company, Arcata, CA.

Folliard, L.B.; Reese, K.P. 1991. Nest site characteristics of northern spotted owls in second-growth forests of northwest California. Annual report for 1990. 24 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.

Forsman, E., Personal Communication, U.S. Department of Agriculture, Forest Service, Corvallis, OR.

Franklin, A., Personal Communication and Personal Observation, U.S. Department of the Interior, U.S. Fish and Wildlife Service, Fort Collins, CA.

Grenier, J. 1991. Review of information on structure of old-growth stands and old-growth stands used by spotted owls in western Oregon and Washington. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Gutiérrez, R., Personal Communication and Personal Observation, Humboldt State University, Arcata, CA.

Hamer, T., Personal Communication, Washington Department of Wildlife, Olympia, WA.

Hamer, T. 1988. Home range size of the barred owl and northern spotted owl in western Washington. Seattle, WA: University of Washington. 86 p. M.S. thesis.

Jimerson, T.; Bingham, B.B.; Solis, D.; MacMeeken, S. 1991a. Draft ecological definition for old-growth Douglas-fir/tanoak/madrone (Society of American Foresters type 234). Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181. 21 p.

Jimerson, T.; Bingham, B.B.; Solis, D.; MacMeeken, S. 1991b. Draft ecological definition for old-growth Pacific Douglas-fir (Society of American Foresters type 229). Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181. 21 p.

Johnson, D., Personal Communication, Oregon Department of Fish and Wildlife, Corvallis, OR.

Kerns, S., Personal Communication, Pacific Lumber Company, Scotia, CA.

Kerns, S.J. 1989. Occurrence of spotted owls in managed timber stands on lands of the Pacific Lumber Company: progress report July 1, 1989. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181. 42 p.

LaHaye, W.S. 1988. Nest site selection and nesting habitat of the northern spotted owl (*Strix occidentalis caurina*) in northwest California. Arcata, CA: Humboldt State University. 111 p. M.S. thesis.

Lehmkuhl, J.F.; Raphael, M.G. [In press]. Habitat pattern around spotted owl locations on the Olympic Peninsula, Washington. Journal of Wildlife Management.

Lint, J., Personal Communication, U.S. Department of the Interior, Bureau of Land Management, Roseburg, OR.

Meyer, J.S.; Irwin, L.L.; Boyce, M.S. 1992. Influence of habitat fragmentation on spotted owl site location, site occupancy, and reproductive status in western Oregon: progress report, January 31, 1992. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Miller, G., Personal Communication, U.S. Department of the Interior, Fish and Wildlife Service, Portland, OR.

Pious, M., Personal Communication, Louisiana-Pacific Corp., Calpella, CA.

Pious, M. 1989. The northern spotted owl in managed, second-growth coastal redwood forests, Mendocino County, California. Preliminary results. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181. 105 p.

Self, S., Personal Communication, Sierra Pacific Industries, Redding, CA.

Simpson Timber Company. 1991. Draft habitat conservation plan for the northern spotted owl. Arcata, CA: Simpson Timber Co. 205 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.

Sisco, C.L.; Gutiérrez, R.J. 1984. Winter ecology of radio-tagged spotted owls on the Six Rivers National Forest, Humboldt Co., California; technical final report. Eureka, CA: U.S. Department of Agriculture, Forest Service, Six Rivers National Forest. 138 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.

Sisco, C.L. 1990. Seasonal home range and habitat ecology of spotted owls in northwestern California. Arcata, CA: Humboldt State University. 81 p. M.S. thesis.

Solis, D.M., Jr. 1983. Summer habitat ecology of spotted owls in northwestern California. Arcata, CA: Humboldt State University. 168 p. M.S. thesis.

Solis, D.M. Jr.; Gutiérrez, R.J. 1990. Summer habitat ecology of northern spotted owls in northwestern California. Condor. 92:739-748.

Spies, T.A.; Franklin, J.F; Thomas, T.B. 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology. 68:1689-1702.

Storm, R., Personal Communication, Oregon State University, Corvallis, OR.

Swindle, K., Personal Communication, U.S. Department of the Interior, Fish and Wildlife Service, Corvallis, OR.

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 Interior, Bureau of Land Management, Fish and Wildlife Service, National Park Service. 427 p.

Van Horne, B. 1983. Density as a misleading indicator of habitat quality. Journal of Wildlife Management. 47:893-901.

Wagner, F., Personal Communication, Oregon State University, Corvallis, OR.

White, G.C.; Garrott, R.A. 1990. Analysis of wildlife radio-tracking data. New York: Academic Press. 383 p.

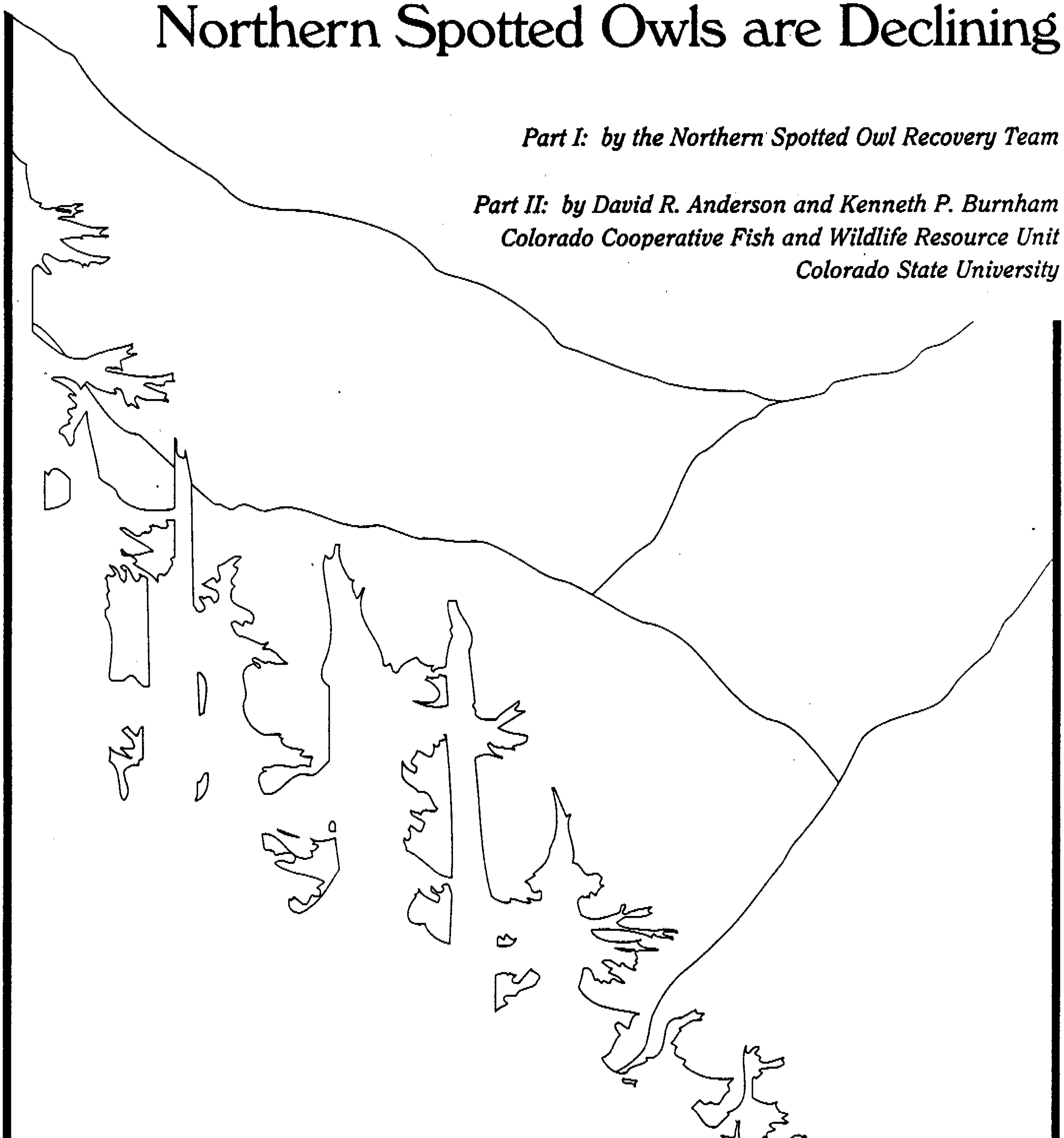
Zabel, C.J.; Bingham, B.B.; McKelvey, K.; Noon, B.R. 1991. Home range size and habitat use patterns of northern spotted owls in northwestern California and southwestern Oregon. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181. 38 p.

Appendix C

Evidence that Populations of Northern Spotted Owls are Declining

Part I: by the Northern Spotted Owl Recovery Team

Part II: by David R. Anderson and Kenneth P. Burnham
Colorado Cooperative Fish and Wildlife Resource Unit
Colorado State University



Contents

Part I: Summary and Evaluation of Existing Evidence

Introduction

Evidence of past and ongoing decline in northern spotted owl populations has been summarized in several reports (Thomas et al. 1990, USDI 1990) including the draft of this recovery plan. However, there is still controversy about the numbers of northern spotted owls, and no general agreement about exact rates of decline in spotted owl populations. Chapter II and Appendix K of the recovery plan present additional discussions of population status. Section II.A. defines terms used in the discussion of populations.

Three types of evidence are used to track trends in owl populations. These are 1) demographic studies in which birth and survival rates are used to estimate population change, 2) repeated counts of territorial owls in specific areas (density data), and 3) correlations of population change with habitat loss. Evidence from these three sources is briefly summarized in Part I of this appendix. Part II of the appendix presents the results from demographic studies of northern spotted owls. That report is reprinted from the draft recovery plan.

Demographic studies

Long-term studies of birth and survival rates of spotted owls were begun in Washington, Oregon, and California between 1985 and 1987. Location of the study areas is shown in Figure C.1. Data from studies during 1985 to 1991 were used to estimate rates of change in the population and were reported in Appendix C of the draft recovery plan. Analysis was done by Drs. John Dominique Lebreton, David Anderson, Ken Burnham, and Rodger Pradel.

That analysis estimated birth and death rates with capture-recapture methods, and used population models to estimate the owl's population trend. These methods have been used widely with other species (Caswell 1989). They are based on the fact that most animal populations with constant birth and death rates will eventually assume a constant rate of population change which can be calculated. The result is a projection, rather than a prediction (Caswell 1989). The calculated rate of population change is not what <u>will</u> occur, but what <u>would</u> occur if the birth and death rates did not change. The actual rate during a particular time, including the time during which the birth and death rate data were gathered, may be quite different from the projected rate depending on the age distribution in the population. These limitations of the technique are particularly germane to the interpretation of the spotted owl information which has been collected during a period of habitat decline. The calculations do not tell us what will occur in the future, but only what would occur if conditions in the population did not change.

The analysis of population change suggested that populations in all five study areas were declining at estimated rates of 6 to 16 percent. A combined analysis of the data from all five areas indicated an overall rate of decline of 7.5 percent. The combined analysis also indicated that adult female survival rates were declining over time. The female survivorship

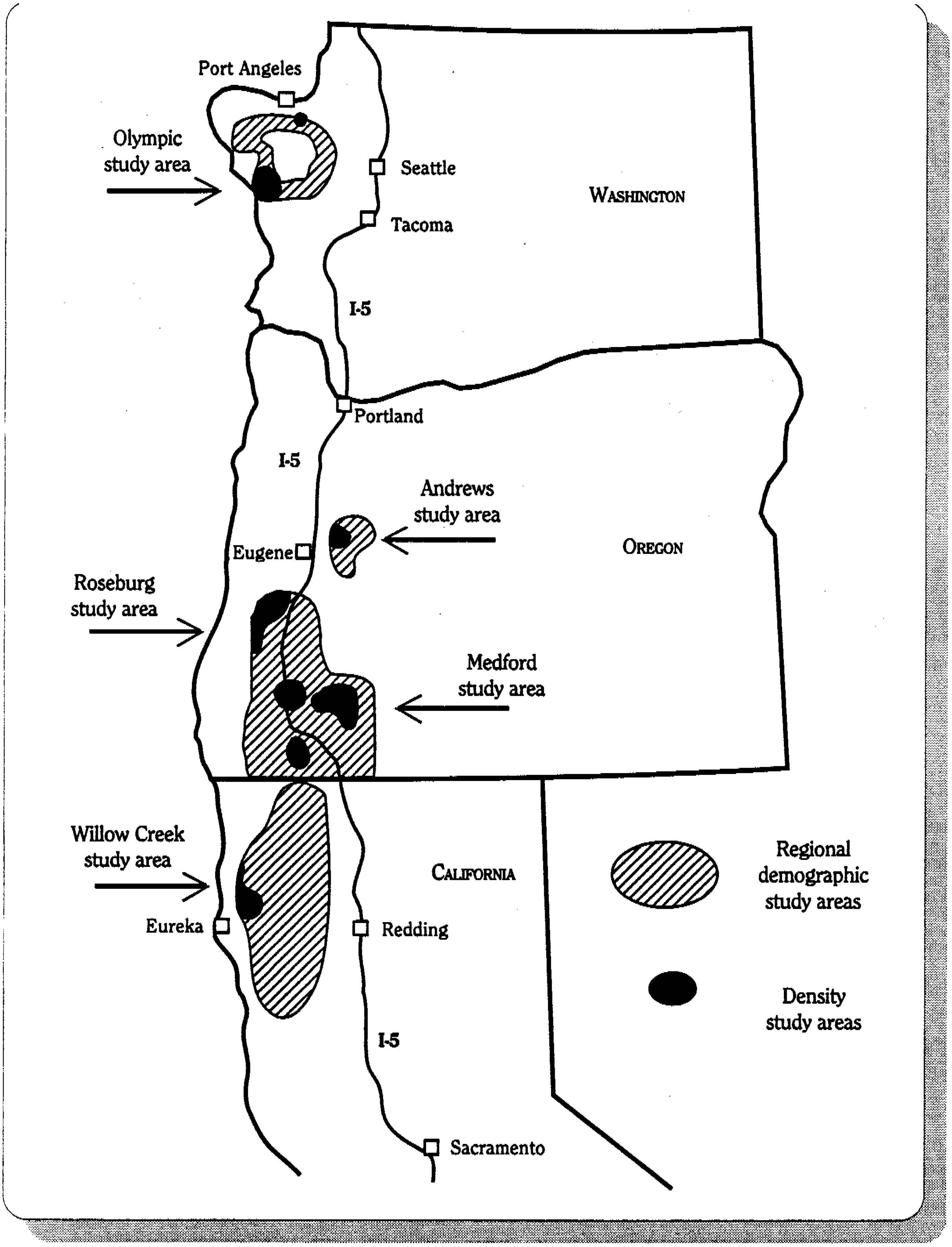


Figure C.1. Demographic study areas.

rate was viewed as the most troubling finding of the analysis. Minor corrections to the birth and death data were made after the publication of the draft recovery plan, but these did not result in significant changes to the conclusions of the analysis (Thomas et al. In Prep.).

Since the initial analysis was completed, an additional year of data has been gathered on the study areas. Thomas et al. (In Prep.) collected 1992 data for four of the five study areas that were analyzed for the draft recovery plan. With the addition of the 1992 data, female survival rates increased slightly for two study areas, decreased slightly for one, and remained the same for one (Thomas et al. In Prep.). Average fecundity rates increased slightly for all four of the areas. In general, 1992 was a very successful year for owl reproduction. New estimates of rates of population change have not been calculated from these new data, but Thomas et al. (In Prep.) do not anticipate that the updated data will produce significantly different population trends or conclusions from those reported in the draft recovery plan.

The results reported in Appendix C of the draft recovery plan generated a great deal of concern about the status of spotted owl populations. Some scientists suggested that the population had dropped below a threshold beyond which the chances of recovery might be limited (Harrison 1992, Kareiva 1992, Orians 1992). As one consequence of these concerns, much attention has been focused on the proper interpretation of the demographic studies and possible biases in the results of the demographic analyses. These possible biases are discussed in Appendix A of the recovery plan and in Part II of this appendix. The biases include possible overestimation of fecundity due to the presence of nonterritorial, nonbreeding owls in the population; possible underestimation of juvenile survival due to permanent emigration from the study area; and possible underestimation of survival due to temporary adult emigration from the study area. In addition to the discussion of biases in this document, Bart (In Prep.) is currently conducting a thorough analysis of their possible magnitude. That study is undergoing peer review and therefore its conclusions are not yet final. However, preliminary results suggest that the population trend estimates are biased downward, and that the bias could be significant. However, it is unclear if bias in the estimation of population change would have any effect on the finding that female owl survival is declining.

New field data may provide some insight into one of the possible biases: underestimation of juvenile owl survival. This information comes from radio-telemetry studies of juvenile owls, and is summarized in Thomas et al. (In Prep.). The data were collected for dispersing juveniles in three areas: 1) the U.S. Bureau of Land Management (BLM) lands surrounding Roseburg, Oregon; 2) the Olympic Peninsula; and 3) the Wenatchee National Forest. These data suggest that survival of dispersing juveniles, at least for the year of study, may be higher than the rates estimated in the demographic studies where juvenile survival information was developed for owls that were banded rather than tracked with radios. The difference may be due to juveniles that emigrate from study areas and remain undetected by standard calling techniques. If true, this would provide empirical evidence that the juvenile survival rates for some years are higher than those used in the population projections. However, Thomas et al. (In Prep.) caution that the results are preliminary, and could be a reflection of mild fall, winter, and spring weather in 1991-1992.

Density of territorial owls

Population trends can also be estimated by tracking density of owls over time (see section II.A. of the recovery plan). Density is simply a measure of the number of owls per unit area. Several study areas have been established throughout the range of the owl where researchers attempt to locate all owls that are present each year. The objective of the studies is to determine the trend in the territorial population of owls. The studies are based on the assumption that the proportion of the population detected in the surveys is approximately constant through time (Caughley 1977). Caution is needed in the interpretation of the results because many owls are not territorial during the breeding season (i.e., they are floaters), and are essentially undetectable on surveys (USDI 1990). Some of these undetected floaters could possibly replace territorial owls that died. Over time, this could change the proportion of the population that was detectable. The result would be a territorial population that appeared to remain stable[1] while the overall population was actually in decline. Surveys of the territorial population would thus fail to detect the decline in overall population size until the floaters had all become territorial or died. Thus, the decline in the population might not be detected in time to take corrective action.

Density information from 12 study areas was summarized by Thomas et al. (In Prep.). Ten of these areas were studied for 3 or more years. Unpublished analysis (Bart pers. comm., Franklin and Ward 1992) of these 10 areas indicated that territorial populations in only two of the areas, near Medford, Oregon, appeared to be declining significantly. Densities on the other eight areas were either essentially stable or slightly increasing.

As with the demographic studies, there are potential biases and limitations in the density data (Thomas et al. In Prep.). These are summarized briefly here.

Owls are long-lived animals with high site fidelity, and they may remain in an area for a period of time even as habitat declines. This would temporarily result in an artificially high population that could not be sustained over time. In effect, there could be a lag time between the loss of habitat and the resulting population decline.

Data collected in the study areas reported by Thomas et al. (In Prep.) and Franklin and Ward (1992) were not based on a consistent technique throughout the study areas. Three surveys per year were used in some study areas, while six were used in others. This should not, however, influence comparisons across time within individual study areas.

Another possible bias in the density studies is the possibility that owl surveyors would locate more owls as they became more familiar with study areas. This could influence the first few years of data from an area, resulting in artificially low numbers reported for those years. One outcome of this could be to erroneously conclude that owl density had increased after the first several years.

Loss of habitat

Habitat decline provides the best source of evidence of long-term declines in owl populations. As habitat declines, wildlife populations dependent on that habitat must inevitably decline. Extreme examples can be found in the western Washington lowlands province and the northern part of the Oregon Coast Range province. In these areas, a combination of harvest activities and natural disturbances has resulted in broad landscapes containing little older forest. Surveys in these areas have detected low densities of spotted owls (Forsman 1988, Hays et al. 1989, Irwin et al. 1989). There is little doubt that owls once occurred in these areas at densities similar to those found in adjacent portions of the owl's range.

[1]The term stable is used here to denote a population that is not following a significant upward or downward trend. Population biologists would normally use the term stationary, but "stable" is used for general understanding.

Throughout most of the owl's range, habitat loss occurs as a result of clear-cutting. The clear-cuts and the young stands that grow up in these areas do not provide suitable habitat for owls for up to several decades (Thomas et al. 1990:182). Timber harvest on federal lands began in the 1950s and continued at a fairly constant rate per decade from 1960 to 1990 (USDI 1990). Figure C.2. (reprinted from USDI 1990) depicts the decline of habitat in areas suited for timber production (i.e., in the timber base) on U.S. Forest Service lands in Washington and Oregon west of the Cascade crest. In 1988, the Forest Service estimated that 40,000 acres, or 1.6 percent, of the remaining owl habitat were being harvested annually (USDA 1988). Habitat loss has been even more extensive on BLM lands in the area. On BLM lands in Oregon habitat loss has been reported at a rate of up to 3 percent per year (USDI 1992). Stands regenerated following clear-cuts on federal lands are generally less than 30 years old and do not provide suitable habitat for owls. On private lands throughout the Douglas-fir-Hemlock Zone, timber harvest began earlier and has been more extensive. Some of the regenerating stands are older on these private lands, but generally they are still too young to support owl populations (Thomas et al. 1990:182-3, Bart and Forsman 1992).

Re-establishment of habitat following timber harvest may occur more quickly in the Redwood Zone in the California Coast province than in other places in the owl's range. Private lands in this province have been extensively harvested, but residual older trees were left in some of these harvest operations. Some of these areas appear to support dense owl populations. For example, Simpson Timber Company lands in California have been particularly well surveyed during the past few years. Forests composed of stands more than 60 years old with residual older trees support owls. Forests composed of younger stands have far fewer owls, suggesting that even in these areas owl populations have declined from historic levels. However, there are no actual data available on historic owl populations in these areas.

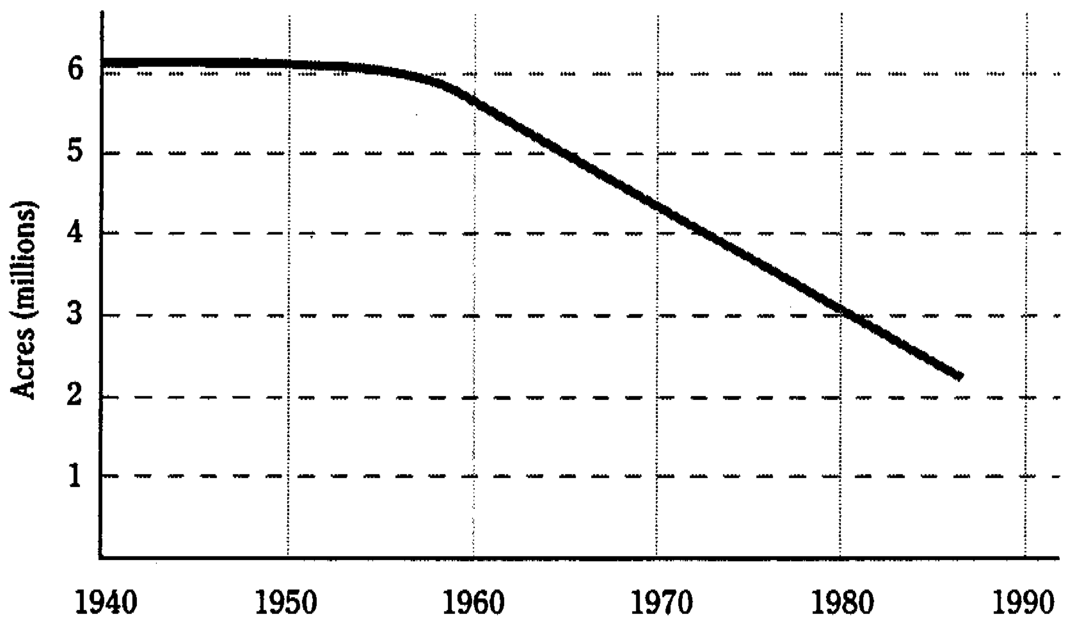


***Figure C.2.** Decline of northern spotted owl habitat on national forest lands suitable for timber production in Oregon and Washington. Adapted from USDI 1990.*

Exceptions to the general pattern of clear-cut harvesting occur in the eastern Oregon and eastern Washington Cascades and Oregon and California Klamath provinces. Selection harvesting has been practiced in some areas in these provinces (for example, on the Yakima Indian Reservation) and it appears to maintain conditions more favorable to owls than does clear-cutting. However, the viability of owl populations in these habitats is unknown.

The near complete elimination of suitable habitat from areas like the western Washington lowlands province is believed to have drastically reduced owl densities, and there is other evidence of a clear relationship between the proportion of a landscape covered by suitable habitat and the density of owls (e.g., Thomas et al. 1990, Bart and Forsman 1992). For example, in a rangewide study (Bart and Forsman 1992), heavily harvested areas (areas with less than 20 percent suitable habitat) had only 10 to 15 percent as many owls as occurred in lightly harvested areas (areas with more than 60 percent suitable habitat).

Evidence of the relationship between large-scale habitat loss and long-term decline in owl populations is clear. However, it is more difficult to determine the relationship between the relatively small habitat loss that occurs on an annual basis and the rate of decline in owl populations. Thomas et al. (In Prep.) report on one effort to establish this relationship. They studied rates of habitat loss in the five demographic study areas analyzed for the draft recovery plan, and compared those rates to the demographic rates for those study areas for the same years. They also compared habitat loss to the trends in density of territorial owls for the five study areas. The rate of population decline reported from the demographic studies was greater than the rate of habitat loss. However, the population density studies for the five areas indicated populations that were either stable or declining at about the same rate as the rate of habitat loss (Thomas et al. In Prep.).

Summary

Evidence of decline of owl populations comes from several sources including demographic studies, studies of owl densities over time, and loss of owl habitat. Each of these sources has limitations and potential biases, and each probably provides insight into different aspects of population trends. It is entirely possible for population models (based on demographic studies) to show a declining trend, while counts of territorial owls (based on density studies) show a stable or more slowly declining trend. These results would mean that the overall population was declining, and that the entire decline was occurring in the floater segment of the population as floaters moved into vacant territories (Franklin 1992). This condition, of course, could not persist indefinitely. Eventually the floaters would disappear entirely, then the number of territorial owls would begin to decline.

Most importantly, all of the data on population decline have been collected during a period of declining habitat. None of these data can answer critical questions about future trends in population if and when habitat conditions stabilize and improve. At this time, the answers to those questions must be based on professional judgment after consideration of all available evidence. The judgment of northern spotted owl researchers is that the strategy of the recovery plan will result in a stable owl population smaller than the population that currently exists (Appendix K in the recovery plan; Carroll and Lamberson In Press). However, owl populations must continue to be monitored, and the recovery plan must be adjusted as necessary through the adaptive management process. Particular attention must be paid to the concerns about adult female owl survivorship and its relationship to population trend.

The following is a list of the definitions of symbols and terms used in Part II.

Lambda, λ - the finite rate of change in the size of the population of females.

Phi, ϕ - the annual probability of survival of adult females.

ϕ_j - annual probability of survival of juvenile females.

$\phi_j \backslash \lambda$ - 1 - annual survival of juvenile females necessary to maintain a stationary population.

$\hat{SE}$ (λ) - the estimate of the standard error of lambda. Includes the lower case designation also: $\hat{se}$ (λ).

$\hat{SE}$ (ϕ) - the estimate of the standard error of Phi. Includes the lower case designation also: $\hat{se}$ (ϕ).

P-value - the probability of finding a value of a test statistic larger than a given value.

t-test - a standard statistical test that compares the value of a test statistic, t-value, to the student's t distribution.

z-test - a standard statistical test that compares the value of a test statistic, z-value, to the standard normal distribution.

Sigma (upper cvase), Σ - the summation size. This symbol in an equation represents the instruction to sum (add).

var (λ) - the variance of lambda, a measure of the dispersion or variability of lambda.

df - degrees of freedom, which is usually the sample, n, minus 1 (i.e., n–1).

Sigma (lower case), σ - the standard deviation of a population of values.

b - the age-specific fecundity (reproductive) rate for spotted owls. Designated as the number of juvenile females produced per female of age x. See Table C.3 for definition.

SE (b) - the standard error of b, the age-specific fecundity rate.

b(1) - the fecundity rate for 1-year old females.

b(2) - the fecundity rate for 2-year old females.

b - the fecundity rate of adult females.

s - the average annual number of new entries into the adult population (i.e., immigrants).

n - the average population size of northern spotted owls.

p - the probability of observing a banded northern spotted owl in a given year.

$\log_e$ - the natural logarithym of a number.

R - the number of observations of banded spotted owls in year j that were last captured in year i.

variance $\sigma^2 = \sum_{i=1}^{n}(x_i-\bar{x})^2/n-1$.

standard error - square root of the variance.

^ - values shown with the ^ are estimates of the true parameter value.

Part II: Demographic Analysis of Northern Spotted Owl Populations

Introduction

The 1990 status review of the northern spotted owl (USDI 1990) provided estimates of the rate of population change for populations of northern spotted owls in northern California (Willow Creek and surrounding demographic regional study area) and southern Oregon (the Roseburg demographic study area). The population of resident female owls in these areas was shown to be declining at a significant rate. By the fall of 1991, there were 2 additional years of capture-recapture data about these two populations, and three new demographic study areas (Medford in southern Oregon, H.J. Andrews near Blue River, Oregon, and the Olympic Peninsula in northwestern Washington) had sufficient years of capture-recapture data to warrant an intensive analysis (Table C.1). More than 2,000 owls had been marked, and the resighting probability for adult females was approximately 0.8 to 0.9 percent.

This appendix provides estimates of the rate of population change of resident, territorial females in these five large study areas. Analysis methods (e.g., model building, model selection, tests of model fit, parameter estimation, and inference procedures concerning the rate of population change) are those used in USDI (1990) with some extensions. The key references on methodology are Burnham and Anderson (1992) and Lebreton et al. In Press). The analyses of data were done during September-October 1991, during two intensive workshops held in Fort Collins, Colorado. The analyses were completed by six biologists working on the northern spotted owl--two French scientists, two professors from Colorado State University with special expertise in the analysis of capture-recapture data, and two U.S. Fish and Wildlife Service employees from the Colorado Cooperative Fish and Wildlife Research Unit.

Table C.1. Summary information about the five demographic study areas.

Study Area	Approximate Size thousand (acres)	Years of Marking	Total Individuals Marked
Northwestern California	4,000	1985-91	400
H.J. Andrews (western Oregon)	116	1987-91	358
Medford (southwestern Oregon)	4,050	1985-91	703
Roseburg (southwestern Oregon)	1,700	1985-91	589
Olympic Peninsula (northwestern Washington)	965	1987-91	302

Results and Discussion

Two parameters are of critical interest; λ = finite (i.e., annual) rate of change in the size of the population of females, and ϕ = annual probability of survival of adult females. Maximum likelihood estimates of these parameters are shown as $\hat{\lambda}$ and $\hat{\phi}$ respectively, along with estimates of their precision (i.e., $\hat{se}(\hat{\lambda})$ and $\hat{se}(\hat{\phi})$). If the number of resident females is "stationary," then $\lambda = 1$, while if the population is declining, then $\lambda < 1$. Thus, there is interest in testing the null hypothesis $H_o: \lambda \leq 1$ against the alternative hypothesis $H_a: \lambda < 1$. Proper estimation of l answers the critical question, "Have the resident, territorial females replaced themselves?"

Parameter Estimates for Individual Study Areas

The estimation of λ was based on the Leslie-Lefkovitch approach summarized in USDI (1990). Under this method, estimates of age-specific survival and fecundity are needed for the female component of the population. Model selection for the estimation of survival probabilities relied on the Akaike Information Criterion (AIC), however some use of likelihood ratio tests was made. Data from the five study areas supported only two age-classes for annual survival estimates (juvenile and all older classes = "adults"). Estimates of these parameters and measures of their precision are presented in Table C.2.

Estimates of age-specific fecundity of females also followed the procedures in USDI (1990), and these are summarized in Table C.3 with a measure of the precision of the estimates.

Estimates of λ, computed from the estimates in Tables C.2.and C.3, estimated precision and test statistics related to the null hypothesis (presented earlier) appear in Table C.4. While there are several potential biases in these estimates, it is clear from Table C.4 that the population of resident, territorial females has declined in each of the five study areas. The simple average of the estimates was $\hat{\lambda} = 0.9022$ which indicates a rate of decline of approxi-

Table C.2. Estimates of age-specific annual survival rates for female northern spotted owls.

Study Area	First Year		All Later Years	
	$\hat{\phi}_J$	$\hat{se}(\hat{\phi}_J)$	$\hat{\phi}_J$	$\hat{se}(\hat{\phi}_J)$
Northwestern California	0.1946	0.0509	0.8507	0.0224
H.J. Andrews (western Oregon)	0.3112	0.1033	0.8365	0.0312
Medford (southwestern Oregon)	0.2002	0.0513	0.7854	0.0258
Roseburg (southwestern Oregon)[a]	0.2829	0.0366	0.8583	0.0131
Olympic Peninsula (northwestern Washington)[a]	0.0707	0.0282	0.8603	0.0264

[a] No sex-specific differences in adult survival were detectable, thus, the estimate of adult female survival includes adult males.

Table C.3. Estimates of age-specific fecundity ($\hat{b}$) for female northern spotted owls (number of juvenile females/female of age x).

	Subadult 1 (12 mos.)		Subadult 2 (24 mos.)		Adult (36 mos.)	
Study Area	($\hat{b}_1$)	$\hat{se}(\hat{b}_1)$	($\hat{b}_2$)	$\hat{se}(\hat{b}_2)$	($\hat{b}$)	$\hat{se}(\hat{b})$
Northwestern California	0.1154	0.0576	0.2286	0.0659	0.3576	0.0245
H.J. Andrews (western Oregon)	0.1430	0.0780	0.1430	0.0780	0.3270	0.0500
Medford (southwestern Oregon)	0.1110	0.0386	0.1110	0.0386	0.3233	0.4880
Roseburg (southwestern Oregon)[a]	0.0938	0.0547	0.0938	0.0547	0.3304	0.0385
Olympic Peninsula (northwestern Washington)[a]	0.1000	0.0667	0.1000	0.0667	0.3327	0.0784

[a] Year-specific differences in ($\hat{b}$).

mately 10 percent per year during 1985-1991. Thus, the resident population was not replacing itself in any of the five large study areas. This is a critical finding. In each case, λ is significantly less than 1 (see test statistics and P-values in Table C.4). No statistical inference is made concerning λ prior to these years of study or in the future. These estimates of λ represent a 5- or 6-year "snapshot" of the average annual change in the female component of these five populations.

Table C.4. Estimates of the finite rate of annual population change (λ) for female northern spotted owls in five independent study areas throughout their range. Also shown are test statistics and P values for the test of the null hypothesis that $\lambda > 1$ vs. $\lambda < 1$.

Study Area	$\hat{\lambda}$	$\hat{se}(\hat{\lambda})$	t or z	P
Northwestern California	0.9153	0.0433	-1.9561	0.0252
H.J. Andrews (western Oregon)	0.9276	0.0437	-1.6567	0.0488
Medford (southwestern Oregon)	0.8444	0.0304	-5.1184	0.0000
Roseburg (southwestern Oregon)	0.9405	0.0182	-3.2692	0.0005
Olympic Peninsula (northwestern Washington)	0.8828	0.0280	-4.1857	0.0000
Simple average and t-test	0.9021	0.0173	-5.7532	0.0024
Simple average and z-test	0.9021	0.0153	-6.4155	0.0000

The t-test is based on the empirical variance among the five independent estimates of λ, while the z-test is based on the theoretical standard error of $\hat{\lambda}$ (i.e., $\sqrt{\Sigma \text{var}(\hat{\lambda}_i)}/5$). The t-test allows for significant variation in λ within the five study areas, however, a test for such variation was not significant (K^2=5.1409, 4 df, P=0.2731; Burnham et al. (1987:264-269)). The estimated standard error of the true $\hat{\lambda}$ across the five study areas ($\hat{\sigma}_\lambda$) was 0.0267 (95 percent confidence interval is 0.0 to 0.1073). Both tests indicate a strong rejection of the null hypothesis, and one must conclude that these populations are declining.

Capture-recapture methods allow estimates of the number of new entries into the population of resident, territorial females (standard Jolly-Seber estimates; USDI (1990:35-36)). Estimates of this quantity, averaged over years, are provided in Table C.5. Study of the results of these analyses indicated that statistically significant immigration had occurred each year in all five study areas. The estimates of the number of new entries (B^) provide insight into how populations in each area have been augmented by immigration from outside the study areas. These findings are consistent with those in the 1990 status review (USDI 1990).

Meta-analysis

The majority of the capture-recapture data comes from adult birds (i.e., nonjuveniles) and therefore a sophisticated attempt was made to model and understand these data for each of the five study areas. Models of capture-recapture data must properly treat two types of parameters; conditional survival probabilities (ϕ) and conditional recapture probabilities (p) and how these vary across study areas (g). Age was not a factor in this analysis as only adults were treated, and sex was not a factor as only females were of particular interest. For theoretical reasons, much of the analysis was done on logit(ϕ) and logit(p), where, in general, $\text{logit}(\theta) = \log_e(\theta/(1-\theta))$. The parameters R and p might vary by year (t), and models were derived to allow for this effect. Time (t) in years was considered in two ways. First, the notation t denoted any significant variability in ϕ or p over years. Second, T was used to denote a linear trend in time in either logit(ϕ) or logit(p). Thus, a model allowing survival probabilities to vary across areas (g) and recapture probabilities to vary across years was denoted as (ϕ_g,P_T).

Table C.5. Estimates of the average annual number of new entries ($\hat{B}$) into the adult population and the estimated average population size ($\hat{N}$) of northern spotted owls.[a]

Study Area	$\hat{B}$	$\hat{se}(\hat{B})$	$\hat{N}$	$\hat{se}(\hat{N})$
Northwestern California	14.76	0.84	49.71	2.46
H.J. Andrews (western Oregon)	15.57	1.48	60.06	4.15
Medford (southwestern Oregon)	54.97	3.26	91.80	7.87
Roseburg (southwestern Oregon)	36.69	2.21	99.68	7.57
Olympic Peninsula (northwestern Washington)	24.44	1.06	51.20	3.56

[a] The estimates of $\hat{B}$ and $\hat{N}$ and measures of precision were made using program JOLLY (Pollock et al. 1990).

More complex models allowed several effects to be considered in a likelihood framework. An asterisk (*) denoted independent factors (e.g., g*t indicated that year-dependent parameters were incorporated in a model separately for each study area). Models employing a logit-linear structure were denoted by a "+" (e.g., g+t would indicate a model whereby study area was indexed by dummy variables, and parameters across time would be parallel on a logit scale) (see Hosmer and Lemeshow 1989). In all models, a log-likelihood ($\log_e(L)$) was used as the basis for statistical inference and estimation of model parameters was based on maximum likelihood methods. The model selection method (AIC) was objective; neighboring models were explored using likelihood ratio tests.

Using the conventions just discussed, either ϕ or p could be modeled in eight ways: g*t, g+t, t, g*T, g+T, T, g or the null case, denoted ·. Combinations of these eight structures for ϕ and p lead to 64 models of the five data sets on adult females. Table C.6 presents the number of model parameters, $-2\cdot\log_e(L)$, and AIC for each of the models considered.

While the AIC-selected model was (ϕ_T, p_{g*T}), some neighboring models were tested to allow a deeper understanding of the data. These tests retain a very general model structure for the recapture probabilities. Three tests were of particular interest:

Test 1. (ϕ, p_{g*T}) vs. (ϕ_t, p_{g*T}), $\chi^2 = 11.9666$, 5 df, $P = 0.035$.
Here, one concludes that there is significant year-specificity in adult female survival.
Test 2. (ϕ, p_{g*T}) vs. (ϕ_T, p_{g*T}), $\chi^2 = 4.930$, 1 df, $P = 0.026$.
Here, one concludes that there is a significant linear trend in logit(ϕ).
Test 3. (ϕ_T, p_{g*T}) vs. (ϕ_t, p_{g*T}), $\chi^2 = 7.036$, 4 df, $P = 0.134$.
Here, one concludes that there is no reason to use four additional parameters to let R vary by year, when a linear trend is satisfactory.

Finally, a Wald test (two-sided) of the significance of the slope in the relationship between logit(ϕ) vs. T is,

$z = -2.287$, $P = 0.011$. Thus, one concludes that the slope is significant.

This comprehensive analysis indicated a decreasing trend in annual adult female survival rate for the populations in the five study areas (Table C.7). This finding is important because λ is critically influenced by the adult female survival (i.e., juvenile survival and fecundity are relatively less important in their influence on λ). Because the evidence strongly indicates that R decreased during the 1985-91 period, one must infer that λ also decreased over this period. That is, the rate of population decline was accelerating during the study period.

Biases in $\hat{\lambda}$

Estimates of juvenile survival have been contentious because estimates are biased low if some juveniles leave the study area, survive a full year, and never return to the study area. To the extent that these three events happen, juvenile survival is underestimated, and estimates of λ are too low (i.e., the true value of λ is probably larger than estimated).

Two approaches were employed to obtain more reasonable estimates of juvenile survival, ϕ_J. First, the maximum estimate of juvenile survival from the five study areas ($\phi_J = 0.311$, $\hat{se} = 0.103$) was used (cases 1 and 2 in Table C.8). Second, data on juvenile survival from the best production year for the Medford and Roseburg areas were pooled to obtain a maximum estimate ($\phi_J = 0.3065$, $\hat{se} = 0.0764$) and this was used (cases 3 and 4, in Table C.8). The Medford and Roseburg areas are large in size and adjacent to each other. Thus, the

Table C.6. Summary of statistics related to model selection, based on 64 models. For each model the three table entries are number of model parameters, $-2 \cdot \log_e(L)$, and AIC. The best model is indicated by the box.**

Survival Rate ϕ	Recapture Rate, p							
	g*t	G+t	t	g*T	g+T	T	g	-
g*t	47 1664.54 1758.54	36 1681.92 1753.92	31 1700.07 1762.07	36 1674.01 1746.01	32 1683.27 1747.27	28 1701.75 1757.35	31 1686.76 1748.76	27 1705.23 1759.23
g+l	36 1672.76 1744.76	20 1694.44 1734.44	16 1713.53 1745.53	20 1689.23 1729.23	16 1698.32 1730.32	12 1715.82 1739.82	15 1703.48 1733.48	11 1719.62 1741.61
t	31 1673.82 1735.82	16 1702.36 1734.36	11 1721.30 1743.30	16 1691.92 1723.92	12 1705.49 1729.49	8 1722.69 1738.69	11 1708.83 1730.83	7 1725.85 1739.85
g*T	36 1674.09 1746.09	20 1696.88 1736.88	16 1714.06 1746.06	20 1690.32 1730.32	16 1698.65 1730.65	12 1717.14 1741.14	15 1701.63 1731.63	11 1720.15 1742.15
g+T	32 1677.43 1741.43	16 1705.04 1737.04	12 1719.75 1743.75	16 1696.17 1728.17	12 1706.46 1730.46	8 1723.24 1739.24	11 1710.89 1732.89	7 1726.14 1740.14
T	28 1678.54 1734.54	12 1711.22 1735.22	8 1725.85 1741.85	[12 1698.96 1722.96]	8 1714.22 1730.22	4 1730.82 1738.82	7 1716.35 1730.35	3 1732.83 1738.83
g	31 1678.39 1740.39	15 1708.71 1738.71	11 1721.44 1743.44	15 1701.81 1731.81	11 1714.77 1736.77	7 1729.76 1743.76	10 1715.12 1735.12	6 1729.90 1741.90
.	27 1679.11 1733.11	11 1712.14 1734.14	7 1726.42 1750.42	11 1703.89 1725.89	7 1719.31 1733.31	3 1735.57 1741.57	6 1719.33 1731.33	2 1735.60 1739.60

** = Akaike Information Criterian.

number of dispersing juveniles that survived and never returned is minimized in this approach. In each of the four cases, an attempt was made to use a realistic estimate of juvenile survival as one of the estimates affecting λ. Cases 1 and 3 allowed adult female survival to decline, while cases 2 and 4 used an estimate of the average adult female survival from the pooled data. Table C.2 provides estimates of $\lambda = 1$. In each of the four cases, there was strong statistical evidence of a declining population.

An additional perspective concerning this source of potential bias can be gained by examining the value for juvenile survival necessary to force $\lambda = 1$ (with the same adult survival and fecundity values). The large increases in estimated juvenile survival, shown here, seem unfounded.

Table C.7. Estimates of average adult female survival (ϕ) during 1985-91 for the northern spotted owl, based on the best model out of 64 for the pooling of data across the five study areas.

Year	$\hat{\phi}$	$\hat{se}(\hat{\phi})$
1985-86	0.8880	0.0242
1986-87	0.8727	0.0202
1987-88	0.8556	0.0157
1988-89	0.8367	0.0124
1989-90	0.8158	0.0146
1990-91	0.7929	0.0231

Study Area	$\hat{\phi}_j \mid \lambda = 1$	% increase
Northwestern California	0.49	151
H.J. Andrews (western Oregon)	0.60	93
Medford (southwestern Oregon)	0.89	345
Roseburg (southwestern Oregon)	0.53	87
Olympic Peninsula (northwestern Washington)	0.52	632
Average	**0.61**	**190**

Table C.8. Estimates of the finite rate of annual population change (λ) for the northern spotted owl obtained by pooling all the data across the five study areas. Cases (explained in the text) make differing assumptions about juvenile survival rates.

Case	Years	Female Survival Rate	$\hat{\phi}_j$	λ	$\hat{se}(\lambda)$	z	P
1	1985-86	Declining	f_{max1}[a]	0.9813	0.0373	-0.4879	0.3128
1	1990-91	Declining	f_{max1}[a]	0.8857	0.0362	-3.1575	0.0008
2	1985-91	Constant	f_{max1}	0.9259	0.0312	-2.3750	0.0088
3	1985-86	Declining	f_{max2}[b]	0.9805	0.0322	-0.6056	0.2724
3	1990-91	Declining	f_{max2}[b]	0.8844	0.0312	-3.7051	0.0001
4	1985-91	Constant	f_{max2}	0.9246	0.0251	-3.0040	0.0013

[a] The survival rate of juveniles was used for the area with the highest survival rate.
[b] The year with the highest survival was used for the Medford and Roseburg areas, thus the emigration was lowest.

In summary, even with optimistic assumptions about juvenile survival rates, the best information suggests that the population of resident, territorial owls has declined, on average, at an estimated rate of 7.5 percent each year during the 1985-91 period and that this rate of decline probably has accelerated in recent years.

Senescence is another potential problem; unaccounted for senescence leads to overestimation of λ. Likewise, it seems clear that fecundity is overestimated each year and this overestimation is more severe in years of poor production. This source of bias in λ also tends to overestimate λ.

Sandland and Kirkwood (1981) noted that the recapture probabilities can be correlated and this leads to biases in the estimate of survival. This effect was tested, but no evidence of this effect was found. This effect is a minor problem when recapture probabilities are so high (i.e., 0.80-0.90).

Conclusions

Populations of resident, territorial females in all five large study areas have declined significantly, at an estimated average rate of 7.5 percent per year during the 1985-91 period. The parameter most important in λ is the annual survival rate of adult females and this parameter has decreased significantly during the 1985-91 period. Thus, the rate of population decline has probably accelerated.

Literature Cited (Both Parts)

Bart, J., Personal Communication, Ohio State University, Columbus, OH.

Bart, J. [In Preparation]. Evaluation of population trend estimates for northern spotted owls calculated using capture-recapture and population projection methods. Ohio State University, Columbus, OH.

Bart, J.; Forsman, E.D. 1992. Dependence of northern spotted owls (*Strix occidentalis caurina*) on old-growth forest in the western United States. Biological Conservation. 62:95-100.

Burnham, K.P.; Anderson, D.R. 1992. Data-based selection of an appropriate model: The key to modern data analysis. Pages 16-30. in: McCullough, D.R.; Barrett, R.H., eds. Wildlife 2001: Populations. Oakland, CA: Elsevier Applied Science.

Burnham, K.P.; Anderson, D.R.; White, G.C.; Brownie, C.; Pollock, K.H. 1987. Design and analysis methods for fish survival experiments based on release-recapture. Bethesda, MD. American Fisheries Society, Monograph 5. 437 p.

Carroll, J.E.; Lamberson, R.H. [In Press]. The owl's odyssey. A continuous model for the dispersal of territorial species. Society for Industrial and Applied Mathematics. Vol. 52. 14 p.

Caswell, H. 1989. Matrix population models. Sunderland, MA. Sinauer Associates, Inc. 328 p.

Caughley, G. 1977. Analysis of vertebrate populations. New York, NY: John Wiley and Sons. 234 p.

Forsman, E.D. 1988. A survey of spotted owls in young forests in the northern Coast Range of Oregon. Murrelet. 69:65-68.

Franklin, A.B. 1992. Population regulation in northern spotted owls: Theoretical implications for management. Pages 815-827. in: McCullough, D.R,; Barrett, R.H., eds. Wildlife 2001: Populations. Oakland, CA: Elsevier Applied Science.

Franklin, A.B.; Ward, J.P. 1992. Density of northern spotted owls: a meta-analysis. Presentation at the annual meeting of the Raptor Research Foundation. November 12, 1992. Bellevue, WA. Unpublished Report. 29 p. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Harrison, S. 1992. Declaration to the United States District Court for the Western District of Washington at Seattle. 30 March 1992. 5 p.

Hays, D.W.; Allen, H.L.; Egtvedt, L.H. 1989. Preliminary report: Spotted owl surveys of randomly selected transects in Washington. Washington Department of Wildlife, Wildlife Management, Nongame. Olympia, WA. Unpublished report. 31 p. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Hosmer, D.W.; Lemeshow, Jr., S.; 1989. Applied logistic regression. New York, NY: John Wiley and Sons, Inc. 328 p.

Irwin, L.L.; Fleming, T.L.; Speich, S.M.; Buchanan, J.B. 1989. Spotted owl presence in managed forests of southwestern Washington. National Council of the Paper Industry for Air and Stream Improvement. West Coast Regional Center, Corvallis, OR. Unpublished report. 30 p. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Kareiva, P. 1992. Declaration to the United States District Court for the Western District of Washington at Seattle. 28 March 1992. 18 p.

Lebreton, J.D.; Burnham, K.P.; Clobert, J.; Anderson, D.R. [In Press]. Modeling survival and testing biological hypotheses using marked animals: A unified approach with case studies. Ecological Monograph.

Orians, G. 1992. Declaration to the United States District Court for the Western District of Washington at Seattle. 20 March 1992. 8 p.

Pollock, K.H.; Nichols, J.D.; Brownie, C.; Hines, J.E. 1990. Statistical inference for capture-recapture experiments. Wildlife Monograph. 107:97

Sandland, R.L.; Kirkwood, P. 1981. Estimation of survival in marked populations with possibly dependent sighting probabilities. Biometrika. 68:531-541.

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, B.R.; Verner, J. 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.; Forsman, E.D.; Gunderson, A.G.; Holthausen, R.S.; Marcot, B.G.; Raphael, M.G.; Reeves, G.H.; Sedell, J.R.; Solis, D.M. [In Preparation]. Report of the Scientific Analysis Team. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR.

U.S. Department of Agriculture, Forest Service. 1988. Final supplement to the environmental impact statement for an amendment to the Pacific Northwest regional guide. Portland, OR. 2 volumes.

U.S. Department of the Interior, Bureau of Land Management. 1992. Roseburg District: draft resource management plan and environmental impact statement. Oregon State Office. Portland, OR. 2 volumes.

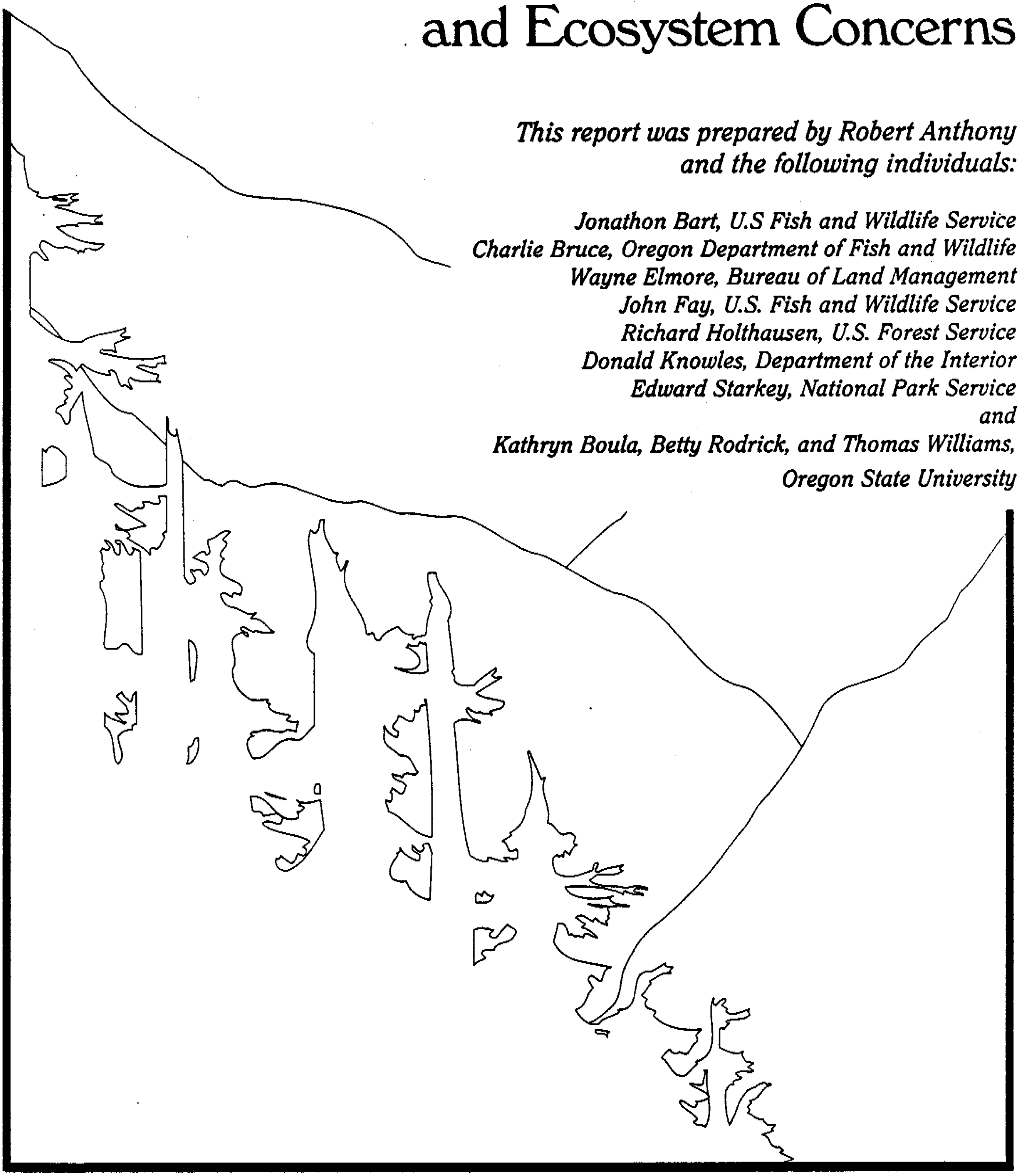
U.S. Department of the Interior, Fish and Wildlife Service. 1990. 1990 status review: northern spotted owl. Portland, OR. 94 p.

Appendix D

Consideration of Other Species and Ecosystem Concerns

This report was prepared by Robert Anthony and the following individuals:

Jonathon Bart, U.S Fish and Wildlife Service
Charlie Bruce, Oregon Department of Fish and Wildlife
Wayne Elmore, Bureau of Land Management
John Fay, U.S. Fish and Wildlife Service
Richard Holthausen, U.S. Forest Service
Donald Knowles, Department of the Interior
Edward Starkey, National Park Service
and
Kathryn Boula, Betty Rodrick, and Thomas Williams, Oregon State University



Contents

Introduction

More than 450 species of birds, mammals, and amphibians occur in forests west of the crest of the Cascade Mountains in Oregon and Washington (Brown 1985:37), as well as 178 species of freshwater and anadromous fishes. The number of plant species, including vascular and nonvascular plants, is also large. The number of invertebrate species is large, but cannot be determined accurately because many arthropods and molluscs have not been described and named (Lattin pers. comm.; Frest pers. comm.). However, more than 3,400 species of arthropods have been reported from the H.J. Andrews Experimental Forest Cascade Mountains in Oregon (Parsons et al. 1991). The Cascade Mountains region is about three times richer in mammalian species and about twice as rich in species of breeding birds as the coniferous forests of the coastal plains of the southeastern United States (Harris 1984:45). This high species richness reflects a great diversity of communities, ranging from estuarine to freshwater, from coastal to montane, and from prairie to temperate rain forest. Of the higher vertebrates (those other than fishes), about 58 percent are birds, 30 percent are mammals, 7 percent are amphibians, and 5 percent are reptiles (Harris 1984:47). In addition to the high species richness of mammals and birds, many unique faunal types are endemic to the Pacific Northwest. For example, the genus Phenacomys (*Arborimus*: tree voles) occurs only in western Oregon and northwestern California, and the region has more species of mammalian insectivores than any other part of temperate North America. Numerous species are narrowly or broadly endemic to western Oregon and Washington and northwestern California. The region also contains the tailed frog, one of the most primitive extant amphibians, which has been essentially unchanged in the fossil record for millions of years. Although the amphibians are not as rich in species as the birds and mammals, most of the species are narrowly or broadly endemic to the Pacific Northwest (e.g., Oregon slender salamander, Siskiyou Mountain salamander) (Bury et al. 1991). In addition, there is evidence of a decline of amphibian populations in many parts of the world (Blaustein and Wake 1990). The number of amphibians that are associated closely with streams (Bury 1988) and the many dwindling fish stocks (Nehlsen et al. 1991) exemplify the importance of riparian ecosystems in coniferous forests.

The northern spotted owl is associated with late-successional forests (mature and old-growth forests) in the Pacific Northwest (Forsman et al. 1984, Thomas et al. 1990), and optimal habitat for the species usually is found in old-growth forests that are more than 200 years old. Because of its association with late-successional forests, the spotted owl has been used as an indicator species for these forests. The owl is well-suited for this role in many respects because of its preference for mature or old-growth forests and its large home range size that varies from 1,000 to 10,000 acres from California to northern Washington (Thomas et al. 1990:194). The amount of mature and old-growth forest within a pair's home range also varies considerably from north to south (Thomas et al. 1990:195). The species' preferred habitat for nesting, roosting, and foraging throughout most of its range is old-growth coniferous forests. However, late-successional forests are extremely diverse in structure and function, and it is clear that the owl cannot represent all the key components of these forests.

Secretary of the Interior Manuel Lujan's charge to the Recovery Team included the following statement: "There are other forest ecosystem species that may be candidates for listing under the Endangered Species Act which may benefit from any recovery plan for the northern spotted owl. To the extent possible, the team should assess the relative benefits to these species from the implementation of various recovery options" (memo to the Recovery Team: February 5, 1991). As a result of this directive, a committee of the

Recovery Team was formed during the initial meeting to address this task. A working principle of the committee was that the recovery plan should take advantage of opportunities to benefit other species and ecosystems.

Description of Late-Successional Forests

Coniferous forests in the Pacific Northwest succeed through three biological stages of development: young, mature, and old-growth. In this appendix, late-successional forests refer to mature and old-growth stages as described by Ruggiero et al. (1991:47-60). Precise definition of old-growth forests is difficult because characteristics are influenced by a number of variables including species composition and climate. However, an interagency task group developed interim definitions for old-growth Douglas-fir and mixed-conifer forests (USDA 1984). The task group suggested that the transition from mature forest to old-growth begins at about 175 or 200 years of age for Douglas-fir forests, with continuing change until these forests are much older. Specific characteristics vary with site but include: a) two or more species of trees with a wide range of sizes and ages of large trees, usually Douglas-fir, with diameters of more than 30 inches or ages older than 200 years; b) multilayered canopy; c) one to four conifer snags per acre with diameters larger than 20 inches and heights more than 15 feet; and d) 10 to 15 tons of down logs per acre with two to four down logs per acre having diameters larger than 24 inches and lengths longer than 50 feet. The special significance of old-growth forests lies in the combination of characteristics they possess, rather than in any unique attribute. This was recognized explicitly in the interim definition of old-growth forests (USDA 1986) and the use of multiple criteria rather than single attributes to characterize these forests. Species composition and specific structural attributes vary with location. In northern California, mixed-conifer and mixed-evergreen forests contain Douglas-fir, white fir, sugar pine, and ponderosa pine in addition to deciduous species such as tanoak, Pacific madrone, and canyon live oak. In Oregon and Washington, Douglas-fir, western hemlock, Sitka spruce, and Pacific silver fir are common.

Throughout much of the region, total precipitation is high and the climate is moderate. Within old-growth stands, the climate is especially moderate, and many of the organisms that inhabit these forests cannot tolerate extreme heat or dryness. The combination of mild climate and year-round food supplies results in a high level of plant and animal diversity.

Historically, these forests did not extend throughout the landscape in an unbroken expanse of old-growth trees. Within the region there are mountainous areas that typically are dissected heavily by streams and rivers, as well as large expanses of less rugged terrain. Also, natural disturbances such as fires, wind, insect infestations, diseases, and volcanic eruptions created a mosaic of different-aged stands. This disturbance regime resulted in a patchy landscape and a diverse variety of habitats for animals. Natural disturbances differed significantly from clear-cut harvesting of timber. Intervals between fires west of the Cascade Mountains typically were much longer than those between harvests, and fires did not result in the relatively fine-grained fragmentation of habitats associated with clear-cut harvesting. The amount of coarse woody debris left afterward is the most significant difference between natural disturbance and logging. Far more wood is removed by timber harvest than by fire, which may destroy only a few large trees and consume less than 20 percent of the coarse woody debris (Spies and Cline 1988).

Many attributes in these late-successional forests are important for wildlife. The forests are dominated by exceptionally long-lived conifer trees, and, in the absence of disturbance, natural succession is a relatively slow process, especially during late seral stages. Thus, stable habitats are provided for species that cannot disperse readily from one suitable habitat to another. Large conifers also provide significant horizontal and vertical complexity. Individual trees have deep crowns, often with trunks and limbs that are deformed or scarred by wind, lightning, or mistletoe infection. Broken tree tops and irregular branches provide nesting habitat for many species. The understory of shade-tolerant trees, such as western hemlock, provides further vertical diversity. Openings develop in the canopy as a result of mortality of dominant trees. As the canopy opens, sunlight penetrates to the forest floor, and a diverse layer of shrubs and forbs develops, further increasing spatial complexity of the forest.

Perhaps one of the most important features of old-growth forests is the great quantity of dead wood they contain. Biomass of snags and down logs reaches 80 tons per acre in stands 500 years old (Spies and Cline 1988) with about one-third of this in snags and two-thirds in down logs (Perry pers. comm.). Snags provide shelter and nest sites for a number of bird and mammal species. Harris and Maser (1984) suggest that elimination of snags in a mature, unmanaged Douglas-fir forest in the Cascade Mountains would reduce the number of resident wildlife species (not including bats) from 90 to about 80. Elimination of snags and down logs would reduce the number to about 60. Snags are especially important to nonmigratory birds; Mannan (1977) found that about 60 percent of bird species in Douglas-fir forests during the winter were cavity-nesters.

Down logs are important features in terrestrial and aquatic habitats. They contribute to structural diversity, provide hiding cover for small animals, and provide moist microhabitats during dry periods. Dead and decaying wood on the forest floor contain important water reserves that buffer the effects of the summer drought periods typical of the region (Perry 1991). Down logs are also important elements of stream ecosystems. They provide baffles and dams that create pools and backwaters, increasing diversity of habitats within these systems. Down logs and coarse woody debris also provide food for aquatic insects, which in turn provide food for predators at higher trophic levels. Fish biomass is related closely to quantity of coarse woody debris in Pacific Northwest streams (Harmon et al. 1986). Streams in managed forests typically contain few large logs. There is not likely to be additional recruitment of extremely large diameter logs because rotation cycles are too short to permit the growth and mortality of extremely large trees.

Large numbers of terrestrial organisms also use coarse woody debris for food and shelter. Important examples include the northern flying squirrel and western red-backed vole. These important spotted owl prey species feed on mycorrhizal fungi, which appear to be associated with decaying logs (Maser et al. 1985, Ure and Maser 1982). Other vertebrates that use logs include salamanders, shrews, and martens (McComb 1991), as well as large numbers of invertebrates such as insects, slugs, and centipedes (Harmon et al. 1986, Parsons et al. 1991).

Older forests are productive and valuable as wildlife habitat although their value in this regard often has been underestimated. Isaac (1952) referred to old-growth forests as "biological deserts." Norse (1990) suggested that this misperception was partly a result of preoccupation with game species, which tend to be less abundant in mature forests than in early seral environments.

Because of the complex combination of characteristics required, it is doubtful that managed forests with short rotations and even-aged management can provide habitat for the numerous species associated with older forests. It is unlikely that a planted and even-aged, managed stand ever could simulate an old-growth system. However, habitat for many species can be provided in a managed environment; therefore, conservation efforts for many organisms associated with older forests, including the northern spotted owl, should include a combination of reserves and managed forests. Reserves would provide true old-growth environments for those species with narrow ecological tolerance, and management practices for managed forests could be adapted to maintain populations of less specialized species that are commonly associated with late-successional forests.

Northern Spotted Owl as an Indicator Species

Concern for northern spotted owls and debate over management of their habitat has been a persistent issue in Pacific Northwest forestry for two decades (USDA 1988, Thomas et al. 1990). However, spotted owls rarely have been the sole focus of this debate. Most frequently they have been used as a symbol of general concerns about the fate of old forests in the Pacific Northwest. The U.S. Forest Service recognized this general concern by designating northern spotted owls as a management indicator species in the forest planning process (USDA 1984). Management for owls and other indicator species was advanced as a way to adequately provide for the needs of several hundred other species associated with late-successional forests (USDA 1988).

Biological indicators have been used successfully as gauges of environmental conditions in some situations (Thomas 1972). However, the use of vertebrate species as indicators for other vertebrates has proven unsuccessful in several studies (Mannan et al. 1984, Szaro 1986), and the concept has been questioned. The attempted uses of vertebrate indicators and reasons for failure of the vertebrate indicator concept were summarized by Landres et al. (1988). Vertebrates have been used as indicators of population trends and of habitat quality for other species. Their use as indicators of population trends for other species is likely to fail because each species responds to a different complex of habitat and climatic factors and is affected by interactions with other species. Mechanisms of population regulation also differ among species, making it even less likely that one could indicate the population trends of another. The use of vertebrates as indicators for habitat quality for other species is equally problematic. The factors that influence habitat quality are similar to those that influence population density. The probability is small that one species can adequately represent those factors for a number of other species.

Given the likelihood that no vertebrate can adequately represent a whole community of organisms, what are the potential hazards of establishing a management strategy based solely on habitat needs of spotted owls? First, at a landscape scale, the locations of conservation areas established to meet the needs of owls may not adequately provide for other species that have restricted ranges within the range of the spotted owl. Examples of this concern include the marbled murrelet, which occurs primarily in the coastal forests, and some amphibian and mollusc species that have extremely small ranges (see later sections in this appendix). These species could be missed entirely by a system of reserves established for owls. Second, the spacing of conservation areas for owls may not accommodate movement of species that have much more limited dispersal capabilities. Amphibians, small mammals, and most invertebrates have limited ability to move among large established areas that are long distances apart. Finally, at the stand level, the specific habitat conditions that are maintained for owls may not provide habitat for other species. For example, silvicultural practices in very young (less than 40 years) stands that are aimed at producing habitat structure for owls will not provide the branch structure associated with marbled murrelet nest sites. Ruggiero et al. (1988) stated that as management becomes more tightly directed at a single species, it is less likely to provide for other species. Baker and Schonewald-Cox (1986) concluded that "Incorrectly assuming that other species are receiving protection as a result of the protection of [an indicator] can result in the inadvertent loss of those other species."

These cautions on the use of indicators were used in several ways in developing the recovery plan. First, in formulating the overall strategy for spotted owl recovery, the Recovery Team evaluated the overlap between possible spotted owl management areas and the ranges and locations of other species that were judged to be priorities. Second, in developing recommendations for management practices in designated conservation areas (DCAs), the Recovery Team attempted to look beyond the habitat attributes associated with spotted owls. Wherever possible, the Recovery Team used the structure and function of late-successional forests as a benchmark for recommendations on management activities. This ensured that those activities would help provide habitat for other species and not focus so specifically on spotted owls that other species were inadvertently harmed.

Riparian Ecosystems and Spotted Owls

Riparian areas are among the most ecologically important components of forest landscapes. There are several definitions for riparian areas, but basically they are areas where soils contain free or unbound water and are recognized by unique vegetation types adjacent to lakes, streams, rivers, ponds, marshes, seeps, or bogs. They form boundaries between different ecosystems and provide connectivity for interchange and dispersal for plants and animals.

Spotted owls often are associated with riparian areas within their home ranges. Forsman (1976) first noted this relationship; he reported that all but three nests he located were within 425 yards of water. Later, Forsman et al. (1984) noted the same relationship for a larger sample of nest sites. Using radio-telemetry, Solis (1983) and Solis and Gutiérrez (1990) also reported that roosting and foraging sites were more likely to be found on the lower one third of slopes (i.e., near streams within the owl's home ranges) than elsewhere. Finally, Blakesley et al. (1992) report a similar relationship in northwestern California. Their study analyzed all roost and nest sites used by an entire population of owls during a 5-year period. Thus, analysis of individual selection and population selection have noted an association of spotted owls with riparian areas. However, this association decreases as one travels north within the range of the northern spotted owl.

The association of spotted owls with streams and associated vegetation is not well understood, but there may be several reasons for the observed relationship: 1) riparian areas usually are cooler, which may facilitate thermoregulation in the owls (Barrows and Barrows 1978; Barrows 1981); 2) riparian areas in the Pacific Northwest often are more productive areas in terms of tree growth, and this may promote more rapid development of suitable nest sites; 3) riparian areas usually support a more diverse biota than adjacent areas, resulting in the structural diversity that is characteristic of spotted owl habitat; and 4) riparian systems are more floristically rich and consequently may support higher numbers and abundance of prey species.

The Approach

A committee of the Recovery Team was formed to address concerns for other species and older forest ecosystems. The committee was composed of the following Recovery Team members and staff:

Robert Anthony (Chairman), U.S. Fish and Wildlife Service
Jonathan Bart, U.S. Fish and Wildlife Service
Charlie Bruce, Oregon Department of Fish and Wildlife
Wayne Elmore, U.S. Bureau of Land Management
John Fay, U.S. Fish and Wildlife Service
Richard Holthausen, U.S. Forest Service
Donald Knowles, U.S. Department of the Interior
Edward Starkey, National Park Service

Later in the process, Kathryn Boula, Thomas Williams, Betty Rodrick, and Rosemary Stussy were hired to help with various aspects of the information gathering and writing of this section of the recovery plan. The group also contracted responsibilities for parts of the biota to outside scientists, including Eric Cummins of the Washington Department of Wildlife (marbled murrelets); Joseph Beatty, Oregon State University (salamanders); Andrew Blaustein, Oregon State University (toads and frogs); Terrence Frest, Deixis Consultants (molluscs); Jack Lattin, Oregon State University (invertebrates); Andrew Moldenke, Oregon State University (invertebrates); Daniel Rosenburg, Redwood Sciences Lab (spotted owl prey); and Robert Storm, Oregon State University (salamanders).

Developing the List of Other Species

The committee's first decision was to consider all components of the biota associated with late-successional forests and spotted owl habitat. The scope of this effort was focused on species that were federally listed as threatened or endangered, candidates for federal or state listing, state sensitive and species of special concern, and species that are associated with late-successional forests within the range of the owl. The definition of late-successional forests used in this appendix includes both mature and old-growth forests as described by Ruggiero et al. (1991:47-60). The general approach consisted of the following:

1) Delineate the area of focus (i.e., the range of the northern spotted owl).

2) Compile a list of threatened and endangered, candidate, sensitive, and older-forest associated species.

3) Develop a short list of priority species by determining which species:
   a) occur within the range of the northern spotted owl,
   b) are more abundant in older forests,
   c) are in most need of conservation measures.

4) Acquire definitions and maps of important habitat for the list of priority species.

5) Develop a geographic information system (GIS) mapping scheme to overlay important areas of habitat for the priority species with potential conservation areas for the spotted owl.

6) Identify areas of high species richness.

The list of species was developed in a series of meetings with more than 60 biologists, other scientists, and managers from the Pacific Northwest who had a wide array of expertise. The committee also reviewed lists of threatened and endangered, candidate, and sensitive species from the U.S. Fish and Wildlife Service, Washington Department of Wildlife, Oregon Department of Fish and Wildlife, and California Department of Fish and Game. To identify species associated with late-successional forests, the committee reviewed the results of the Forest Service's Old-Growth Wildlife Habitat Research Program (Ruggiero et al. 1991a, Brown 1985, Thomas et al. In Prep.). A series of meetings on other species and ecosystem concerns was conducted by members of the committee from May through August 1991. The committee met several times, and members of the committee conducted more than 25 meetings with outside biologists, other scientists, and managers in the three states. Records of the committee's consultation with other individuals are included in the recovery plan's administrative record.

Identification of Priority Species and Assemblages

The short list of priority species represents a consensus of the committee members. Highest priorities were assigned to species that are closely associated with late-successional forests, threatened or endangered species, or species that are candidates for listing in at least parts of their geographic range. Attention also was given to species that have restricted geographic ranges or are endemic to the Pacific Northwest; species that have been designated as management indicator species of older forests by the Forest Service (i.e., pileated woodpecker, northern goshawk, fisher, marten); and spotted owl prey species (woodrats, flying squirrel, red tree voles, red-backed vole).

In developing the list of species, it became apparent that riparian ecosystems in coniferous forests were of particular importance and concern. The importance of these ecosystems is demonstrated by the numerous species of native fishes, amphibians, molluscs, aquatic insects, small mammals, and birds that are associated with them. In addition, spotted owls often are associated with riparian areas.

A short list of priority species was developed and concerns related to riparian ecosystems were identified. Committee members reviewed numerous publications, geographic ranges, status of populations, natural history, habitat associations, and factors affecting populations and habitat. In addition, the committee sponsored a 2-day workshop about priority species and riparian ecosystems to which scientists were invited to present information about priority species. The workshop included opportunities for questions and answers at the end of each presentation. In all, 16 speakers presented information about the marbled murrelet, northern goshawk, bald eagle, marten, fisher, riparian ecology, native fishes, amphibians, spotted owl prey, vascular plants, fungi, and ecological corridors. Transcripts of the entire workshop are in the recovery plan's administrative record. Initially, there was a manual mapping exercise that designated land ownerships, habitat conservation areas for the owl from the Interagency Scientific Committee (ISC) (Thomas et al. 1990), critical habitat areas as proposed by the FWS (USDI 1992), and significant old-growth areas as designated by a congressional scientific panel (Johnson et al. 1991). Later, this effort was incorporated into a GIS mapping procedure that allowed more efficient evaluation of options.

List of Threatened and Endangered, Candidate, Sensitive, and Older Forest Associated Species

The list of species considered in the recovery plan for the northern spotted owl includes 39 birds, 28 mammals, 27 amphibians and reptiles, 28 fishes, 58 molluscs, 91 arthropods, 207 vascular plants, and 190 nonvascular plants. Of these species, seven (bald eagle, marbled murrelet, peregrine falcon, gray wolf, grizzly bear, Sacramento River winter chinook salmon, McDonald's rock cress) are federally listed as threatened or endangered, and several fish stocks are proposed for federal listing. More recently, the northern goshawk has been petitioned for listing throughout the western United States. More than 140 species are listed or designated as sensitive species or species of special concern in one or more of the three states and could become candidates for federal listing in the future. Of the species considered in the recovery plan, 482 species of birds, mammals, amphibians, and plants are associated with or closely associated with late-successional forests (Brown 1985, Ruggiero et al. 1991b, Thomas et al. In Prep.). "Closely associated" species are those whose abundance was statistically significantly greater in one forest seral stage than another. Species "associated with" a forest class are those found to be numerically more abundant in one seral stage than another, but differences were not statistically significant. Although many species were detected in older Douglas-fir forests in the study, the list includes only those species for which significant statistical or ecological correlations with older Douglas-fir forests were detected. Additional species occur in late-successional forests that were not detected by Ruggiero et al. (1991b). These species include the bald eagle, which uses older forests for nesting (Anthony and Isaacs 1989) and communal roosting (Anthony et al. 1982), and the northern goshawk on the Olympic Peninsula in Washington (Hayes pers. comm.) and in northwestern California (Hall 1984). The list of species associated with late-successional forests is useful in determining the number and variety of species that might become candidates for listing as threatened or endangered if all of these forests are converted to short-rotation, even-aged forests.

Birds

Thirty-nine species of birds are on the list for consideration in the recovery plan (Table D.1). The bald eagle is federally listed as threatened in Oregon and Washington and endangered in California, and the peregrine falcon is listed as endangered in all three states. The marbled murrelet has been listed as threatened in all three states, and there has been a petition for listing the northern goshawk throughout the western United States. The pileated woodpecker and the white-headed woodpecker are management indicator species for the Forest Service because of their strong association with older forests on the west and east sides of the Cascade Mountains, respectively. The Vaux's swift, white-headed woodpecker, and chestnut-backed chickadee are broadly endemic to the Pacific Northwest, and 36 of the 39 species are associated with or closely associated with older forests in one or more of the three states (Ruggiero et al. 1991a). The marbled murrelet is of particular concern to the Recovery Team because of its strong association with late-successional forests for nesting and the recent listing as threatened in Oregon, Washington, and California. Further, its use of older forests for nesting is unique; marbled murrelets use large moss-covered limbs for nest construction, and these structures are found only on the oldest trees in a stand. Twelve of the species on the list for consideration in the recovery plan belong to a group of birds, the cavity-nesters (pileated woodpecker, white-headed

Table D.1. A list of threatened and endangered, sensitive, candidate, and old-growth associated birds within the range of the northern spotted owl.

Species	Status[a,b]				Old forest Association[c]			Endemic[d]		Priority Species	Riparian Associate	References[e]
		State										
	Fed	WA	OR	CA	WA	OR	CA	L	B			
Marbled murrelet *Brachyramphus marmoratus*	T	C	SC	E	*	*	*			X	X	5,9,12
Harlequin duck *Histrionicus histrionicus*	C2	G	SR	SC	+	+					X	14
Barrow's goldeneye *Bucepthala islandica*					+	+	+				X	14
Bufflehead *Bucephala albeola*					+	+	+				X	14
Wood duck *Aix sponsa*					+	+	+				X	14
Hooded merganser *Lophodytes cucullatus*					+	+	+				X	14
Northern goshawk *Accipiter gentilis*	C2	C	SC	SC	+	+	+			X		8,11
Peregrine falcon *Falcon peregrinus*	E	E	E									
Bald eagle *Haliaeetus leucocephalus*	T	T	T	E	*	*	*			X	X	1,2
Mountain quail *Oreortyx pictus*	C2											
Flammulated owl *Otus flammeolus*		C	SC			+						6
Northern pygmy owl *Glaucidium gnoma*			SU			+						12,14
Great gray owl *Strix nebulosa*		M	SV	E	+	+						14
Barred owl *Strix varia*					+	+						14

continues

Continued

Species	Status[a,b] Fed	State WA	State OR	State CA	Old forest Association[c] WA	OR	CA	Endemic[d] L	B	Priority Species	Riparian Associate	References[e]
Vaux's swift *Chaetura vauxi*		C			*	*			X			12,14
Pileated woodpecker *Dryocopus pileatus*		C	SC		+	+	+					4,12,14
White-headed woodpecker *Picoides albolarvatus*		C	SC		+	+			X			3,14
Black-backed woodpecker *Picoides articus*		M	SC		+	+						7,14
Hairy woodpecker *Picoides villosus*					+	*	*					12
Three-toed woodpecker *Picoides tridactylus*						+						7
Williamson's sapsucker *Sphyrapicus thryoideus*					+	+						14
Red-breasted sapsucker *Sphyrapicus ruber*					+	+	*					10,12
Western flycatcher *Empidonax difficilis*					+	+	*					10,12
Hammond's flycatcher *Empidonax hammondii*					+	+	*		X			13,14
Willow flycatcher *Empidonax traillii*				E							X	
Chestnut-backed chickadee *Parus rufescens*					+	+	+		X			10,12
Brown creeper *Certhia americana*					+	+	*					12
Winter wren *Troglodytes troglodytes*					+	+	+					10,12
Red-breasted nuthatch *Sitta canadensis*					+	+						12
White-breasted nuthatch *Sitta pygmaea*					+	+						14
Pigmy nuthatch *Sitta pygmaea*					+	+						14

Continues

Continued

Species	Status[a,b] Fed	State WA	State OR	State CA	Old forest Association[c] WA	OR	CA	Endemic[d] L	B	Priority Species	Riparian Associate	References[e]
Golden-crowned kinglet *Regulus satrapa*					+	+						14
Hermit warbler *Dendroica occidentalis*							*					10,12
Wilson warbler *Wilsonia pusilla*					+	+	+					10,12,14
Warbling vireo *Vireo gilvus*					+	+	+					10,14
Red crossbill *Loxia curvirostra*					+	+						12
Western Tanager *Parenga ludovisciana*					+	+						12
Varied thrush *Ixoreus naevius*					+	+			X			12
Hermit thrush *Catharus guttatus*							*					10

[a] Federal status: E-endangered, T-threatened, C-candidate, PrT-proposed threatened, Pet-petition pending; State status: WA: C-candidate, M-monitor, X-extirpated, G-game; OR: SC-sensitive (critical), SV-sensitive (vulnerable), SR-sensitive (rare), SU-sensitive (undetermined), X-extirpated; CA: SCT-state candidate for listing as threatened, SC-species of concern, E-endangered.

[b] Sources for state status: California Department of Fish and Game (1991a); Oregon Department of Fish and Wildlife (1991b); Washington Department of Wildlife (1991a); Washington Department of Wildlife (1991b).

[c] +: old-growth associated; *: close old-growth associated (see Ruggiero et al. 1991).

[d] Endemic: L-local, B-broadly; see Ruggiero et al. (1991) for definition and list of endemic species.

[e] References: 1) Anthony et al. (1982), 2) Anthony and Isaacs (1989), 3) Bull (1990), 4) Bull (pers. comm.), 5) Cummins (1991), 6) Goggans (1986), 7) Goggans et al. (1987), 8) Hayward et al. (1990), 9) Nelson (1990), 10) Raphael (1985), 11) Reynolds et al. (1982), 12) Ruggiero et al. (1991), 13) Sakai and Noon (1991), 14) Brown et al. (1985).

woodpecker, three-toed woodpecker, black-backed woodpecker, hairy woodpecker, red-breasted sapsucker, Williamson's sapsucker, chestnut-backed chickadee, winter wren, red-breasted nuthatch, white-breasted nuthatch, and flammulated owl), that requires snags for nesting and/or foraging. Optimal habitat for these species is found in old-growth forests, where the abundance of large snags is greatest (Nelson 1989, Mannan et al. 1980). Of the 39 species of birds, three (marbled murrelet, bald eagle, northern goshawk) were chosen as priority species.

Mammals

Twenty-eight species of mammals are on the list for consideration in the recovery plan (Table D.2). Two species, the gray wolf and grizzly bear, are federally listed as endangered, and the western big-eared bat is a candidate for state listing in Washington and Oregon. The marten is a management indicator species for the Forest Service because of its association with late-successional forests. The red tree voles, white-footed vole, western red-backed vole, and shrew mole are endemic to the Pacific Northwest (Figures D.1 and D.2). Twenty-two of the 28 species are associated with or closely associated with older forests in one or more of the three states, and 11 of these species are bats for which there is little information. Five species are associated with riparian areas. Six species belong to a group that is prey of the northern spotted owl, including the northern flying squirrel, red tree voles, western red-backed vole, dusky-footed woodrat, and bushy-tailed woodrat (Thomas et al. 1990; Figure D.2). As a group, they represent the major prey species of the owl other than the deer mouse and snowshoe hare (Forsman et al. 1984, Thomas et al. 1990). The red tree voles, red-backed vole, and northern flying squirrel are associated with late-successional forests throughout most of their ranges in this region (Carey 1989), with the exception of the flying squirrel in Oregon's Cascade Mountains, where Rosenberg and Anthony (1992) found similar densities in old- and second-growth forests. Of the 28 species, 9 were chosen as priority species that would be most likely to benefit from measures taken to recover the owl. Six of these species are prey of the northern spotted owl and were chosen solely for that reason.

Amphibians and Reptiles

Twenty-seven species of amphibians and reptiles are on the list for consideration in the recovery plan, including 19 salamanders, 6 toads and frogs, 1 snake, and 1 turtle (Table D.3). None of the species is federally listed as threatened or endangered, but the western spotted frog has been petitioned for listing and four species of salamanders in the genus *Plethodon* are candidates for listing. Fifteen of the species are directly associated with riparian areas and 17 are associated with older forests. All but seven of the species are designated as "species of special concern" in one or more of the three states. Most of the amphibians are endemic to the Pacific Northwest (Beatty et al. 1991), and some of the species (e.g., Oregon slender, Larch Mountain, Siskiyou Mountain, and Van Dyke's salamanders) have very restricted distributions (Figures D.3 - D.5). Most of the species have specific habitat requirements; their dispersal capabilities are limited; and there is considerable genetic variability within species. The clouded, Olympic, and Oregon slender salamanders are closely associated with coarse woody debris. Populations of this group have not been surveyed sufficiently to assess the status of many of the species' populations. Their special natural history traits include low mobility and dependency on moist environments for at least part of their life cycles. They have been included as priorities

Table D.2. **A list of threatened and endangered, sensitive, candidate, and old-growth associated mammals within the range of the northern spotted owl.**

Species	Status[a,b]				Old forest Association[c]			Endemic[d]		Priority	Riparian	
		State										
	Fed	WA	OR	CA	WA	OR	CA	L	B	Species	Associate	References[e]
Pacific shrew						+		X			X	5,10
Sorex pacificus												
Shrew mole					+	+		X				5,9
Neurotrichus gibbsii												
Fringed myotis		M	SV			*						5
Myotis thysanodes												
Long-legged myotis		M			*	*						5,9
Myotis volans												
Western big-eared bat	C2	C	SC	SC								
Plecotus townsendii												
Silver-haired bat					+	*						5,9
Lasionycteris noctivagans												
Hoary bat					+	+						9
Lasiurus cinereus												
Little brown myotis					*	*						5
Myotis lucifugus												
Long-eared myotis					*	*						5
Myotis evotis												
Keen's myotis					*	*						5
Myotis keenii												
California myotis					*	*						5
Myotis californicus												
Yuma myotis					*	*						5
Myotis yumanenis												
Big brown bat						*						5
Eptesicus fuscus												
Douglas squirrel					+		+					5,10
Tamiasciurus douglasi												
Northern flying squirrel				SC		*				X		5,8
Glaucomys sabrinus												

Continues

Continued

Species	Status[a,b]				Old forest Association[c]			Endemic[d]		Priority Species	Riparian Associate	References[e]
	Fed	State										
		WA	OR	CA	WA	OR	CA	L	B			
Bushy-tailed woodrat *Neotoma cinerea*									X	X	X	9
Dusky-footed woodrat *Neotoma fuscipes*				SC			*		X	X	X	4,9
Red tree vole *Phenacomys longicaudus*						*		X		X		1,5,9
Red tree vole *Phenacomys pomo*				SC			+	X		X		2,5,9
White-footed vole *Phenacomys albipes*			SR	SC				X			X	1,9
Western red-backed vole *Clethrionomys californicus*						+	+	X		X		4,5,9
Forest deer mouse *Peromyscus oreas*					*			X		X		5
Grizzly bear *Ursus arctos*	T	E	X	X						X		9
Gray wolf *Canis lupis*	E	E	X	X						X		
Marten *Martes americana*		G	S	S	+	+	+			X	X	3,9
Fisher *Martes pennanti*	C2	S	S	SC	+	+	+			X		5,9
Woverine *Gulo gulo*	C2	M	T	T								9
Lynx *Lynx canadensis*	C2				+							7

[a] Federal status: E-endangered, T-threatened, C-candidate, PrT-proposed threatened, Pet-petition pending; State status: WA: C-candidate, M-monitor, X-extirpated, G-game; OR: SC-sensitive(critical), SV-sensitive(vulnerable), SR-sensitive(rare), SU-sensitive(undetermined), X-extirpated; CA: SCT-state candidate for listing as threatened, SC-species of concern, E-endangered.

[b] Sources for state status:
California Department of Fish and Game (1991a); Oregon Department of Fish and Wildlife (1991); Washington Department of Wildlife (1991a); Washington Department of Wildlife (1991b).

[c] +: old-growth associated; *: close old-growth associated (see Ruggiero et al. 1991).

[d] Endemic: L-local, B-broadly; see Ruggiero et al. (1991) for definition and list of endemic species.

[e] References: 1) Gomez (1992), 2) Johnson and George (1991), 3) Marshall (1991), 4) Raphael (1985), 5) Ruggiero et al. (1991), 6) Rosenberg (1991), 7) Koehler and Brittell (1990), 8) Carey (1992), 9) Brown et al. (1985), 10) Raphael (1988).

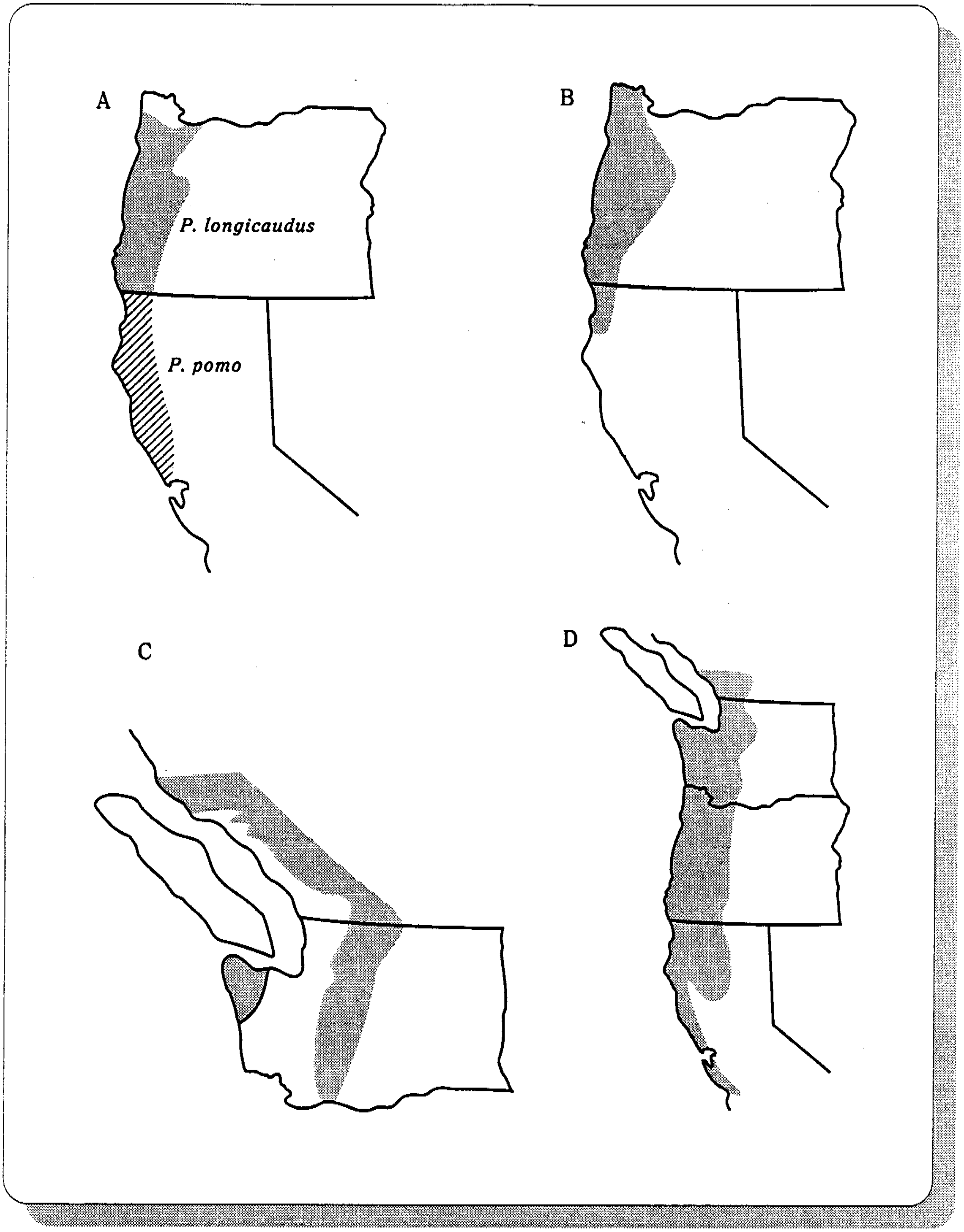


Figure D.1. *Distribution of: a) red tree voles (Phenacomys longicaudus, P. pomo), b) white-footed vole (P. albipes), c) forest deer mouse (Peromyscus oreas), and d) shrew mole (Neurotrichus gibbsii).*

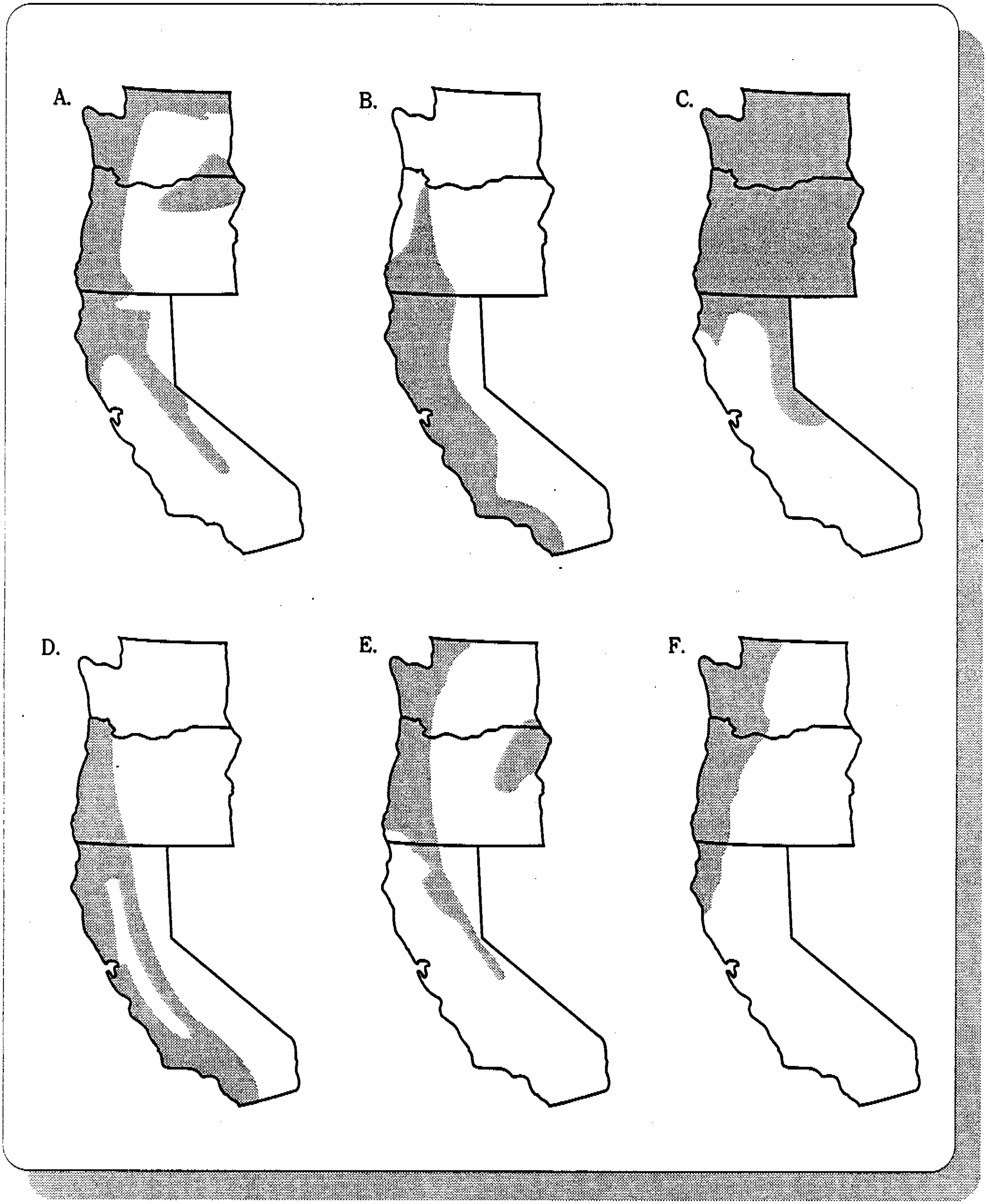


Figure D.2. *Distribution within Washington, Oregon, and California of the major prey species of the northern spotted owl: a) northern flying squirrel, b) dusky-footed woodrat, c) bushy-tailed woodrat, d) brush rabbit, e) snowshoe hare, f) western red-backed vole.* Adapted from Ingles (1976), with the permission of the publishers. Stanford University Press. Copyright 1947, 1954, and 1965 by the Board of Trustees of the Leland Stanford Junior University.

Table D.3. A list of threatened and endangered, sensitive, candidate, and old-growth associated reptiles and amphibians within the range of the northern spotted owl.

Species	Status[a,b]				Old forest Association[c]			Endemic[d]		Priority Species	Riparian Associate	References[e]
	Fed	State WA	State OR	State CA	WA	OR	CA	L	B			
Northwestern salamander *Ambystoma gracile*					*	+		X			X	3,5
Pacific giant salamander *Dicamptodon tenebrosus*					+	*	*		X	X	X	3,4,5
Cope's giant salamander *Dicamptodon copei*					+			X		X	X	3
Olympic salamander (4 species) *Rhyacotriton olympicus*		SC	SC	SC	+	*	*		X	X	X	3,4,5
Clouded salamander *Aneides ferreus*			SC			+	+	X				3
Black salamander *Aneides flavipunctatus*			SC						X			3,5
Oregon slender salamander *Batrachoseps wrighti*			SC			+		X		X		1,3,5
California slender salamander *Batrachoseps attenuatus*					+	+						5
Ensatina *Ensatina eschscholtzii*							+					3,5
Dunn's salamander *Plethodon dunni*		C				+		X				3,5
Del Norte salamander *Plethodon elongatus*	C2		SC	SC			*	X		X		1,3,5
Larch Mountain salamander *Plethodon larselli*	C2	C	SC			*		X		X		1,5
Siskiyou Mountain salamander *Plethodon stormi*	C2		SC	T				X		X		1,5
Van Dyke's salamander *Plethodon vandykei*	C3	C			+			X		X	X	2,5
Western red-backed salamander *Plethodon vehiculum*					+	+		X				3,5

Continues

Continued

Species	Status[a,b]				Old forest Association[c]			Endemic[d]		Priority Species	Riparian Associate	References[e]
	Fed	State WA	State OR	State CA	WA	OR	CA	L	B			
Shasta salamander *Hydromantes shastae*	C2			T				X				1
Western toad *Bufo boreas*											X	2,5
Tailed frog *Ascaphus truei*		SC	SC	SC	+	*	*		X	X	X	1,3,4,5
Red-legged frog *Rana aurora*	C2		SC	SC					X		X	1,3
Foothill yellow-legged frog *Rana boylei*			SC	SC					X		X	1,3
Cascades frog *Rana cascadae*	C2		SC	SC					X		X	1
Western spotted frog *Rana pretiosa*	C2	C	SC								X	1
Western pond turtle *Clemmys marmorata*	C2	T	SC	SC					X		X	1
Sharp-tailed snake *Contia tenuis*			SC						X			1

[a] Federal status: E-endangered, T-threatened, C-candidate, PrT-proposed threatened, Pet-petition pending; State status: WA: C-candidate, M-monitor, X-extirpated, G-game; OR: SC-sensitive (critical), SV-sensitive (vulnerable), SR-sensitive (rare), SU-sensitive (undetermined), X-extirpated; CA: SCT-state candidate for listing as threatened, SC-species of concern, E-endangered.
[b] Sources for state status: California Department of Fish and Game (1991a); Oregon Department of Fish and Wildlife (1991); Washington Department of Wildlife (1991a); Washington Department of Wildlife (1991b).
[c] +: old-growth associated; *: close old-growth associated (see Ruggiero et al. 1991).
[d] Endemic: L-local, B-broadly; see Ruggiero et al. (1991) and Beatty et al. (1991) for definition and list of endemic species.
[e] References: 1) Beatty et al. (1991), 2) Beatty pers. comm., 3) Ruggiero et al. (1991), 4) Gomez (1992), 5) Brown et al. (1985).

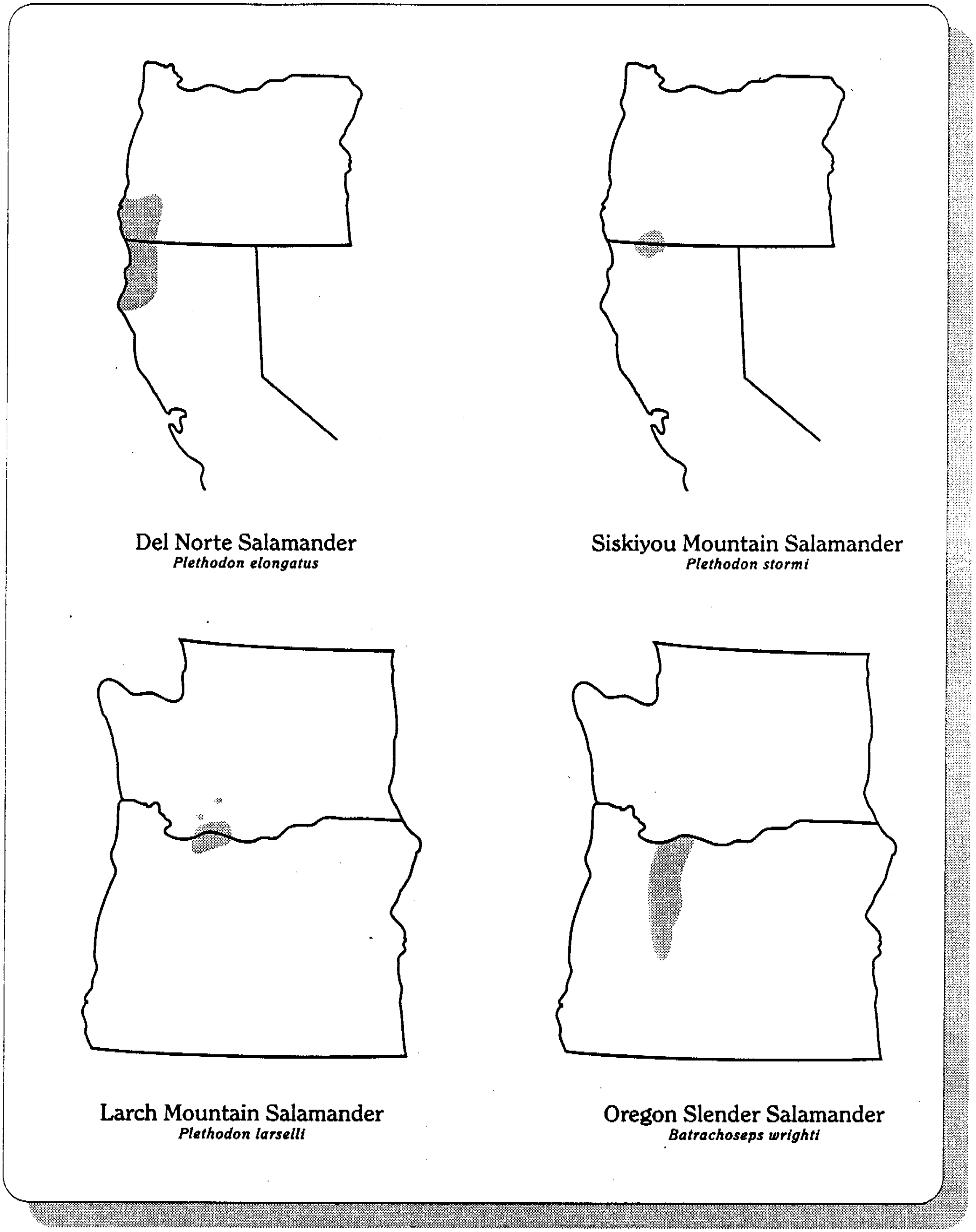


***Figure D.3**. Geographic range of Del Norte, Siskiyou Mountain, Larch Mountain, and Oregon Slender Salamanders.*

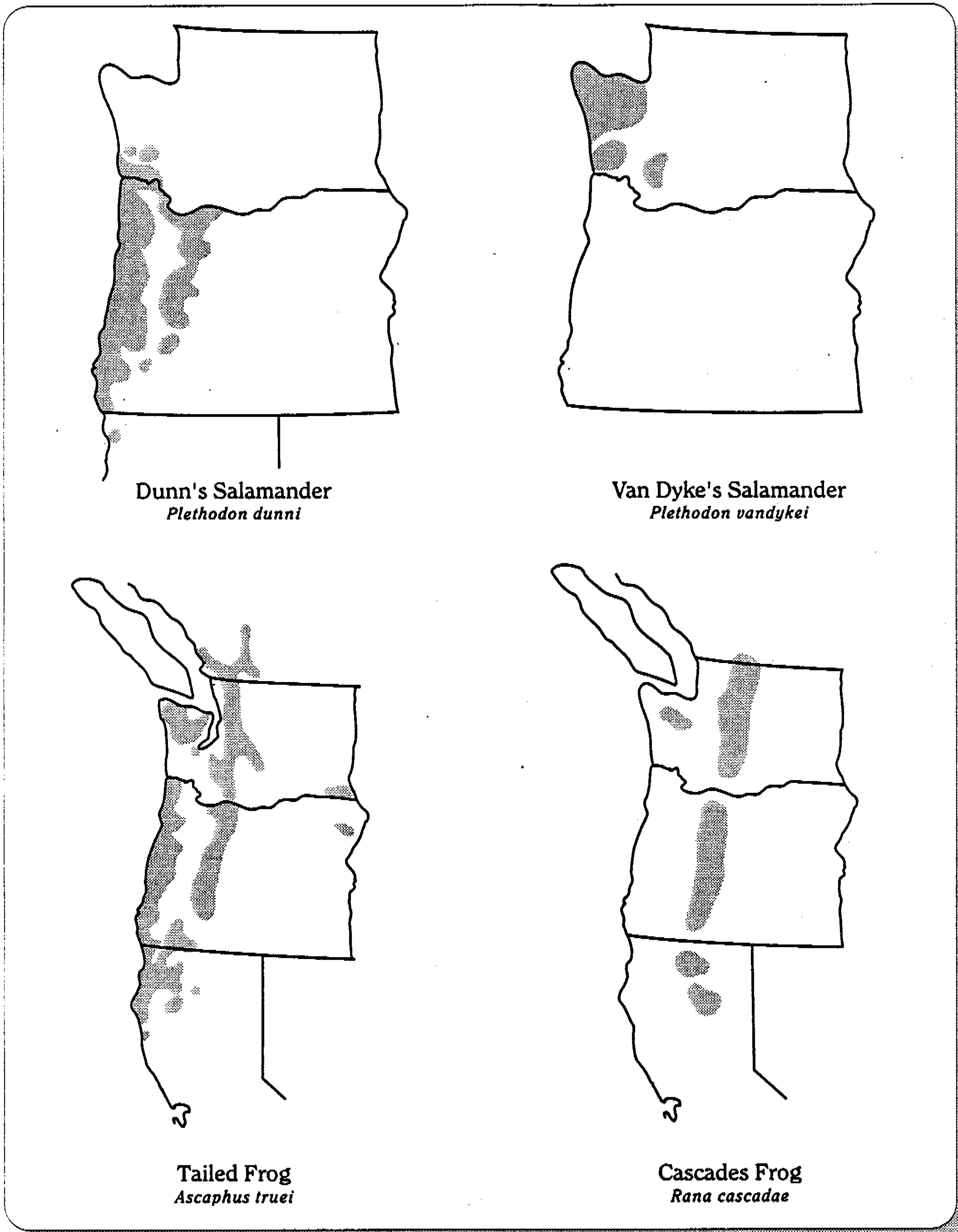


Figure D.4. *Geographic range of Dunn's salamander, Van Dyke's salamander, tailed frog, and Cascades frog in the Pacific Northwest.*

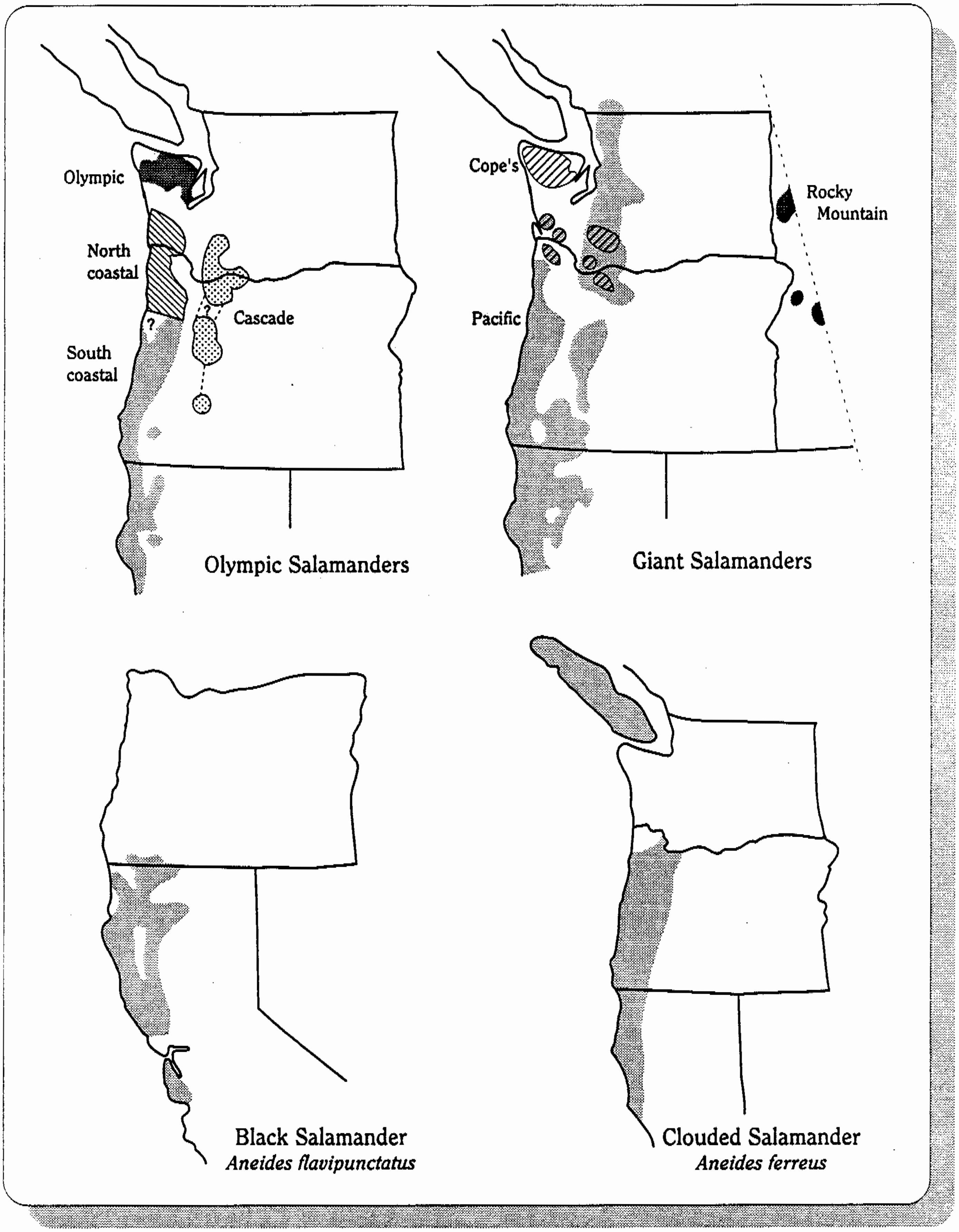


Figure D.5. *Geographic range of Olympic salamanders, giant salamanders, black salamanders, and clouded salamanders.*

among a group of riparian associates because information is limited about the status of their populations. In addition, there is evidence of a decline in amphibians around the world, including the Pacific Northwest (Blaustein and Wake 1990). The cause of this decline is not known, but includes loss of habitat. Bury (1983) and Corn and Bury (1989) found that logging had negative effects on the tailed frog, Oregon slender salamander, and Pacific giant salamander. Gomez (1992) found the tailed frog and Pacific giant salamander in greatest numbers in riparian areas of mature and old-growth forests in comparison to deciduous forest, pole-sized stands, and early clear-cuts.

In addition to the riparian associates that are identified in Table D.3, the committee designated the Oregon slender, Larch Mountain, Siskiyou Mountain, Del Norte, Pacific giant, Cope's giant, and Olympic salamanders (four species), and tailed frog as priority species. Selection of these species was based on their extremely restricted geographic range, association with late -successional forests, or status as candidates for federal listing. Because of their restricted ranges (Figures D.3 - D.5), there is a need for some protection through minor alterations in the location of DCAs.

Fishes

The list of fishes for consideration in the recovery plan includes 28 species in western Washington and Oregon and northwestern California (Table D.4). One stock, the Sacramento River winter chinook salmon, is federally listed as threatened, and the rest of the species are designated as "species of special concern" by the states in which they occur. Of particular concern is the large list of streams with stocks at risk and the number of these stocks that is considered at risk in Oregon, Washington, and California (Nehlsen et al. 1991, Williams et al. 1989, Moyle et al. 1989), including 85 streams and 178 fish stocks in California, 177 streams and 386 stocks in Oregon, and 92 streams and 215 stocks in Washington. The section on riparian ecosystems and native fishes (later in this appendix) provides a more thorough description of the stocks by species and lists the streams with stocks considered at risk by each state. That section also describes the importance of riparian ecosystems and provides a general framework for riparian zone management.

Molluscs[1]

Fifty-eight species of rare and endemic molluscs occur within the range of the northern spotted owl; 10 are candidates for federal listing, and 29 are "species of special concern" (Table D.5). Of these 58 species, the Karok land snail is a category 1 candidate for federal listing and 9 other species are rated as category 2 candidates (see Table D.5 for definition of categories). The 58 species include 23 aquatic and 35 land forms, and only one species occurs in all three states. Many of the species are endemic to only one state (Frest and Johannes 1991). Dispersal capability of this group of invertebrates is low, particularly for the terrestrial species. At least 43 species are considered to be old-growth associates (Frest pers. comm.); 45 are riparian associates.

Several of the land and freshwater molluscs (bivalve and snail) in the west coast states have limited geographic ranges. Most of these species are confined to a coastal belt that extends

[1] Largely extracted from information supplied by Terrence Frest of Deixis Consultants (letter of 17 September 1991).

Table D.4. A list of threatened and endangered, sensitive, candidate, and "species of concern" fishes within the range of the northern spotted owl.

Species	Status[a,b]				Considered at Risk[c]	Priority Species	Riparian Associate
		State					
	Fed	WA	OR	CA			
Bigeye marbled sculpin *Cottus klamathensis macrops*				SC			X
Bull trout *Salvelinus confluentus*	C2		SR	E		X	X
Chum salmon *Oncorhynchus keta*			SR		X	X	X
Clear Lake hitch *Lavinia exilicauda chi*				SC			X
Coho salmon *Oncorhynchus kisutch*			SR	SC	X	X	X
Fall chinook salmon *Oncorhynchus tshawytscha*			SR	SC	X	X	X
Gualala roach *Lavinia symmetricus parvipinnis*				SC	X		X
Jenny Creek sucker *Catostomus rimiculus* subsp.	C2				X		X
Klamath River lamprey *Lampetra similis*				SC			X
Millicoma dace *Rhinichthys cataractae* ssp.				SC			X
Navarro roach *Lavinia symmetricus navarroensis*				SC			X
Nooky (Chehalis) dace *Rhinichthys cataractae* ssp.		M			X		X
Olympic mudminnow *Novumbra hubbsi*	C2	C					X
Pink salmon *Oncorhynchus gorbuscha*				SC	X		X
Pit roach *Lavinia symmetricus mitrulus*				SC			X
Redband trout *Oncorhynchus mykiss* subsp.	C2		SV	SC	X	X	X
Reticulate sculpin *Cottus perplexus*		M		SC			X
Rough sculpin *Cottus asperrimus*	C2			T			X
Russian River tule perch *Hysterocarpus traski pomo*				SC	X		X
Sacramento splittail *Pogonichthys macrolepidotus*	C2			SC			X
Sacramento River winter chinook salmon *Oncorhynchus tshawytscha*	T			E	X	X	X

Continues-

Continued

Species	Status[a,b] Fed	State WA	State OR	State CA	Considered at Risk[c]	Priority Species	Riparian Associate
Salish sucker *Catostomus* sp.		M			X	X	X
Sea run cutthroat trout *Oncorhynchus clarki clarki*			SR	SC	X	X	X
Spring chinook salmon *Oncorhynchus tshawytscha*				SC	X	X	X
Sockeye salmon *Oncorhynchus nerka*					X	X	X
Summer chinook salmon *Oncorhynchus tshawytscha*					X	X	X
Summer steelhead trout *Oncorhynchus mykiss*				SC	X	X	X
Tidewater goby *Eucylogobius newberryi*	C2			SC	X		X
Tomales roach *Lavinia symmetricus* subsp.				SC			X
Umpqua chub *Oregonichthys kalawatseti*			SR				X
Oregon chub *Oregonichthys crameri*	PrE		SR				X
Winter steelhead trout *Oncorhynchus mykiss*					X	X	X

WA = Washington OR = Oregon CA = California

[a]*Federal status:* E = endangered, T = threatened, C = candidate, C2 = category 2 candidate, U.S. Fish and Wildlife Service candidates that need additional information to propose as threatened or endangered under the Endangered Species Act. PrE = proposed endangered. Pet = petition pending.

[b]*State status:* WA: C = candidate, M = monitor, X = extirpated, G = game; OR: SC = sensitive (critical), SV = sensitive (vulnerable), SR = sensitive (rare), SU = sensitive (undetermined), X = extirpated; CA: SCT = state candidate for listing as threatened, SC = species of concern, E = endangered. Sources (states): California Department of Fish and Game (1991a). Oregon Department of Fish and Wildlife (1991), Washington Department of Wildlife (1991a and 1991b).

[c]See Moyle et al. (1989), Nehlsen et al. (1991), Williams et al. (1989).

only from the Cascade crest to the Pacific Ocean. Within the owl's range, there are three distinct land snail provinces. The Oregon province extends from coastal British Columbia just into extreme northern California; the Washington province extends east from the Cascade crest; and the California province is coastal from northern California.

There are sizable endemic species clusters in the land snail genera *Monadenia, Trilobopsis, Megomphix, Haplotrema, Vespericola*, and *Hemphillia*. Physical factors limiting their distribution include geologic history, substrate (some are restricted to limestone, e.g., the candidate *Monadenia troglodytes*, endemic to the Siskiyou Mountains and the area around Mt. Shasta), moisture requirements, and cover. In general, land snails in this region require relatively undisturbed cover. Most of them thrive in lowland forests and the areas around springs. Many species seem to be associated specifically with lowland old-growth forests, and most are extremely limited in distribution. The malone jumping slug, *Hemphillia malonei*, occurs only on the slopes of Mt. Hood. The genus *Megomphix* is known only from sites in the Puget Sound region and in the Willapa Hills, of southwestern Washington. In recent years, only one site has been found to support *Megomphix hemphilli*.

Table D.5. A list of molluscs that are candidates for listing and are of special concern in the range of the northern spotted owl.

	Status[a]								
		State			Old Forest[b]	Endemic[b]		Priority	Riparian
Species	Fed	WA	OR	CA	Association	L	B	Species	Associate
Columbia pebblesnail *Fluminicola columbiana*	C2					WA,OR			X
Shortface lanx *Fisherola nuttalli nuttalli*	C3						WA,OR		
Dalles sideband *Monadenia fidelis minor*	C2					WA,OR			
No common name *Monadenia troglodytes chaceana*	C2				X	CA		X	X
Shasta sideband *Monadenia troglodytes troglodytes*	C2				X	CA		X	X
Wintu sideband *Monadenia troglodytes wintu*	C2				X	CA		X	X
Rocky coast sideband *Monadenia fidelis pronotis*	C2					CA		X	X
Trinity bristlesnail *Monadenia setosa*	C2			T	X	CA		X	X
Karok hesperian *Vespericola karokorum*	C1				X	CA		X	X
Barren juga *Juga hemphilli hemphilli*		SC	SC		X	WA,OR		X	X
Dalles juga *Juga hemphilli dallesensis*		SC	SC		X	WA,OR			X
No common name *Juga hemphilli* subsp.		SC	SC		X	WA,OR			X
Brown juga *Juga (J.)* n. sp. 1		SC	SC		X	WA,OR			X
Tall juga *Juga (J.)* n. sp. 3			SC		X	OR			X
No common name *Juga (O.)* n. sp. 1		SC				WA			X
No common name *Juga (O.)* n. sp. 2			SC			OR			X
Scalloped juga *Juga (C.) actifilosa*			SC		X	OR,CA			X
Topaz juga *Juga (C.) occata*			SC			OR			X
No common name *Amnicola (L.)* n. sp.		SC	SC		X	WA,OR			X
Nerite rams-horn *Vorticifex neritoides*		SC	SC			WA,OR		X	
Rotund physa *Physella columbiana*		SC	SC			WA,OR		X	
Vagrant pebblesnail *Fluminicola seminalis*			SC		X	OR,CA			X

Continues

Continued

Species	Status[a] Fed	State WA	State OR	State CA	Old Forest[b] Association	Endemic[b] L	Endemic[b] B	Priority Species	Riparian Associate
Highcap lanx *Lanx alta*			SC		X	OR,CA			
Kneecap lanx *Lanx patelloides*			SC			OR,CA			
Great Basin rams-horn *Helisoma newberryi newberryi*			SC			OR,CA			X
Columbia hesperian *Vespericola columbiana columbiana*		SC	SC			WA,OR			
Malone jumping-slug *Hemphillia malonei*			SC		X	OR		X	X
Panther jumping-slug *Hemphillia pantherina*		SC			X	WA		X	X
Warty jumping-slug *Hemphillia glandulosa glandulosa*		SC	SC		X	WA,OR		X	X
Burrington jumping-slug *Hemphillia barringtoni*		SC			X	WA			X
Blue-gray tail-dropper *Prophysaon coeruleum*		SC	SC		X	WA,OR		X	X
Papillose tail-dropper *Prophysaon dubium*		SC	SC		X	WA,OR		X	X
Columbia sideband *Monodenia fidelis columbiana*		SC	SC		X	WA,OR		X	X
Green sideband *Monadenia fidelis beryllica*			SC		X	OR			X
Traveling sideband *Monadenia fiddelis celeuthia*			SC		X	OR		X	X
Yellow-base sideband *Monadenia fidelis ochromphalous*					X	CA		X	X
Tawny sideband *Monadenia fidelis leonina*					X	CA		X	X
No common name *Monadenia fidelis klamathica*					X	CA		X	X
Klamath sideband *Monadenia churchi*					X	CA			X
Shasta chaparral *Trilobopsis roperi*					X	CA		X	X
Tehama chaparral *Trilobasis tehamana*					X	CA		X	X
Shasta hesperian *Vespericola shasta*					X	CA		X	X
Siskiyou hesperian *Vespericola sierrana*					X	CA		X	X
Large hesperian *Vespericola megasoma euthales*					X	CA		X	X
Oregon megomphix *Megomphix hemphilli*		SC	SC		X	WA,OR		X	X

Continues

Continued

Species	Status[a] Fed	State WA	OR	CA	Old Forest[b] Association	Endemic[b] L	B	Priority Species	Riparian Associate
Willamette floater *Anodonta wahlametensis*		SC	SC				X		
No common name *Juga (Oreobasis) chacei*					X				X
No common name *Juga (Oreobasis) orickensis*					X				X
Rotund lanx *Lanx subrotundata*					X				
No common name *Monadenia callipeplus*					X			X	X
No common name *Monadenia cristulata*					X			X	?
No common name *Monadenia fidelis salmonensis*					X			X	X
No common name *Monadenia fidelis scottiana*					X			X	?
No common name *Monadenia rotifera*					X			X	?
Hooded lancetooth *Haplotrema voyanum*					X				?
Oregon shoulderband *Helminthoglypta hertleini*									X
Evening fieldslug *Deroceras hesperium*					X			X	X
California floater *Anodonta californiensis*	C2	SC	SC	SC			X		X

WA = Washington OR = Oregon CA = California
[a]*Status:* E = endangered, T = threatened, C = candidate, C1 = cateorgy 1 candidate, taxa for which the U.S. Fish and Wildlife Service has sufficient information to support a proposal to list as threatened or endangered under the Endangered Species Act. C2 = category 2 candidate, U.S. Fish and Wildlife Service candidates that need additional information to propose as threatened or endangered under the Endangered Species Act. C3 = Taxa which have proven to be more abundant or widespread than previously believed and/or which have no identifiable threats. This status is based only on the most recent published Candidate Notice of Review. SC = species of concern (Frest and Johannes 1991).
[b]Frest and Johannes (1991).
L = local B = broadly

The delineation of freshwater mollusc provinces is similar to that of land snails. The Pacific drainage province is situated similarly to the coastal land snail provinces. The Columbia drainage province is a separate unit; and the Interior drainage province intersects the range of the spotted owl in northern California. Endemic clusters are noted most in the family Hydrobiidae and in the genus *Juga*. The family Lancidae is mostly coastal and occurs mainly in a few streams in southwestern Oregon and northwestern California. Species confined to single streams or springs are not uncommon. Many small and some large taxa are restricted to particular streams in the area such as, the Rogue and Umpqua systems in Oregon; the Klamath and upper Sacramento in California; the lower Columbia and Columbia River Gorge in Washington and Oregon; or to one or a few coastal streams. Generally, molluscs are affected by any increase in siltation, decrease in flow, nutrient enrichment, and damming or other flow impediments. The rare and endemic forms are particularly affected.

Some examples of species with limited distribution include a largely undescribed species cluster in *Juga*, restricted to a few streams in the western Columbia River Gorge, Washington, and Oregon; the species *Juga* (C.) *acutifilosa*, known from only eight spring sites in northern California and southwestern Oregon; and *Vorticifex neritoides* and *Physella columbiana*, both restricted to the lower 60 miles of the Columbia River. Narrowly endemic molluscs often are closely associated with other endemic groups or species. For example, endemic arthopods and molluscs frequently inhabit the same springs in the Columbia River Gorge, and *Fluminicola* species are associated with the Jenny Creek sucker and redband trout.

In land and freshwater forms, most narrow endemics have been discovered only within the last decade and presumably many more will be found. Recently (spring and summer 1991), for example, a new endemic cluster of five *Fluminicola* species was discovered that is restricted to two creeks and associated springs on the California-Oregon border in the Siskiyou Mountains.

Arthropods and Other Invertebrates

The litter and soil of the forest floor are the site of some of the highest biological diversity found anywhere. Scientists estimate that about 8,000 species of arthropods inhabit a single study site in an Oregon old-growth forest, most of them in the soil (Lattin and Moldenke pers. comm.). To date, taxonomists have been able to identify 3,400 arthropod species at the H.J. Andrews Experimental Forest (about 45 miles east of Eugene, Oregon) (Parsons et al. 1991). Invertebrates of the forest soil are critical in determining the long-term productivity of the forest. The soil under a square yard of forest may hold as many as 200,000 mites from a single suborder, plus tens of thousands of other mites, beetles, centipedes, pseudoscorpions, springtails, and "microspiders." Most of these species probably are undescribed. The structure and function of temperate forest soils may be determined by the dietary habits of the soil arthropods. They are the basic consumers of the forest floor where they ingest and process massive amounts of organic litter and debris, from large logs to bits of moss. The richness of arthropod species in old-growth forests suggests a great number of different processes and functions, but little is known about how these arthropods interact and survive. Several species that are prominent in older forests occur infrequently in young forests; further study undoubtedly will reveal others (Moldenke pers. comm.).

Ninety-one species of arthropods within the range of the northern spotted owl are associated with late-successional forests and are listed as "species of special concern" or category 2 candidate species for federal listing (Table D.6). Thirty-four species are category 2 candidate species and the remainder are designated "species of special concern." Thirty-four of the species are aquatic and the remainder are terrestrial forms. Twenty-three of the species are endemic to Oregon; six to California, and none is found in all three states. This list is not exhaustive, but is representative.

Several significant points can be made about the arthropods as a group that are relevant to the recovery plan for spotted owls. First, many species are flightless, which means that their dispersal capabilities are limited. Second, the flightless condition is believed to reflect habitat stability and permanence over a long time period. Some old-forest associates have highly disjunct distributions and are found only in undisturbed forests. They share similar distribution patterns on the west side of the Cascade Mountains from British Columbia south to southern Oregon and northern California (i.e., they are endemic to the Pacific

Table D.6. List of threatened, endangered, candiadate, sensitive, or older-forest associated arthropods in the range of the northern spotted owl (information from J. D. Lattin, Oregon State University, see the recovery plan's administrative record).

Species	Federal Status	Old forest Associates	Riparian Association	References
Phylum Arthropoda				
Class Diplopoda (millipedes)				
Order Chordeumatida				
Family Caseyidae				
Caseya benedictae		X		2
Caseya briophila		X		2
Caseya bucketti		X		2
Caseya longiloba		X		2
Caseya megasoma		X		2
Caseya megasoma		X		2
Caseya shastaensis		X		2
Harpaphe haydeniana		X		1
Metopiona sheari		X		2
Ochrogramma heterogona		X		2
Ochrogramma formulosa		X		2
Ochrogramma haigi		X		2
Opiona bifurcata		X		2
Opiona casualis		X		2
Opiona communis angusta		X		2
Opiona confusa		X		2
Opiona distincta		X		2
Opiona exigua		X		2
Opiona facetia		X		2
Opiona fisheri		X		2
Opiona goedeni		X		2
Opiona scytonotoides		X		2
Opiona siliquae		X		2
Tuhaphe levii		X		2
Class Arachnida				
Order Araneida (spiders)				
Family Agelenidae				
Cybaeina minuta		X		2
Order Phalangida (harvestman)				
Cryptomaster leviathan		X		2
Isolachus spinosus		X		2
Pentanychus hamatus		X		2
Pentanchyus clavatus		X		2
Pentanchyus bilobatus		X		2
Pentanchyus flavescens		X		2
Pentanchyus pacificus		X		2

Continues

Continued

Species	Federal Status	Old forest Associates	Riparian Association	References
Class Insecta (insects)				
Order Orthoptera				
Boonacris alticola		X		1
Pristoceuthophilus celatus		X		1
Pristoceuthophilus cercalis		X		1
Pristoceuthophilus sargentae		X		1
Tropidischia xanthostoma		X		1
Order Hemiptera				
Boreostolis americanus		X		1
Plinthisus longisetosus		X		1
Thylochromus nitidulus		X		1
Eurychilopterella sp.		X		1
Phytocoris nobilis		X		1
Pithanus maerkelii		X		1
Polymerus castellaeni		X		1
Vanduzeenia borealis		X		1
Acalypta lillianis		X		1
Acalypta saundersi		X		1
Derephysia foliacea		X		1
Order Coleoptera				
Pterecus humboldti		X		2
Cychrus tuberculatus		X		1
Metrius contractus		X		1
Promecognathus laevissimus		X		1
Zacotus mathewsii		X		1
Omus dejeani		X		1
Lobosoma horridum		X		1
Acneus beeri	C2		X	1
Acneus burnelli	C2			1
Cicindela columbica			X	1
Pterostichus rothi				1
Order Plecoptera				
Nemoura wahkeena	C2		X	1
Solperia fenderi	C2		X	1
Order Trichoptera				
Eobrachycentrus gelidae	C2		X	1
Agapetus denningi	C2		X	1
Homoplecta schuhi	C2		X	1
Ochrotrichia alsea	C2		X	1
Lepidostoma goedeni	C2		X	1
Apatania tavaia	C2		X	1
Farula davisi	C2		X	1
Farula jewetti	C2		X	1
Farula reaperi	C2		X	1
Limnephilus alconura	C2		X	1

Continues

Continued

Species	Federal Status	Old forest Associates	Riparian Association	References
Limnephilus atereus	C2		X	1
Neothremma andersoni	C2		X	1
Oligophlebodes mostbento	C2		X	1
Philocasca oron	C2		X	1
Dolophilodes oregona	C2		X	1
Tinodes siskiyou	C2		X	1
Rhyacophila ambilis	C2		X	1
Rhyacophila colonus	C2		X	1
Rhyacophila fenderi	C2		X	1
Rhyacophila haddocki	C2		X	1
Rhyacophila lineata	C2		X	1
Rhyacophila mosana	C2		X	1
Rhyacophila unipunctata	C2		X	1
Desmona bethula	C2		X	1
Cryptochia shasta	C2		X	1
Goeracea oregona	C1		X	1
Neothremma genella	C2		X	1
Neothremma siskyou	C2		X	1
Ochrotrichia vertreesi	C2		X	1
Abellan hydropsyche	C2		X	1

a Federal status: E: endangered; T: threatened; C: candidate.

References:
1 = J. D. Lattin, Oregon State University, the recovery plan's administrative record.
2 = Olson, David M. 1992. The northern spotted owl conservation strategy: implications for Pacific Northwest forest invertebrates and associated ecosystem processes. Final Contract Report Prepared for the Northern Spotted Owl EIS Team, USDA Forest Service. The Xerces Society, Portland, OR. 51 pp + map.

Northwest). Many of the species native to this region have not been described or named, and the number of known species probably represents less than half of the estimated species (Lattin pers. comm.).

Fifty-five species of terrestrial arthropods, most of which are wingless and flightless, are considered to be old-growth associates (Lattin and Moldenke 1992, Olson 1992). Camel crickets of the genus *Pristoceuthophilus* and *Tropidischia xanthostoma* are found in old-growth forests in the Hemlock and Silver-fir Zones, and they occur on the forest floor under logs and debris. Some species in this group of older-forest associates belong to small genera and are considered rare, including *Boreostolis americanus*, *Metrius contractus*, *Promecognathus laevissimus*, *Zacotus mathewsii*, and *Lobosoma horridum*. All of these species belong to genera that have only one or two described species and are often relics of past geologic history. One unique predator-prey relationship exists in this group between the prey species *Harpaphe haydeniana* and the predator *Promecognathus laevissimus*. *H. haydeniana* is a millipede that is an important shredder of litter. The species produces hydrocyanic gas when disturbed, which is a deterrent to most predators except *P. laevissimus*, which is a ground beetle that is tolerant of cyanide gas and found in mature forests on the west side of the Cascade Mountains.

Table D.7. Insects associated with course woody debris in western Oregon Cascades.

Species	Feeding Habitats[a]	Stage in Log[b]	Recorded Hosts/Habitats[c]	Reference[d]
Buprestis aurulenta L.	Xylo	Imm	Psme, *Abies, Pinus, Picea*	1
Leptura obliterata Hald.	Xylo	Imm	Psme, Tshe, *Abies, Picea, Pinus, Sequ.*	1,4
Spondylis upiformis Mann.	Xylo	Imm	roots of pine or fir ?	4
Silvanus bidentatus F.	Pred-Scav?	Ad+Imm	subcortical	3
Cossonus ponderosai VanD.	Xylo?	Ad+Imm	under bark of *Pinus*	1,3
Pissodes piperi Hopkins	Xylo?	Imm	*Abies;* root crown of damaged trees	1
Platycerus orgeonensis Westw.	Xylo	Ad?+Imm	rotting *Quercus, Acer, Alnus, Fraxinus*	1
Platypus wilsoni Swaine	Xylo-Fung	Ad+Imm	Psme, *Abies,* Tshe	1
Dendroctonus pseudotsugae Hopk.	Xylo	Ad+Imm	Psme, Tshe, *Larix;* under bark	2
Gnathotrichus retusus (LeC.)	Xylo-Fung	Ad+Imm	Psme, *Pinus, Picea, Alnus, Populus;* in sapwood	2
Trypodendron lineatum (01.)	Xylo-Fung	Ad+Imm	Psme, *Abies, Tshe, Picea, Pinus, Thpl;* in sapwood	1,2
Ostoma ferruginea L.	Fung	Ad+Imm	Fung-Polyporaceae under bark	3
Medetera aldrichii Wheeler	Pred	Imm	Prey-bark beetles and woodborers	1
Xylophagus cinctus DeGeer	Pred	Imm	under bark	
Camponotus spp.	Pred-Scav?	Ad+Imm	mine wood of various conifers	1
Urocerus albicornis (F.)	Xylo-Fung	Imm	*Abies,* Psme, Tshe, Thpl, *Pinus, Picea*	1
Zootermopsis angusticollis (Hagen)	Xylo	Ad+Imm	many kinds of wood	1

[a]Xylo = feeds on wood. Pred = predaceous. Fung = fungi. Scav = scavenger.
[b]Ad = adult. Imm = immature.
[c]Psme = *Pseudotsuga menzeisii,* Thpl = *Thuya plicata,* Tshe = *Tsuga heterophylla,* Sequ = *Sequoia.*
[d]See J. D. Lattin, Administrative Record.

There are also 17 species of insects from 13 families (Table D.7) that are associated with coarse woody debris in western coniferous forests (Lattin pers. comm.). The decomposition of coarse woody debris is a slow process in a natural ecosystem, and in the Pacific Northwest many hundreds of invertebrate species have evolved to utilize logs for food or habitat (Schowalter et al. 1991, Parsons et al. 1991, Moldenke unpublished data). Though many of these species may have similar ecologic roles, the natural process is not understood enough to know whether some or many are redundant for system function. However, the diversity of species itself may be a useful management tool to detect changes in the effects that logs may be exerting on the old-growth system.

Vascular Plants

Two hundred and seven species of vascular plants that occur within the range of the northern spotted owl are associated with late-successional forests or are listed as "species of special concern" by one or more of the three states (Table D.8). One hundred and nineteen of the species are associated with late-successional forests (Ruggiero et al. 1991b, Thomas et al. In Prep.). These plants include several species that have generated significant interest including the Pacific yew and Port Orford cedar. The Pacific yew especially is of interest because of the chemical taxol, which can be extracted from yew bark and is being tested as an anti-cancer drug. This species has some important implications to human health concerns in the world. Port Orford cedar occurs only in a restricted area of northwestern California and southwestern Oregon and is susceptible to root disease. Increased road construction and vehicular traffic may be spreading this disease and having an effect on populations of this species. No opportunities were identified specifically to provide measures to benefit these two species, but local managers should consider the importance of both species.

The list of vascular plants that are candidates for listing, species of special concern, or associated with late-successional forests is extensive and diverse. Most of the species are associated with late-successional forests which raises some concern for their welfare in intensively managed forests. However, a panel of experts (Thomas et al. In Prep.) recently rated the population viability of most of these species as high under the ISC strategy (Thomas et al. 1990), which is the basis of the recovery plan for the northern spotted owl.

Nonvascular Plants

The list of nonvascular plants contains numerous species that are associated with live or dead wood, soil, rock, or water (Table D.9). Most of species were identified as being associated with late-successional forests by Ruggiero et al. (1991b) or the Forest Service (Thomas et al. In Prep.). Of these species, two are species of special concern in one or more of the three states. Lichens of the genus *Lobaria* occur primarily in the canopy of coniferous forests, and their abundance in these canopies becomes greater as a stand develops into an old-growth forest. These organisms are characteristic of late-successional forests in the Pacific Northwest and provide important food for several animal species, most notably ungulates and northern flying squirrels. These food sources are particularly important during the winter when other foods are scarce. The most noble polypore (*Oxyporus nobilissimus*) has been found only three times and was associated with late-successional forests on each occasion.

The role of mycorrhizal fungi in coniferous forests is important to ecosystem function (Trappe and Fogel 1977) because of the symbiotic relationship between truffle fungi and the roots of vascular plants. Each organism derives a benefit from the relationship; the fungi take up nutrients such as potassium, phosphorus, nitrogen, and sodium, and these are translocated to the associated coniferous trees. Conversely, the fungi depend on the host tree for phytosynthates of carbon. Small animals eat truffle fungi and disperse their spores (Maser et al. 1978b). Mushrooms also are consumed which compliments spore dispersal by wind. The functional role of mycorrhizal fungi in coniferous forests has been described by Trappe and Fogel (1977). The following is their characterization of this role:

> "The great majority of vascular plants have evolved to a dependence on mycorrhizae as the most metabolically active parts of their root systems. Most woody plants require mycorrhizae to survive, and most herbaceous plants need them to thrive. Despite their relatively small biomass, the mycorrhizal fungi (mycobionts) are vital for uptake and accumulation of ions from soil and translocation to hosts because of their high metabolic rate and strategically diffuse distribution in the upper soil layers. The mycobionts produce enzymes, auxins, vitamins, cytokinins, and other compounds that increase rootlet size and longevity. They commonly protect rootlets from pathogens. They absorb and translocate water to the host. Most mycobionts, in turn, depend on their hosts for

Table D.8. List of candidate, sensitive, and old-growth associated vascular plants within the range of the northern spotted owl.

Species	Common Name	Federal Status[a]	Status State[b] WA	OR	CA	Old Forest Associate[c]	Endemic[d] Local	Broadly	Riparian Association	References[e]
Achlys triphylla	Vanilla leaf					X				1,2,3
Adenocaulon bicolor	Trail plant					X				1,2,3
Adiantum pedatum	Western maidenhair fern					X				3
Allotropa virgata	Sugar stick					X				1,2,3
Anemone deltoidea	Threeleaf anemone					X				3
Angelica tomentosa	California angelica					X				3
Antenaria suffrutescens	Pussytoes	C3				X				1
Apocynum pumilum	Dogbane					X				1,3
Arabis aculeolata	Waldo rock cress	C3						X		
Arabis macdonaldiana	McDonald's rock cress	E			E			X		
Arabis serpentinicola	Preston Peak rock cress	C2					X			
A. suffrutescens horizontalis	Crater Lake rock cress	C2		C						
Arceuthobium tsugense	Dwarf mistletoe					X				3
Arctostaphylos klamathensis	Klamath manzanita	C2								
Arnica latifolia	Mountain arnica					X				3
Asarum caudatum	Wild ginger					X				2,3
Asarum hartwegii	Wild ginger					X				2,3
Asarum wagneri	Green-flowered wild ginger			C1		X				3
Aster gormanii	Gorman aster	C2		C						
Aster vialis	Wayside aster	C2		C						
Astragalus peckii	Peck's milk-vetch	C2		C						
Astragalus tegetarioides	Bastard kentrophyta	C2		C					X	
Bensoniella oregana	Bensoniella	C2		C	R	X				3
Berberis nervosa mendocinensis	Hardy Creek barberry	C2								
Berberis pumila	Dwarf mahonia					X				3
Boschniakia strobilacea	Ground cone					X				1,3
Botrychium ascendens				C		X				3
Botrychium crenulatum	Southwestern moonwort	C2		C		X				3
Botrychium minganense	Victorin's grape fern		S			X				3
Botrychium montanum	Mountain grape-fern					X				3

Continues

Continued

Species	Common Name	Federal Status[a]	Status State[b] WA	OR	CA	Old Forest Associate[c]	Endemic[d] Local	Broadly	Riparian Association	References[e]
Botrychium pumicola	Crater Lake (pumice) grapefer	C1		C						3
Brodiaea coronaria rosea	Indian Valley brodiaea	C2								
Calamagrostis tweedyi	Reedgrass	C2								
Calochortus greenei	Green's mariposa lilly	C2		C						
Calochortus howellii	Howell's mariposa lily	C2		C						
Calochortus persistens	Siskiyou mariposa lilly	C2			R					
Calochortus raichei	The Cedars globe-lilly	C2								
Calypso bulbosa	Fairly-slipper					X				2,3
Campanula californica	Swamp harebell	C2							X	
Campanula wilkinsiana	Wilkin's harebell	C3								
Cardamine gemmata	Purple toothwart	C2		C				X		
Castilleja chlorotica	Green-tinged paintbrush	C2		C						
Castilleja cryptantha	Obscure Indian paintbrush	C2								
Chamaecyparis lawsoniana	Port Orford cedar					X	X			3
Chamaecyparis nootkatensis	Alaska yellow cedar					X				3
Chimaphila menziesii	Pipsissewa					X				1,3
Chimaphilia umbellata	Common pipsissiwa					X				1,2,3
Cimicifuga elata	Tall bugbane		S	C		X				3
Clarkia borealis	Arid northern clarkia	C2								
Clintonia uniflora	Queen's cup					X				2,3
Collomia mazama	Crater Lake collomia	C2		C						
Coptis asplenifolia	Spleenwort-leaved goldthread		S			X	X		X	3
Coptis laciniata	Goldthread					X				1,2,3
Corallorhiza maculata	Pacific coral root					X				3
Corallorhiza mertensiana	Purple coral-root					X				2,3
Cordylanthus tenus pallescens	Pallid birds-beak	C2								
Cornus canadensis	Bunch berry					X				2
Corydalis aquae-gelidae	Clackamas corydalis	C2	T	C				X	X	
Cryptantha crinita	Silky cryptantha	C2								
Cupressus bakeri	Baker's cypress					X				3
Cupressus pygmaea	Mendocino cypress	C2								
Cypripedium fasciculatum	Clustered lady's slipper		T	C		X				3
Cypripedium montanum	Mountain lady's slipper					X				3

Continued

Continued

Species	Common Name	Federal Status[a]	State Status[b] WA	State Status[b] OR	State Status[b] CA	Old Forest Associate[c]	Endemic[d] Local	Endemic[d] Broadly	Riparian Association	References[e]
Delphinium viridescens	Wenatchee larkspur		E			X				
Dentaria californica	Toothwort					X				3
Disporum hookeri	Fairy bell					X				1,3
Draba carnosula	Mt. Eddy draba	C2								
Dryopteris austriaca	Spreading wood-fern					X				3
Eburophyton austinae	Phantom orchid					X				1,3
Epilobium siskiyouense	Siskiyou willow herb	C3		C						
Erigeron howellii	Howell's daisy	C2		C						
Eriogonum alpinum	Trinity buckwheat	C2			E					
Eriogonum hirtellum	Klamath Mt. buckwheat	C3								
Eriogonum kelloggii	Red Mt. (Kellogg's) buckwheat	C1			E					
Eriogonum pendulum	Waldo buckwheat	C3						X		
Erythronium montanum	Avalanche lily					X				3
Erythronium revolutum	Pink fawn lily		S			X		X		
Frasera umpquaensis	Umpqua swertia	C2		C						
Fritillaria gentneri	Gentner's mission-bells	C2		C		X				3
Galium kamtschaticum	Boreal bedstraw		S			X		X		3
Galium serpenticum scotticum	Scott Mt. bedstraw	C3					X			
Gaultheria humifusa	Western wintergreen					X				3
Gaultheria ovatifolia	Oregon wintergreen					X				3
Gentiana setigera	Mendocino (Waldo) gentian	C2		C						
Goodyera oblongifolia	Rattlesnake plantain					X				1,2,3
Gratiola heterosepala	Boggs Lake hedge-hyssop	C2		C	E				X	
Gymnocarpium dryopteris	Oak fern					X				3
Habenaria orbiculata	Large round-leaved rein-orchid					X				3
Habenaria saccata	Slender bog orchid					X				3
Habenaria unalascensis	Alaska rein-orchid					X				3
Hackelia venusta	Showy stickweed	C1								
Haplopappus Whitneyi discoides	Whitney haplopappus					X				3
Happlopappus racemosa congestus		C3				X				1
Hemitomes congestum	Gnome plant					X				3
Hieracium scouleri	Woolly-weed					X				3
Horkelia hendersonii	Henderson's horkelia	C2		C						

Continues

Continued

Species	Common Name	Federal Status[a]	Status State[b] WA	OR	CA	Old Forest Associate[c]	Endemic[d] Local	Broadly	Riparian Association	References[e]
Hypopitys monotropa	Pinesap					X				3
Ivesia pickeringii	Pickering's ivesia	C2					X			
Juglans hindsii	Hinds' walnut	C2								
Lathyrus biflorus	Two-flowered lathyrus	C2					X			
Lathyrus polyphyllus	Leafy peavine					X				3
Lewisia cotyledon heckneri	Heckner's lewisia	C3								
Lewisia cotyledon purdyi	Purdy's lewisia	C2		C						
Lewisia stebbinsii	Stebbin's lewisia	C2								
Limnanthes floccosa bellingerian	Bellinger's meadow-foam	C2		C						
Linanthus nuttallii howell	Howell's (Mt. Tedoc) linanthus	C2					X			
Linnaea borealis	Twin flower					X				2
Linnaea borealis longifolia						X				1,3
Listera borealis	Northern twayblade		S			X				3
Listera caurina	Western twayblade					X				3
Listera convallarioides	Broad-lipped twayblade					X				3
Listera cordata	Twayblade					X				3
Lomatium peckianum	Peck's lomatium	C3								
Lupinus antoninus	Anthony Peak lupine	C2								
Lupinus constancei	The Lassics lupine	C2					X			
Lupinus cusickii	Cusick's lupine	C2		C						
Lupinus milo-bakeri	Milo Baker's lupine	C2			T					
Luzula hitchcockii	Smooth woodrush					X				3
Lysichitum americanum	Skunk cabbage					X				3
Madia sebbinsii	Stebbin's madia	C3					X			
Malacothamnus mendocinensis	Mendocino bush-mallow	C2								
Melica subulata	Melic grass					X				1,3
Menziesia ferruginea	Fool's huckleberry					X				3
Microseris howellii	Howell's microseris	C2		C						
Mimulus pygmaeus	Egg Lake (Pigmy) monkey flower	C2		C					X	
Minuartia decumbens	The Lassics sandwort	C2					X			
Mitella breweri	Brewer's mitrewort					X				3
Monardella purpurea	Siskiyou monardella	C3				X				1
Monotropa uniflora	Indian pipe					X				3

Continues

Continued

Species	Common Name	Federal Status[a]	Status State[b] WA	OR	CA	Old Forest Associate[c]	Endemic[d] Local	Broadly	Riparian Association	References[e]
Oxalis oregana	Redwood sorrel					X				1,3
Penstemon barrettiae	Barrett's penstemon	C2		C						
Penstemon glaucinus	Beardtongue	C2		C						
Penstemon peckii	Peck's penstemon	C2		C						
Perideridia gairdneri gairdneri	Gairdner's yampah	C2								
Phacelia dalesiana	Scott Mt. (Trinity) phacelia	C2								
Phacelia greenei	Scott Valley phacelia	C2								
Phlox adsurgens	Woodland phlox					X				3
Phlox hirsuta	Yreka phlox	C1			E		X			
Picea breweriana	Brewer spruce					X				3
Pinus contorta bolanderi	Bolander's beach pine	C2								
Pityopis californica	Pinefoot					X	X			2,3
Platanthera obtusata	Small northern bog orchid		S			X				3
Pleuricospora fimbriolata	Fringed pine-sap		S			X				1,2,3
Pleuropogon hooverianus	Northcoast semaphore grass	C2			R					
Poa fibrata	Lassen County bluegrass	C2								
Poa laxiflora	Loose-flowered bluegrass					X				3
Polystichum munitum var. imbrica	Imbricate sword-fern					X				3
Pterospora andromedea	Woodland pinedrops					X				3
Pyrola asarifolia	Alpine pyrola					X				2,3
Pyrola chlorantha	Greenish wintergreen					X				3
Pyrola dentata	Toothleaf pyrola					X				3
Pyrola picta	White vein pyrola					X				3
Pyrola picta ssp. dentata	Nootka wintergreen					X				3
Pyrola secunda	One-sided pyrola					X				3
Pyrola uniflora	Single flowered pyrola					X				3
Rorippa columbiae	Columbia yellow-cress	C2		C						
Rubus lasiococcus	Dwarf bramble					X				3
Rubus nivalis	Snow bramble					X				3
Rubus pedatus	Fiveleaved bramble					X				3
Sanicula peckiana	Peck's sanicle	C3				X				1
Sanicula trayci	Tracy's sanicle	C2								
Sarcodes sanguinea	Snow Plant					X				3

Continues

Continued

Species	Common Name	Federal Status[a]	Status State[b] WA	OR	CA	Old Forest Associate[c]	Endemic[d] Local	Broadly	Riparian Association	References[e]
Satureja douglasii	Yerba buena					X				3
Sedum laxum eastwoodiae	Red Mountain stonecrop	C1								
Sedum laxum flavidum	Pale yellow stonecrop	C3								
Sedum oblanceolatum	Applegate stonecrop	C2		C						
Sedum obtusatum paradisum	Canyon Creek stonecrop	C2								
Sedum radiatum depauperatum	Small star-fruited stonecrop	C2								
Selaginella oregana	Oregon selaginella					X				3
Senecio hesperius	Western senecio	C2		C						
Sidalcea oregana calva	Oregon checker-mallow		T			X	X			
Sidalcea setosa	Bristly sidalcea	C2								
Silene campanulata campanulata	Red Mountain catchfly	C1			E		X			
Silene invisa	Short-petaled campion	C3								
Silene marmorensis	Somes Bar campion	C2								
Silene nuda						X				3
Sisyrinchium sarmentosum	Pale blue-eyed grass	C2		C						
Smilacina racemosa	Solomons seal					X				1,3
Smilacina stellata	Star-flowered solomon-plume					X				3
Sophora leachiana	Western sophora	C2		C						
Streptanthus batrachopus	Tamalpais streptanthus	C2								
Streptanthus howellii	Howell's jewelflower	C3						X		
Streptanthus ssp.	Pit River jewelflower	C2								
Streptopus amplexifolius	Clasping-leaved twisted-stalk					X				3
Streptopus roseus	Rosy twisted-stalk					X				3
Streptopus streptopoides	Twisted-stalk					X				3
Sullivantia oregana	Oregon sullivantia	C2		C						
Synthyris schizantha	Fringed synthyris					X				3
Tauschia howellii	Howell's tauschia	C2		C						
Taxus brevifolia	Pacific yew					X				2,3
Thuja plicata	Western red cedar					X				3
Tiarella trifoliata	Three-leaved foamflower					X				3
Tiarella unifoliata	Coolwort foamflower					X				3
Trillium ovatum	Wake-robin					X				1,3
Trillium ovatum ssp. oettingeri	Salmon Mtns. Wakerobin					X				3

Continues

Continued

Species	Common Name	Federal Status[a]	Status State[b] WA OR CA	Old Forest Associate[c]	Endemic[d] Local	Endemic[d] Broadly	Riparian Association	References[e]
Vaccinium alaskaense	Alaska huckleberry			X				3
Vaccinium membranaceum	Thin-leaved huckleberry			X				2,3
Vaccinium ovalifolium	Oval-leaf huckleberry			X				3
Vaccinium parvifolium	Red huckleberry			X				3
Vancouveria hexandra	Inside-out flower			X		X		1,2,3
Vancouveria planipetala	Inside-out flower			X				3
Vicia americana var. villosa	American vetch			X				3
Viola glabella	Pioneer violet			X				3
Viola orbiculata	Round-leaved violet			X				3
Viola renifolia	Kidney-leaved violet		EX	X				3
Whipplea modesta	Yerba de Selva			X				3
Xerophyllum tenax	Beargrass			X				3

[a] Federal status: E-endangered, C-candidate; State status: CA: E-endangered, T-threatened, R-rare; WA: E-endangered, T-threatened, S-sensitive; OR: C-candidate.
[b] California Department of Fish and Game (1991b) and Washington Natural Heritage Program (1990).
[c] Ruggiero et al. (1991), USDA (1993).
[d] Endemic: see Ruggiero et al. (1991) for definition and list of endemic species.
[e] References: 1) Bruce Bingham, Old-growth Douglas-fir Program, USFS, Pacific Southwest Research Station, Arcata, California (see recovery plan's administrative record), 2) Ruggiero et al. (1991), Thomas et al. In Prep.

Table D.9. A list of nonvascular plant species highly associated with older forest within the range of the northern spotted owl (source of information: Thomas et al. In Prep.).

1. Live wood

Lichens

Alectoria sarmentosa
Bacidia herrei
Bryoria capillaris
Bryoria tortuosa
Calicium abietinum
Calicium adaequatum
Calicium adspersum
Calicium glaucellum
Calicium viride
Cavernularia hultenii
Cavernularia lophyrea
Cetraria californica
Cetrelia cetrarioides
Chaenotheca chrysocephala
Chaenotheca ferruginea
Chaenotheca subroscida
Collema nigrescens
Dendriscocaulon intricatulum
Heterodermia leucomelos
Hypnum circinale
Hypocenomyce friesii
Hypogymnia duplicata
Hypogymnia oceanica
Hypogymnia rugosa
Leptogium cyanescens
Lichinodium canadense
Lobaria hallii
Lobaria linita
Lobaria oregana
Lobaria pulmonaria[ab]
Lopadium pezizoideum
Microcalicium arenarium
Nephroma antiquorum
Nephroma isidiosum
Nephroma occultum
Pannaria leucostictoides
Pannaria rubigninosa
Pannaria saubinetii
Parmotrema chinense
Parmotrema crinitum
Platismatia norvegica
Pseudocyphellaria anomala
Pseudocyphellaria anthraspis
Pseudocyphellaria aurata
Pseudocyphellaria croccata
Pseudocyphellaria rainierensis
Ramalina thrausta
Sphaerophorus globosus
Sticta weigelii
Usnea longissima
Teloschistes flavicans

Liverworts

Douinia ovata
Herbertus aduncus
Herbertus sakuraii
Ptilidium californicum (CA only)
Ptilidium californicum (OR & WA)
Radula bolanderi
Scapania bolanderi

Mosses

Antitrichia curtipendula
Iwatsukiella leucotricha
Pseudoleskea stenophylla
Pterigynandrum filiforme
Ulota megalospora (CA only)

2. Decaying wood

Lichens

Icmadophila ericetorum

Liverworts

Bazzania ambigua
Bazzania denudata
Bazzania tricrenata
Blepharostoma trichophyllum
Calypogeia azurea
Calypogeia fissa
Calypogeia muelleriana
Calypogeia suecica
Cephalozia bicuspidata lammersi
Cephalozia connivens
Cephalozia lunulifolia
Diplophyllum albicans
Diplophyllum plicatum
Geocalyx graveolens
Kurzia makinoana
Lepidozia reptans
Lophocolea bidentata
Lophocolea cuspidata
Lophocolea heterophylla
Lophozia incisa
Lophozia longiflora
Riccardia latifrons
Riccardia palmata
Scapania umbrosa

Mosses

Brotherella roellii (WA Cascades)
Buxbaumia piperi
Buxbaumia viridis
Herzogiella seligeri
Orthodontium gracile (Redwoods of no. Calif.)
Plagiothecium undulatum
Pseudoleskea saviana
Pseudotaxiphyllum elegans
Rhizomnium glabrescens
Tetraphis geniculata
Tetraphis pellucida

3. Soil and bases of trees

Lichens

Peltigera neopolydactyla
Peltigera pacifica

Liverworts

Scapania americana

Mosses

Anthoceros bulbiculosus
Bartramiopsis lescurii
Brachythecium hylotapetum
Ditrichum schimperi
Epipterygium tozeri
Fissidens pauperculus
Isopterygiopsis pulchella
Plagiomnium insigne
Pohlia pacifica

Continues

Continued

Rhizomnium nudum
Rhytidiopsis robusta
Roellia roellii
Schistostega pennata
Trichodon cylindricus

4. Rock

Liverworts

Apometzgeria pubescens
Gymnomitrion obtusum
Metzgeria conjugata
Plagiochila asplenioides
Plagiochila porelloides
Radula brunnea

Mosses

Andreaea heinemanii
Andreaea schofioldiana
Bartramia pomiformis
Byrum gemmascens
Heterocladium macounii
Heterocladium procurrens
Lescuraea incurvata
Plagiothecium piliferum
Pseudoleskea incurvata
Pseudoleskea patens
Pseudoleskea radicosa
Thamnobryum neckeroides
Timmia austriaca

5. Water

Liverworts

Conocephalum conicum
Pellia neesiana
Tritomaria exsecta
Tritomaria exsectiformis
Tritomaria quinquedentata

Mosses

Dichodontium pellucidum
Dicranella palustra
Hookeria lucens
Hygrohypnum bestii
Pleuroziopsis ruthenica
Porotrichum bigelovii
Rhytidiadelphus subpinnatus

6. Other

Fungi

Albatrellus caeryliopus
Aleuria rhenana
Catathelasma ventricosa
Collybia bakerensis
Collybia racemosa
Cortinarius boulderensis
Cortinarius cyanites
Cortinarius olympianus
Cortinarius rainerensis
Cortinarius tabluaris
Cortinarius variipes
Cortinarius valgus
Elaphomyces granulatus
Elaphomyces muricatus
Ganoderma tsugae
Ganoderma oregana
Geopora cooperi
Gomphus kauffmanii
Gymnopilus punctifolius
Hericium abietis
Hysterangium crassirhachis
Hysterangium setchelli
Laetiporus sulfureus
Mycena lilacifolia
Mycena marginella
Mythicomyces corneipes
Otidea leporina
Otidea onotica
Otidea smithii
Oxyporus nobilissimus[a]
Phaeocollybia kauffmanii
Pholiota scamba
Pholiota pulchella
Pleurocybella porrigens
Polyozellus multiplex
Rhizopogon atroviolaceus
Rhodocybe speciosa
Sarcosphaera eximia
Sarcosoma mexicana
Sparasis radicata
Tricholomopsis fulvescens
Tuber rufum

Mosses

Ulota obtusiuscula

[a] Listed as sensitive in the state of Washington, Washington Nartural Heritage Program (1990).
[b] Reference: Ruggiero et al. (1991) and Thomas et al. In Prep.

carbon products. Except for orchid mycobionts, few are capable of decomposing organic matter, although their respiration contributes significantly to evolution of carbon dioxide from soil. The fungal mycelium and sporocarps are sources of accumulated nutrients and energy for decomposers and consumers. Nutrients and carbon can be transferred from one vascular plant to another by a shared mycorrhizal mycelium. The several thousand species of fungi believed to form mycorrhizae encompass great physiological diversity. They differ in numerous ways, including degree of host specificity, resistance to environmental extremes, selectivity in ion uptake, and production of biologically active products. Net effects of one mycobiont on a host can differ from those of another, although overall functions are shared by most. As key links in below ground nutrient and energy cycling, mycorrhizae and their mycobionts can be ignored only at substantial peril of reaching unreal conclusions about ecosystem processes."

This explanation gives some sense of the importance of fungi in the function of coniferous forests. In addition, two of the spotted owl's primary prey species (northern flying squirrel and red-backed vole) consume fungi as their primary food (Maser et al. 1978b), so that fungi are an important link in the owl's food chain.

Summary

Six hundred and sixty-eight species of plants and animals were considered in the recovery planning process for the northern spotted owl (Table D.10). Of those, 7 are federally listed as threatened or endangered, more than 150 are candidates for listing, 27 are listed as threatened or endangered in one or more of the three states, and 144 are "species of

Table D.10. A summary of 668 animals and plants considered in the recovery planning process for the northern spotted owl.

Animals/Plants	Federally Listed	Candidate for Listing	State Listed	Species of Special Concern	Endemic	Older-Forest Associate	Riparian Associate
Birds (39)	3	3	5	10	5	36	8
Mammals (28)	2	4	3	10	9	22	5
Amphibians[a] (27)	0	9	3	19	23	17	15
Fishes (28)	1	8	3	25	NA	NA	28
Molluscs (58)	0	10	1	29	47	43	45
Arthropods (91)	0	34	0	0	–	55	34
Vascular Plants (207)	1	94	12	49	23	119	6
Nonvascular Plants (190)	0	0	0	2	–	190	12
Total (N=668)	**7**	**162**	**27**	**144**	**107**	**482**	**153**

[a] Includes two reptiles, the sharp-tailed snake and western pond turtle.
– = unknown.
NA = not applicable.

special concern" in at least one of the three states. In addition, the list of 28 fish species includes approximately 779 stocks that are considered at risk and may become candidates for listing in the future. More than 100 of the species are narrowly or broadly endemic to the Pacific Northwest and 482 are associated with late-successional forests. The large number of candidates for federal listing, species of special concern, and endemic species emphasizes the importance of considering other species in the owl recovery plan. In addition, the large number of riparian associated species (approximately 150), plus the number of fish stocks at risk emphasize the importance of riparian areas.

Of the 668 species considered, the committee identified 18 priority species (marbled murrelet, bald eagle, northern goshawk, marten, fisher, grizzly bear, gray wolf, Oregon slender salamander, Siskiyou Mountain salamander, Larch Mountain salamander, Del Norte salamander, Olympic salamander–four species, Pacific giant salamander, Cope's giant salamander, tailed frog); a larger group of riparian-associated species including fishes, amphibians, mammals, insects, and molluscs; and a small group of prey species for the northern spotted owl (flying squirrel, bushy-tailed woodrat, dusky-footed woodrat, red tree voles, and western red-backed vole). Of these, the marbled murrelet and the numerous fish stocks were given highest priority. The bald eagle, northern goshawk, marten, fisher, grizzly bear, and gray wolf were assigned lower priority, because the bald eagle, grizzly bear, and gray wolf already are protected under the Endangered Species Act; and sufficient information was lacking about northern goshawks, martens, and fishers to modify the recovery plan. The 10 salamanders have extremely restricted home ranges and were considered in the delineation of DCAs for the owl; however, the degree to which this could be accomplished was influenced by the spacing criteria for DCAs.

Biology of Owl Prey, Riparian Ecosystems, and Ecology of Other Priority Species

Food Webs of Late-Successional Forests

Temperate coniferous forests of the Pacific Northwest are unique among the forests of the world for a number of reasons (Waring and Franklin 1979), and the structural and functional diversity of these forests provides habitat for a diverse array of plants and animals. Of particular interest is the high species richness of birds, mammals, amphibians, molluscs, arthropods, and plants that characterize the complex food webs in these forests. Among the vertebrate and invertebrate fauna, there are numerous species of granivores, detritivores, folivores, herbivores, fungivores, and a diverse group of aquatic species including fishes, amphibians, and arthropods (Harris 1984:52). The mammalian order of insectivores (shrews and moles) is represented in Pacific Northwest forests by more species than in any other temperate or boreal forest in North America. Two of the most important food webs in these coniferous forests include foliage- and fungi-eating mammals (referred to as folivores and fungivores, respectively) that are prey for the northern spotted owl.

Two folivores that inhabit coniferous forests in the Pacific Northwest belong to the genus *Phenacomys* (*Arborimus*), which is restricted to western Oregon and northwestern California (Figure D.1a). The red tree voles (*Phenacomys longicaudus, P. pomo*) are particularly unusual among rodents in that they live almost their entire lives in the canopy of Douglas-fir trees. These species are associated with old-growth Douglas-fir forests (Aubry et al. 1991, Ruggiero et al. 1991b), although they do occur in lower numbers in forests of other tree species and younger successional stages. The diet of the *P. longicaudus* is almost entirely needles of Douglas-fir (Maser et al. 1981). In turn, this species is one of the primary prey species of the northern spotted owl in the Cascade Mountains of Oregon (Forsman et al. 1984). The third species in this genus is the white-footed vole (*Phenacomys albipes*), an extremely rare species that is not associated with the forest canopy (Figure D.1.b). Because of its rarity, much less is known about this species. For example, of approximately 10,000 individual small mammals and amphibians trapped with pitfall traps in the Oregon Coast Range, only 60 were white-footed voles (Gomez 1992). He found this species to be more abundant in deciduous forests than elsewhere, and it was associated with riparian areas where deciduous vegetation was more abundant. Voth et al. (1983) suggested that the species' diet is restricted to foliage of deciduous plants.

A second important food web in coniferous forests in the Pacific Northwest involves fungivores. Although a number of species eat fungi, the western red-backed vole and the northern flying squirrel are most notable in this group. The northern flying squirrel is the primary prey species for the northern spotted owl in Washington and most of Oregon. The red-backed vole is among the top five prey species (Forsman et al. 1984, Thomas et al. 1990) and is endemic to the Pacific Northwest (Figure D.5.a). Old-growth forests are optimal habitat for the flying squirrel and the red-backed vole. The red-backed vole spends most of its time in underground burrows and feeds on the fruiting bodies of hypogeous fungi (Maser et al. 1978a). Many mammals consume fungi, but few depend on this food source to the extent that the red-backed vole does. Gashwiler (1959, 1970) and Goertz (1964) reported a decrease or elimination of this species following clear-cutting. The decrease is believed to have resulted from the disappearance of hypogeous fungi after this form of timber harvest (Maser et al. 1978b). Hypogeous fungi form symbiotic relationships with the roots of coniferous trees, and these associations are important to the overall health of the trees (see the preceding section about fungi). The northern flying squirrel also consumes fungi (McKeever 1960, Maser et al. 1978b), at least seasonally, although it spends most of its time in the forest canopy. The flying squirrel also eats epiphytic lichens that are abundant in the forest canopy. The northern flying squirrel, red tree vole, and red-backed vole comprise more than 75 percent of the diet of the spotted owl in the Oregon Cascade Mountains, so their dependence on the production of fir needles, fungi, and lichens in coniferous forests is important to these food webs and the owl.

Spotted Owl Prey[2]

The availability of energy for maintenance and reproduction is important to all organisms, so to properly manage an animal, the ecology of its food sources must be considered. Although dietary requirements of a predator may be met by a large range of sources, many species, and the spotted owl in particular, are selective in the prey they feed upon. Although a variety of species is eaten by the owl, only a few species make up the majority of the owl's diet in a given region. More than 90 percent of the spotted owl prey consists of mammals (Forsman et al. 1984). Spotted owl diets and the habitat associations of its prey were reviewed thoroughly by Thomas et al. (1990:201). This section summarizes their report and adds recently published information that augments their work.

The diet of northern spotted owls varies regionally, but within a region it is typically dominated by two or three species (Thomas et al. 1990). Composition of diets varies seasonally (Forsman et al. 1984) but appears to be stable over time based on studies during different years (Thomas et al. 1990). Flying squirrels (*Glaucomys sabrinus*) and woodrats (*Neotoma cinerea* and *N. fuscipes*) dominate the diet in mesic Douglas-fir and dry mixed-

[2]Contributed by Daniel Rosenberg, Redwood Sciences Laboratory, U.S. Forest Service, Arcata, California

conifer forests, respectively (Thomas et al. 1990). Snowshoe hares (*Lepus americanus*) and brush rabbits (*Sylvilagus bachmani*) typically represent less than 10 percent of the prey based on number of prey taken, but because of their larger size, they have been reported to comprise up to 25 percent of the prey biomass (Forsman et al. 1984:43). Red tree voles (*Phenacomys longicaudus, P. pomo*) and deer mice (*Peromyscus maniculatus*) may constitute more than 30 percent of prey numbers and more than 10 percent of prey biomass regionally (Thomas et al. 1990). Western red-backed voles (*Clethrionomys californicus*) usually comprise a smaller percentage of the diet than do red tree voles and deer mice, which is generally less than 5 percent of prey biomass (Forsman et al. 1984:41). Pocket gophers (*Thomomys mazama* and possibly *T. talpoides*) found in the owl's diet at higher elevation sites and east of the Cascade crest. They comprise up to 16 percent of the diet (by weight) during late spring and summer in some locations (Forsman et al. 1984:40).

Northern Flying Squirrels. Northern flying squirrels have a broad distribution throughout coniferous forests and are found in western Washington, Oregon, and northern California (Figure D.5.a). Flying squirrels are arboreal mammals and are not resident in recent clear-cuts. They nest in many substrates, including cavities in live and dead trees. Density does not appear to be strongly dependent on stand age alone. In the Oregon Coast Range, flying squirrels were more abundant in old-growth than in second-growth stands during some, but not all, years of a study by Carey et al. (1992). Similar densities were reported in old-growth and second-growth stands in the Oregon Cascades (Rosenberg and Anthony 1992). In an ongoing study in true fir (*Abies* spp.) forests in Lassen National Forest (north-central California), preliminary data suggest squirrel densities are markedly lower in an intensively managed shelterwood cut than in young- and old-growth stands (Waters pers. comm.).

Woodrats. The dusky-footed woodrat (*N. fuscipes*) is limited in distribution to parts of western Oregon and most of western California (Figure D.2.b) and is associated with mixed-conifer forests. The bushy-tailed woodrat (*N. cinerea*) is found throughout Washington and Oregon, and in parts of northern California (Figure D.2.c). Woodrats are associated with seral stages that have abundant understory vegetation and coarse woody debris, such as early-successional stages (recent clear-cuts) and older seral stages (Thomas et al. 1990); bushy-tailed woodrats also are associated with rocky areas, such as talus slopes (Thomas et al. 1990). These two species comprise a larger portion of the owl's diet in the southern parts of its range particularly in the lower elevations of northern California.

Deer mice. The deer mouse (*Peromyscus maniculatus*) is one of the most widely distributed mammal species in North America and is found throughout Oregon, Washington, and California. Such a wide-ranging species would be expected to be a habitat generalist, and data from the Pacific Northwest support this contention. The deer mouse does not show consistent preferences for particular stand ages (Thomas et al. 1990), but it is more abundant in late-successional forests (Ruggerio et al. 1991a). The forest deer mouse (*P. oreas*) inhabits older forests in western Washington and southern British Columbia (Figure D.2.c). Because of its extensive use of tree canopies, it is probably an important prey species for owls in Washington (West 1991), but its importance is difficult to document because skulls of the species are hard to identify from the common deer mouse in regurgitated owl pellets.

Red tree voles. The red tree voles (*Phenacomys* ssp.) have the most restricted distribution of all the species preyed upon by spotted owls. Before the California population (*P. pomo*) was proposed as a separate species from the Oregon (*P. longicaudus*) species (Johnson and George 1991), the range of the red tree vole included parts of western Oregon and northwestern California (Figure D.1.a). The California population now is considered a separate species based on morphometric and genetic data. Habitat associations of these species are based on relatively small sample sizes, but there is greater relative abundance of the species with increasing stand age, with the highest densities in old-growth forests (Corn and Bury 1991, Ruggiero et al. 1991b, Gomez 1992).

Rabbits and Hares. Brush rabbits occur in most of western Oregon and California and appear to be absent from Washington (Figure D.2.f). Snowshoe hares are found in western Oregon and Washington, and into north-central California (Figure D.2.e). No research has been conducted to specifically study habitat associations of lagomorphs in relationship to spotted owl habitat. In general, these species occupy brushy, densely vegetated habitats (Thomas et al. 1990) and are not more abundant in older forests. It is primarily young of the year that are preyed upon by spotted owls (Forsman et al. 1984:41), so dispersal habitat may be most important when considering these species as spotted owl prey.

Red-backed voles. The western red-backed vole (*Cleithrionomys californicus*) occurs throughout western Oregon and northwestern California, and the southern red-backed vole (*C. gapperi*) occurs in western Washington (Figure D.2.f). Western red-backed voles live in a variety of forested habitats, but densities are low in recently burned clear-cuts and their occurrence may be positively associated with woody debris (reviewed by Alexander and Verts In Press). No differences in abundance of *Cleithrionomys* spp. were found in unmanaged young (30 to 70 years) Douglas-fir stands compared to older seral stages (Corn and Bury 1991, Gilbert and Allwine 1991, West 1991), but abundance was much lower in managed young stands than in old-growth stands in the Oregon Cascades (Rosenberg and Anthony 1990). Gomez (1992) found greater abundances of western red-backed voles in mature and old-growth forests in the Oregon Coast Range as compared to the shrub, pole-sized, and deciduous stands.

Pocket Gophers. The mazama pocket gophers (*Thomomys mazama*) occurs in western Washington and Oregon and in northwestern California, and northern Pocket gophers (*T. talpoides*) occurs principally east of the crest of the Cascade crest. Both species are found in open areas with high forb cover as well as in forests of early- and late-successional stages (Burton and Black 1978, Scrivner and Smith 1981). We are unaware of any comparative study of the habitat associations of these two species.

Managing prey for the northern spotted owl. Recent research on prey species was motivated, in part, by an interest in increasing prey abundance through silvicultural prescriptions. The results to date do not show consistent patterns that would allow this to be achieved. This, combined with the difficulty in assessing the relationship between prey abundance and availability, makes the feasibility of manipulating prey densities to increase owl use of forests questionable. Experimental manipulations of habitat and assessments of prey response (as well as owl response) are needed to test the effectiveness of management techniques. Failure of habitat models to predict animal response in locations and years other than the ones from which the data originally were collected is a common problem (Noon 1986). This probably results from the numerous factors besides habitat that affect animal populations (Noon 1986). The ability to manipulate habitat to increase prey availability is difficult because of the complex interaction of predator and prey.

Ecology of Riparian Ecosystems and Native Fishes

The committee's list includes approximately 150 species of animals that are associated with riparian areas. This list of species is diverse and includes 8 birds, 5 mammals, 15 amphibians, 45 molluscs, and 34 arthropods as well as 28 fish species. Riparian associates comprise approximately one-fourth of the other species considered as a result of Secretary Lujan's request. The association to riparian areas by these species indicates the importance of riparian areas in the recovery plan for the spotted owl.

Riparian ecosystems represent a small proportion of the land base (generally less than 5 percent), but they provide habitat for a rich and diverse group of plants and animals. A large number of fish stocks has been identified as being at risk (Nehlsen et al. 1991, Moyle et al. 1989, Williams et al. 1989), in part because of intensive timber harvest along streams in many areas (see section on Native Fishes). The importance of riparian ecosystems, their roles in coniferous forests, and their potential importance as ecological corridors among DCAs is discussed next.

Riparian Ecosystems

Ecologists and land managers recently recognized the importance of structure and function of riparian zones for terrestrial and aquatic ecosystems (Gregory et al. 1988, Knight and Bottorf 1984, Meehan et al. 1977, Beschta 1989). These functions include stream shading, bank stabilization, nutrient uptake, input of leaves and needles into streams, sediment filtering, bank building, and the contribution of large down wood (Elmore and Beschta 1987, Gregory et al. 1988). The contrast in communities and physical environment creates rich patterns of processes and structure that are the basis for the high biotic diversity found in riparian zones (Gregory et al. 1988).

Management. The segregation of riparian areas from other ecosystems by state and federal agencies is a common management approach. The result predominately has been the development of federal policies and state forest practices that allow varying intensities of forest activities. The states of California, Washington, and Oregon have addressed riparian ecosystems in their forest practices rules. The states also are involved in an extensive monitoring program to evaluate the effectiveness of these rules.

In general, federal agencies are consistent in their approach to the classification of streams. Streams are segregated into four classes based on the presence or absence of fishes, the uses of the water (e.g., domestic use by cities, recreation), and whether the stream is a significant contributor to a higher-class stream. The states use predominately the same process but have delineated their streams by consolidating the categories into as few as two or as many as four classes. Timber harvest regulations, however, vary among states and are less restrictive under state forest practices laws than under federal management guidelines. Regulations in the states range from retention of as few as 21 conifers per 1,000 feet of stream in one state to 50 trees in another. None of the three states' laws addresses full floodplain function.

Not all riparian policies address small upper watershed tributaries, full floodplain function, and small wetland areas within the terrestrial forest matrix. The result is a landscape with various widths of protection along stream systems that allows varying degrees of harvest. This buffer strip concept appears to be inherently unstable, biologically and physically (Gregory et al. 1988). Changes in natural patterns and composition of streamside vegetation have major short- and long-term consequences to channel characteristics and morphology, streambed and channel stability, ecosystem functioning, wildlife habitat, and the biological productivity of streams and wetlands (Elmore and Beschta 1987).

Riparian areas and wetlands provide some of the most important wildlife habitat in the forestlands of the western states. Their use as habitat generally is greater than that of surrounding areas because the major life requirements for many species are present (Oakley et al. 1985). They are used for foraging and watering, breeding, raising young, hiding and resting, and thermal cover. Of the 414 wildlife species in Oregon and Washington, 359 (87 percent) use riparian zones or wetlands during some season(s) or part(s) of their life cycle. Of these species, 318 use one or more of the plant communities directly associated with riparian zones and wetlands (Oakley et al. 1985). Use is similar in California. Riparian areas support a diverse arthropod fauna, and many of these species are important food items for vertebrate animals (Lattin pers. comm.). In addition to wildlife species directly dependent on riparian areas, populations in adjacent areas are influenced strongly by the riparian community (Stevens et al. 1977). Management aimed at maintenance or protection of riparian zones is extremely important because of the many species that use these areas (Carothers 1977).

Stream riparian areas are more common than wetlands in the forested systems of the West. Oakley et al. (1985) identified six major reasons that riparian and wetland areas are important for wildlife:

1. They contain the three critical habitat components: food, cover, and water.

2. They contain a greater diversity of plant species and vegetative structure than adjacent uplands.

3. The elongated shape of most riparian zones maximizes edge effect with the surrounding forest as well as with water.

4. They have different microclimates from surrounding coniferous forests due to increased humidity, a higher rate of transpiration, and greater air movement.

5. They serve as natural migration routes and travel corridors.

6. They play a major role in maintaining water quality and quantity.

Riparian and wetland areas also are important for many other types of land uses. Highly productive timber sites frequently occur along or around these areas. Recreation, road locations, mining activities, road building material, and home sites also are among the many other important uses. For these reasons and many others, riparian and wetland areas are recognized as critical areas in multiple-use management and planning.

Connectivity of habitats along riparian zones : Connectivity of a conservation system is the extent to which individuals of various species can move among blocks of like habitat or preserves. Riparian zones are of well-known value to many species, and old-growth forests are often particularly well developed in riparian areas because fires tend to occur in these areas less often and with lower intensity. Riparian zones may also be used by migratory and dispersing individuals of many species and would be excellent areas to provide connectivity between conservation areas that are characterized by late-successional forests (Harris 1984). Ensuring adequate connectivity is an important consideration of any conservation strategy and may be easier for spotted owls than for many other species, particularly ones with poor dispersal ability (e.g., molluscs, flightless insects, amphibians). Riparian zones may be especially valuable both for ensuring connectivity and providing breeding habitat for numerous species.

Connectivity helps maintain population viability in four ways. First, it facilitates movement among populations and decreases the probability of local extinction. Factors leading to local extinctions may include demographic events, genetic drift or inbreeding depression, or large-scale environmental events. Secondly, connectivity facilitates natal or juvenile dispersal, which optimizes levels of inbreeding/outbreeding, parent-offspring competition, and the exploitation of new habitats in changing environments. Thirdly, connectivity facilitates migratory movements and movements within the animals' home range. Lastly, connectivity permits range expansion, which is particularly adaptive during periods of climatic change. Therefore, connectivity is important for an number of ecological reasons. Three general approaches to maintaining connectivity are establishing movement corridors, ensuring suitable habitat for dispersal within the forest matrix, and providing continuous breeding habitat.

Summary. Employment of an ecosystem perspective in developing policy and management guidance allows for an assessment of riparian function, structure, and interaction with adjoining ecosystems. This process will provide self-sustaining streamside forests that will ensure the desired conditions of riparian resources for the future (Gregory and Ashkenas 1990). A single prescription for riparian management will not address the variation in riparian resources that occurs throughout the region's forests (Gregory and Ashkenas 1990). For example, areas within the range of the northern spotted owl east of the Cascade Mountains in Oregon require different considerations than do coastal areas. Landscape-level and basin-level considerations should be evaluated prior to the development of site-specific prescriptions for riparian management.

The committee identified the following as appropriate management considerations in riparian areas:

- Recognize the unique value of riparian areas within the context of the environment in which they are located.
- Consider landscape connectivity.
- Consider full floodplain function.
- Recognize the importance of all stream systems, regardless of size, and view these streams and their associated riparian areas from a basin and landscape perspective.
- Maintain species and age-class distributions of streamside vegetation that will provide large woody debris to the forest floor and stream channel.
- Restore natural processes within the stream channel and the riparian management zone.
- Monitor restoration activities to determine if desired results are achieved.

Native Fishes

Twenty-eight species comprising approximately 1,181 native fish stocks occur in approximately 455 streams, rivers, lakes, and estuaries within the range of the northern spotted owl. Of these, there are 354 streams with stocks at risk, and 779 stocks that are considered at risk. Any of these fish stocks would benefit from the recovery plan for the owl and the conservation of late-successional forests. Throughout the owl's range, most aquatic habitat has been impacted in some way by land-use activities. Restoration of depleted stocks (the stock concept is discussed next) and protection of currently secure stocks depends on suitable habitat for all life stages of those stocks.

This inventory of species and stocks is not complete, owing to the extensive range of the northern spotted owl and the scarcity of information about species other than those of particular commercial or sporting interest. Little genetic identification of fish stocks has been done in the region; therefore distinct stocks may have been overlooked. In general, there are two major life history patterns among fishes in these areas, anadromous (spawning in fresh water and maturing in salt water) and resident (remaining in fresh water). Salmonids make up a major portion of the stocks identified within the range of the northern spotted owl. Information about distribution, stock size, and habitat requirements generally are available for these species because of their economic importance and recreational value.

Stock concept. The term "stock" was adopted 51 years ago, shortly after the first attempts to describe stocks of Pacific salmon and discuss their importance to management of the species (McIntyre 1983). After reviewing the results of early marking experiments, Rich (1939) concluded that Pacific salmon were divided into many local populations or what we now refer to as stocks (Ricker 1972). Anadromous salmonid species comprise populations that originate from specific watersheds as juveniles and generally return to their natal streams to spawn. This life cycle results in a large degree of reproductive isolation of interbreeding individuals or stocks (Ricker 1972). Stocks represent unique genetic entities, and loss of a stock is irreversible. It is at the stock level that conservation and management of salmon is taking place. Additional documentation and discussion of fish stocks can be found in Nehlsen et al. (1991).

Effects of land-use activities on fishes and fish habitat. The condition of watersheds dictates the physical and chemical makeup of the streams that drain them and of the lakes that lie within them (Meehan 1991). Vannote et al. (1980) proposed a "river continuum concept" based on a continuous gradient in physical variables within a river system from headwaters to mouth. This gradient leads to a continuum of biotic adjustments and consistent patterns of loading, transport, utilization, and storage of organic matter along the length of a river (Vannote et al. 1980). Management of fish habitat, and therefore fish populations, requires consideration of the habitat within the watershed to accommodate stream and terrestrial processes that work in concert throughout the basin.

Gradients within the "river continuum" also provide a basis for assessing cumulative effects. For example, fine sediment is transported from high gradient to low gradient areas, where it can accumulate to levels that affect fisheries. The translocation downstream and the contribution from several sources make traditional cause-and-effect evaluation of cumulative effects difficult, if not impossible. Multiple ownerships complicate the issue and may impede evaluation of upstream effects.

Many land-use activities can affect aquatic habitat and fish populations. Such activities include road construction, timber harvest, livestock grazing, hydroelectric development, chemical applications, mining, and recreation. The effects of road construction and timber harvest, which are significant within the range of the spotted owl, are discussed next.

Roads. Roads can modify natural drainage systems and accelerate erosion processes; these changes can alter physical processes in streams, leading to changes in streamflow regimes, channel configuration, sediment transport and storage, substrate composition, and stability of slopes adjacent to streams (Furniss et al. 1991). Increased sediment input from roads can affect fish habitat. The principle source of sediment entering streams is by mass soil movements and surface erosion processes (Swanston 1991), although forest roads can substantially increase the frequency of mass soil movements in steep watersheds (Everest et al. 1987). Furniss et al. (1991:297-323) found that rarely can roads be constructed without some effect on fish habitat. However, roads that have been properly planned, constructed, and maintained have minimized these effects. Regular maintenance of roads to reduce impacts on fish habitat should be practiced on all roads, not just those that are actively used.

Timber harvest. Effects of timber harvest and silvicultural treatments (planting, thinning, burning, mechanical site preparation, and application of chemicals) on stream ecosystems are complex (Meehan 1991). Various timber harvest strategies ranging from clear-cutting to long-rotation selective harvest, affect fish habitat in different ways. In general, the effects of timber harvest on fish habitat include increased sedimentation and water temperatures, changes in seasonal flow patterns, quantity and distribution of woody debris, and channel morphology (Chamberlin et al. 1991:181-205).

Quantity and timing of sediment entry into stream systems are important in determining habitat quality for fishes. Specific substrate conditions are required for spawning, rearing, and over-wintering. Increases in fine sediment from logging activities have been shown to decrease survival of salmonid fry (Scrivener and Brownlee 1982). Substrate conditions also are important for salamanders, aquatic insects, and aquatic plants that contribute to energy processing in aquatic environments.

When streamside trees are removed, increased light may stimulate primary production (Murphy and Meehan 1991). Increased periphyton (algae and associated microorganisms growing attached to any submerged surface) production after canopy removal may increase the abundance of invertebrates and fishes, mainly by increasing the quantity of detritus (Murphy and Meehan 1991). Increased primary production from canopy removal may last for a short period of time and then diminish due to canopy closure, which is often denser in even-aged, second-growth forests than in older forests (Murphy and Meehan 1991). In addition, cumulative downstream effects of increased water temperature may create downstream areas that are not suitable for native fishes.

Among the most important long-term effects of forest management activities on fish habitat in western North America have been changes in distribution and abundance of large woody debris (more than 14 inches in diameter) in streams (Hicks et al. 1991). Large woody debris plays a critical role in controlling stream channel morphology, regulating the movement and storage of inorganic and organic material, and in creating and maintaining fish habitat (Hicks et al. 1991). Debris removal was common in the 1960s and 1970s and often was encouraged by fisheries biologists to improve fish access to upstream areas. Since then, the importance of woody debris in stream channel form and function has been recognized. Removal of large woody debris from stream channels has been shown to adversely affect fish populations. Debris removal can cause a decline in channel stability and a corresponding reduction in the quality and quantity of pools and cover (Hicks et al. 1991).

Removal of large trees from riparian zones has caused long-term reduction in the recruitment of large woody debris to stream channels, leading to a reduction in the quality of fish habitat (Hicks et al. 1991). Murphy and Koski (1989) modeled the depletion and input of large woody debris from second-growth forests. Their model indicated that 90 years later, clear-cut logging without a buffer strip would reduce large woody debris by 70 percent, and recovery to prelogging levels would take more than 250 years.

The use of buffer strips has been shown to reduce the localized effects of streamside timber harvest. Murphy et al. (1986) found that streams with buffer strips did not consistently differ from streams in old-growth forests; streams in clear-cuts without buffer strips had more periphyton, lower channel stability, and less canopy, pool volume, large woody debris, and undercut banks than streams in old-growth forests.

Summary. Twenty-eight species comprising more than 1,193 fish stocks were identified within the range of the northern spotted owl. A total of 779 stocks (Table D.11) are 1) federally listed as threatened or endangered, 2) candidates for federal listing, 3) species of special concern (state), or 4) are considered at risk by Nehlsen et al. (1991), Moyle et al. (1989), or Williams et al. (1989). These stocks occur in 354 streams throughout the Pacific

Table D.11. List of fish stocks of various species and the number of stocks at risk.

Species/Stock	California Number of Stocks Total	California At Risk	Oregon Number of Stocks Total	Oregon At Risk	Washington Number of Stocks Total	Washington At Risk
Bigeye marbled sculpin	1	1				
Bull trout	1	1	31	31	13	13
Chum salmon	8		41	41	35	19
Clear Lake hitch	1	1				
Coho salmon	45	45	114	114	33	13
Fall chinook salmon	51	15	54	54	22	21
Gualala roach	1	1				
Jenny Creek sucker	1	1	1	1		
Klamath River lamprey	5	5				
Millicoma dace			3	3		
Navarro roach	2	2				
Nooky (Chehalis) dace					33	33
Olympic mudminnow					13	13
Pink salmon	4	4			8	3
Pit roach	1	1				
Redband trout	7	7	5	5		
Reticulate sculpin	2	2				
Rough sculpin	1	1				
Russian River tule perch	1	1				
Sacramento splittail	2	2				
Sacramento winter chinook salmon	1	1				
Salish sucker					18	18
Sea-run cutthroat trout	21	21	88	52	72	24
Sockeye salmon	0	EXTINCT	2	1	8	2
Spring chinook salmon	16	16	40	13	32	10
Summer chinook salmon			1	1	4	2
Summer steelhead trout	33	33	38	8	35	14
Tidewater goby	14	14				
Tomales roach	1	1				
Umpqua chub			3	3		
Willamette chub			6	6		
Winter steelhead trout	68	2	101	53	39	30
Total	**288**	**178**	**528**	**386**	**365**	**215**

Northwest (Tables D.12, D.13, and D.14) that could provide habitat connectivity among owl conservation areas. Streams included on these lists may need special consideration when land management activities are planned. If future fisheries' inventories reveal additional streams containing stocks at risk, these streams may need similar protection. Since data are incomplete about the identification of unique fish stocks throughout the range of the spotted owl, each stock should be considered individually to reduce the risk of losing a genetically distinct stock.

Table D.12. California streams (or stream reaches) identified as containing at least one fish stock that is considered to be at risk.

		Steelhead Trout		Salmon				Sea-run Cutthroat Trout		
				Chinook			Coho			
Basin	Stream	Sum	Win	Spr	Sum	Fall			Other[a]	Ref.[b]
Albion	Albion River					X			16X	2,7
Russian	Austin Creek		P				X			3
Klamath	Beaver Creek		P			P	X		7X	1,3,4,5
Big	Big River		P				X		16X	2,3,7
Klamath	Blue Creek	X	P			P	X	X		1,3,4
Klamath	Bluff Creek	X	P			P	X			1,3,4
Klamath	Bogus Creek		P			P	X			1,3
Klamath	Boise Creek	X					X			4
Sacramento	Bull Creek								11X	3,7
Klamath	Camp Creek	X	P			P				1,3
Klamath	Canyon Creek	X	P	X		P				3,4,5
Klamath	Clear Creek	X	P	X		P				4
Clear Lake	Clear Lake								4X	5
Klamath	Dillon Creek	X	P			P				4
Klamath	E.ast Fork Indian Creek	X	P			P				3
Eel	Eel River	X				X	X	X	3P,16X	2,5,6,7
Klamath	Elk Creek	X	P			P				4
Humboldt	Elk River					X	X	X		1,6,7
Rogue	Elliot Creek								12X	5
Humboldt	Freshwater Creek					X	X	X		3,6,7
Garcia	Garcia River		P				X		9X,16X	2,3,5,7
Klamath	Grider Creek		P			P	X			3
Gulala	Gulala River		P				X		5X,16X	2,3,5,7
Klamath	Hayfork Creek	X	P							3
Klamath	Horse Linto Creek	X	P			P	X	X		1,3,4
Smith	Hurdygurdy Creek		P			P		X		3
Klamath	Indian Creek	X	P			P				3,4,5
Humboldt	Jacoby Creek					X	X	X		3,6,7
Smith	Jones Creek		P			P		X		3
Klamath	Kidder Creek		P						7X	3,5
Klamath	Klamath River	X		X			X	X		2,6
Redwood	Lacks Creek		P				X			3
Laqunitas	Laqunitas Creek		P				X			3
Humboldt	Little River					X		X		6,7
Little	Little River		P				X			3
Klamath	Little Shasta River								7X	5
Klamath	Lower Klamath R	X		X		P	X	X	3P,9X	2,5,6,7,
Klamath	Lower Klamath Tributaries					X				6,7
Mad	Mad River	X				X	X	X	3P,9X,16X	2,5,6,7
Humboldt	Maple Creek					X		X		6,7
Mattole	Mattole River		P			X	X		3P,16X	
Sacramento	McCloud River								2X,11X	3,4

Continues

Continued

Basin	Stream	Steelhead Trout		Salmon				Sea-run Cutthroat Trout	Other[a]	Ref.[b]
				Chinook			Coho			
		Sum	Win	Spr	Sum	Fall				
Humboldt	McDonald Creek		P			X		X		1,6,7,
Rogue	Middle Fork Applegate River								12X	5
Eel	Middle Fork Eel River	X	P							4,5,6
Smith	Middle Fork Smith River			X						6
Klamath	Mill Creek	X	P				X			3,4
Smith	Mill Creek		P			P	X	X		3
Smith	N. Fork Smith River			X					6	
Klamath	N. Fork Trinity River	X	P	X		P				4,5,6
Napa	Napa River		X						15X	5,6
Navarro	Navarro River		P				X		8X,16X	2,3,5,7
Klamath	New River	X	P	X		P	X			3,4,5,6
Noyo	Noyo River		P				X		16X	2,3,7
Laqunitas	Olema Creek		P				X			3
Sacramento	Pit River								1X,10X,13X	2,3,5,7
Redwood	Prairie Creek		P			P	X	X		3,6
Sacramento	Racoon Creek								11X	3,7
Klamath	Red Cap Creek	X				P	X			4,5
Redwood	Redwood Creek	X	P			X	X	X	3P,16X	2,3,5,6,7
Smith	Rowdy Creek		P			P	X	X		3,6
Klamath	Rush Creek		P			P	X			3
Russian Gulch	Russian Gulch Creek		P				X			3
Russian	Russian River		P			X	X		3P,8X,9X, 14X,16X	2,3,5,6,7
Smith	S. Fork Smith River	X	P	X		P	X	X		1,3,6
Klamath	S. Fork Trinity River	X	P	X		P				3,4,5,6
Salmon	Salmon Creek						X		16X	2,7
Klamath	Salmon River	X	P	X		P				3,4,5
Klamath	Scott River	X				X				1,6
Klamath	Seiad Creek		P			P	X			3
Klamath	Shasta River					X			7X	5,6,7
Klamath	Small Tributaries to Hayfork Creek		P				X			3
Smith	Smith River	X	P	X		X	X	X	3P,16X	2,3,4,6,7
Sacramento	Tate Creek								11X	3,7
Klamath	Tish Tang Creek	X	P			P	X			3,4
Klamath	Trinity River	X		X				X		2
Klamath	Ukonom Creek	X	P			P				3
Klamath	Upper Klamath River	X		X		P	X		6X,7X	2,5,6
Sacramento	Upper McCloud River								11X	3,7
Eel	Upper S. Fork Eel River	P	X	3						

Continues

Continued

Basin	Stream	Steelhead Trout		Salmon				Sea-run Cutthroat Trout	Other[a]	Ref.[b]
				Chinook			Coho			
		Sum	Win	Spr	Sum	Fall				
Sacramento	Upper Sacramento River		X	X					3P,11X,15X, 18X	2,5,6,7
Eel	Van Duzen River	X								5,6
Walker	Walker Creek		P				X		16X,17X	2,3,5,7
Sacramento	Whisky Creek								11X	3,7
Klamath	Wooley Creek	X		X		P				4,5,6

X = endangered, threatened, candidate, or species of concern on federal or state list or identified at risk by Moyle et al. (1989), Nehlsen et al. (1991), or Williams et al. (1989).
P = stock is present in stream.
Spr = Spring Sum = Summer Win = Winter
[a]*Other species:* 1) bigeye marbled sculpin, 2) bull trout, 3) chum salmon, 4) Clear Lake hitch, 5) Gualala roach, 6) Jenny Creek sucker, 7) Klamath River lamprey, 8) Navarro roach, 9) pink salmon, 10) Pit roach, 11) redband trout, 12) reticulate sculpin, 13) rough sculpin, 14) Russian River tule perch, 15) Sacramento splittail, 16) tidewater goby, 17) Tomales roach, 18) Sacramento River winter chinook salmon.
[b]*References:* 1) California Department of Fish and Game. 1991 Comments to 26 November 1991 draft of Appendix D. See administrative record. 2) Frissell (1991), 3) Gerstung (1991). California Department of Fish and Game. Correspondence and transcripts of Other Species and Ecosystem Issues in Recovery Planning for the Northern Spotted Owl: technical workshop. Volume 1, August 8, 1991. Portland, Oregon. See administrative record. 4) Johnson et al. (1991); 5) Moyle et al. (1989). 6) Nehlsen et al. (1991). 7) Williams et al. (1989).

Table D.13. Oregon streams (or stream reaches) identified as containing at least one fish stock that is considered to be at risk.

Basin	Stream	Steelhead Trout		Salmon				Sea-run Cutthroat Trout	Other[a]	Ref.[b]
				Chinook			Coho			
		Sum	Win	Spr	Sum	Fall				
Alsea	Alsea River		X	X			X	X	2X	1,3
Alsea	Alsea estuary						X	X		3,4
McKenzie R.	Anderson Creek			P					1X	2
Deschutes	Badger Creek								5X	2
Columbia	Bear Creek		X			X				3
Columbia	Beaver Creek		X				X			3
Mid. Coast	Beaver Creek						X			3
Rogue	Beaver Creek	P	P				X			2
Umpqua	Big Bend Creek	P		P			X			4
Columbia	Big Creek		X			X	X	X	2X	1,3
Mid. Coast	Big Creek		X				X	X		2,3,4
Rogue	Billings Creek					X				3
Santiam	Boulder Creek								1X	2
Nestucca	Boulder Creek		X				X	P		2,3,4
Umpqua	Boulder Creek	P	P	P			X	X		2,4
Willamette	Calapooia River		X							3
Umpqua	Calf Creek	P	P	P			X	X		2
Deschutes	Candle Creek								1X	4
Rogue	Canyon Creek		P			X				4

Continues

Continued

Basin	Stream	Steelhead Trout		Salmon				Sea-run Cutthroat Trout	Other[a]	Ref.[b]
				Chinook			Coho			
		Sum	Win	Spr	Sum	Fall				
Mid Coast	Cape Creek		X				X	X	2X	3,4
Illinois	Cave Creek		P			X				2
Columbia	Chenowth Creek		X				X			3
Klamath	Cherry Creek								1X	2
South Coast	Chetco		P			X	X	X	2X	1,3,4
Willamette	Clackamas River	P	X	X			X	X	1X	1,2,3
Columbia	Clatskanie River		X			X	X			3
North Coast	Coal Creek		P				X	P	2X	4
Willamette	Collawash/Hot Springs Fork			P			X			2
Rogue	Collier Creek					X				3
South Coast	Coos River					X	X	X	2X	1,3
Umpqua	Copeland Creek	P	P	P			X	X		2,4
Coquille	Coquille River			X			X	X	2X	1,3
Deschutes	Crooked River								1X	4
Mid. Coast	Cummins Creek		X				X	X	2X	2,3,4
McKenzie R.	Deer Creek			P					1X	2
Salmon	Deer Creek						X	P		4
Deschutes	Deschutes River								1X,6X	1,2,3,4
Alsea	Drift Creek		X	X		X	X	P		2,3,4
Siletz	Drift Creek	X	X	X		X	X	P		2,3
Sixes	Dry Creek					X	X	P	2X	2,4
Columbia	Eagle Creek	X	X	P			X			2,3
Nehalem	East Fork Foley Creek							P	2X	4
Rogue	East Fork Illinois River		X			X	X	P		3,4
Winchuck	East Fork Winchuck River		P			X	X	P		4
South Coast	Elk River		P			X	X	X	2X	1,2,3,4
South Coast	Emily Creek		P			X	X	X		2,3,4
South Coast	Euchre Creek					X	X	X	2X	1,3
Klamath	Evening Creek								1X	2
Willamette	Fern Creek Shady Del								8X	2
Columbia	Fifteen Mile Creek	P	X							2,3
Willamette	Fish Creek	P	P	P			X			2
South Coast	Floras Creek						X	X	2X	1,3
Alsea	Flynn Creek						X	P		4
Rogue	Foster Creek					X				3
Umpqua	Franklin Creek		P				X	X		2,4
Willamette	French Pete Creek								1X	4
Columbia	Gnat Creek		X			X	X			3
Willamette	Gray								8X	4
Rogue	Grayback Creek		P			X	X			2
Siuslaw	Greenleaf Creek		P				X			4
Columbia	Herman Creek	X	X				X			3
Hood	Hood River	X	X	X		X	X	X	1X	1,3
Willamette	Horse Creek								1X	

Continues

Continued

Basin	Stream	Steelhead Trout		Salmon				Sea-run Cutthroat Trout	Other[a]	Ref.[b]
				Chinook			Coho			
		Sum	Win	Spr	Sum	Fall				
Rogue	Horse Sign Creek					X				3
South Coast	Hunter Creek					X				3
Rogue	Illinois River		X			X	X	P		1,3,4
Rogue	Indigo Creek		X			X		P		2,3
Deschutes	Jack Creek								1X	4
S. Umpqua	Jackson Creek		P	P			X	P		4
Klamath	Jenny Creek								3X	4
Rogue	Jim Hunt Creek					X				3
Deschutes	Jordon Creek								5X	2
North Coast	Kilchis River		X				X	X	2X	1,3
McKenzie R.	Kink Creek			P					1X	2
Columbia	Klaskanine River		X			X	X		2X	3
Rogue	Lawson Creek		X			X	X	P		2,3,4
Columbia	Lewis and Clark River		X			X	X	X	2X	1,3
Nestucca	Limestone Creek		X				X	P		2,3,4
Columbia	Lindsey Creek						X			3
Rogue	Little Applegate River	P					X			2
Wilson	Little N. Fork Wilson River						X	P		4
Rogue	Lobster Creek					X				3
Willamette	Lost Creek Scott Creek								1X	2
Rogue	Lower Rogue River	X				X	X	X	2X	1,3
Umpqua	Lower Umpqua River					X	X	2X,7X	1,3	
Deschutes	Marsh Creek								1X	2
Willamette	McKenzie River		P	X					1X,8X	1,2,3,4
Deschutes	Metolius River			P					1X,6P	1,2,4
Miami	Miami River		P				X	X	2X	1,3
Willamette	Lower Willamette River			X		X			8X	1,3
Hood	Middle Fork Hood River	P	P				X		1X	4
Willamette	Middle Fork Willamette River								1X,8X	1,4
Columbia	Mill Creek		X				X			3
Coos	Millicoma River								4X	4
Columbia	Milton Creek		X				X			3
Willamette	Molalla River		X							3
Columbia	Mosier Creek		X				X			3
Necanicum	Necanicum River						X	X	2X	1,3
Nehalem	Nehalem River				X		X	X	2X	1,3,4
Nestucca	Nestucca River		X				X	X	2X	1,3,4
North Coast	Netarts Bay								2X	3
Nestucca	Niagara Creek		X				X	P		2,3,4
Rogue	N. Fork Lobster Creek					X	X	P		4

Continues

Continued

Basin	Stream	Steelhead Trout		Salmon				Sea-run Cutthroat Trout	Other[a]	Ref.[b]
				Chinook			Coho			
		Sum	Win	Spr	Sum	Fall				
Trask	N. Fork N. Fork Trask River						X	P		4
Siletz	N. Fork Siletz River			P			X	P	4	
Umpqua	N. Fork Smith River	P			X	X	X		2	
Trask	N. Fork Trask						X	P		4
Umpqua	N. Umpqua River	P	P	P		X	X	X	7X	1,2,3,4
Willamette	Oak Grove	P	P	P			X			2
Deschutes	Odell Creek								1X	2
McKenzie R.	Olallie Creek			P					1X	2
Rogue	Palmer Creek	P	P				X			2
South Coast	Pistol River					X	X	X	2X	1,3
Columbia	Plympton Creek					X				3
Nestucca	Powder Creek		X				X	P		2,3,4
Willamette	Pudding River		X							3
Rogue	Quosatana Creek	P	P			X		P		2,3
Deschutes	Roaring Creek								1X	4
Willamette	Roaring River		P	P			X		1X	2,4
Mid Coast	Rock Creek		X				X	X	2X	2,3,4
N. Coast	Rock Creek						X	X		3,4
Deschutes	Rock Creek								5X	2
Columbia	Rock Creek		X							3
Rogue	Rogue River			P		X	X	P		4
Rogue	Rough and Ready Creek		P				X	P		4
Coos	South Coos River								4X	4
Coquille	South Fork Coquille River	P	P	P		X	X	P		2
Willamette	South Fork McKenzie River	P		P					1X	2,4
Umpqua	South Umpqua River	P	P	X		X	P	7X	1,2,3,4	
Mid Coast	Salmon River		X				X	X	2X	1,3
Sandy	Salmon River	P	P	P			X			2,4
Salmon	Salmon estuary					X	X	X		3,4
Nehalem	Salmonberry River		P			X		P		4
Sandy	Sandy River	P		X		X	X	X		1,3
Willamette	Santiam River		X	X					1X,8X	1,3
Columbia	Scappose Creek		X				X		2X	3
Yachats	School Fork						X	P		4
Klamath	Seven Mile Creek								1X	2
Rogue	Shasta Costa Creek	X	P			X	X	P		2,3,4
Siletz	Siletz River	X	X	X		X	X	X	2X	1,3,4
Rogue	Silver Creek		X			X		P		2,3
Siuslaw	Siuslaw River		P				X	X	2X	1,3
Sixes	Sixes River						X	X	2X	1,3
Sixes	Sixes estuary						X	X	2X	3,4
Umpqua	Steamboat Creek	P	P	P			X	X		2,4
Klamath	Sun Creek								1X	4
Siuslaw	Sweet Creek		P			X	X	X		2
McKenzie R	Sweetwater Creek			P					1X	2

Continues

Continued

		Steelhead Trout		Salmon				Sea-run Cutthroat		
				Chinook			Coho			
Basin	Stream	Sum	Win	Spr	Sum	Fall		Trout	Other[a]	Ref.[b]
Columbia	Tanner Creek		X						2X	3
South Coast	Taylor Creek						X			2
Mid Coast	Tenmile Creek		X				X	X	2X	2,3,4
Columbia	Three Mile Creek		X							3
Nestucca	Three Rivers		X			X	X	P		2,3
Tillamook	Tillamook Bay		X				X		2X	3
Tillamook	Tillamook River		X				X	X	2X	1,3
Coos	Tioga Creek								4X	4
Nestucca	Tony Creek		X				X	P		2,3,4
Deschutes	Trapper Creek								1X	4
Trask	Trask River						X	X	2X	1,3
Deschutes	Tygh Creek								5X	2
Rogue	Upper E. Fork Illinois River		P			X	X			2
Mid. Coast	Upper Knowles		P				X			4
Hood	Upper Middle Fork Hood River	P	P				X		1X	4
Rogue	Upper Rogue River	X					X	P		1,3,4
Umpqua	Upper S. Umpqua River			X			X	P		3,4
Columbia	Viento Creek						X			3
Umpqua	Wassen Creek		P				X	X		2
Hood	W. Fork Hood River	P				X	X		2	
Deschutes	White River								5X	2
Wilson	Wilson River		X				X	X	2X	1,3
South Coast	Winchuck River		P			X	X	X	2X	1,2,3
South Coast	Winchuck estuary					X	X	X		3,4
Mid Coast	Yachats River		X			X	X	X	2X	1,2,3,4
Rogue	Yale Creek	P	P				X			2
Yaquina	Yaquina River		X			X	X	X	2X	1,3
Columbia	Youngs River		X			X	X	X	2X	1,3

X = endangered, threatened, candidate, or species of concern on federal or state list or identified by Nehlsen et al. (1991), or Williams et al. (1989).
P = stock is present in stream.
Spr = spring
Sum = summer
Win = winter
[a]*Other species:* 1) bull trout, 2) chum salmon, 3) Jenny Creek sucker, 4) Millicoma dace, 5) redband trout, 6) sockeye salmon, 7) Umpqua Oregon chub, 8) Willamette Oregon chub.
[b]*References:* 1) Frissell (1991), 2) Johnson et al. (1991), 3) Nehlsen et al. (1991), 4) Oregon Chapter of the American Fisheries Society (1991). Draft: Watershed classification/biodiversity list. See Administrative Record.

Table D.14. Washington streams (or stream reaches) identified as containing at least one fish stock that is considered to be at risk.

Basin	Stream	Steelhead Trout Sum	Steelhead Trout Win	Salmon Chinook Spr	Salmon Chinook Sum	Salmon Chinook Fall	Salmon Coho	Sea-run Cutthroat Trout	Other[a]	Ref.[b]
Columbia	Abernathy Creek		X			X			2X	3
Columbia	Alder Creek	X								3
Skagit	Baker River							P	3X,6X,7X	1,3
Naches	Bumping/American River			P					1X	2
Quillayute	Bogachiel River							P	3X	1
Columbia	Catherine Creek		X							3
Puget Sound	Chambers Creek						X		2X	3
Grays	Chehalis River							X	3X,4X	1,3
Columbia	Chinook River					X				3
Queets	Clearwater River							P	3X,4X	1
Yakima	Cle Elum River								1X,7P	2
Columbia	Coal Creek		X						2X	3
Columbia	Collins Creek		X							3
Quinault	Cook Creek								4X	2
Mid. Coast	Copalis River							P	3X,4X	1
Coweeman	Coweeman River		X			X		X		3
Cowlitz	Cowlitz River	P	X			X	X	X	2P	1,3
Columbia	Crooked Creek					X			2X	3
Puget Sound	Deschutes River							X	3X,6X	1,3
Hood Canal	Dewatto River		X					P	2P	1,3
Hood Canal	Dosewallips River			X				P	2P	1,3
Hood Canal	Duckabush River		P			X	P	P	2P	1,2,3
Strait JDF	Dungeness River			X		X		P	2P,5X	1,2,3
Puget Sound	Duwamish-Green Rivers			P				P	2X,3X,6X	1
Lewis	East Fork Lewis River	X	X						2,3	
Columbia	Elochoman River		X			X	X	X	2X	1,3
Strait JDF	Elwha River			X			X	P	2X,5X,7	1,2,3
Columbia	Entiat River	X		P	P		P		1X	1,2,3
Columbia	Germany Creek		X			X			2X	3
Grays	Grays Harbor							X		3
Columbia	Grays River		X			X	X	X	2X	1,3
Puget Sound	Green River							X		3
Columbia	Hamilton Creek		X					X	2X	3
Columbia	Hardy Creek								2X	3
N. Coast	Hoh River							P	3X	1
Puget Sound	Hood Canal								2X	3
Puget Sound	Hood Canal Tributairies							X		3
Grays	Hoquim River							P	3X,4X	1
Grays	Humptulips River							P	3X,4X	1
Wenatchee	Icicle Creek	P							1X	2
Wenatchee	Ingalis Creek	P							1X	2
Columbia	Jim Crow Creek					X			2X	3
Columbia	Kalama River		X			X	X	X		3
Columbia	Klickitat River	X	X	X				P		1,3
Puget Sound	Lake Washington		X							3
Lewis	Lewis River	P	P	P		X	X	X	1X,2X	1,2,3
Strait JDF	Lyre River						X	P		1,3
Columbia	Major Creek	X	X							3
Hood Canal	Mason Lake							P	3X,6X,7	1
Quinault	McCalla Creek								4X	2

Continues

Continued

Basin	Stream	Steelhead Trout		Salmon				Sea-run Cutthroat Trout	Other[a]	Ref.[b]
				Chinook			Coho			
		Sum	Win	Spr	Sum	Fall				
Columbia	Methow River	X			X		P			1,3
Columbia	Mill Creek		X			X			2X	3
Nooksack	North Fork Nooksack River	P	P	X			P		2P	2,3
Puget Sound	Nisqually River			P				P	2X,3X,6X	1
Nooksack	Nooksack River	X	X	P			X	P	3X,6X	1,3
Willapa	North River							P	3X	1
Ozette	Ozette Lake								7X	1,3
Ozette	Ozette River				X	X	X	P	2X	1,3
Snohomish	Pilchuck River							P	3X,6X	1
Puget Sound	Puyallup River			P		X		X	2P,3X,6X	1,3
N. Coast	Queets River							X	3X,4X	1,3
Mid. Coast	Quinalt River							P	3X,4X	1
Naches	Rattlesnake Creek	P		P					1X	2
Columbia	Rock Creek	X	X					X		3
Willapa	Salmon Creek		X					X	2X	3
Puget Sound	Samish River		X					X	3X,6X	1,3
Chehalis	Satsop River	P		P			P	P	3X,4X	1,2
Columbia	Scappoose Creek		X							3
Skagit	Sauk River	P	P	P			P	P	1X,2,3X,5,6X	1,2
Puget Sound	Skagit River							X	3X,6X	1,3
Columbia	Skamokawa Creek		X			X	P	P	2P	1,3
Hood Canal	Skokomish River		X	X			P	P	2,3X,5X,6X	1,2,3
Chehalis	Skookumchuck River							P	3X,4X	1
Snohomish	Skykomish River	P	P	P				P	1X3X,5,6X	1,2
Puget Sound	Snohomish River			P				X	3X,6X	1,3
Snohomish	Snoqualmie River	X						P	3X,6X	1,3
Nooksack	South Fork Nooksack River	P	P	X			P		2P	2,3
Cowlitz	South Fork Toutle River					X				3
Stilla	Stillagumaish River	X		X				X	3X,6X	1,3
Skagit	Suiattle River	P	P	P			P		1X,2P,5P	2
Hood Canal	Tahuya River		X					P	2,3X,6X	1,3
Yakima	Tieton River								1X	2
Cowlitz	Toutle River		X			X	X	X	2P	1,3
Puget Sound	Tulalip River							X		3
Columbia	Washougal River	X	X			X	X	X	2X	1,3
Columbia	Wenatchee River	X		P			P		1X,7P	1,2,3
Puyallup	White River	P	P	X			P	X	3X,6X	1,2,3
Columbia	White Salmon River	X	X	P		X	P	P	1X	1,2,3
Willapa	Willapa Bay						X		3P	3
Willapa	Willapa River						P	P	3X	1
Columbia	Wind River	X	X					P		1,2,3
Chehalis	Wishkah River							P	3X,4X	1
Columbia	Woodward Creek		X							3
Chehalis	Wynoochee River	P		X				P	3X,4X	1,2,3

X = endangered, threatened, candidate, or species of concern on federal or state list or identified by Nehlsen et al. (1991), or Williams et al.b (1989).
P = stock is present in stream.
Spr = spring   Sum = summer   Win = winter

[a]*Other species:* 1) bull trout, 2) chum salmon, 3) Nooky dace, 4) Olympic mudminnow, 5) pink salmon, 6) Salish sucker, 7) sockeye salmon.
[b]*References:* 1) Frissell, (1991), 2) Johnson et al. (1991), 3) Nehlsen et al. (1991).

Ecology of Other Priority Species

Marbled Murrelet *(Brachyramphus marmoratus)*

Distribution. The marbled murrelet is a seabird that occurs along the Pacific Coast from Alaska to central California throughout the year (Marshall 1988). The species nests in coniferous forests within about 50 miles of the coast in the Pacific Northwest and feeds on the ocean immediately offshore, inland marine waters (i.e., Puget Sound), and freshwater lakes (Carter and Sealy 1986, 1987). Known inland distribution currently decreases north to south, and, to date, the maximum distance the marbled murrelet has been detected inland is 52 miles in the northern Washington Cascades (Cummins pers. comm.), 35 miles in Oregon (Nelson 1990), and 24 miles in California (Paton and Ralph 1988). Inland distribution is now discontinuous in all three states due to loss of nesting habitat (Federal Register 56(119);28363).

Status. In June 1991, the FWS proposed the species for listing as threatened throughout its range in Washington, Oregon, and California, primarily due to the loss of nesting habitat (Federal Register 56(119):28363). At the state and province level, the species currently is listed as endangered in California, sensitive in Oregon and Washington, and threatened in British Columbia. Some legal protection is afforded marbled murrelets in California on state and private lands under the California Forest Practices Act, but not in Oregon or Washington. The California population is considered in danger of extinction because only small isolated populations and habitat remain, and they may be subject to catastrophic disturbances. As a result of the proposed federal listing of the marbled murrelet, the Forest Service and U.S. Bureau of Land Management (BLM) are consulting informally with the FWS on timber sales within 0.5 miles of occupied habitat (Miller pers. comm.).

Current population estimates are 1,650 to 2,000 and 2,000 individuals for California and Oregon, respectively (Sowls et al. 1980, Carter and Erickson 1988, Nelson 1990); and 1,900 to 3,500 breeding pairs in Washington (Speich et al. 1992). Rodway (1990) estimated the population size as 22,500 in British Columbia. Estimates for Alaska range from 50,000 to 250,000 individuals (Mendenhall 1992). The significance of these figures can be put in context with the historical estimate of 60,000 individuals in the California population prior to logging (Larsen 1991). Ninety-six percent of the historical breeding habitat in California is believed to have been eliminated through logging (Larsen 1991). Similar patterns of habitat loss have occurred throughout forests of the west coast. Recent estimates suggest a decline of as high as 83 to 88 percent of historical old-growth habitat (Spies and Franklin 1988, Morrison 1988, Norse 1990).

Natural history and habitat associations. Throughout the species' range, marbled murrelets show a strong dependence on old-growth or mature forests with an old-growth component for nesting (Nelson 1990, Carter and Erickson 1988, Ralph et al. 1990, Paton and Ralph 1988, Hamer 1991). Plant community associations include redwood and Douglas-fir in California, and Douglas-fir, western hemlock, western red cedar, and Sitka spruce in Oregon and Washington. Of 23 nests located to date from Alaska to California, all were in old-growth or mature trees. Nest trees (n=16) averaged 73 inches dbh (range 35 to 106 inches) (Nelson pers. comm.). Nests were primarily on large or deformed limbs with a moss substrate used for nesting. Seventy percent of the inland records of downy young and fledglings compiled by Carter and Sealy (1987) were from old-growth forests and the remainder were located near old-growth. Many additional young and egg remnants have since been located in Washington, all in older forests (Cummins 1991).

In Oregon, Nelson (1990) found that marbled murrelets were most abundant within 12 miles of the coast and decreased significantly from there inland. From stratified random surveys in Oregon, forest stands occupied by marbled murrelets were larger than random sites (Nelson 1990). Larger stands of old-growth in California also had significantly higher numbers of detections of marbled murrelets than smaller stands. The average number of detections also increased as the number of large trees in the stands increased (Paton and Ralph 1988).

In Oregon, stands occupied by marbled murrelets ranged from 25 acres to more than 2,000 acres with a mean of 480 acres. In California the range was 40 to 28,000 acres (Nelson pers. comm.). The relationship between stand size and marbled murrelet productivity is unknown, but smaller stand sizes and greater landscape fragmentation may expose nesting birds to increased predation. Of 21 nests located, in which the nesting outcome was known, 48 percent were lost to predation (Nelson pers. comm.).

In all three states, the remaining habitat is primarily on public lands. In Washington, significant marbled murrelet population numbers are located only in the north Cascades and on Olympic Peninsula, with remnant pockets of suitable habitat located in the southwestern corner of the state, just north of the Columbia River. In Oregon, two-thirds of the remaining population occurs in the central Coast Range in the Siuslaw National Forest and on scattered BLM lands. The remainder of the population is along the southwestern coast in the Siskiyou National Forest. In California, the current population exists primarily in state or federal parks and on private lands along the northern coast and near Santa Cruz in state parks. In California, an estimated 60,000 acres of old-growth forest remain in these areas and another 10,000 acres still exist on private commercial forestlands (Larsen 1991).

Bald Eagle *(Haliaeetus leucocephalus)*

Distribution. Bald eagles occur throughout the North American continent from northern Alaska and Canada to the southern United States and Baja California. Their breeding range includes most of Alaska (except the north slope), southern Canada, the northern United States, and parts of the east and west coasts (Stalmaster 1987). Because they migrate south in the winter to avoid severe winters and shortage of food, their winter distribution is substantially south of their breeding range. Their winter range includes the northwestern and central states and the Alaskan and Canadian seacoasts, where large concentrations occur. Breeding and wintering populations occur along the east coast. The largest breeding populations in the contiguous United States occur in Florida, the Great Lakes states, Chesapeake Bay, and the Pacific Northwest. Winter populations are much more abundant because of the large number of migrants from Alaska and Canada that come to the lower 48 states. Alaska has a wintering population of 35,000 to 45,000, and Washington has the largest winter population in the contiguous states (Stalmaster 1987).

In the Pacific Northwest, the largest populations of breeding eagles occur in the San Juan Islands, Puget Trough, and Olympic Peninsula of Washington; the Klamath Basin and Cascade lakes of Oregon; and Shasta Lake of California. The largest winter concentration occurs in the Klamath Basin of southern Oregon and northern California where more than 1,000 eagles have been counted in one day (Opp pers. comm.). Another large population occurs along the Skagit and Nooksack Rivers in northwestern Washington.

Status. The bald eagle is federally listed as threatened in Washington and Oregon and endangered in California. Breeding populations have been increasing in the Pacific Northwest during the last 15 years as a result of the banning of the pesticide DDT (Henny and Anthony 1989), and winter populations have remained stable or have increased during this time. As of 1990, there were approximately 530, 210, and 108 nesting territories in the states of Washington, Oregon, and California, respectively. Of those nesting territories, approximately 70 percent are on federal lands, and the remainder are on state and private lands in Oregon and California. Conversely, about 60 percent of the nesting territories are on state and private lands in Washington. More than 95 percent of the nesting territories in the three states are within the range of the northern spotted owl. There are 130, 76, and 6 known communal roosts in Washington, Oregon, and California, respectively. More than 95 percent of the communal roosts also are within the range of the owl in Washington and California, whereas less than 10 percent of the roosts in Oregon are within the range of the owl.

Natural history and habitat associations. The bald eagle is the only member of the fish-eating eagle group in North America. It is free ranging for much of its life except in southern or coastal areas where eagles form resident breeding populations throughout the year. The bald eagle forages over water throughout most of its range and for most parts of the year, so its prey is derived from nonforested habitats. Prey consists primarily of fish during the breeding season and waterfowl or carrion during the winter (Stalmaster 1987). However, eagles nest and roost communally in forested habitats throughout their geographic range. Selection of areas for nesting and communal roosting is predominantly in coniferous forests that contain some component of older forests, and these areas are considered essential habitat features for the species (Keister and Anthony 1983, Anthony and Isaacs 1989). The Pacific bald eagle recovery plan (USDI 1986) recognizes the importance of nesting and roosting areas, and it is important to manage these two habitats properly, because timber harvest can have an adverse impact on them.

Present threats to bald eagle populations include illegal shooting, pesticides, human disturbance of foraging and nesting areas, and habitat destruction. The effects of pesticides have decreased since the banning of DDT, but there is still low reproductive success of breeding pairs on the lower Columbia River, which is associated with high levels of DDE and PCBs (Anthony et al. 1993). The increase in human populations and amount of leisure time for recreation has resulted in an increase in human-eagle interactions, and human disturbance has been reported to have effects on nesting (Anthony and Isaacs 1989) and foraging populations (McGarigal et al. 1991, Stalmaster 1987:161). This threat may become more important over time. Habitat destruction is a problem primarily on nonfederal lands where only nest trees and small, surrounding stands of trees are reserved from logging. These nest trees and stands are highly vulnerable to windthrow and other natural mortality.

Northern Goshawk *(Accipiter gentilis)*

Distribution. The northern goshawk inhabits coniferous and deciduous forests in temperate and subarctic regions of the northern hemisphere. In North America, goshawks are known to breed as far south as the Appalachian Mountains in the Southeast and throughout the Rocky Mountains into Mexico. In the western United States, the species nests as far south as the Sierra Nevada of California and the Kaibab Plateau of northern Arizona (Reynolds 1989). The goshawk is an uncommon resident in California. Nesting goshawks have been recorded as far south as Tulare County in the Sierra Nevada, and in the Coast Range to Mendocino County (Grinnell and Miller 1944). Summer sightings of goshawks near Mt. Pinos and in the San Jacinto Mountains suggest that isolated breeding populations may have persisted up to the 1970s.

In Oregon, nesting northern goshawks have been located in the Cascade, Klamath, Ochoco, and Blue Mountains, and smaller ranges in eastern Oregon. Although goshawks are not known to nest in the central or northern portions of the Oregon Coast Range, nests have been located in the Siskiyou Mountains in southwestern Oregon (Marshall 1991). Goshawks breed in all of Washington's forested montane areas, including the Olympic Peninsula, the entire Cascade Range, the Blue and Okanogan Mountains, and the Selkirk Mountains (Jewett et al. 1953).

Status. Northern goshawks historically nested throughout the forested regions of temperate North America. By the 1930s however, breeding populations in the eastern United States were much reduced (Bent 1937). The status of the northern goshawk is not well known for much of the western United States. Most authors believe that the species has declined substantially since the turn of the century, primarily as a result of habitat loss attributed to intensive timber harvest. Bloom et al. (1985) estimated that goshawk populations in California had decreased by 30 percent from historic levels by 1985, with continuing declines of approximately 1 percent per year. Mannan and Meslow (1984) speculated that goshawks could be extirpated from northeastern Oregon forests under timber management regimes that resulted in the liquidation of most of the old-growth forest in the area. Patla (1991) documented an 80 percent decrease in occupancy rates for goshawks in habitat adjacent to timber sales, despite the establishment of buffers around the immediate nest sites. Buffers apparently were unsuccessful in Arizona as well, as Crocker-Bedford (1990) suggested declines of as much as 90 percent in nest occupancy and productivity for an isolated population in northern Arizona.

The northern goshawk is classified as "critical" on the Oregon sensitive species list. "Critical" indicates a species for which listing is pending or for which listing may be appropriate if immediate conservation actions are not taken (Oregon Department Fish and Wildlife 1991). The states of Washington and California also list the northern goshawk as a candidate for state listing and a sensitive species, respectively (Washington Department Wildlife 1991b, California Department of Fish and Game 1990). In July 1991, a petition was filed with the FWS for emergency listing of an isolated population of northern goshawks in the southwestern United States. More recently, the species has been petitioned for listing throughout the western United States. The goshawk is a management indicator species for old-growth dependent species in the Deschutes, Fremont, Wallowa-Whitman, and Winema National Forests in Oregon, and in the Inyo, Klamath, Six Rivers, and Shasta-Trinity National Forests in California.

Natural history and habitat associations. Northern goshawks may be found in deciduous and coniferous forest types, where they typically select nest sites in dense, multistoried mature to old-growth forests with high canopy closure and poorly developed understories. Nest trees tend to be significantly larger in diameter than those of the surrounding stand; nest stands, in turn, often are more dense and include larger diameter stems than adjacent forest stands (Buchanan 1991, Fleming 1987). Snags, stumps, and down logs are important as plucking perches, which are generally located within 55 yards of the nest. This general characterization holds for northern goshawk nests from the Olympic Peninsula (Fleming 1987), south to California and northern Arizona (Austin 1989, Reynolds 1989, Hall 1984), and east into the northern Rocky Mountains (Hayward et al. 1990).

Ongoing research and decades of nest records and incidental sightings indicate that northern goshawks in western North America find optimal habitat in mature and old-growth coniferous forests. The vertical and horizontal structure of older forests contributes to accessible prey and nest sites (trees) substantial enough to support the bulky stick nest. The strength of the association may vary. In Oregon, all but one of 74 nests located by Reynolds and Wight (1978) were situated in dense mature or old-growth stands. Loss of breeding and wintering habitat resulting from harvest of old-growth, reproductive failure, and human disturbance were the primary limiting factors for goshawks (Reynolds

1989). The liquidation of older forests and increasing fragmentation of suitable habitat are probably the most significant threats to northern goshawks. However, little is known about the ecology and habitat relationships of the species in western Oregon and Washington.

Gray Wolf *(Canis lupus)*

Distribution. Wolves formerly occurred throughout the Northern Hemisphere above 20 degrees north latitude in all habitats except deserts. Now they are restricted to the northern portions of North America (primarily Alaska, Canada, and states bordering Canada), eastern Europe, the Soviet Union, China, and northern India. Remnant populations occur in western Europe and Scandinavia and some may remain in Mexico (Mech 1974). Historically, wolves ranged over all of Washington, Oregon, and California. The wolf was extirpated from Washington by the early 1900s and current sightings suggest it has reestablished itself in the mountainous areas of northern Washington (Hansen 1986).

Status. The gray wolf is federally listed as endangered and is listed as endangered by the state of Washington. It has been extirpated in Oregon and California but some individuals (either pure wolf strains or wolf-dog crosses) may exist in the Siskiyou Mountains of southwestern Oregon. Three breeding occurrences (dens) of gray wolves were documented in the north Cascade Mountains of Washington during the spring and summer of 1990: wolf pups and adults were seen or heard in the North Cascades National Park Service Complex, in the Okanogan National Forest, and in the Wenatchee National Forest. Two of the breeding observations of wolves are near spotted owl habitat conservation areas as proposed by Thomas et al. (1990). These breeding occurrences and reports of individual wolves in the Cascade Mountains, Okanogan Highlands, and Selkirk Mountains probably indicate a southern range extension of gray wolf populations from British Columbia.

Natural history and habitat associations. Forested and open habitats supporting ungulate populations are the primary requirements of the gray wolf. Areas that support small mammal populations may be seasonally important for wolves. Gray wolf populations are typically organized into social packs of 2 to 20 individuals. Each pack usually comprises a mated pair and their offspring from several generations. Since each pack consists of several animals, habitat management must consider the food requirements of a large number of wolves, rather than isolated individuals. Wolf pack territories may range in size from 40 to 1,000 square miles. These territories must provide adequate year-round prey (ungulates and small mammals) and secure den sites for birth and raising pups. Dens usually are located in a slightly elevated area of soft soil that provides a dry, easily excavated site. Den sites often receive traditional use and usually are secluded, but occasionally are located near human activity. Rendezvous sites are used for raising pups and are located within 1 to 5 miles of the den in an open area near water. Wolves are particularly sensitive to human activity near den and rendezvous sites (USDI 1987).

Human-induced mortality is the major limiting factor affecting the survival of the gray wolf throughout most of its range. Wolf predation on livestock can cause conflicts with humans, and misconceptions about wolves often lead to indiscriminate shooting. In the absence of human-induced mortality, year-round prey availability is the most significant limiting factor affecting the survival of individual wolves, packs, and local wolf populations (USDI 1987). Although wolves are not particularly associated with older forests, they may benefit from DCAs if the areas remain roadless and free from human disturbance.

Grizzly Bear *(Ursus arctos)*

Distribution. The historic range of the grizzly bear included western North America, roughly from the Mississippi River and Canadian Great Plains west to the Pacific Ocean and from Alaska and the Northwest Territories south to central Mexico. The current range is from the Rocky Mountains' east front in Canada, Montana, and Wyoming to the Pacific Ocean and from Alaska and the Northwest Territories south to portions of Washington, Idaho, Montana, Wyoming, and perhaps Colorado. Current grizzly bear range is less than 2 percent of the historic range in the lower 48 States, and populations total less than 1,000 (USDI 1990). Although the north Cascade and Selkirk Mountains are recognized as grizzly bear ecosystems in the grizzly bear recovery plan, bears may occur in the Okanogan Highlands and Kettle Range as well (Almack pers. comm.). The remote areas occupied by grizzly bears are primarily on federal lands. The Selkirk Mountains ecosystem is designated as a recovery area and the north Cascade Mountains are being evaluated to determine if it is capable of supporting a viable population of grizzly bears. In one 5-year study, four sets of confirmed grizzly bear tracks were found in the north Cascade Mountains of Washington. One grizzly bear skull and a food cache also were found. Washington Department of Wildlife biologists evaluated 128 reports of grizzly bear observations in the north Cascade Mountains. These observations, combined with other incidental sightings, indicate that there is a small, resident population of grizzly bears in the north Cascade Mountains. A technical review team will determine the capability of the north Cascade Mountains to support a viable population of grizzly bears and the FWS will decide whether to designate this area as a recovery zone (Washington Department Wildlife 1990).

Status. The grizzly bear is federally listed as threatened and state listed as endangered in Washington. It is extirpated in Oregon and California. A petition was submitted to the FWS in 1990 to have the grizzly bear in the north Cascade Mountains listed as an endangered, rather than a threatened species. The FWS found the petition was substantive and undertook a review of the bear's status; a finding was made that changing the listing was warranted but that other work precludes any action at this time. Further review is required.

Natural History and Habitat Associations. Grizzly bears remain only in vast, diverse, and remote mountainous habitat. They require a variety of vegetation types for food and for breeding, bedding, and denning activities. These habitats include open areas such as lowland wet meadows and marshes, shrub fields located in avalanche chutes, high-elevation sedge or heath meadows, and stream floodplains. Forest is used for resting and hiding cover. The importance of these habitats to bears varies during the year, and often is determined by the availability of seasonally important foods. Plant materials, including succulent grasses, sedges, forbs, and fruits; fishes; and large mammals are major components of the diet. Carrion, insects, and small mammals such as ground squirrels also are consumed. Grizzly bears usually prepare winter dens in excavated chambers or natural caves located above 5,000 feet on slopes with deep snow. Den sites must have well-drained soil and must be isolated from humans and other animals (Almack 1985).

Human-induced mortality is the major limiting factor restricting grizzly bear populations south of Canada. Availability of seasonally important habitats may be critical to the survival of specific grizzly bear populations. Grizzly bears require large tracts of suitable habitat that are managed to minimize conflicts with humans (USDI 1990). Grizzly bears, like wolves, are not dependent on old-growth forests, but they may benefit from DCAs that remain roadless and free from human disturbance.

Fisher *(Martes pennanti)*

Distribution. The range of the fisher (a small mammalian carnivore) extends south from the forests of central and southeastern Canada to New England and the Great Lakes states in the East and from British Columbia to western Montana and the Sierra Nevada mountains of California in the West (Arthur et al. 1989, Strickland et al. 1982). Prior to European settlement, the fisher occupied all densely forested areas of Washington, with the most dense populations located on the Olympic Peninsula (Aubry pers. comm.). Although rare, the fisher still occurs in the Cascade Mountains, Okanogan Highlands, and on the Olympic Peninsula (Aubry pers. comm.). At one time, the fisher probably was present in all Oregon counties where coniferous forests occurred. Today, the species is known to inhabit forested portions of the Cascade, Klamath, Siskiyou, and Blue Mountains (Marshall 1992). There are few recent reports from the Coast Range, although a fisher sighting was reported from the Hebo Ranger District, Lincoln County, in 1991. The range of the fisher in northwestern California extends from the Oregon border south to Lake and Sonoma Counties. In eastern California, the species has been found near Clear Lake in Lassen County, and as far south as Greenhorn Mountain, Kern County. Fishers range from near sea level in the low coastal areas to above 11,000 feet in the Sierra Nevada (California Department Fish and Game 1986).

Status. A petition was filed with the FWS in 1990 to list the fisher as a threatened species in California, Oregon, and Washington. The petition was denied, based on the inconclusive nature of the information provided. An interagency working group was formed to facilitate sharing new information about fishers, and the FWS included the fisher among its candidate species in 1991. During the last decade, sightings of fishers were recorded in Mt. Rainier, Olympic, and North Cascades National Parks in Washington, but no formal surveys were conducted. Ongoing investigations in Olympic National Park indicate that the fisher may have been extirpated from the Olympic Peninsula as a result of extensive habitat alteration (Aubry pers. comm.). The fisher is a candidate species for listing as threatened or endangered in Washington.

Trapping and incidental loss caused by nontarget strychnine poisoning (from wolf and coyote baits) resulted in declines in Oregon fisher populations by the 1930s (Irwin 1987). Trapping for fishers has been prohibited in Oregon since 1937, but after more than 50 years, populations do not seem to have recovered (Marshall 1992). In 1961, 24 fishers were transplanted from British Columbia to Klamath and Union Counties. No post-release monitoring was conducted, and the status of any resulting fisher population is unknown (Marshall 1992). Incidental sightings in the Cascade, Siskiyou, and Coast Range Mountains continue to be reported, but no standardized surveys have been undertaken to assess population status at the state level (Marshall 1992). The fisher is listed as a sensitive species in Oregon and California. Schempf and White (1977) suggested that fishers were relatively common in the northern coastal mountains of California, but were uncommon or rare in the Sierra Nevada.

Natural history and habitat associations. Fishers inhabit coniferous and mixed-coniferous/deciduous forests. Dense, mature to old-growth forests are preferred during summer for cover and den sites (Jones 1991, Marshall 1992, Washington Department Wildlife 1991b). In Idaho, stands used by fishers during the breeding season had more snags, logs, and large-diameter trees relative to all available habitat. Stands of pole-sized or smaller trees were avoided, as were open, drier habitats. Jones (1991) reported a preference for forested riparian habitats. Fishers in California selected coniferous forests with a hardwood component for summer habitat (Marshall 1992).

Several authors suggest that fishers select habitats with a high degree of overhead cover and avoid large openings (Strickland et al. 1982, Marshall 1992). In Maine, where population densities are quite high in comparison to populations in the western states, fishers are tolerant of low-density rural development and will cross roads and farm fields to travel in forested stands. Summer resting sites may be situated in hollow snags, under logs, brush piles, or root wads. Maternal dens usually are situated high in a hollow snag.

Fishers may use a wider variety of habitats during winter than in summer. Forest structure and prey availability are probably the critical factors in the selection of winter habitat. Jones (1991) found that old-growth stands were important winter habitats for fishers in Idaho, but second-growth stands also were used. Fishers select stands with large remnant trees and/or logs that have survived earlier fires in second-growth. Fishers appeared to select forested riparian areas in winter as well as in summer. Allen (1983) concluded that stands having a high degree of coniferous tree canopy closure provided optimal winter habitat. Jones (1991) found no indication that snow conditions influenced winter habitat use by fishers; other authors suggest that fishers may move to lower elevations to avoid deep snow or to find prey (Marshall 1992).

Small to medium-sized mammals, birds, and carrion dominate the diet of the fisher; however vegetation, molluscs, and other invertebrates also have been identified from digestive tracts (Jones 1991, Arthur et al. 1989). Porcupines are a major prey species wherever they occur within the range of the fisher (Strickland et al. 1982). Red-backed voles and flying squirrels are important prey for the fisher in Idaho and Oregon (Ingram 1973). Grenfell and Fasenfest (1979) found false truffles (*Rhizopogon*) to be an important food of fishers in northern California. Fishers may be common locally in parts of northern California and Maine (California Fish and Game 1986, Arthur 1987); otherwise the species occurs at low densities.

Most authors concur that mature and old-growth forests are important habitats for fishers. While some believe fishers require large contiguous stands of old-growth (Marshall 1992, Washington Department Wildlife 1991b), others emphasize an apparent selection for habitat diversity within the home range (Strickland et al. 1982). Given the large home ranges of fishers, these two views may not be contradictory.

Marten *(Martes americana)*

Distribution. The marten (a small mammalian carnivore) inhabits the boreal forests of North America from Canada and Alaska south to California, Idaho, western Montana, Colorado, Utah, and New Mexico in the West, and the Great Lakes states and northern New England in the East. Historically, the species was common throughout the northeastern United States and most of Canada. Loss of habitat compounded by commercial trapping resulted in the extirpation of martens in most of New England and portions of southeastern Canada by the 1930s (Clark et al. 1987, deVos 1964).

Martens have been recorded from most of the mountainous areas of Washington including the Blue, Cascade, Olympic, and Selkirk Mountains; the Okanogan Highlands; the coastal ranges; and Vancouver Island. Populations are most dense in the Cascade and Selkirk Mountains, and Okanogan Highlands (Washington Department Wildlife 1991b). All of the major mountain ranges in Oregon at one time supported marten populations. The species now occurs primarily in the Cascade, Siskiyou, Wallowa, and Blue Mountains; a few recent records also exist for the Coast Range and the Fremont National Forest in southeastern Oregon (Marshall 1992). *Martes americana humboldtensis* occurs in the coastal coniferous forests of California from Sonoma County north into southwestern Oregon, where it inhabits areas from sea level to more than 4,000 feet in elevation (Grinnell et al. 1937).

Status. In Washington and Oregon, martens are trapped commercially despite their status as sensitive species. Designation as a "priority species" in Washington is aimed at providing guidance for habitat retention and enhancement (Washington Department Wildlife 1991b). Marshall (1992) speculated that the marten in Oregon has declined in numbers in the Coast Range, and viable populations no longer may exist there. Martens probably are most abundant in Oregon in the central and southern Cascade Mountains and in the Blue Mountains. The *M.a. humboldtensis* subspecies is listed as sensitive in California. There, as in other parts of its range, the marten may be vulnerable to over-trapping (Clark et al. 1987).

Natural history and habitat associations. The marten is a management indicator species for old-growth habitats in several national forests in California and most national forests in Oregon and Washington. Martens are known to use a variety of coniferous forest types, and optimal habitat appears to be moist subalpine fir communities more than 100 years old (Koehler et al. 1975). In the Pacific Northwest, martens select dense, mature or old-growth coniferous forests that have abundant snags and down woody debris (Buskirk 1984, Irwin 1987, Hargis and McCullough 1984, Spencer 1981). Martens apparently avoid large open areas within their territories. Hargis (1981) noted that martens would cross but not hunt in small openings during winter. In northern California, martens avoided open areas during all seasons, rarely venturing more than 10 yards into open meadows (Spencer 1981, Spencer et al. 1983). Martens may avoid openings during winter if a combination of deep snow and lack of exposed logs and stumps deny access to prey beneath the snow (Hargis and McCullough 1984, Koehler et al. 1975). Avoidance of openings also may be a defense against aerial predators such as golden eagles and great horned owls (Raine 1982, Hargis and McCullough 1984).

Hargis (1981), Spencer (1981), and Jones and Raphael (1991) documented the marten's affinity for riparian habitats, which are important for abundant food and dense cover. In California, Spencer (1981) found riparian areas were heavily used for foraging, while Jones and Raphael (1991) reported more resting sites in streamside plant communities than in upland plant communities in Washington. Summer resting sites were located in live trees, snags, slash piles, and hollow logs. Where these components are limited, rock slides or the tree canopy may suffice (Irwin 1987, Jones and Raphael 1991). Large old trees, snags, and large hollow logs are also important as den sites. Down woody material, an important component of marten habitat, is especially critical in winter for energy conservation and access to prey. In the central Rocky Mountains, Buskirk et al. (1989) found that martens selected partially decayed stumps and logs as resting sites. They suggested that decomposing wood provided much more effective insulation than snow, allowing martens to conserve energy. Because martens do not hibernate or store large amounts of fat before the onset of winter (Washington Department Wildlife 1991b), maintenance of a positive energy balance is critical to overwinter survival. Stumps, logs, tree wells, and slash piles also provide access to prey under snow cover. Although martens are capable of digging through snow to capture prey, use of woody debris to reach prey is probably energetically less costly (Hargis and McCullough 1984).

Home range size of martens varies with population density, food abundance, and sex (Buskirk et al. 1989, Clark et al. 1987). Martens are opportunistic foragers that will feed on a wide variety of small mammals, birds, reptiles, invertebrates, and plants depending on availability. In Oregon, red-backed voles, flying squirrels, and Douglas' squirrels are important winter prey (Irwin 1987, Marshall 1992). Fruits, insects, and birds, which are mostly absent from the winter diet, may comprise a significant proportion of the summer diet (Irwin 1987). The close association of martens with mature and old-growth coniferous forests has been confirmed in numerous investigations (Irwin 1987, Jones and Raphael 1991, Hargis 1981, Koehler et al. 1975). High canopy closure and abundant coarse woody debris are the two most important components of marten habitat provided by old-growth forests. Forest cover and large woody debris are critical in winter, when they provide cover from predators and insulation from harsh winter conditions. Loss of habitat and timber harvest are the primary limiting factors for marten populations in the Pacific Northwest (Irwin 1987, Marshall 1992, Washington Department Wildlife 1991b). Clear-cutting and stand-replacing fires have significantly reduced the amount of mature and old-growth habitat available. Over-harvesting of martens by commercial trapping is a major concern in California (Grinnell et al. 1937, Gould pers. comm.) and also may be a problem in Washington, where martens are concurrently listed as "game" and as "sensitive." Marten trapping continues in Oregon, but to a limited degree (Irwin 1987).

Amphibians

The committee solicited an account of the ecology of amphibians and reptiles (Beatty et al. 1991) in the course of its examination of other species. The following is extracted from that report.

Twenty-three species or species groups of amphibians and reptiles were identified whose ranges overlap with the distribution of the northern spotted owl and whose ecological requirements appear to be linked with the remaining distribution of older forest ecosystems in the Pacific Northwest. These species represent approximately 40 percent of the extant amphibians and reptiles in the region (Nussbaum et al. 1983, Stebbins 1985). Within this group of animals, eight were designated as priority species by the committee. They are the Olympic salamander (four species), Oregon slender salamander, Pacific giant salamander, Cope's giant salamander, Del Norte salamander, Larch Mountain salamander, Siskiyou Mountain salamander, and tailed frog.

The reasons for selecting these animals as a subset of the 23 species or species groups center on at least two characteristics they share. One is their relatively limited distribution. (Figures D.2 - D.4) The other is their apparently narrow ecological requirements in comparison with close relatives. Distributions are fairly well worked out for most of these animals, but more field work may reveal new populations in what most herpetologists would consider novel habitats. Examples of this finding include the discovery of Larch Mountain salamanders in the central Cascade Mountains of Washington (Aubry et al. 1987) and the Oregon slender salamander east of the Cascade crest (Kirk and Forbes 1991). A related point is that not much is known about the precise ecological requirements of many of these species. Research indicates that amphibian populations may be a significant component, and may play an important functional role in ecosystems, especially with respect to energy flow through the systems.

One of the important characteristics of these animals' biology is the genetic structure of their populations. Evidence indicates that, at least for salamanders, there is considerable genetic differentiation among populations (Wake and Yanev 1986; Good 1989). The results of these studies indicate that each population of these animals is genetically unique and that when one population is extirpated, a portion of the genetic diversity within the species in question is lost and probably is not recoverable. This information, coupled with the concerns raised by Blaustein and Wake (1990) with respect to recent global declines in many amphibian populations, calls for careful consideration of the impacts of management practices on populations of these animals.

Del Norte Salamander *(Plethodon elongatus)*

Distribution and habitat. The Del Norte salamander occurs in humid coastal forests from near Port Orford, Curry County, and Powers, Coos County, Oregon; to near Orick, Humboldt County, California, and inland to near Salyer, Trinity County, and Seiad Valley, Siskiyou County, California, from sea level to around 3,900 feet (Stebbins 1985). It is often found in rock rubble of old riverbeds, road fills, outcrops, and moss-covered talus. It generally occurs in drier situations than the Dunn's salamander (*Plethodon dunni*). Stebbins (1985) and Herrington (1988) found that the Del Norte salamander occurred almost entirely in forested talus areas. Using time-constrained search methods, Raphael (1988) found the species present in all six of his forest seral stages but most abundant in mature and old-growth timber. Abundance seemed correlated with a hardwood understory. Welsh and Lind (1988) found this species to have a higher abundance in older forest stands and a lower relative abundance in drier stands. Welsh (1990) considered the Del Norte salamander (along with the Olympic salamander and the tailed frog) to be a species long associated with elements of the arcto-tertiary forest.

Ecology and management. Welsh (1990) stated that the close association of the Del Norte salamander with old-growth forests probably is due to the presence of microhabitat and microclimate factors that occur there, and that the species has evolved with habitats existing only in these forests. The species retreats to deeper crevices in talus during hot, dry, or cold periods, but may occur under surface objects during warm, wet weather (Beatty pers. obser.). The Del Norte salamander has a fairly limited distribution in southwestern Oregon and northwestern California. Within its range, it most often occurs in moist (not wet) situations, usually associated with talus or rock outcrops in older forests. Raphael (1988) estimated that removal of old-growth fir forest within its range would result in a 75 percent population reduction. Because of its restricted range and association with older forests, no timber harvest should be considered in conservation areas where this species occurs.

Siskiyou Mountain Salamander *(Plethodon stormi)*

Distribution and habitat. The Siskiyou Mountain salamander occurs in Jackson County, Oregon, and northern Siskiyou County, California. It is not sympatric with any other *Plethodon*, but occurs within 9 miles of *P. elongatus* (Brodie 1971). Populations of *P. stormi* are associated closely with talus deposits and fissured rock outcrops. Individuals occasionally may be found under coarse woody debris, but only during the wettest weather and always near talus. Populations are densest on heavily wooded, north-facing slopes with talus (Nussbaum et al. 1983).

Ecology and management. Soil temperatures where *P. stormi* have been collected during daytime were 3.5° to 11.3°C. Individuals are closest to the surface during spring (March to April) and fall (September to early November). However, even in dry summer weather, some may come to the surface to feed at night. They usually lie with their heads near the opening of their shelter and dart forward to snap up small invertebrates. During wet weather, they may crawl over the surface of a talus slope (Nussbaum et al. 1983).

Larch Mountain Salamander *(Plethodon larselli)*

Distribution and habitat. The Larch Mountain salamander has a very restricted range (Herrington and Larsen 1985). It is found only along a 35-mile stretch of the Columbia River Gorge in Washington and Oregon and in other locations in southern Washington (Aubry et al. 1987). It appears to have narrow habitat requirements in stabilized talus ranging in size from one-third to 2 inches with soil deposits in the spaces. No data exist regarding population dynamics of this species. The animals behave as most plethodontid salamanders do; they are active at or near the surface whenever temperature and moisture regimes permit, which could be any day of the year in the Columbia River Gorge (Herrington and Larson 1985, 1987).

Herrington and Larsen (1985) cited one example of a dependent relationship between this salamander and old-growth forests. One of their sites (Mabee Mines Road in Skamania County, Washington) was comprised of two talus slopes separated by a creek. One talus slope had been clear-cut 10 years before their study and no *P. larselli* were found in the clearing. The talus slope directly across the creek from the cut slope contained a population of Larch Mountain salamanders.

Ecology and management. Herrington and Larson (1985) stated that the Columbia River Gorge is a geographic area with many potential uses, many of which could affect populations of these salamanders. Any land-use practice that alters moisture regimes in suitable stabilized talus slopes may cause extirpation of populations of *P. larselli*. Logging, harvesting talus for road building, and housing developments may affect this species adversely, but these effects are not well documented.

The Larch Mountain salamander has an extremely limited range and narrow habitat requirements. The species appears to be an old-growth obligate within most areas of its range (Beatty et al. 1991). Based upon the preceding two points and other factors, Herrington and Larson (1985) recommended that this species be listed as threatened, despite their discovery of new populations in Washington. Clearly, this is an animal of special concern. Based on personal observations by Beatty pers. comm.), it appears that this species must have protection of some kind (in terms of habitat preservation) if viable populations are to be retained. Every effort should be made to provide stabilized talus areas in older forests within its range.

Oregon Slender Salamander *(Batrachoseps wrighti)*

Distribution and habitat. The Oregon slender salamander occurs only in Oregon along the forested west slopes of the Cascade Mountains from the Columbia River south to southern Lane County and ranges in elevation from about 50 feet in the Columbia River Gorge to near 4,300 feet in the Cascade Mountains. The species recently has been collected in Wasco County, Oregon, extending its distribution east of the Cascade crest (Nussbaum et al. 1983, Stebbins 1985, Kirk 1991).

The Oregon slender salamander appears to be most common in mature Douglas-fir forests on west slopes of the Cascade Mountains, but it also occurs in second-growth forest, and in fairly recent lava flows a few miles west of Santiam Pass, Linn County. It is seldom found in clear-cuts, but has been collected under surface debris in open, second-growth forests during a damp spring. The species also is found under the bark of decaying Douglas-fir logs or deep within such logs (Nussbaum et al. 1983, Storm pers. obser.). It also frequents moist woods of Douglas-fir, maple, hemlock, and red cedar (Stebbins 1985). In late spring and summer, it retreats to underground refugia (Nussbaum et al. 1983).

Bury and Corn (1988a) found *B. wrighti* in damp to wet old-growth, in mature forest, and in clear-cuts. Within these areas, they found 62.3 percent of the Oregon slender salamanders inside logs and 87 percent in or near logs. They stated, "The Oregon slender salamander seems to be associated with coarse woody debris in older decay classes, which is a characteristic feature of old-growth forests." Herrington (1988) observed *B. wrighti* in talus habitats more often than in other areas. This species was included in a list of species that he believed were capable of carrying out their entire life cycle within talus habitats.

Ecology and Management. Substrate temperatures where salamanders were found in May varied from 10.8° to 13.8° C (Nussbaum et al. 1983). Stebbins (1951) presented details of his collection sites, indicating microhabitat preferences. Individuals of this species often are found clumped, with two or more being together under the same object. When disturbed, they usually coil their bodies like a watchspring and if further disturbed, flip about violently by coiling and uncoiling their bodies. If seized by the tail, *B. wrighti* can shed it at any segment. Near Hidden Lake, Lane County, Oregon, 13 percent of the adult salamanders lacked tails or were regenerating them (Nussbaum et al. 1983, Stebbins 1951).

The Oregon slender salamander is endemic to the forested west slopes of the Cascade Mountains north of southern Lane County, Oregon. Studies have shown it to prefer older forests and to use, with frequency, large decaying logs typical of such forests. Further studies of precise ecological requirements are needed, but it seems obvious that harvesting older forests is likely to affect populations of this species (Beatty et al. 1991). Therefore, older forest preserves would benefit this species.

Giant Salamanders *(Dicamptodon* spp.*)*

Since all Dicamptodon salamanders share similar habitat requirements and reproductive biology, they will be discussed as a single entity, except where appropriate. These animals are probably the largest terrestrial caudate amphibians.

Detailed historical descriptions of the genus and *D. ensatus* are provided by Anderson (1969) and Nussbaum (1976). Nussbaum (1970) described the first cryptic species (*D. copei*) within the genus, and Good (1989) detailed the biochemical evidence he used to describe additional enigmatic taxa within *D. ensatus*. Electrophoretic studies (Daugherty et al. 1983, Good 1989) indicate that there may be biologically significant levels of genetic discontinuity between groups of populations throughout the range. Moreover, the observed heterogeneity among the groups is consistent with that which is used to differentiate species. These scientists have elected to split *D. ensatus* into a group of three cryptic species, two of which are within the range of the northern spotted owl (*D. copei* and *D. tenebrosus*). This adds new responsibilities to the construction of any management plan for this array of salamanders.

Distribution and habitat. Disjunct populations inhabiting the Rocky Mountains of Idaho and Montana (see range map) have been designated *D. aterrimus* by Good (1989) and Daugherty et al. (1983). Populations of concern to this report are found in northwestern California, Oregon, Washington, and extreme southwestern British Columbia. Good's (1989) *D. ensatus* is found in the San Francisco Bay area, his *D. tenebrosus* from lower Sonoma County, California, through southwestern British Columbia. Nussbaum's (1970) *D. copei* is found in the Columbia River Gorge (both Oregon and Washington sides), the Olympic Peninsula, the Willapa Hills, and the southeastern Washington Cascade Mountains (Figure D.5).

Adults are common in many areas, but they are nocturnal and secretive. They can be found in moist coniferous forests under bark, logs, and rocks, and wandering about on the forest floor (Beatty et al. 1991). During the breeding season they can be found in or near streams and are also resident in talus slopes associated with road cuts throughout most of their range (Nussbaum et al. 1983, Stebbins 1985, Beatty et al. pers. obser.). Gomez (1992) found Pacific giant salamanders to be most abundant in riparian areas of mature and old-growth forests as compared to upland sites and young and deciduous forests.

Ecology and management. Larval giant salamanders feed upon a wide variety of aquatic invertebrates and vertebrates (fish, tadpoles, and conspecifics). Predators on larval forms include fishes, weasels, water shrews, and other giant salamanders. Metamorphic individuals have a reputation for being voracious predators. Stomach analyses have showed that they eat terrestrial invertebrates as well as many kinds of vertebrates (snakes, shrews, and birds) (Metter 1963, Nussbaum et al. 1983, Stebbins 1985).

The effects of logging on stream amphibians has been examined by Corn and Bury (1989). They were able to compare densities of salamanders in logged versus unlogged reaches of streams in areas where stream gradients were high and low. The major effects of logging on habitats of these salamanders seems most severe on low-gradient reaches of streams that have been disturbed by timber harvest. Disturbance adjacent to lower-gradient areas in the stream or along the banks of higher-gradient riparian areas allows the deposition of sediment, which fills cracks and crevices in lower reaches, making the habitat unsuitable. A second effect, which is limited to clear-cut areas on higher gradient streams, is the enhancement of population densities due to increased primary and herbivore production from the of the canopy (Hawkins et al. 1983). This may be a short-term improvement as no long-term published studies dealing with population dynamics exist.

Olympic Salamanders *(Rhyacotriton* spp.*)*

Range and habitat. This group of species is the sole member of the subfamily Rhyacotritoninae and ranges from the Olympic Peninsula of northwestern Washington southward to Mendocino, California, in humid coastal forests, entirely west of the Cascade crest (Anderson 1969; Figure D.4). This group is comprised of four different species which has been revised by Good and his coworkers.

These salamanders are found in and near small, rapidly flowing, well-shaded and permanent streams with clear, cold (usually 6° to 10° C) water (Stebbins 1951). They are seldom more than 3 feet from free-running water (Nussbaum and Tait 1977). Small cold (8° to 12° C in summer) streams with water seeping through moss-covered gravel are preferred habitats. Larvae occur in small mountain streams, spring heads, and seepages from sea level to about 3,900 feet (Nussbaum et al. 1983).

Ecology and management. Olympic salamanders apparently require fairly low ambient temperatures. Adults may occasionally be found under objects a few feet from water after heavy rains, but this is unusual (Nussbaum et al. 1983). Corn and Bury (1989) compared four species of aquatic amphibians in 23 streams in uncut forests versus those in forests logged 14 to 40 years ago in the central Oregon Coast Range. The density and biomass of the four species (including *Rhyacotriton* spp.) were significantly higher (2 to 7X) in the streams of uncut forests, because streams in logged stands generally possessed smaller substrate material, caused by increased sedimentation. Where *Rhyacotriton* spp. occur in and adjacent to small headwater streams, their existence is threatened by timber harvest (Bury and Corn 1988b).

Rhyacotriton spp. are fairly widespread in the Pacific Northwest and are most likely to occur in or adjacent to higher order, cold streams in forested areas. Because of the requirement for permanently cold water in smaller streams, Olympic salamanders are highly susceptible to forest practices that remove canopy cover and elevate water temperatures (Beatty et al. 1991).

Tailed Frog *(Ascaphus truei)*

Distribution and habitat. Tailed frogs are found west of the Cascade crest from British Columbia to northwestern California. They are also found in extreme northwestern Oregon, southwestern Washington, northern Idaho, and northwestern Montana. Tailed frogs may be found from sea level to over 6,500 feet. They are usually found near or in fast-flowing, permanent streams in forests. The tadpoles of the tailed frog are unique among northwestern larvae because their oral disc is modified into a sucking organ that enables them to cling to rocks in swift current. In the Oregon Coast Range, Gomez (1992) found tailed frogs to be most abundant in riparian areas of mature and old-growth forests as compared to upland sites and young and deciduous forests.

Ecology and management. Adults eat a wide variety of invertebrates including snails, ticks, spiders, mites, and numerous insect species (Nussbaum et al. 1983). Pacific giant salamanders (*Dicamptodon*) are a major predator of *A. truei* tadpoles (Metter 1963, Duellman and Trueb 1986). Populations of *A. truei* may be decimated by natural disasters such as floods that greatly reduce larval populations (Metter 1968).

Ascaphus truei is probably the amphibian most likely to be affected by old-growth habitat loss and habitat destruction. Tailed frogs are closely associated with fast-flowing streams in forested areas and are commonly found within old-growth forests (Bury 1983, Bury and Corn 1988a and 1988b, Raphael 1988, Welsh and Lind 1988, Corn and Bury 1989). Bury (1983) found *A. truei* on undisturbed old-growth sites but found none in logged areas. Bury and Corn (1988b) considered *A. truei* to be "sensitive to timber harvest" and stated that the survival of this species may depend upon protection of cool flowing streams that the species requires for breeding purposes and larval development. In logged stands, tailed frogs are most often found in streams where uncut timber still remains upstream (Corn and Bury 1989). Tailed frogs are likely to be affected by increased water temperature that occurs after clear-cutting (Bury and Corn 1988b).

Because of the extreme philopatry and tendency for *A. truei* populations to be extremely disjunct (Daugherty and Sheldon 1982), recolonization after local extinction may take a relatively long time. Therefore, some populations may not recover from habitat destruction.

Conservation of Other Species and Ecosystems

A primary stated purpose of the Endangered Species Act is " . . . to provide a means whereby the ecosystems upon which endangered species and threatened species depend may be conserved . . . " (section 2(b)). The draft recovery plan was criticized for failure to fully address management actions needed to conserve the late-successional forests upon which the owl and other species depend. The draft recovery plan also was criticized for failure to fully disclose how well the needs of other species would be met. This was linked to a concern that the recovery plan would be portrayed as being sufficient for the conservation needs of other species and late-successional forest ecosystems. The purpose of this section is to discuss the potential effects of the recovery plan on other species and their population viability.

Assessment of the population viability of other species under the recovery plan can be done only in a qualitative way at this point in time, and the Recovery Team has not done an independent assessment of population viability. However, the Forest Service has assessed the viability of other species under each of its alternatives for management of the northern spotted owl (Thomas et al. In Prep.), and members of the Recovery Team participated in that process.

None of the alternatives assessed by the Forest Service was identical to the recovery plan. However, one alternative was the ISC strategy (Thomas et al. 1990) which formed the original basis for the recovery plan. Reviewing the results for this alternative can supply some information about how well the recovery plan would provide for other species associated with late successional forests. Several distinctions between the Forest Service alternative (i.e., the ISC strategy) and the recovery plan should, however, be kept in mind.

The ISC strategy and the recovery plan are based on similar guidelines for 1) sizing and spacing of conservation areas, 2) maintenance of suitable habitat inside conservation areas, and 3) management of the federal matrix for dispersal habitat. However, there are two significant differences between the strategies that could influence the assessment for other species. First, the Forest Service assessed the effects of the ISC strategy on other species only on national forest lands. In contrast, the recovery plan makes recommendations for all federal lands and for some nonfederal lands. Second, the locations of conservation areas were adjusted in the recovery plan to provide greater benefits to other species, particularly marbled murrelets and streams with fish stocks at risk. For these two reasons, assessments of population viability based on the recovery plan could be more positive than the assessments done by the Forest Service for the ISC strategy.

The Forest Service's assessment of population viability of other species was not quantitative, because information about ecology and population dynamics of many of the species was lacking and there was not sufficient time to conduct a quantitative viability assessment. The viability ratings should be interpreted as a qualitative assessment of potential, longer-term effects of implementing habitat management plans for northern spotted owls. They are not quantitative, statistical analyses of species' demographics and populations trends.

The Forest Service's assessment of other species was conducted by several panels of experts who were familiar with specific groups of organisms, particularly plants, birds, mammals, amphibians, and fishes. For more information about the Forest Service's process, methods, rating scheme, participants, and detailed results, see Thomas et al. (In Prep.).

The Forest Service's assessment began with a list of 1,377 species of plants and animals including 214 stocks of fishes (Table D.15). This was reduced to a short list of species that are closely associated with late-successional forests or components of these forests based on published literature or the opinions of the panels of experts. In some cases, the expert panels divided species into distinct geographic "ranges," and these were tallied separately. The final short list included 667 species, species ranges, or stocks. The short list is similar in number and species composition to the list of species considered in the recovery plan and includes 38 species or ranges of birds, 35 mammals, 21 amphibians, 112 fish stocks, 149 invertebrates, 122 vascular plants, and 190 nonvascular plants. The major exception is that the recovery plan includes federally listed species and species that are candidates for listing whereas the Forest Service did not include these species unless they are closely associated with late-successional forests.

The Forest Service's assessment of population viability was conducted on the short list of 667 species, species' ranges, or stocks under each of five alternatives including A) the current forest management plans, B) the ISC strategy (Thomas et al. 1990), C) the ISC strategy plus lands designated as critical habitat by the FWS (USDI 1992), D) the ISC strategy plus all other suitable owl habitat, and E) the multi-resource strategy developed by

Table D.15. Numbers of species, subpopulations, and fish stocks evaluated by the U.S. Forest Service for population viability under the ISC (Thomas et al. 1990) strategy (Alternative B)[a].

Taxon	Long List	Short List	Medium Risk of Extirpation	High Risk of Extirpation
Nonvascular plants	190	190	34	4
Vascular plants	500	122	0	0
Invertebrates[b]	149	149	0	149
Fishes	214	112	112	112
Amphibians	28	21	5	7
Reptiles	10	0	0	0
Birds	119	38	8	1
Mammal	67	35	3	5
Total	**1377**	**667**	**50**	**278**

[a] Information was taken from Thomas et al. (1993).
[b] The Forest Service did not compile a long list of all invertebrates; but focused only on those species clsoely associated with old-growth forests.

the National Forest Products Association and American Forest Council. The population viability of each species, species in portions of their range, or stock of fish were evaluated by a panel of experts on a qualitative scale as high, medium high, medium, medium low, or low (see Thomas et al. In Prep. for definitions). These ratings indicated the likelihood that the species' population would remain viable and well-distributed through a 50-year time period.

To summarize the final ratings, the Forest Service defined two categories of species that could be at risk under the ISC strategy. Species whose viability was ranked "medium" by the panels were categorized as having "medium" risk of extirpation. Species whose viability was ranked "medium low" or "low" by the panels were categorized as having "high" risk of extirpation. Extirpation was defined as potential loss of a species within one or more of the national forests within the owl's range during an approximately 50-year period.

Population Viability

Invertebrates**:** There was not enough information about molluscs and arthropods to assess their risk of extirpation on an individual species basis. As a result, all invertebrates that were placed on the "short" list of species at risk were rated as high extirpation risks under all alternatives. Invertebrates play key and diverse roles in late-successional forests, as decomposers of organic material, pollinators of flowers, and prey for a wide variety of invertebrates and vertebrates. At least 79 of the invertebrate species are highly associated with riparian areas and probably would benefit from riparian protection.

Fish: One hundred and twelve of the 214 fish stocks were evaluated as having high risk of extirpation under all five of the alternatives. The rating of fish stocks was based on the fact that none of the alternatives contained an option for protection of watersheds and riparian zones. The Forest Service's assessment emphasizes the importance of riparian areas and fish stocks in coniferous forests of the Pacific Northwest. It also stresses the need for riparian management at the watershed level in addition to the types of measures proposed in the ISC strategy and the recovery plan.

Nonvascular plants: One hundred and ninety nonvascular plants were evaluated for risks to population viability. Under the ISC strategy (alternative B), 38 species or subpopulations were judged to have a medium or high risk of extirpation, including 18 fungi, 2 lichens, 6 liverworts, and 12 mosses. Four (2 percent) of the species were judged to have a high risk of extirpation; they included one fungus and three mosses. Substantial scientific information is lacking for some 39 additional species or subpopulations and they could not be rated by the panel.

Vascular plants: One hundred and twenty-two vascular plants were evaluated for risks to population viability. These included a wide variety of saprophytes, root parasites, orchids, grape ferns, heaths, shrub heaths, coniferous trees, ferns, grasses, and other herbaceous forms. Under the ISC strategy, none of the vascular plants was judged to have a medium or high risk of extirpation. However, scientific information is lacking for at least 10 species.

Amphibians: Twenty-one species or subpopulations of amphibians were evaluated for risks to population viability. Under the ISC strategy, 12 of the species or subpopulations were judged to have a medium or high risk of extirpation. Seven of these were rated at high risk. The 12 species or subpopulations included 11 salamanders and the tailed frog. Most of the species that were considered at risk of extirpation belong to the genera *Pleithodon* or *Rhyacotriton*. Most of the Pleithodons have very restricted geographic ranges (Figures D.3, D.4), and the Olympic salamanders are associated with cold streams. One species, the Van Dyke's salamander, was considered in two parts of its range, and both were judged to have a medium risk of extirpation. Most of the 12 species or subpopulations have narrow geographic distributions and occur in localized riparian, headwater, or talus rock habitats. Therefore, they would benefit from riparian protection.

Reptiles: Ten species of reptiles were evaluated for association with late-successional forests. None of these species was deemed to be closely associated with late-successional forests, so no further assessments were conducted.

Birds: Thirty-eight bird species or subpopulations were evaluated for risks to population viability. Under the ISC strategy, nine species or subpopulations were judged to have a medium risk of extirpation and one species (marbled murrelet) had a high risk of extirpation. Species that were judged to have a medium risk of extirpation included several species at the edge of their ranges (e.g., black-backed woodpecker, white-headed woodpecker, pygmy nuthatch, great gray owl) or species that use riparian areas (e.g., bufflehead, harlequin duck). The northern goshawk was also judged to have a medium risk of extirpation.

Mammals: Thirty-five species or subpopulations of mammals were evaluated for risks to population viability. Under the ISC strategy, eight species or subpopulations were judged to have a medium risk of extirpation and five had a high risk of extirpation. Martens were judged to have a medium risk of extirpation in three portions of their range and a high risk of extirpation in two portions. Fisher populations were rated as having a medium risk of extirpation in two portions of their range and high risk of extirpation in one portion. Both species of red tree voles had a high risk of extirpation. Lynx, which occur on the edge of the owl's range in northern Washington, were rated as a medium extirpation risk. Scientific information is lacking for at least 10 other species, most of which are bats.

Summary

A total of 667 species, species ranges, or stocks of vascular and nonvascular plants, amphibians, birds, mammals, and fish was evaluated for risk to population viability. Under the ISC strategy (alternative B), 328 species, species ranges, or stocks were judged to have a high or medium risk of extirpation. Of these, 278 were judged to be at high risk. This included 149 invertebrate species that were not rated by alternative and 112 fish stocks that were rated high risk for all alternatives. These numbers can be put in better perspective by comparing them to those from the other alternatives (Table D.16, Figure D.6, Figure D.7). For example, alternative E (the timber industry's proposal) has the greatest number of species with a medium or high risk of extirpation (462). Alternative A (the forest plans) also has a large number of species at medium or high risk of extirpation (447). In contrast, alternative D, which would preserve all the remaining suitable owl habitat, has the least number of species at medium or high risk of extirpation (302). The numbers for the ISC strategy (alternative B) are only slightly larger than those for alternative D, so these two alternatives compare favorably (328 versus 302).

A conservation strategy like that proposed by the ISC will have considerable benefits to other species of plants and vertebrate animals. Of the 406 species or species ranges of plants and terrestrial vertebrates (excluding invertebrates and fish stocks) associated with old-growth forests and evaluated by the Forest Service (Thomas et al. In Prep.), approximately 16 percent were estimated to have a medium or high risk of extirpation in the next 50 years under the ISC strategy. Only 4 percent were estimated to be at high risk of extirpation within that time. These estimates demonstrate the potential benefits of the ISC strategy to other species and late-successional forests in the Pacific Northwest. The recovery plan is likely to have similar benefits. In addition, some of the species that are considered to be at risk of extirpation occur in a minor portion of the owl's range (e.g., lynx, black-backed woodpecker, pygmy nuthatch); therefore any conservation strategy for

Table D.16. Number of species, species ranges, or fish stocks at risk of extirpation under each of 5 possible strategies for spotted owl conservation. Data taken from Thomas et al. (In Prep.) Evaluations are only for national forests.

	Medium Risk					High Risk				
Taxon	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
Non-vascular plants	84	34	27	15	65	49	4	4	4	82
Vascular plants	4	0	2	2	4	0	0	0	0	1
Invertebrates	0	0	0	0	0	149	149	149	149	149
Fish stocks	0	0	0	0	0	112	112	112	112	112
Amphibians	9	5	4	2	2	11	7	7	6	18
Birds	15	8	6	5	11	2	1	1	1	6
Mammals	5	3	5	5	3	7	5	3	1	9
Total	117	50	44	29	85	330	278	276	273	377

A = current forest plans.
B = Interagency Scientific Committee (ISC) strategy (Thomas et al. 1990).
C = ISC strategy plus lands designated as critical habitat (USDI 1992).
D = ISC strategy plus all other nesting, roosting, and foraging habitat.
E = Multi-resource strategy developments by the National Forest Products Association and the American Forest Council.

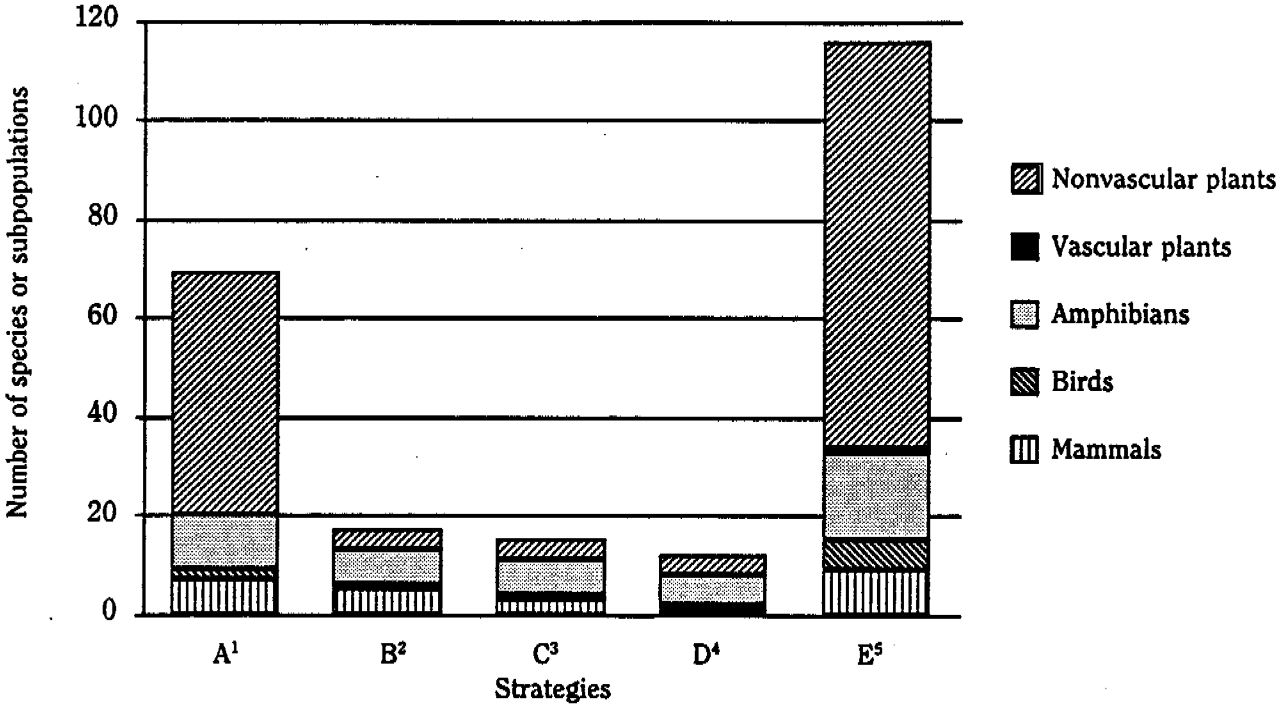


Figure D.6. *Species or subpopulations of plants and terrestrial vertebrates that were evaluated as having a medium risk of extirpation under five possible strategies for spotted owl conservation.*

[1]Current Forest Plans.
[2]ISC strategy (Thomas et al. 1990).
[3]ISC strategy plus lands designated as critical habitat (USDI 1992).
[4]ISC strategy plus all other nesting, roosting and foraging habitat.
[5]Multi-resource strategy developeds by the National Forest Products Association and the American Forest Council.

the owl will have a minor influence on their populations. Obviously, additional efforts beyond owl conservation would be needed to mitigate potential risks to all species, particularly for marbled murrelets and the numerous fish stocks.

Thomas et al. (In Prep.) describe four mitigation measures beyond the ISC strategy that would reduce the extirpation risks for other species associated with old-growth forests. These include measures for riparian habitat, marbled murrelets, rare and locally endemic species, and other sensitive upland species. Protection of riparian areas would have benefits to other organisms besides fishes. Of the species of vertebrates that were considered to have medium or high risk of extirpation, 3 subpopulations of mammals, 2 species of birds, and 10 species or subpopulations of amphibians are associated with riparian areas. Therefore, riparian protection could reduce the number of species or subpopulations that have a risk of extirpation by at least 15 species or subpopulations of higher vertebrates plus the 112 fish stocks. Mitigation for marbled murrelets and for other sensitive or endemic species would conserve additional biological diversity in late-successional forests.

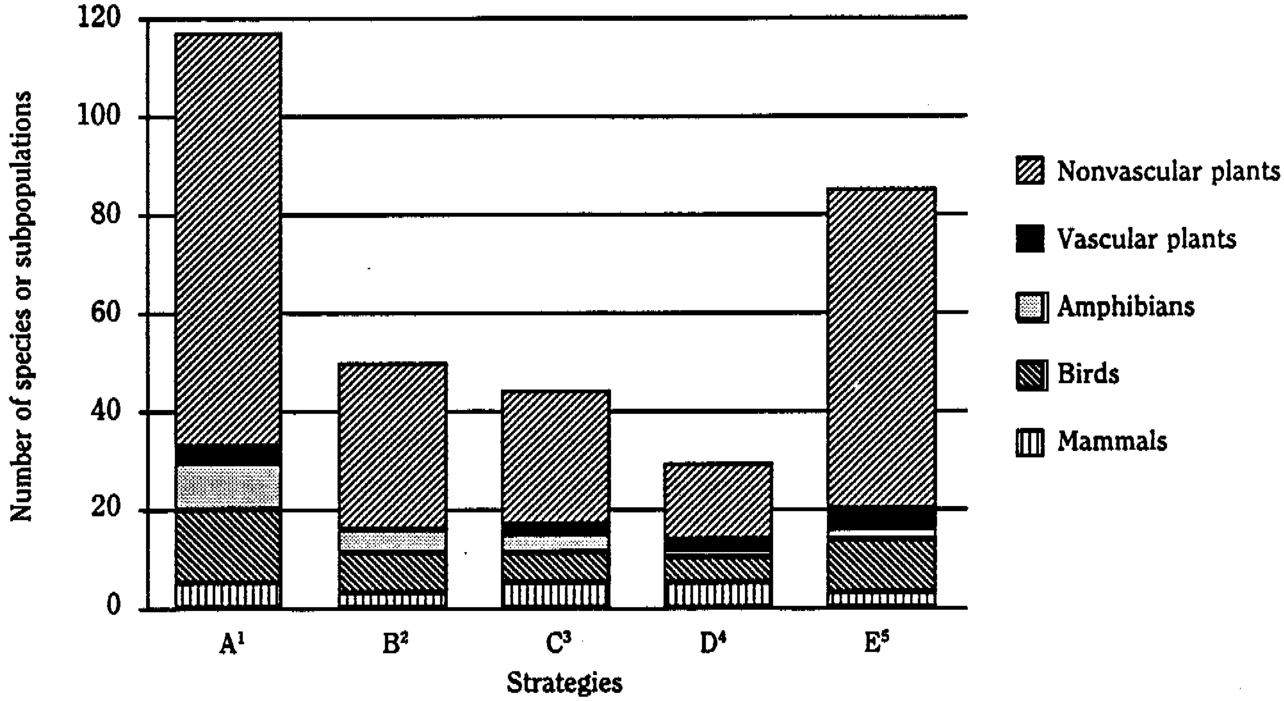


***Figure D.7.** Species or subpopulations of plants and terrestrial vertebrates that were evaluated as having a high risk of extirpation under five possible strategies for spotted owl conservation.*

[1]Current Forest Plans.
[2]ISC strategy (Thomas et al. 1990).
[3]ISC strategy plus lands designated as critical habitat (USDI 1992).
[4]ISC strategy plus all other nesting, roosting and foraging habitat.
[5]Multi-resource strategy developeds by the National Forest Products Association and the American Forest Council.

Summary and Conclusions

As a result of Secretary Lujan's directive, the Recovery Team considered the needs of other species associated with older-forest ecosystems and assessed the benefits to others species from various recovery options. We emphasized species that were federally listed as threatened or endangered, candidates for federal listing, state sensitive or species of special concern, and species associated with older forests. We assembled a list of 668 species of plants and animals that meet the criteria and occur within the range of the northern spotted owl. We also provided descriptions of late-successional forests and riparian ecosystems, unique food webs of late-successional forests, the use of the spotted owl as an indicator species, the potential population viability of species under the ISC strategy, and the biology of spotted owl prey. In this section, we present an overview of the committee's work and accomplishments and how we were able to include benefits to other species in the owl recovery plan; this section summarizes information in section III.I. of the recovery plan as well as this appendix.

The list of 668 species is comprised of 39 species of birds, 28 mammals, 27 amphibians and reptiles, 28 fish, 58 molluscs, 91 arthropods, 207 vascular plants, and 190 nonvascular plants. Seven species are federally listed as threatened or endangered (bald eagle, marbled murrelet, peregrine falcon, grizzly bear, gray wolf, Sacramento River winter chinook salmon, McDonald's rock cress), and the northern goshawk has been petitioned for listing. One hundred sixty two species were candidates for federal listing, and more than 150 species were listed as threatened or endangered or designated as sensitive or species of special concern in one or more of the three states. More than 100 species are narrowly or broadly endemic to the Pacific Northwest and 482 are associated with older forests. The large number of species on the list emphasizes the relevance of considering other species in the owl recovery plan.

The committee's work has emphasized the importance of riparian ecosystems in coniferous forests of the Pacific Northwest. Of the 668 species that met our criteria, approximately one fourth (150) are associated with riparian areas, including 28 species of fishes, 45 molluscs, 34 arthropods, 15 amphibians, 18 plants, 5 mammals, and 8 birds. The 28 species of fishes include approximately 800 stocks that are considered at risk and may become candidates for listing in the future. The numerous riparian associated species plus the number of fish stocks that are considered at risk stress the importance of riparian areas within the range of the northern spotted owl. As a result, we have provided a brief synopsis of the ecology and management of riparian ecosystems.

In addition to assembling a list of species for consideration in the northern spotted owl recovery plan, the committee developed a short list of priority species. This list was given the most emphasis in the recovery plan and includes 18 species (bald eagle, marbled murrelet, northern goshawk, marten, fisher, gray wolf, grizzly bear, Oregon slender salamander, Siskiyou Mountain salamander, Larch Mountain salamander, Del Norte salamander, Olympic salamanders–four species, Pacific giant salamander, Cope's giant salamander, and tailed frog); a large group of riparian associated species; and a small group of species that are preyed upon by the owl (northern flying squirrel, dusky-footed woodrat, bushy-tailed woodrat, deer mouse, western red-backed vole, and red tree voles). Of these species, the marbled murrelet and the numerous fish stocks that are considered at risk were assigned the highest priority. We compiled information about the distribution, biology, and habitat relationships of the priority species and about the ecology of riparian ecosystems. This information was used to influence the boundaries and management of DCAs.

In considering the needs of other species in the recovery plan, the Recovery Team took advantage of opportunities to benefit other species without increasing the costs of the plan. This was done by altering the size and location of DCAs to attain maximum benefit for owls and incorporate other species to the extent possible. Information about other species was used in several ways in the development of the recovery plan. First, in development of the overall strategy for the recovery plan, the Recovery Team evaluated the overlap between possible owl conservation areas and the geographic ranges of the list of priority species. Second, in developing recommendations for specific management practices in DCAs and the forest matrix surrounding DCAs, the Recovery Team attempted to look beyond the habitat needs of spotted owls. The Recovery Team used the characteristics of late-successional forests, wherever possible, in developing guidelines for management recommendations.

As a result of these activities, the Recovery Team was able to locate DCAs so that they include more than 900 locations of other species, namely 622 locations where marbled murrelets have been detected, 121 northern goshawk nest sites, 58 marten locations, 37 fisher locations, and 96 bald eagle nest sites. The greatest benefits to other species will be for marbled murrelets in the Oregon and California Coast Ranges where 204 and 200 locations of marbled murrelet detections, respectively, were included in DCAs. The DCAs also include 2,014 miles of streams with fish stocks that are considered at risk. The greatest benefits to fish stocks will be achieved in the Oregon and California Klamath provinces where 763 miles of stream were included in DCAs. Inclusion of streams and of other species sites in DCAs, along with the conservation of late-successional forests for owl habitat, will provide benefits to other species within the range of the spotted owl. However, the marbled murrelet and the numerous fish stocks will probably require further conservation efforts in the future, as is the case for most of the other priority species. The conservation needs of arthropods and molluscs are particularly elusive at the present time, because we do not know enough about the geographic distributions or the habitat associations of many of these organisms. In addition, there are many species yet to be described and named within these two groups.

Management guidelines for DCAs were designed to maintain suitable habitat for spotted owls and to develop suitable habitat in stands that are currently unsuitable (see section III.C. about silviculture, salvage, and catastrophic risk). These guidelines are written to conserve owl habitat and the characteristics of late-successional forests. As a result, the forests within DCAs will provide habitat for a wide array of other species. For example, the guidelines for salvage of trees after catastrophic events (primarily wind and fire) are designed to provide coarse woody debris (snags and down logs) during a 100-year period. This management will contribute to the habitat requirements of a number of cavity dwellers including cavity-nesting birds and flying squirrels which make extensive use of snags. The recommendations will also promote suitable habitat conditions for martens, salamanders, numerous arthropods, fungi, and small mammals by providing coarse woody debris on the forest floor. The retention of coarse woody debris in riparian areas will provide habitat for fishes and other aquatic organisms. In addition, the forest matrix on federal lands will be managed to protect residual habitat areas, reserved pair areas, and managed pair areas for owls where the DCA network is deficient or there is a risk of catastrophic disturbance. These guidelines will provide short-term habitat for many species that are associated with late-successional forests. Managed pair areas will provide habitat for other species if management strategies include long rotations and uneven-aged management with the goal of providing large trees, snags, and coarse woody debris.

Lastly, we recommend further surveys, inventory, and research on other species so that their habitat needs can be identified more accurately in the future (see section III.I.). We provided a list of birds, mammals, amphibians, and fishes that are suggested for further review of the status of their populations, and provided a partial list of research topics. Research on arthropods and molluscs is one of the highest priorities. There is a need to understand the responses of all organisms to various silvicultural practices other than clear-cut timber harvest. Information about the ecological requirements of these species will be needed to develop management strategies to sustain populations of all organisms that are well distributed throughout their ranges. As adaptive management for the spotted owl proceeds during the next several decades, the effects of management on other species will need to be considered so that these species will not be deleteriously affected.

Literature Cited

Alexander, L.; Verts, B.J. 1992. *Clethrionomys californicus*. Mammal. Species. 406:1-6.

Allen, A.W. 1983. Habitat suitability index models: fisher. Fort Collins, CO: U.S. Department of the Interior, Fish and Wildlife Service. 19 p.

Almack, J.A., Personal Communication, Washington Department of Wildlife, Olympia, WA.

Almack, J.A. 1985. An evaluation of grizzly bear habitat in the Selkirk Mountains of north Idaho. Moscow, ID: University of Moscow. 87 p. M.S. thesis.

Anderson, J.D. 1969. *Dicamptodon* and *D. ensatus* in: Catalogue of American amphibians and reptiles. 76.1-76.2.

Anthony, R.G.; Isaacs, F.B. 1989. Characteristics of bald eagle nest sites in Oregon. Journal of Wildlife Management. 53:148-159.

Anthony, R.G.; Garrett, M.G.; Schuler, C.A. 1993. Environmental contaminants in bald eagles in the Columbia River estuary. Journal of Wildlife Management. 57:10-19.

Anthony, R.G.; Knight, R.L.; Allen, G.T. [and others]. 1982. Habitat use by nesting and roosting bald eagles in the Pacific Northwest. Transactions, North American Wildlife and Natural Resources Conference. 47:332-342.

Arthur, S.M. 1987. Ecology of fishers in south-central Maine. Orono, ME: University of Maine. 112 p. Ph.D. dissertation.

Arthur, S.M.; Krohn, W.B; Gilbert, J.R. 1989. Habitat use and diet of fishers. Journal of Wildlife Management. 53:680-688.

Aubry, K., Personal Communication, U.S. Department of Agriculture, Forest Service, Olympia, WA.

Aubry, K.B.; Crites, M.J.; West, S.D. 1991. Regional patterns of small mammal abundance and community composition in Oregon and Washington. Pages 285-294 in: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.M., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Aubry, K.B.; Senger, C.M.; Crawford R.L. 1987. Discovery of Larch Mountain salamanders (*Plethodon larselli)* in the Central Cascade Range of Washington. Biological Conservation. 42:147-152.

Austin, K. 1989. Habitat use of nesting goshawk in northern California. Corvallis, OR: Oregon State University, Department of Fisheries and Wildlife. 23 p. M.S. thesis research proposal.

Baker, R.J.; Shonewald-Cox, C.M. 1986. Management strategies for improving population viability. Pages 73-87 in: Wilcox, B.A.; Brussard, P.F.; Marcot, B.G., eds. The Management of Viable Populations: Theory, Applications and Case Studies. Palo Alto, CA: Stanford University, Center for Conservation Biology.

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

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

Beatty, J., Personal Communication and Personal Observation, Oregon State University, Corvallis, OR.

Beatty, J.J.; Blaustein, A.R.; Storm, R.M. 1991. The biology of amphibians and reptiles. 78 p. Unpublished report. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR.

Bent, A.C. 1937. Life histories of North American birds of prey: Part 1. U.S. National Museum Bulletin 167. U.S. Department of the Interior. Washington, D.C. 409 p.

Blakesley, J.A.; Franklin, A.B.; Gutierrez, R.J. 1992. Spotted owl roost and nest site selection in northwestern California. Journal of Wildlife Management 56(2):388-392.

Blaustein, A.R.; Wake, D.B. 1990. Declining amphibian populations: A global phenomena? Trends in Ecology and Evolution. 5:203-204.

Bloom, P.H.; Stewart, G.R.; Walton, B.J. 1985. The status of the northern goshawk in California, 1981-1983. Branch Administration Report 85-1. Sacramento, CA: California Department of Fish and Game, Wildlife Management. 24 p.

Brodie, E.D., Jr. 1971. *Plethodon stormi* in: Catalogue of American amphibians and reptiles. 103.1-103.2.

Brown, E.R., ed. 1985. Management of wildlife and fish habitats in forests of western Oregon and Washington. Publication No. R6-F&WL-192-1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 332 p.

Buchannan, J.B. 1991. Spotted owl nest site characteristics in mixed-conifer forests of the eastern Cascade Mountains, Washington. Seattle, WA: University of Washington. 140 p. M.S. thesis.

Bull, E., Personal Communication, Washington Department of Agriculture, Forest Service, LaGrande, OR.

Bull, E.I. 1980. Resource partitioning among woodpeckers in Northeast Oregon. Moscow, ID: University of Idaho. 54 p. Ph.D. dissertation.

Burton, D.H.; Black, H.C. 1978. Feeding habits of Mazama pocket gophers in south-central Oregon. Journal of Wildlife Management. 42:383-390.

Bury, R.B. 1983. Differences in amphibian populations in logged and old-growth redwood forest. Northwest Science. 57:167-178.

Bury, R.B. 1988. Habitat relationships and ecological importance of amphibians and reptiles. Pages 61-76 in: Raedeke, K.J., ed. Streamside management: riparian wildlife and forestry interactions. Institute of Forest Resources Contribution 59. Seattle, WA: University of Washington.

Bury, R.B.; Corn, P.S. 1988a. Douglas-fir forests in the Oregon and Washington Cascades: Relation of the herpetofauna to stand age and moisture. Pages 11-22 in: R.C. Szaro et al., eds. Management of Amphibians, Reptiles and Small Mammals in North America. General Technical Report RM-166. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Bury, R.B.; Corn, P.S. 1988b. Responses of aquatic and streamside amphibians to timber harvest: A review. Pages 165-181 in: Raedeke, K.J., ed. Streamside management: riparian wildlife and forestry interactions. Institute of Forest Resources Contribution 59. Seattle, WA: University of Washington.

Bury, R.B.; Corn, P.S.; Aubry, K.B. 1991. Regional patterns of terrestrial amphibian communities in Oregon and Washington. Pages 341-350 in: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.M., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 533 p.

Buskirk, S.W. 1984. Seasonal use of resting sites by marten in south-central Alaska. Journal of Wildlife Management. 48:950-953.

Buskirk, S.W.; Forrest, S.C.; Raphael, M.G.; Harlow, H.J. 1989. Winter resting site ecology of marten in the central Rocky Mountains. Journal of Wildlife Management. 53:191-196.

California Department of Fish and Game. 1986. Mammalian species of special concern in California. Sacramento, CA: California Department of Fish and Game. 112 p.

California Department of Fish and Game. 1990. Sensitive Species List. Sacramento, CA: California Department of Fish and Game. 3 p.

California Department of Fish and Game. 1991a. Natural diversity data base, special animals. Sacramento, CA: California Department of Fish and Game. 22 p.

California Department of Fish and Game. 1991b. Designated endangered, threatened or plants. Sacramento, CA: California Department of Fish and Game, Natural Heritage Division, Endangered Plant Program. 16 p.

Carey, A.B. 1989. Wildlife associated with old-growth forests in the Pacific Northwest. Natural Areas Journal. 151-162.

Carey, A.B.; Horton, S.P.; Biswell, B.L. 1992. Northern spotted owls: influence of prey base and landscape character. Ecological Monographs. 62(2):223-250.

Carothers, S.W. 1977. Importance, preservation, and management of riparian habitats; an overview. Pages 2-4 in: Johnson, R.R.; Jones, D.A., tech. coords. Importance, preservation and management of riparian habitat: a symposium. General Technical Report RM-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Carter, H.R.; Erickson, R.A. 1988. Population status and conservation problems of the marbled murrelet in California, 1892-1987. Sacramento, CA: California Department of Fish and Game; final report; contract FG7569. 68 p.

Carter, H.R.; Sealy, S.G. 1986. Year-round use of coastal lakes by marbled murrelets. Condor. 88:473-477.

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

Chamberlin, T.W.; Harr, R.D.; Everest, F.H. 1991. Timber harvesting, silviculture, and watershed processes. American Fisheries Society Special Publication. 19:181-205.

Clark, T.W.; Anderson, E; Douglas, C.; Strickland, M. 1987. *Martes americana*. American Society of Mammalogy. 289:1-8.

Corn, P.S.; Bury, R.B. 1989. Logging in western Oregon: responses of headwater habitats and stream amphibians. Forest Ecology and Management. 29:39-57.

Corn, P.S.; Bury, R.B. 1991. Small mammal communities in the Oregon Coast Range. Pages 241-254 in: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.M., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 533 p.

Crocker-Bedford, D.C. 1990. Goshawk reproduction and forest management. Wildlife Society Bulletin. 18:262-269.

Cummins, E., Personal Communication, Washington Department of Wildlife, Olympia, WA.

Cummins, E. 1991. Marbled murrelet status in Washington. Pages 9-29 in: transcript from technical workshop in other species and ecosystem issues in recovery planning for the northern spotted owl. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Daugherty, C.H.; Allendorf, F.W.; Dunlop, W.W.; Knudsen, K.L. 1983. Systematic implications of geographic patterns of genetic variation in the genus *Dicamptodon*. Copeia. 1983:679-691.

Daugherty, C.H.; Sheldon, A.L. 1982. Age-specific movement patterns of the tailed frog *Ascaphus truei*. Herpetologica. 38:468-474.

deVos, A. 1964. Range changes of mammals in the Great Lakes region. American Midland Naturalist. 71:210-231.

Duellman, W.E.; Trueb, L. 1986. Biology of Amphibians. New York: McGraw-Hill. 670 p.

Elmore, W.; Beschta, R.L. 1987. Riparian areas: perceptions in management. Rangelands. 9:260-265.

Everest, F.H.; Beschta, R.L.; Scrivener, J.C., [and others]. 1987. Fine sediment and salmonid production: a paradox. Pages 98-142 in: Salo; Cundy, eds. Streamside management: forestry and fishery interactions. Institute of Forest Resources Contribution 57. Seattle, WA: University of Washington.

Fleming, T. 1987. Northern goshawk status and habitat associations in western Washington, with special emphasis on the Olympic Peninsula. Olympia, WA: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 45 p.

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

Forsman, E.D.; Meslow, E.C.; Wight, H.M. 1984. Distribution and biology of the spotted owl in Oregon. Wildlife Monographs 87. 64 p.

Frest, T., Personal Communication, Deixis Consultants, Seattle, WA.

Frest, T.J.; Johannes, E.J. 1991. Present and potential candidate molluscs occurring within the range of the northern spotted owl. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Northern Spotted Owl Recovery Team; final report; contract P53354. 30 p.

Frissell, C.A. 1991. Topology of extinction and endangerment of native fishes in the Pacific Northwest and California (USA). Department of Fisheries and Wildlife, Oregon State University, Corvallis, OR. Unpublished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Furniss, M.J.; Roelofs, T.D.; Yee, C.S. 1991. Road construction and maintenance. American Fisheries Society Special Publication. 19:297-323.

Gashwiler, J.S. 1959. Small mammal study in west-central Oregon. Journal of Mammalogy. 40:128-139.

Gashwiler, J.S. 1970. Plant and animal changes on a clearcut in west-central Oregon. Ecology. 51:1018-1026.

Gilbert, F.F.; Allwine, R. 1991. Small mammal communities in the Oregon Cascade Range. Pages 257-268 in: Ruggiero, L.F.; Aubry, K.B.; Carey, A.B.; Huff, M.M., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 533 p.

Goertz, J.W. 1964. Habitats of three Oregon voles. Ecology. 45:846-848.

Goggans, R. 1986. Habitat use by flammulated owls in Northeastern Oregon. Corvallis, OR: Oregon State University. 54 p. M.S. thesis.

Goggans, R.; Dixon, R.; Seminara, L.C. 1987. Habitat use by three-toed and black-backed woodpecker, Deschutes National Forest, Oregon. Nongame Project Report No. 87-3-02. Portland, OR: Oregon Department of Fish and Wildlife. 50 p.

Gomez, D.M. 1992. Influence of riparian and upslope vegetation on small-mammal and herpetofaunal abundance in five forest types. Corvallis, OR: Oregon State University. 118 p. M.S. thesis.

Good, D.A. 1989. Hybridization and cryptic species in *Dicamptodon* (Caudata: Dicamptodontidae). Evolution. 43:728-744.

Gould, G., Personal Communication, California Department of Fish and Game, Sacramento, CA.

Gregory, S.; Ashkenas, L. 1990. Riparian Management Guide: Willamette National Forest. Eugene, OR: U.S. Department of Agriculture, Forest Service, Willamette National Forest. 120 p.

Grenfell, W.E.; Fasenfest, M. 1979. Winter food habits of fishers, *Martes pennanti*, in northwestern California. Sacramento, CA: California Fish and Game. 65:184-189.

Gregory, S.V.; Lamberti, G.A.; Moore, K.M.S. 1988. Influence of valley floor landforms on stream ecosystems. Pages 3-8 in: Abell, D.L., tech. coord. Proceedings of the California riparian systems conference: protection, management, and restoration for the 1990s; 1988 September. General Technical Report PSW-110. Berkeley, CA: U.S. Department of Agricvulture, Forest Service, Pacific Southwest Forest and Range Experiment Station.

Grinnell, J.; Dixon, J.S.; Linsdale, J.M. 1937. Fur-bearing mammals of California. Berkeley, CA: University of California Press. 777 p.

Grinnell, J., Miller, A.H. 1944. *Acipiter gentilis antricap*-American goshawk. Pages 97-98 in: Grinnell, J.; Miller, A.H. The distribution of the birds of California. Berkeley, CA: Cooper Ornithological Club.

Hall, P. 1984. Characterization of nesting habitat of goshawks (*Accipiter gentilis*) in northwestern California. Arcata, CA: Humboldt State University. 70 p. M.S. thesis.

Hamer, T.E. 1991. Habitat relationships of marbled murrelets (*Brachyramphus marmoratus*) in western Washington. Olympia, WA: Washington Department of Wildlife; final report. 20 p.

Hansen, J.J. 1986. Wolves of northern Idaho and northeastern Washington. Montana Cooperative Wildlife Research Unit. Missoula, MT: U.S. Department of the Interior, Fish and Wildlife Service. In cooperation with: University of Montana.

Hargis, C.D. 1981. Winter habitat utilization and food habits of pine martens in Yosemite National Park. Berkeley, CA: University of California. 57 p. M.S. thesis.

Hargis, C.D.; McCullough, D.R. 1984. Winter diet and habitat selection of marten in Yosemite National Park. Journal of Wildlife Management. 48:140-146.

Harmon, M.E.; Franklin, J.F.; Swanson, FJ., [and others]. 1986. Ecology of coarse woody debris in temperate ecosystems. Advances in Ecological Research. 15:133-302.

Harris, L.D. 1984. The fragmented forest. University Chicago Press. 211 p.

Harris, L.D.; Maser, C. 1984. Animal community characteristics. Pages 44-68 in: Harris, L.D., ed. The fragmented forest. Chicago: University of Chicago Press. 211 p.

Hawkins, C.P.; Murphy, M.L.; Anderson, N.H.; Wilzbach, M.A. 1983. Density of fish and salamanders in relation to riparian canopy and physical habitat in streams of the northwestern United States. Canadian Journal of Fisheries and Aquatic Sciences. 40:1173-1185.

Hays, D., Personal Communication, Washington Department of Wildlife, Olympia, WA.

Hayward, G.D.; Holland, T.; Escano, R. 1990. Goshawk habitat relationships. Pages 19-25 in: Warren, N., ed. Old growth habitats and associated wildlife species in the northern Rocky Mountains. Paper no. R1-90-42. Missoula, MT: U.S. Department of Agriculture. Forest Service, Northern Region, Wildlife Habitat Relationships Program.

Henny, C.; Anthony, R.G. 1989. Status of bald eagle and osprey. Pages 66-82 in: Pendleto, B.G.; ed. Proceedings of the western raptor management symposium workshop; Washington, D.C.: National Wildlife Federation. Science and Technical Series No. 12. Institute for Wildlife Research.

Herrington, R.E. 1988. Talus use by amphibians and reptiles in the Pacific Northwest. Pages 216-221 in: Management of amphibians, reptiles, and small mammals in North America. General Technical Report RM-166. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Herrington, R.E.; Larsen, J.H., Jr. 1985. The current status, habitat requirements and management of the Larch Mountain salamander. Biological Conservation. 34:169-179.

Herrington, R.E.; Larsen, J.H., Jr. 1987. Reproductive biology of the Larch Mountain salamander (*Plethodon larselli* Burns). Journal of Herpetology. 21:48-56.

Hicks, B.J.; Hall, J.D.; Bisson, P.A.; Sedell, J.R. 1991. Responses of salmonids to habitat changes. American Fisheries Society Special Publication. 19:483-518.

Ingles, L.G. 1976. Mammals of the Pacific States. Stanford, CA: Stanford University Press. 506 p.

Ingram, R. 1973. Wolverine, fisher and marten in central Oregon. Administrative Report 73-2. Bend, OR: Oregon Department of Fish and Wildlife, Central Region. 41 p.

Irwin, L. 1987. Review of minimum management requirements for indicator species: pine marten and pileated woodpeckers. Technical Bulletin No. 522. Corvallis, OR: National Council Paper Industry for Air and Stream Improvement. 24 p.

Isaac, L.A. 1952. Biological aspects of forest conservation in Washington and Oregon. Pages 12-15 in: Proceedings: 13th Annual Biology Colloquium: Corvallis, OR: Oregon State University.

Jewett, G.G.; Taylor, W.P.; Shaw, W.T.; Aldrich, J.W. 1953. The birds of Washington. Seattle, WA: University of Washington Press. 767 p.

Johnson, K.N.; Franklin, J.F.; Thomas, J.W.; Gordon, J. 1991. Alternatives for management of late-successional forests of the Pacific Northwest. A report to the U.S. House of Representatives Committee on Agriculture and Committee on Merchant Marine and Fisheries. 59 p. plus illustrations.

Johnson, M.L.; George, S.B. 1991. Species limits within the *Arborimus longicaudus* species complex (Mammalia: Rodentia) with a description of a new species from California. Contributions in Science. 429:1-16.

Jones, J.L. 1991. Habitat use of fisher in north-central Idaho. Moscow, ID: University of Idaho. 147 p. M.S. thesis.

Jones, L.C.; Raphael, M.G. 1991. Ecology and management of marten in fragmented habitats of the Pacific Northwest. Fiscal year 1990 progress report. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 60 p.

Keister, G.P., Jr.; Anthony, R.G. 1983. Characteristics of bald eagle communal roosts in the Klamath Basin, Oregon and California. Journal of Wildlife Management. 47:1072-1079.

Kirk, J.J. 1991. *Batrachoseps wrighti*: Hood River County. Herpetological Review. 22:22.

Kirk J.J.; Forbes, R.D. 1991. Geographic distribution: *Batrachoseps wrighti*. Herpetological Review. 22:22-23.

Knight, A.W.; Bottorf, R.L. 1984. The importance of riparian vegetation to stream ecosystems. Pages 160-167 in: Warner, R.E.; Hendrix, K.M., eds. Proceedings, California riparian systems; Berkeley, CA: University of California Press.

Koehler, G.M.; Brittell, J.D. 1990. Managing spruce-fir habitat for lynx and snowshoe hares. Journal of Forestry 88:10-14.

Koehler, G.M.; Moore, W.R.; Taylor, R. 1975. Preserving the pine marten: management guidelines for western forests. Western Wildlands. 2:31-36.

Landres, P.B.; Verner, J.; Thomas, J.W. 1988. Ecological uses of vertebrate indicator species: a critique. Conservation Biology. 2:316-328.

Larsen, C.J. 1991. Report to the Fish and Game Commission: A status review of the marbled murrelet (*Brachyramphus marmoratus*) in California. Department Candidate Species Status Report 91-1. Sacramento, CA: California Department of Fish and Game, Nongame Bird and Mammal Section. 30 p. plus appendices.

Lattin, J., Personal Communication, Oregon State University, Corvallis, OR.

Lattin, J.D.; Moldenke, A.R. 1992. Ecologically sensitive invertebrate taxa of Pacific Northwest old-growth conifer forests. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Northern Spotted Owl Recovery Team; report. 42 p.

Mannan, R.W. 1977. Use of snags by birds: Douglas-fir region, western Oregon. Corvallis, OR: Oregon State University. 114 p. M.S. thesis.

Mannan, R.W.; Meslow, E.C. 1984. Bird populations and vegetation characteristics in managed and old-growth forests, northeastern Oregon. Journal of Wildlife Management. 48:1219-1238.

Mannan, R.W.; Meslow, E.C.; Wight, H.M. 1980. Use of snags by birds in Douglas-fir forests, western Oregon. Journal of Wildlife Management. 44:787-797.

Mannan, R.W.; Morrison, M.L.; E.C. Meslow. 1984. Comment: the use of guilds in forest bird management. Wildlife Society Bulletin. 12:426-430.

Marshall, D. 1992. Threatened and sensitive wildlife of Oregon's forests and woodlands. Portland, OR: Oregon Department of Fish and Wildlife. 66 p.

Marshall, D.B. 1988. Status of the marbled murrelet in North America: with special emphasis on populations in California, Oregon, and Washington. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Biological Report. 88(30). 19 p.

Maser, C.; Mate, B.R.; Franklin, J.F.; Dryness, C.T. 1981. Natural history of Oregon coast mammals. General Technical Report PNW-133. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 496 p.

Maser, C.; Trappe, J.M.; Ure, D.C. 1978a. Implications of small mammal mycophagy to the management of western coniferous forests. Transactions of North American Wildlife Natural Resources Conference. 43:78-88.

Maser, C.; Trappe, J.M.; Nussbaum, R.A. 1978b. Fungal-small mammal inter-relationships with emphasis on Oregon coniferous forests. Ecology. 59:799-809.

Maser, Z.; Maser, C.; Trappe, J.M. 1985. Food habits of the northern flying squirrel in Oregon. Canadian Journal Zoology. 63:1084-1085.

McComb, W.C. 1991. The role of dead wood in habitat of spotted owl prey and other old forest vertebrates: report to the northern spotted owl recovery team. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Northern Spotted Owl Recovery Team. 57 p.

McGarigal, K.; Anthony, R.G.; Isaacs, F.B. 1991. Human-eagle interactions on the Columbia River estuary. Wildlife Monographs 115. 47 p.

McIntyre, J.D. 1983. Differentiation of anadromous salmonid stocks. Pages 9-15 in: Walton. J.; Houston, D.B., eds. Proceedings of Olympic wild fish conference; Port Angeles, WA.

McKeever, S. 1960. Food of the northern flying squirrel in northwestern California. Journal of Mammalogy. 41:270-71.

Mech, D.L. 1974. *Canis lupus*. Mammal Species. 37:1-6.

Meehan, W.R. 1991. Introduction and overview. American Fisheries Society Special Publication. 19:1-15.

Meehan, W.R.; Swanson, F.J.; Sedell, J.R. 1977. Influences of riparian vegetation on aquatic ecosystems with particular references to salmonid fishers and their food supply. Pages 137-145 in: Johnson, R.R.; Jones, D.A.; eds. Symposium, Importance, Preservation and Management of Riparian Habitat; General Technical Report RM-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Mendenhall, V.M. 1992. Distribution, breeding, records, and conservation problems of the marbled murrelet in Alaska. Pages 5-16 in: Carter, H.R.; Morrison, M.L.; eds. Status and conservation of the marbled murrelet in North America. Proceedings of Western Foundation of Vertebrate Zoology. Vol. 5(1), Camarillo, CA.

Metter, D.E. 1963. Stomach contents of Idaho larval *Dicamptodon*. Copeia. 1963:435-436.

Metter, D.E. 1968. The influence of floods on population structure of *Ascaphus truei* Stejneger. Journal of Herpetology. 1:1-4.

Miller, G., Personal Communication, U.S. Department of the Interior, U.S. Fish and Wildlife Service, Portland, OR.

Moldenke, A., Personal Communiction and Unpublished Data, Oregon State University, Corvallis, OR.

Morrison, P.H. 1988. Old-growth in the Pacific Northwest: a status report. Washington, D.C.: The Wilderness Society. 46 p.

Moyle, P.B.; Williams, J.E.; Wikramanayake, E.D. 1989. Fish species of special concern of California. Rancho Cordova, CA: California Department of Fish and Game, Inland Fisheries Division; final report; contract no. 7337. 222 p.

Murphy, M.L.; Koski, K.V. 1989. Input and depletion of woody debris in Alaska streams and implications for streamside management. North American Journal Fisheries Management. 9:427-436.

Murphy, M.L.; Meehan, W.R. 1991. Stream ecosystems. American Fisheries Society Special Publication. 19:17-46.

Murphy, M.L.; Heifetz, J.; Johnson, S.W., [and others]. 1986. Effects of clear-cut logging with and without buffer strips on juvenile salmonids in Alaskan streams. Canadian Journal of Fisheries and Aquatic Sciences. 43:1521-1533.

Nehlsen, W.; Williams, J.E.; Lichatowich, J.A. 1991. Pacific salmon at the crossroads: Stocks at risk from California, Oregon, Idaho, and Washington. Fisheries. 16:4-21.

Nelson, S., Personal Communication, Oregon State University, Corvallis, OR.

Nelson, S.K. 1989. Habitat use and densities of cavity-nesting birds in the Oregon Coast Ranges. Corvallis, OR: Oregon State University. 157 p. M.S. thesis.

Nelson, S.K. 1990. Distribution of the marbled murrelet in western Oregon. Portland, OR: Oregon Department of Fish and Wildlife, Nongame Wildlife Research Program; final report; contract 89-9-02. 46 p.

Noon, B.R. 1986. Summary: Biometric approaches to modeling - the researcher's viewpoint. Pages 197-202 in: Verner, J., [and others]. Wildlife 2000: modeling habitat relationships of terrestrial vertebrates. Madison, WI: University of Wisconsin Press. 470 p.

Norse, W.A. 1990. Ancient forests of the Pacific Northwest. Washington, D.C.: Island Press. 327 p.

Nussbaum, R.A. 1970. *Dicamptodon copei*, n. sp., from the Pacific Northwest, USA. (Amphibia:Caudata: *Ambystomatidae*). Copeia. 1970:506-514.

Nussbaum, R.A. 1976. Geographic variation and systematics of salamanders of the genus *Dicamptodon* Strauch (Ambystomatidae). Miscellaneous Publication Museum of Zoology. Ann Arbor, MI: University of Michigan Press. 149:1-94.

Nussbaum, R.A.; Tait, C.K. 1977. Aspects of the life history and ecology of the Olympic salamander, *Rhyacotriton olympicus* (Gaige). American Midland Naturalist. 98:176-199.

Nussbaum, R.A.; Brodie, E.D., Jr.; Storm, R.M. 1983. Amphibians and reptiles of the Pacific Northwest. Moscow, ID: University of Idaho Press. 332 p.

Oakley, A.L.; Collins, J.A.; Everson, L.B., [and others]. 1985. Riparian zones and freshwater wetlands. Pages 57-80 in: Brown, R.E., ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. Publication No. R6-F&WL:1985. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

O'Neil, T.; Witmer, G. 1991. Assessing cumulative impacts to elk and mule deer in the Salmon River Basin, Idaho. Applied Animal Behavioral Science. 29:225-238.

Olson, D.M. 1992. The Northern Spotted Owl conservation strategy: Implications for Pacific Northwest forest invertebrates and associated exosystem processes. Portland, OR: U.S. Department of Agriculture, Forest Service, Northern Spotted Owl EIS Team; report. 50 p.

Opp. R., Personal Communication, Oregon Department of Fish and Wildlife, Corvallis, WA.

Oregon Department of Fish and Wildlife. 1991. Sensitive species list: 17 September 1991. Portland, OR: Oregon Department of Fish and Wildlife, Wildlife Division.

Oregon Natural Heritage Program. 1991. Rare, threatened and endangered plants and animals of Oregon. Portland, OR: Oregon Natural Heritage Program. 64 p.

Parsons, G.L.; Cassis, G.; Moldenke, A.R., [and others]. 1991. Invertebrates of the H.J. Andrews Experimental Forest, western Cascade Mountains, Oregon. Technical

Bulletin V. An annotated list of insects and other arthropods at the H.J. Andrews Experimental Forest. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 166 p.

Patla, S. 1991. Northern goshawk monitoring project report. St. Anthony, ID: U.S. Department of Agriculture, Forest Service, Targhee National Forest; contractor's final report. 52 p.

Paton, P.W.; Ralph, C.J. 1988. Geographic distribution of the marbled murrelet in California at inland sites during the 1988 breeding season. Sacramento, CA: California Department of Fish and Game, Nongame Bird and Mammal Section; final report; contract FG7569. 35 p.

Perry, D., Personal Communication, Oregon State University, Corvallis, OR.

Perry, D. 1991. The ecology of coarse woody debris in Pacific Northwest forests: Overview and the role of down logs in ecosystem processes: report to the Northern Spotted Owl Recovery Team. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Northern Spotted Owl Recovery Team. 39 p.

Raine, R.M. 1982. Ranges of juvenile fisher, *Martes pennanati* and marten, *Martes americana*, in southeastern Manitoba. Canadian Field Naturalist. 96:431-438.

Ralph, C.J.; Miller, S.L.; Naslund, N.L., [and others]. 1990. Marbled murrelet research during 1989 in northern and central California. Sacramento, CA: California Department of Fish and Game, Nongame Bird and Mammal Section; interim report. 39 p.

Raphael, M.G. 1985. Administrative study of relationships between wildlife and old-growth forest stands. San Francisco, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region; final report; Supplement R)-44 under Master Agreement No. 21-395. 19 p. plus illustrations.

Raphael, M.G. 1988. Long-term trends in abundance of amphibians in Douglas-fir forests of northwestern California. Pages 23-31 in: Szaro, R.C.; Severson, K.E.; Patton, D.R. Management of amphibians, reptiles, and small mammals in North America. General Technical Report RM-166. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Reynolds, R.T. 1989. Accipiters. Pages 92-110 in: Pendleton, B.G.; Proceedings of the western raptor symposium and workshop; Washington, D.C. National Wildlife Federation Science and Technical Series No. 12. Institute for Wildlife Research.

Reynolds, R.T.; Wight, H.M. 1978. Distribution, density, and productivity of accipiter hawks breeding in Oregon. Wilson Bulletin. 90:182-196.

Reynolds, R.T.; Meslow, E.C.; Wight, H.M. 1982. Nesting habitat of coexisting accipiter in Oregon. Journal of Wildlife Management. 46:124-138.

Rich, W.M. 1939. Local populations and migration in relation to the conservation of Pacific salmon in the western states and Alaska. Contribution No. 1. Oregon Fish Commission. [Reprinted from the Migration and Conservation of Salmon, Publication No. 8 of the American Association for the Advancement of Science, Science Press, Lancaster, PA.]

Ricker, W.E. 1972. Hereditary and environmental factors affecting certain salmonid populations. Pages 19-160 in: Simon, R.C.; Larkin, P.A., eds. The stock concept in Pacific salmon. Vancouver, Canada: University of British Columbia.

Rodway, M.S. 1990. Status report on the marbled murrelet *Brachyramphus marmoratus*. Ottawa, Canada: Committee on the Status of Endangered Wildlife in Canada. 59 p.

Rosenberg, D.K. 1991. Characteristics of northern flying squirrel and Townsend's chipmunk populations in second- and old-growth forests. Corvallis, OR: Oregon State University. 61 p. M.S. thesis.

Rosenberg, D.K.; Anthony, R.G. 1990. Abundance of small mammals in second- and old-growth Douglas-fir forests. Corvallis, OR: Oregon Cooperative Wildlife Research Unit. 10 p. Unpublished report. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 NE 11th Ave., Portland, OR 97232-4181.

Rosenberg, D.K.; Anthony; R.G. 1992. Characteristics of northern flying squirrel populations in young second- and old-growth forests in western Oregon. Canadian Journal of Zoology. 70:161-166.

Ruggerio, L.F; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. 1991a. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 533 p.

Ruggiero, L.F.; Holthausen, R.S.; Marcot, B.G., [and others]. 1988. Ecological dependency: the concept and its implications for research and management. Transactions of the North American Wildlife and Natural Resources Conference. 53:115-126.

Ruggiero, L.F.; Jones, L.L.C.; Aubry, K.B. 1991b. Plant and animal habitat associations in Douglas-fir forests of the Pacific Northwest: an overview. Pages 447-462 in: Ruggerio, L.E.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 533 p.

Sakai, H.F.; Noon, B.R. 1991. Nest-site characteristics of Hammond's and Pacific-slope flycatchers in northern California. Condor. 93:563-574.

Schempf, P.F.; White, M. 1977. Status of six furbearer populations in the mountains of northern California. San Francisco, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Region. 51 p. Unpublished Report. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Schowalter, T.D.; Caldwell, B.A.; Carpenter, S.E., [and others]. 1991. Decomposition of fallen trees: effects of initial conditions and heterotroph colonization rates. Pages 371-381 in: King, K.P., ed. Tropical ecosystems and management. Wiley Eastern, Ltd., London.

Scrivener, J.C.; Brownlee, M.J. 1982. An analysis of Carnation Creek gravel - quality, data, 1973 to 1981. Pages 154-176 in: Hartman, G.F., ed. Proceedings of the Carnation Creek Workshop: a 10-year review; Pacific Biological Station. Nanaîmo, British Columbia, Canada.

Scrivner, J.H.; Smith, H.D. 1981. Pocket gophers (*Thomomys talpoides*) in successional stages of spruce-fir forests in Idaho. Great Basin Naturalist. 41:362-367.

Solis, D.M. 1983. Summer habitat ecology of spotted owls in northwestern California. Arcata, CA: Humboldt State University. 169 p. M.S. thesis.

Solis, D.M.; Gutierrez, R.J. 1990. Summer habitat ecology of northern spotted owl in Northwest California. Condor. 92:739-748.

Sowls, A.L.; DeGange, A.R.; Nelson, J.W.; Lester, G.S. 1980. Catalogue of California seabird colonies. FWS/OBS/80/37. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Biological Service Program. 371 p.

Speich, S.M.; Wahl, R.T.; Manuwal, D.A. 1992. The numbers of marbled murrelets in Washington marine waters. Pages 48-60 in: Carter, H.R.; Morrison, M.L.; eds. Status and conservation of the marbled murrelet in North America. Proceedings of the Western Foundation Vertebrate Zoology; Vol. 5(1), Camarillo, CA.

Spencer, W.D. 1981. Pine marten habitat preferences at Sagehen Creek, California. Berkeley, CA: University of California. 121 p. M.S. thesis.

Spencer, W.D.; Barrett, R.H.; Zielinski, W.J. 1983. Marten habitat preferences in the northern Sierra Nevada. Journal of Wildlife Management. 47:1181-1186.

Spies, T.A.; Cline, S.P. 1988. Coarse woody debris in forests and plantations of coastal Oregon. Pages 5-23 in: Maser, C.; Tarrant, R.F.; Trappe, J.M.; Franklin, J.F., eds. From the forest to the sea: A story of fallen trees. General Technical Report PNW-GTR-229. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

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

Stalmaster, M.V. 1987. The Bald Eagle. New York: Universal Books. 227 p.

Stebbins, R.C. 1951. Amphibians of Western North America. Berkeley and Los Angeles, CA: University of California Press. 539 p.

Stebbins, R.C. 1985. Peterson field guides: Western amphibians and reptiles. Boston: Houghton Mifflin Co. 336 p.

Stevens, L.E.; Brown, B.T.; Simpson, J.M.; Johnson, R.R. 1977. The importance of riparian habitat to migrating birds. Pages 156-164 in: Johnson, R.R.; Jones, D.A., tech. coords. Importance, preservation and management of riparian habitat; a symposium. General Technical Report RM-GTR-43. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

Storm, R., Personal Communication, Oregon State University, Corvallis, OR.

Strickland, M A.; Douglas, C.W.; Novak, M.; Hunziger, N.P. 1982. Fisher. Pages 586-598 in: Chapman, J.A.; Feldhammer, G.A., eds. Wild mammals of North America, biology, management and economics. Baltimore, MD: The Johns Hopkins University Press.

Swanston, D.N. 1991. Natural processes. American Fisheries Society Publication. 19:139-179.

Szaro, R.C. 1986. Guild management: an evaluation of avian guilds as a predictive tool. Environmental Management. 10:681-688.

Thomas, J.W.; Forsman, E.D.; Gunderson, A.G.; Holthausen, R.S.; Marcot, B.G.; Raphael, M.G.; Reeves, G.H.; Sedell, J.R.; Solis, D.M. [In preparation.]. Report of the Scientific Analysis Team. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR.

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, National Park Service. 427 p.

Thomas, W.A. 1972. Indicators of environmental quality: An overview. Pages 1-5 in: Thomas, W.A., ed. Indicators of Environmental Quality. New York: Plenum Press.

Trappe, J M.; Fogel, R.D. 1977. Ecosystematic functions of mycorrhizae. Pages 205-214 in: The below ground ecosystem: A synthesis of plant-associated processes. Forest Service Series Publication No. 26. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. In cooperation with: Colorado State University.

Ure, D.C.; Maser, C. 1982. Mycophagy of red-backed voles in Oregon and Washington. Canadian Journal of Zoology. 60:3307-3315.

U.S. Department of Agriculture, Forest Service. 1984. Regional guide for the Pacific Northwest Region. Portland, OR.

U.S. Department of Agriculture, Forest Service. 1986. Interim definitions for old-growth Douglas-fir and mixed-conifer forests in the Pacific Northwest and California. Research Note PNW-447. Portland, OR: Pacific Northwest Forest and Range Experiment Station. 7 p.

U.S. Department of Agriculture, Forest Service. 1988. Final supplement to the environmental impact statement for an amendment to the Pacific Northwest regional guide. Vol. 1: Spotted owl guidelines. Portland, OR.

U.S. Department of the Interior, Fish and Wildlife Service. 1986. Pacific bald eagle recovery plan. Portland, OR. 160 p.

U.S. Department of the Interior, Fish and Wildlife Service. 1987. Northern Rocky Mountain wolf recovery plan. Washington, D.C. 119 p.

U.S. Department of the Interior, Fish and Wildlife Service. 1990. Draft revised grizzly bear recovery plan. Missoula, MT. 107 p.

U.S. Department of the Interior, Fish and Wildlife Service. 1992. Critical habitat for the northern spotted owl. Portland, OR. 73 p.

Vannote, R.L.; Minshall, G.W.; Cummins, K., [and others]. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Science. 37:130-137.

Voth, E.; Maser, C.; Johnson, M. 1983. Food Habits of *Aborimus albipes*, the white-footed vole, in Oregon. Northwest Science. 57:1-7.

Wake, D.B.; Yanev, K.P. 1986. Geographic variation in allozymes in a "ring species," the plethodontid salamander *Ensatina eschscholtzii* of western North America. Evolution. 40:702-715.

Waring, R.H.; Franklin, J.F. 1979. The evergreen coniferous forests of the Pacific Northwest. Science. 204:1380-1386.

Washington Department of Wildlife. 1990. Endangered and threatened species status report. Olympia, WA. 8 p.

Washington Department of Wildlife. 1991a. Management recommendations for priority species. Olympia, WA. 170 p.

Washington Department of Wildlife. 1991b. Species of concern list, nongame program. Olympia, WA: Wildlife Management Division. 7 p.

Washington Natural Heritage Program. 1990. Endangered, threatened and sensitive vascular plants of Washington. Olympia, WA: Department of Natural Resources. 52 p.

Waters, J. Personal Communication, U.S. Department of Agriculture, Forest Service, Arcata, CA.

Welsh, H.H., Jr. 1990. Relictual amphibians and old-growth forests. Conservation Biology. 4(3):309-319.

Welsh, H.H., Jr.; Lind, A.J. 1988. Old-growth forests and the distribution of the terrestrial herpetofauna. Pages 439-458 in: Beatty, J., ed. Management of amphibians, reptiles, and small mammals in North America. General Technical Report RM-GTR-166. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station.

West, S.D. 1991. Small mammal communities in the southern Washington Cascade Range. Pages 269-283 in: Ruggerio, L.E.; Aubry, K.B.; Carey, A.B.; Huff, M.H., tech. coords. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-285. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 533 p.

Williams, J.E.; Johnson, J.E.; Hendrickson, D.A., [and others]. 1989. Fishes of North America endangered, threatened, or of special concern: 1989. Fisheries. 14:2-20.

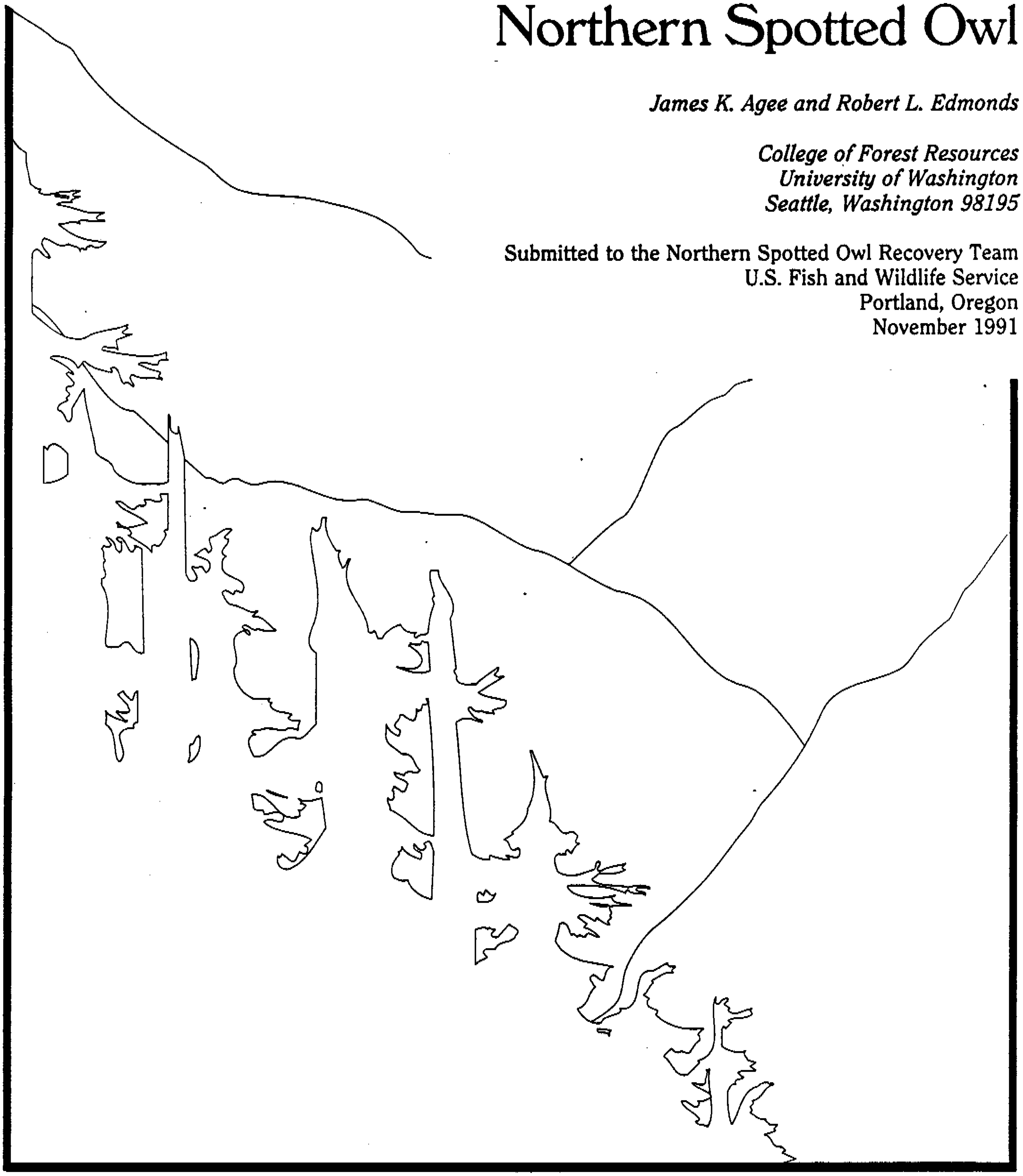
Appendix E

Forest Protection Guidelines for the Northern Spotted Owl

James K. Agee and Robert L. Edmonds

College of Forest Resources
University of Washington
Seattle, Washington 98195

Submitted to the Northern Spotted Owl Recovery Team
U.S. Fish and Wildlife Service
Portland, Oregon
November 1991



Summary

The strategy for protecting the northern spotted owl (*Strix occidentalis caurina*) revolves around large management zones called designated conservation areas (DCAs). Most discussion has centered on slowing or stopping timber harvest activities within such areas and leaving them in "protected" status. However, throughout the range of the northern spotted owl, natural disturbance patterns have a long history and were sometimes catastrophic, eliminating owl habitat for decades to centuries. In other areas, disturbances were frequent and of low magnitude, keeping forest stands fairly open.

This report discusses the nature of these historic disturbance patterns, management effects on forests during the past century, likely impacts of "total protection" attempts, and guidelines intended to reduce probabilities of catastrophic disturbance during the next century. In producing these guidelines, larger scale issues such as global change were not considered. The consequences of global warming, for example, might affect not only forest structure and species composition but owl physiology and predator/prey abundance. Our long-term projections and recommendations must be qualified in this respect.

The range of the owl has been divided into three arbitrary "subregions" for the purposes of this report (Figure E.1). The three subregions defined included the West Cascades subregion, the Klamath subregion, and the East Cascades subregion. This division was based on groupings of disturbance regimes including fire, wind, insects, and diseases. Locally significant disturbance factors such as ice damage along streams or animal damage were ignored, as was volcanic disturbance. We clearly recognize that the descriptions we provide, being those of modal conditions, do not represent the entire range of conditions across each subregion. A gradient of disturbance types and patterns exists on the landscape, but could not be summarized easily. Site-specific forest protection strategies will need to be developed by adapting general trends to individual DCAs within a subregion.

The report first describes the nature of the major disturbance factors, recognizing the need to focus on those disturbances likely to remove significant portions of DCAs in a single or extended event. The probability of such catastrophic disturbance is summarized in Table E.1. The risk levels shown are subjective, but indicate some clear trends. The probability of catastrophic disturbance on a wide scale is lowest in the West Cascade subregion. The Klamath subregion has a higher probability of catastrophic disturbance, but is somewhat buffered by its wider physiographic and tree species diversity. For insects and diseases, which often tend to be one or several tree species-specific, affected species may be replaced by nonaffected species, and quickly replace forest structure needed for owl habitat. The East Cascades subregion is the subregion most at risk, and significant catastrophic disturbance already may be underway.

A "hands-off" policy is not recommended for any of the subregions. Management may be more passive in some subregions than others, but active management is necessary to preserve spotted owl habitat in all three subregions. A summary of the forest protection strategies (Table E.2) indicates that active management will be particularly necessary in the Klamath and East Cascades subregions.

Fire suppression in those regions has helped to create a broader landscape pattern of multiple-canopied stands with thick understories, thought to be suitable for northern spotted owl habitat. The forest protection strategies recommended here will reduce some of that habitat to more effectively protect the rest. Such forests, in their present condition,

are also more likely to be catastrophically disturbed because of higher physiological stress, caused by increased tree density, higher fire hazard, and higher horizontal and vertical fuel continuity.

Recommendations to reduce owl habitat in order to save it may seem a paradox. We believe that such implementation will, in the long run, better protect owl habitat than a more short-sighted attempt to continue total protection. Active management in some areas to reduce the probability of large-scale catastrophic events is the most rational management direction.

Table E.1. Synopsis of catastrophic risk levels from four natural disturbance agents in the three forest subregions.

Disturbance Agent	West Cascades Subregion	Klamath Subregion	East Cascades Subregion
Fire	Low	High	High
Wind	Moderate-Low*	Low**	Low
Insects	Low	Moderate	High
Diseases	Low	Moderate	High

*may be high in areas close to the coast
**may be moderate in areas close to the coast

Table E.2. Summary of risk (in bold letters) and forest protection guidelines for natural disturbance agents within the three subregions.

Disturbance Agent	**Risk and Forest Protection Guidelines in the West Cascades Subregion**
Fire	**Low** given aggressive fire control strategy with high level of detection and initial attack. Areas often will have poor access. Generally no treatment of slash recommended. Constrain natural fire policies in natural areas where owl habitat is defined as the primary management objective.
Wind	**Moderate** with high risk along coast and less inland. Sitka Spruce Zone highest risk, along with fragmented forest (areas with high density of patch cuts). Avoid further fragmentation, possibly feather edges of susceptible stands. In windthrow-prone areas where thinning is recommended to increase development of suitable owl structure, generally remove less than 30 percent of basal area.
Insects	**Low** Salvage of burned or windthrown timber may be needed in some situations to prevent insect population buildup.
Diseases	**Low** Endemic diseases likely to continue, unlikely to be catastrophic. Some, like mistletoe, may enhance owl habitat.

Disturbance Agent	**Risk and Forest Protection Guidelines in the Klamath Subregion**
Fire	**High** except in higher elevation White and Red Fir Zones and along coast in moist coastal redwood. Need a site-specific fuelbreak zone linked with area treatment (underburning a primary strategy) to reduce potential wildfire severity and extent. This may reduce owl habitat to some extent in treated areas in order to preserve it elsewhere.
Wind	**Low** except along coast. Leave windfirm redwood and Douglas-fir in any coastal thinnings or manipulations; may want to feather edges of existing fragmented forest.
Insects	**Moderate** with some fuel treatment after harvest or wildfire to prevent insect population buildup. Underburning should eventually result in healthier stands with lower stress levels.
Diseases	**Moderate** with disease extent likely to increase with continued fire suppression. Higher tree species diversity tends to buffer impact on owl habitat, however.

Disturbance Agent	**Risk and Forest Protection Guidelines in the East Cascades Subregion**
Fire	**High** will need fuelbreak system plus substantial underburning, particularly in lower-elevation habitat, to break up fuel continuity. South aspects a high priority: fewer nest sites there. Subsequent wildfire severity and extent reduced at some cost to existing owl habitat.
Wind	**Low** with some increased wind damage expected if total fire suppression continues and disease continues to increase.
Insects	**High** Stand density control is imperative on most sites to reduce stocking and stress on existing stands. Extensive thinning could increase root rot problems. Mortality already occurring in pine.
Diseases	**High** Diseases likely to increase in absence of fire. Underburning may help to control some disease by burning out stumps harboring disease organisms.

Contents

I. Introduction

The long-term protection of habitat for the northern spotted owl (*Strix occidentalis caurina*) revolves around large protected areas called designated conservation areas (DCAs). This strategy assumes that by protecting fairly large blocks of suitable habitat, and spacing these blocks throughout the range of the species, there is reasonable assurance that the viability of the subspecies will be maintained. A major assumption of this strategy is that the DCA network will perpetually provide suitable habitat for the spotted owl. Some redundancy is provided in the network to compensate for potential loss of habitat in individual DCAs. A primary threat to the owl to date has been clear-cutting of mature to old-growth stands; the DCA strategy assumes elimination or major reduction in timber removal within DCAs as well as between them. A primary threat in the future for established DCAs will be the probability of damage or destruction by a variety of "natural" disturbance agents: fire, wind, insects, and diseases. The purpose of this report is to describe the nature of these threats, the probability of success of a total protection strategy, and guidelines to increase the probability of successful maintenance of conditions within DCAs suitable for spotted owls in the face of such threats.

A. Definition of Suitable Habitat

The following description of habitat for the northern spotted owl is abstracted from the proposed critical habitat rules published in the *Federal Register* on May 6, 1991 (vol. 56, no. 87). The northern spotted owl is known from most of the major types of coniferous forests in the Pacific Northwest. Spotted owls seem to avoid subalpine forests, but have been found as low as 70 feet elevation in the Olympic Peninsula and as high as 6,000 feet elevation in California. Spotted owls commonly use Douglas-fir (*Pseudotsuga menziesii*) and mixed-conifer forests in California. In that area, habitat tends to be discontinuous in a mosaic pattern. In Washington's coastal forests, the spotted owl is found in forests dominated by Douglas-fir and western hemlock (*Tsuga heterophylla*). At higher elevations spotted owls use Pacific silver fir (*Abies amabilis*), while on the east side of the Cascades, Douglas-fir and grand fir (*Abies grandis*) are used.

The age of a forest is not as important a factor in determining habitat suitability as are vegetational and structural elements. Components of northern spotted owl nesting habitat are: 1) moderate to high canopy closure (60 to 80 percent or more); a multilayered, multispecies canopy dominated by large (more than 30 inches dbh) overstory trees; 2) a high incidence of large trees with various deformities (e.g., large cavities, broken tops, mistletoe infections, and other evidence of decadence); 3) numerous large snags; 4) large accumulations of fallen trees and woody debris on the ground; and 5) sufficient open space beneath the canopy for owls to fly (Thomas et al. 1990). Old-growth or mixed-species stands typically require a minimum of 150 to 200 years to attain these aforementioned attributes. Attributes of breeding and roosting habitat are sometimes found in younger stands, especially those with remnants of the earlier stand that was disturbed by fire, wind storms, inefficient logging operations, or high-grading. However, nearly all nest and roost sites are found in the portions of these stands with the oldest components. In the Oregon Coast Ranges, Oregon Cascades, Washington Cascades, Olympic Peninsula, and Klamath Province, owls use old forests more than expected for foraging and roosting.

B. Selection of Forest Types

At the time this report was prepared, fall 1991, a final set of DCAs was not available for analysis. Therefore, we chose three forest "subregions" typical of the range of conditions found in northern spotted owl habitat from Washington through northwestern California. Each subregion has a unique forest species composition, environment, and mix of disturbance agents. Effects of natural disturbance and successful protection scenarios are likely to vary by subregion. This scenario will also vary within subregion, as there is more within-subregion variation than can be adequately represented by the three "modal" scenarios presented in this report.

The first forest type is the wet-cool type including all of the Sitka Spruce (*Picea sitchensis*) Zone and most of the Western Hemlock Zone (Franklin and Dyrness 1973), ranging into the lower Pacific Silver Fir Zone, with less emphasis on the drier plant associations, particularly toward the south within the Western Hemlock Zone. We call this the *West Cascades* subregion (Figure E.1). The second type is the Mixed-Evergreen/Mixed-Conifer

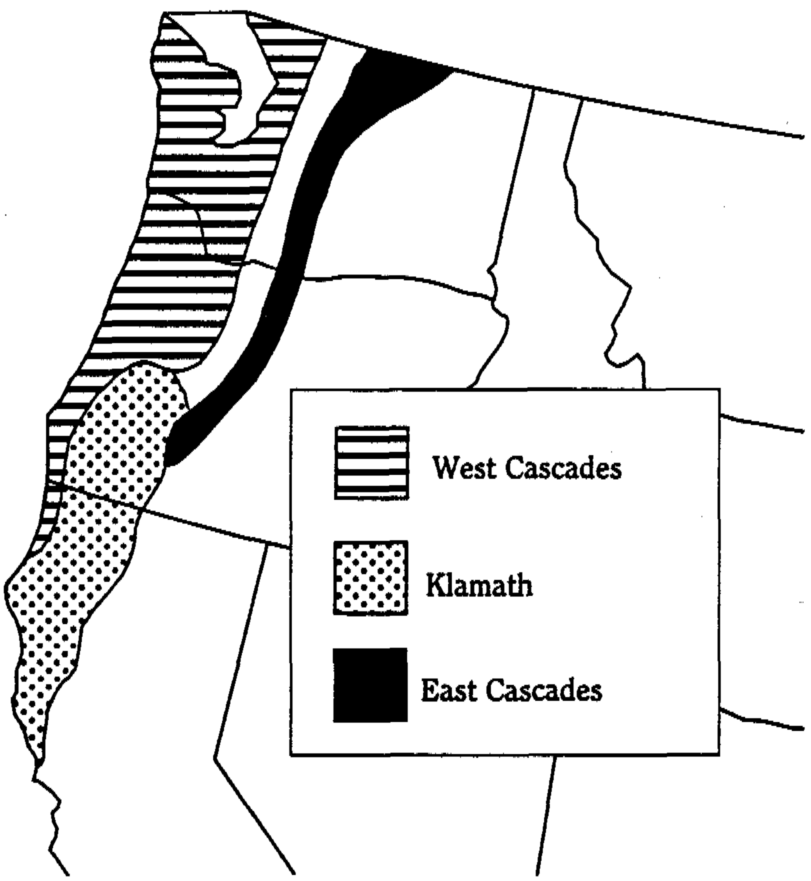


Figure E.1. *General geographical range of the three subregions defined in this report. Where subregions meet, there is an overlap that is not represented in this figure.*

Zone of southwestern Oregon/northwestern California, which we call the *Klamath* subregion. The third type is the Grand Fir/Douglas-fir Zone of the eastern Cascades, which we call the *East Cascades* subregion. While these are not wholly homogeneous subregions, they encompass the range of variability expected in northern spotted owl habitat protection scenarios.

C. Characteristics of Forest Types of the Three Subregions

The general characteristics of the forest types of the Pacific Northwest are well described in Franklin and Dyrness (1973). A skeletal description of the subregions included in this report is made to provide a brief context for the sections of the report to follow. In the West Cascades subregion, northern spotted owls are found in the Sitka Spruce Zone, the Western Hemlock Zone, and into the Pacific Silver Fir Zone, the latter of which is not fully described here, although some owls may live in these forests. The Sitka Spruce Zone is a narrow coastal strip normally a few miles wide, except where it extends up river valleys. Its proximity to the ocean and summer fogs, and presence of Sitka spruce (Table E.3), differentiate this zone from the Western Hemlock Zone, which has many of the same species.

The Western Hemlock Zone (Table E.3) occurs over much of the lowlands west of the Cascade Mountains, and is often dominated by Douglas-fir as the major seral tree species;

Table E.3. Major tree species in the region and their relative importance by subregion.

Species	West Cascades		Klamath		East Cascades	
	Sitka Spruce Zone	Western Hemlock Zone	Mixed-conifer Zone	Mixed-evergreen Zone	Douglas-fir Zone	Grand Fir Zone
Sitka spruce	M	m	–	–	–	–
Western redcedar	M	M	–	–	–	–
Western hemlock	M	M	–	–	–	–
Douglas-fir	m	M	M	M	M	M
Pacific silver fir	–	m	–	–	–	–
Pacific madrone	m	m	M	–	–	–
Tanoak	–	–	M	–	–	–
White/grand fir	–	–	M	m	m	M
Ponderosa pine	–	–	M	M	M	m
Lodgepole pine	–	–	m	–	m	M
Western larch	–	–	–	–	–	M

M = major species m = minor species
Note: Not all species in a type are listed. Some that are listed above may be classed as absent (–) because they are present in special environments only (e.g., riparian) or are not widely distributed across the type.
Source: Forest Zones (adapted from Franklin and Dyrness 1973).

western hemlock is commonly found in all canopy layers in old-growth forest. Its upper boundary with the Pacific Silver Fir Zone often corresponds to the line of perennial snowpack in winter months. The portion of the Pacific Silver Fir Zone which contains owl habitat also has Douglas-fir as a seral species, but increasingly Pacific silver fir replaces western hemlock as the late successional tree dominant. The wetter plant associations may receive up to 160 inches of annual precipitation, and the driest plant associations may receive as little as 25 inches. Discussion of disturbance and forest protection for this zone is most applicable to the wetter plant associations (those with more than about 60 inches of annual precipitation). The drier western hemlock plant associations are on an environmental gradient toward the Mixed-Conifer Zone discussed for the Klamath subregion, environmentally if not geographically.

The Klamath subregion forests include those of the Mixed-Evergreen Zone, the Mixed-Conifer Zone, and the White Fir Zone, the latter of which is a moist and cool transition normally above either of the other two zones in southern Oregon and northern California. Douglas-fir is a common dominant in both forest types. In the Mixed-Conifer Zone, ponderosa pine, white or grand fir, sugar pine (*Pinus lambertiana*) or incense-cedar (*Calocedrus decurrens*) may be codominants. In the Mixed-Evergreen Zone, madrone (*Arbutus menziesii*), tanoak (*Lithocarpus densiflorus*), black oak (*Quercus kelloggii*), and canyon live oak (*Quercus chrysolepis*) are common lower canopy dominants, while in the Mixed-Conifer Zone, white fir is commonly the lower canopy dominant.

The East Cascades subregion includes the mid-elevation Douglas-fir and Grand Fir Zones sandwiched between higher elevation subalpine forest and lower elevation ponderosa pine forests. In some locations, particularly northern Washington, the Grand Fir Zone is absent. Douglas-fir tends to be a canopy dominant, sometimes with western larch (*Larix occidentalis*) and/or ponderosa pine (*Pinus ponderosa*). Grand fir in the Grand Fir Zone, and Douglas-fir in the Douglas-fir Zone, are the most shade-tolerant species and may be well represented in the lower canopy layers.

II. Major Natural Disturbance Factors of the Region

Traditional theories of disturbance in ecosystems have held that disturbance must be a major event and must originate outside the ecosystem (i.e., be exogenous) (White 1979). We now embrace a much broader concept of disturbance, recognizing a disturbance gradient from minor to major and the endogenous component of many disturbances (due either to biotic agents or ecosystem states that encourage disturbance to occur). As we accept this broader concept, we thereby create a fuzzier image of disturbance.

Disturbance is a difficult word to define. A simple definition is to "interrupt" or "break up a quiet or settled order." Forest ecosystems, we know, are not "quiet or settled orders," but when do the natural, normal rhythms of the system oscillate to a point where they become "abnormal"? There is no easy answer, but White and Pickett (1985) suggest that disturbance can be defined as " . . . any relatively discrete event in time that disrupts ecosystem, community, or population structure and changes resources, substrate availability, or the physical environment." It may be characterized by such descriptors as frequency, magnitude, extent, predictability, synergism, and timing (White and Pickett 1985). It may include processes such as forest fire, wind, insect, and disease outbreaks, ice and freeze damage, landslides, floods, and others. Disturbance need not be either a disaster or a catastrophe.

In Pacific Northwest forests, the primary disturbance factors of concern in DCA protection are fire, wind, insects, and diseases. This report therefore focuses on these and omits the minor disturbance factors that normally are of limited extent and major disturbance factors such as volcanoes.

A. Fire

The combination and interaction of fire frequency, intensity, and extent that occur in an ecosystem are known as a fire regime. The fire regimes of Pacific Northwest forests span a wide gradient of variation (Agee 1981). Natural fire regimes ranged from infrequent (hundreds of years) stand replacement fires, to very frequent (several years) low-intensity surface fires that had little effect on the canopy trees. The fire regime is a way to synthesize the effects of fire by combining many of the descriptors listed earlier. Although fire regimes can be described on the basis of characters of the disturbance itself (Heinselman 1981), or character of the vegetation (Davis et al. 1980), another way is by defining the fire regime on the basis of fire effects, or severity (Agee 1990). The system using fire severity is defined in terms of fire effects on dominant tree species, and works well for application to owl habitat. For the Pacific Northwest, three levels of fire severity are recognized (Figure E.2): high, moderate, and low. Northern spotted owls occur in forests subjected to all three fire severity types.

A high severity fire is one that topkills most of the vegetation in the stand (70 to 80 percent plus of the basal area); a moderate severity fire topkills 20 to 70 percent; and a low severity

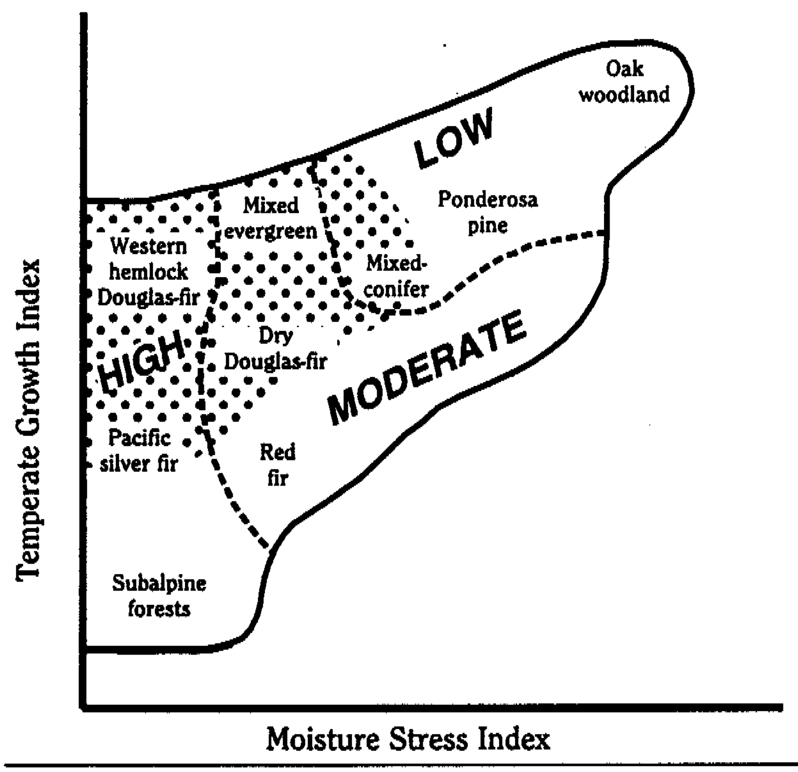


Figure E.2. *Fire severity regimes of the Pacific Northwest. Major forest types are ordinated on temperature and moisture axes, and then defined as high, moderate, or low severity regimes. The types enclosed by the stippled pattern are those where the northern spotted owl is found.*

fire topkills less than 20 percent of the basal area. Fire, in a silvicultural sense, tends to thin from below, first taking smaller trees and/or those less fire-resistant (thin-barked, for example). It must be recognized that each regime is defined on the basis of the modal severity but that fires of other severity levels are likely to occur as well (Figure E.3). The most complex fire regimes are the moderate ones because of the mix of expected fire severities, while the low and high fire severity regimes are generally more predictable. Management activities over decades, such as successful fire protection, can change low or moderate severity fire regimes to moderate to high severity fire regimes. Descriptions of fire regimes in later sections of the report will refer to these severity diagrams.

Within the DCA system lightning will be the largest single source of ignition for fires. Lightning is the primary source of forest fires worldwide, with as many as 44,000 thunderstorms occurring daily over the earth (Trewartha 1968). Thunderstorm activity is relatively mild in the Pacific Northwest. While Portland, Oregon, and Tacoma, Washington, average 5 thunderstorm days per year, and Baker, Oregon, and Walla Walla, Washington, average 10 to 15, southeastern areas such as Mobile, Alabama, average about 75 thunderstorm days per year (Alexander 1924). However, in the southeast only 2 percent of wildfires are lightning-caused, while in the Pacific states 37 percent of ignitions originate from lightning (Taylor 1974). Some lightning storms in the Pacific Northwest are very localized and others are regional in extent. The regional storms can ignite hundreds of fires almost simultaneously and pose the greatest type of fire threat to DCAs. Lightning detection systems can pinpoint where the lightning is striking, but crews may not arrive in time to suppress the fire while it is small.

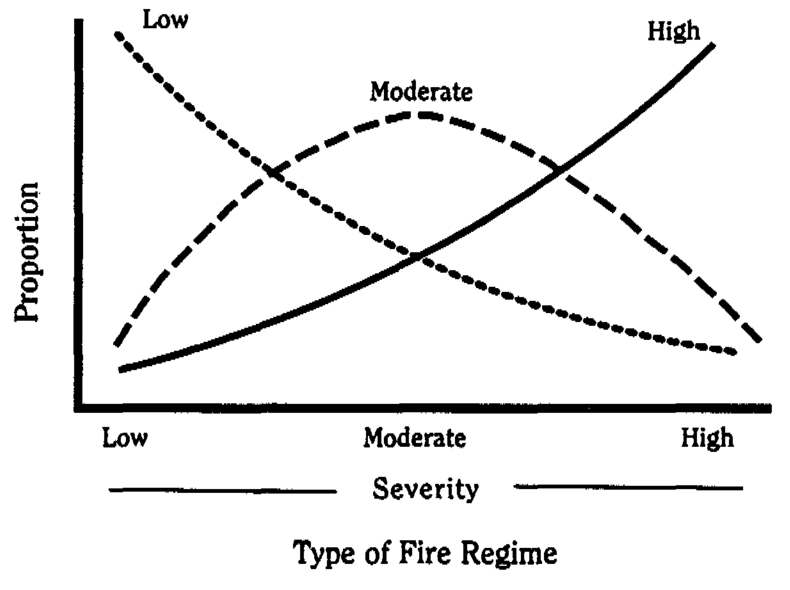


Figure E.3. *A range of fire severity levels is found within each fire regime depicted in Figure E.2. The proportions of the various fire severity levels are shown by the lines of the graph. As fire severity regimes move on the left-to-right gradient from low to high, the proportion of low severity fires decreases while high severity fires increase. Moderate severity fires peak in the moderate severity regime, which is the most complex fire regime in terms of fire effects.*

In the past, human ignitions have been locally significant in the West Cascades subregion, particularly Indian burning of grasslands and oak woodlands (Boyd 1986, Teensma 1987, Norton 1979, White 1980). In the East Cascade subregion, Indian burning was more common in the forest (Shinn 1980, Barrett and Arno 1982). Today's human ignitions (recreation, logging, debris burning causes) are partially amenable to management actions through education (Keep Green campaigns) or by limiting access (complete or weather-related road closures).

B. Wind

Most of the information about wind as a disturbance factor is from coastal areas exposed to the Pacific Ocean winds. This area includes the Sitka Spruce Zone, as defined by Franklin and Dyrness (1973), and the adjacent Western Hemlock Zone.

The successional dynamics of these coastal forests are complex because of the types and intensities of disturbances that have interacted with the forests over time. In the absence of disturbance over many centuries, western hemlock and western red cedar (*Thuja plicata*) would dominate the forests of this zone. In the presence of major periodic disturbance such as fire, which removes almost all of the pre-existing stand, Douglas-fir would initially dominate on upland sites and red alder (*Alnus rubra*) would initially dominate on very wet sites, gradually being replaced by hemlock and cedar. Sitka spruce appears to be a "gap-phase" species capable of regenerating in small openings created by windthrow or overstory mortality (Hines 1971). Large fires and blowdowns do occur in spruce-hemlock forests, but smaller scale events may be equally important forces in forest stand development (Harcombe 1986).

Wind appears to have been the most important disturbance factor for the forests of the Sitka Spruce Zone (Ruth and Harris 1979). Most wind-dominated stands have "pit and mound" topography. It is a hummocky ground topography caused by uprooting of tree stems by wind, causing the pit, and subsequent sloughing of the soil material from the base of the uprooted stem, creating the adjacent mound. Usually, the prevailing wind direction creates a pattern of pits on the upwind side and mounds on the downwind (direction of tree fall) side. Most recent windthrown trees also are oriented downwind, although jackstrawing also may occur.

Studies of windthrow in Washington and Oregon suggest most damaging winds are from the southwest (Ruth and Yoder 1953, Steinbrenner and Gessel 1956), or occasionally the east (Gratkowski 1956). Blowdown is more important on poorly drained soils (Gratkowski 1956), or where the area is oriented across the direction of the prevailing winds (Moore and McDonald 1974). Species' tolerances to wind may be site-specific. Western hemlock and Pacific silver fir are generally prone to windthrow, western red cedar and Sitka spruce at times may be windfirm, and Douglas-fir has been described as both wind-tolerant and wind-sensitive (Boe 1965, Moore and McDonald 1974, Henderson et al. 1989). Dominants in a stand are often more windfirm than intermediate crown-class trees (Boe 1965, Gordon 1973).

The frequency of winds strong enough to affect stand dynamics cannot be determined with much accuracy. However, topographic situations suggest that flat lands or slopes/ridges exposed to the southwest will be least sheltered. In areas where clear-cutting occurs, the lee side of the patch is most susceptible to accelerated windthrow. Areas sheltered from these winds will suffer less blowdown. For example, at Fort Clatsop near Astoria, Oregon, Merriwether Lewis noted on February 15, 1806: "... the S.W. winds are frequently very violent on the coast when we are but little sensible of them at Fort Clatsop, in Consequence of the lofty and thickly timbered fir country which surrounds us from that quarter, from the south to the N. East" (Thwaites 1905).

C. Insects

Insects cause many problems in Pacific Northwest forests and there are thousands of species (Furniss and Carolin 1977). Only a few, however, have major impacts on forests. Insects in Table E.4 are listed according to their activity in forests; e.g., defoliators, terminal miners, bark beetles, aphids and scale insects, and wood borers. Other parts of trees, such as cones, are affected, but these are not included in Table E.4 because they have little impact on forest structure. Note that there are generally fewer insect species having a major impact on forests in the West Cascades subregion than in the other two subregions. Defoliators and bark beetles are important in the East Cascades and Klamath subregions. There, they can create large landscape level disturbance causing tree mortality over thousands of acres. In the West Cascades subregion disturbances are smaller, but occasionally large epidemics of defoliators occur; e.g., the western hemlock looper which had outbreak periods in 1889-1891, 1911-1914, 1929-1932, 1943-1946, and 1961-1963. These outbreaks generally occurred in extensive old-growth hemlock stands (Furniss and Carolin 1977).

Each insect has its own ecological niche and function in western forests and each kind of tree is host to many insects. Some tree species, however, are more attractive to insects than others. For example, pines and oaks are infested by far more insects than are redwoods and yews. Some insects play a major role in the life cycle and structure of extensive forest areas, such as the western pine beetle in ponderosa pine forests (Furniss and Carolin 1977). With forest harvesting and management many of these insects became destructive and now are controlled artificially.

Most western forest insects are native, although a few, such as the balsam wooly adelgid, have been introduced. Numbers of insects tend to fluctuate widely and some periodically become epidemic, such as the Douglas-fir tussock moth and spruce budworm. Several bark beetle species also have become epidemic, especially in drier areas. Fire control practices and early forest harvesting practices in the last 75 years are generally thought to have contributed to increases in bark beetle populations by creating populations of stressed trees. Bark beetles tend to cause the highest amounts of insect-related mortality. In healthy ecosystems insects generally remain in small numbers with outbreaks often precipitated by plant stress (e.g., caused by drought, nutrient deficiencies, and air pollution). With predicted global climate change, many plant species could become stressed as temperature and precipitation change beyond their tolerance level (Perry and Borchers 1990). This, plus the fact that insect populations usually grow faster in warmer, drier climates, could lead to large outbreaks. However, climate changes may suppress some insects.

Defoliating insects cause reduced radial growth and height increment, topkilling, and reduced regeneration; they also sometimes kill extensive stands (Swetnam and Lynch 1989). Heavy defoliation by Douglas-fir tussock moth of Douglas-fir and grand fir in north central Idaho caused growth of host species to decrease 75 to 90 percent in 1 year (Brubaker 1978). Normal growth rates returned 3 to 4 years after maximum defoliation, however. Some researchers report increased radial growth of trees after defoliation

Table E.4. Important forest insects in the West Cascades, Klamath, and East Cascades subregions.

Common Name	Causal Agent	Tree Species
	West Cascades Subregion	
DEFOLIATORS		
Western hemlock looper	*Lambdina fiscellaria lugubrosa*	Western hemlock mostly, also associated Sitka spruce, Pacific silver fir, and Douglas-fir
Forest tent caterpillar	*Malacosoma disstria*	Alder
TERMINAL MINERS		
Sitka spruce weevil	*Pissodes sitchensis*	Sitka spruce
BARK BEETLES, WEEVILS, AND PINHOLE BORERS		
Douglas-fir beetle	*Dendroctonus pseudotsugae*	Douglas-fir
Hylastes root bark beetle	*Hylastes nigricinus*	Douglas-fir
Root weevil	*Pissodes fasciatus*	Douglas-fir
	Steremnius carinatus	Douglas-fir
Ambrosia beetle	*Platypus* spp., *Gnathotrichus* spp., *Trypodendron* spp.	All conifers
Silver fir beetle	*Pseudohylesinus sericeus*	Pacific silver fir, western hemlock, Douglas-fir
SCALES AND APHIDS		
Cooley spruce gall aphid	*Adelges cooleyi*	Douglas-fir, spruce
CARPENTER ANTS AND WOOD BORERS		
Carpenter ant	*Camponotus pennsylvanicus*	All species
Wood borer	*Buprestids and Cerambycids*	All conifers

continues—

continued–

Common Name	Causal Agent	Tree Species
	Klamath Subregion	
DEFOLIATORS		
Pandora moth	*Coloradia pandora*	Ponderosa pine, sugar pine
Douglas-fir tussock moth	*Orygia pseudotsugata*	Douglas-fir, ponderosa pine
Western spruce budworm	*Choristoneura occidentalis*	Douglas-fir, grand fir
BARK BEETLES		
Douglas-fir beetle	*Dendroctonus pseudotsugae*	Douglas-fir
Mountain pine beetle	*Dendroctonus ponderosae*	Ponderosa, sugar, lodgepole, western white pines
Red turpentine beetle	*Dendroctonus valens*	Ponderosa, lodgepole, sugar, Jeffrey, western white pines
Western pine beetle	*Dendroctonus brevicomis*	Ponderosa pine
Pine engraver beetle	*Ips* spp.	Pines
Fir engraver	*Scolytus ventralis*	True firs
Ambrosia beetle	*Platypus* spp., *Gnathotrichus* spp., *Trypodendron* spp.	All conifers
Flatheaded fir borer	*Melanophila drummondi*	Douglas-fir, true firs
California flat-headed borer	*Melanophila californica*	Jeffrey, sugar, ponderosa pines
SCALES AND APHIDS		
Cooley spruce gall aphid	*Adelges cooleyi*	Douglas-fir, spruce
CARPENTER ANTS and WOOD BORERS		
Carpenter ant	*Camponotus pennsylvanicus*	All species
Wood borer	*Buprestids and Cerambycids*	All conifers

continues–

continued–

Common Name	Causal Agent	Tree Species
	East Cascades Subregion	
DEFOLIATORS		
Douglas-fir tussock moth	*Orygia pseudotsugata*	Douglas-fir, ponderosa pine
Western spruce budworm	*Choristoneura occidentalis*	Douglas-fir, grand fir, larch
Larch sawfly	*Pristiphora erichsonii*	Larch
Larch casebearer	*Coleophora laricella*	Larch
TERMINAL MINERS		
Western pine shoot borer	*Eucosma sonomona*	Ponderosa and lodgepole pines
BARK BEETLES AND PINHOLE BORERS		
Douglas-fir beetle	*Dendroctonus pseudotsugae*	Douglas-fir
Mountain pine beetle	*Dendroctonus ponderosae*	Ponderosa, white, lodgepole pines
Red turpentine beetle	*Dendroctonus valens*	Pines
Pine engraver beetle	*Ips* spp.	Pines
Fir engraver	*Scolytus ventralis*	True firs
Western pine beetle	*Dendroctonus brevicomis*	Ponderosa pine
Ambrosia beetle	*Platypus* spp., *Gnathotrichus* spp., *Trypodendron* spp.	All conifers
SCALES AND APHIDS		
Cooley spruce gall aphid	*Adelges cooleyi*	Douglas-fir, spruce
Balsam wooly adelgid	*Adelges piceae*	Grand fir
CARPENTER ANTS AND WOOD BORERS		
Carpenter ant	*Camponotus pennsylvanicus*	All species
Wood borer	*Buprestids and Cerambycids*	All conifers

Source: Furniss and Carolin (1977), Pettinger and Goheen (1972), Holsten et al. (1985), Hagle et al. (1987), Johnson and Lyon (1988), and Partridge et al. (undated).

(Stoszek 1988, Wickman 1990). Lowest levels of defoliation usually are associated with later stages of succession (old-growth) (Stoszek 1988).

Many of the trees killed by bark beetles and defoliators also are being attacked by root diseases and it is sometimes difficult or even impossible to separate the effects of insects and diseases, especially in drier forest types. Snags and down wood from insect-killed trees increase forest fire hazard but provide important wildlife habitat.

D. Diseases

Forest diseases in the Pacific Northwest are caused mainly by fungi and dwarf mistletoes. Bacteria, viruses, and nematodes also cause diseases but to a minor extent. The major diseases can be classified as foliage diseases, heart rots or bole decays; stem and branch diseases (cankers, rusts, dwarf mistletoes); root rots; and cone and seed diseases. More recently "decline diseases" have been recognized whereby trees tend to decline and slowly die during a period of years. Decline usually occurs in areas where chronic levels of air pollution or drought have induced stress allowing insects and diseases to gain a foothold.

Although the general types of diseases are similar in the West Cascades, Klamath, and East Cascades subregions, the species of fungi and dwarf mistletoes tend to change with the tree species. Some disease organisms have broad host ranges while others have relatively narrow host ranges (Table E.5). There are hundreds of disease organisms in these forests

Table E.5. Important forest diseases in the West Cascades, Klamath, and East Cascades subregions.

Common Name	Causal Agent	Tree Species
	West Cascades Subregion	
FOLIAGE DISEASES		
Swiss needle cast	*Phaeocryptopus gaumanii*	Douglas-fir
Rhabdocline needle cast	*Rhabdocline pseudotsugae*	Douglas-fir
Brown felt blight	*Herpotrichia nigra*	True firs
Cedar leaf blight	*Didymascella thujina*	Western redcedar
Bynum's blight	*Lophodermella morbida*	Ponderosa pine
ROOT ROTS		
Phellinus root rot	*Phellinus weirii*	Douglas-fir, mountain hemlock most susceptible
Armillaria root disease	*Armillaria ostoyae*	All conifers (Douglas-fir most susceptible)
Annosus root and butt rot	*Heterobasidion annosum*	Western hemlock and true firs most susceptible

continues—

continued–

Common Name	Causal Agent	Tree Species
Black stain root disease	*Leptographium wageneri*	Douglas-fir most susceptible
Rhizina root rot	*Rhizina undulata*	Douglas-fir
HEART ROTS AND DECAYS		
White pocket rot	*Phellinus pini*	Douglas-fir
Annosus root and butt rot	*Heterobasidion annosum*	Western hemlock and true firs most susceptible, Sitka spruce
Velvet top fungus	*Phaeolus schweinitzii*	Douglas-fir, true firs
Sulphur fungus	*Laetoporus sulphureus*	Douglas-fir, spruce
(No common name)	*Poria asiatica*	Western redcedar
Red belt fungus	*Fomes pinicola*	All dead conifers
Pouch fungus	*Cryptoporus volvatus*	Dead conifers
Artists conk	*Ganoderma applanatum*	Hardwoods, conifers
False tinder fungus	*Phellinus ignarius*	Hardwoods
MISTLETOES		
Western hemlock dwarf mistletoe	*Arceuthobium tsugense*	Western hemlock
Oak mistletoe	*Phoradendron* spp.	Oaks
RUSTS		
Western gall rust	*Endocronartium harknessii*	Shore pine, lodgepole pine
White pine blister rust (introduced)	*Cronartium ribicola*	Western white pine
CANKERS		
Phomopsis canker	*Diaporthe lokoyae*	Douglas-fir
	Klamath Subregion	
FOLIAGE DISEASES		
Elytroderma needle cast	*Elytroderma deformans*	Ponderosa pine
Red band needle disease	*Dothistroma pini*	Ponderosa pine
Lohphodermium complex	*Lophodermium pinastri*	Sugar pine

continues–

continued—

Common Name	Causal Agent	Tree Species
ROOT ROTS		
Phellinus root rot	*Phellinus weirii*	Douglas-fir
Armillaria root disease	*Armillaria ostoyae*	All conifers (Douglas-fir and ponderosa pine most suscept-tible)
Annosus root and butt rot	*Heterobasidion annosum*	Ponderosa pine most susceptible, white fir
Port Orford cedar	*Phytophthora lateralis*	Port Orford cedar
Black stain root disease	*Leptographium wageneri*	Douglas-fir and pines
HEART ROTS AND DECAYS		
White pocket rot	*Phellinus pini*	Douglas-fir, pines, true firs
Velvet top fungus	*Phaeolus schweinitzii*	Douglas-fir, pines, true firs, incense cedar
Pocket dry rot	*Polyporus amarus*	Incense cedar
Sulphur fungus	*Laetoporus sulphureus*	Douglas-fir, true firs, pines
(no common name)	*Poria sequoiae*	Coast redwood
Red belt fungus	*Fomes pinicola*	All dead conifers
Pouch fungus	*Polyporus volvatus*	Dead conifers
MISTLETOES		
Douglas-fir dwarf mistletoe	*Arceuthobium douglasii*	Douglas-fir
Western dwarf mistletoe	*A. campylopodum*	Ponderosa pine
Sugar pine dwarf mistletoe	*A. californicum*	Sugar pine
True fir dwarf mistletoe	*A. abietinum*	White and grand fir
Incense-cedar mistletoe	*Phoradendron juniperinum ssp. libocedri*	Incense cedar
Oak mistletoe	*Phoradendron* spp.	Oaks

continues—

continued–

Common Name	Causal Agent	Tree Species
RUSTS		
Western gall rust	*Endocronartium harknessii*	Shore pine, lodgepole pine
White pine blister rust (introduced)	*Cronartium ribicola*	Western white, sugar pine
Incense cedar rust	*Gymnosporangium libocedri*	Incense cedar
	East Cascades Subregion	
FOLIAGE DISEASES		
Elytroderma needle cast	*Elytroderma deformans*	Ponderosa pine
Larch needle blight	*Hypodermella laricis*	Western larch
ROOT ROTS		
Phellinus root rot	*Phellinus weirii*	Douglas-fir, western red cedar
Armillaria root disease	*Armillaria ostoyae*	All conifers (Douglas -fir and ponderosa pine most susceptible)
Annosus root and butt rot	*Heterobasidion annosum*	Ponderosa pine most susceptible
Tomentosus root rot	*Inonotus tomentosus*	True firs, ponderosa and lodgepole pines
HEART ROTS AND DECAYS		
White pocket rot	*Phellinus pini*	Douglas-fir, pines, true firs, larch, hemlock, western redcedar
Velvet top fungus	*Phaeolus schweinitzii*	Douglas-fir, pines, true firs, larch, western redcedar
Sulphur fungus	*Laetoporus sulphureus*	Douglas-fir, true firs, pines, larch, western redcedar
Indian paint fungus	*Echinodontium tinctorium*	True firs, hemlock, western redcedar
Quinine conk	*Fomitopsis officinalis*	Douglas-fir, pines, larch

continues–

continued–

Common Name	Causal Agent	Tree Species
Red belt fungus	*Fomes pinicola*	All dead conifers
Pouch fungus	*Cryptoporus volvatus*	Dead conifers, especially ponderosa and lodgepole pines
MISTLETOES		
Douglas-fir dwarf mistletoe	*Arceuthobium douglasii*	Douglas-fir
Western dwarf mistletoe	*A. campylopodum*	Ponderosa pine
Lodgepole pine dwarf mistletoe	*A. americanum*	Lodgepole pine
Larch dwarf mistletoe	*A. laricis*	Western larch
Oak mistletoe	*Phoradendron* sp.	Oaks
Incense cedar mistletoe	*Phoradendron juniperinum* ssp. *libocedri*	Incense cedar
RUSTS		
Western gall rust	*Endocronartium harknessii*	Shore pine, lodgepole pine
Comandra blister rust	*Cronartium comandrae*	Ponderosa pine, lodgepole pine
White pine blister rust	*Cronartium ribicola* (introduced)	Western white pine

Source: Bega (1979), Boyce (1961), Hadfield et al. (1986), Hagel et al. (1987), Hepting (1971), Holsten et al. (1985), Partridge et al. (undated), Pettinger (1972), Sinclair et al. (1987), and USDA Forest Service (1983).

but only the most important organisms; i.e., those likely to strongly influence the structure of forests, are listed in Table E.5. Most of the diseases in the region are native. White pine blister rust, however, was introduced and has had a major impact on populations of five-needled pines.

The type of disease typically changes as forest succession proceeds (Table E.6). Root rots tend to be more important in the early stages of succession while heart rots and other decays and dwarf mistletoes tend to be more important in later stages of succession, especially in old-growth forests. Root rots, however, can be an important disturbance in old-growth forests; e.g., *Phellinus weirii* in 150- to 250-year-old mountain hemlock stands in central Oregon (Waring et al. 1987). Franklin et al. (1987) implicated diseases as a major cause of tree mortality in old-growth forests, especially in the West Cascades subregion. Diseases are probably a more important cause of mortality than insects in this subregion.

Table E.6. Changes in causes and rates of tree mortality during forest successional stages in the Douglas-fir region of the Pacific Northwest.

	Stage				
	Prevegetative Closure	**Full Vegetative Cover**	**Closed Tree Canopy**	**Mature Forest**	**Old Forest**
Approximate Period (years)	0 to 5	5 to 20	20 to 100	100 to 200	>200
Mortality Rate	Very high	High	High to medium	Medium to low	Medium to low
Typical Mortality Causes	Environmental stress, predation, pathogens	Interspecific competition, environmental stress, pathogens, predation	Intraspecific competition, pathogens, wind	Pathogens, wind, competition	Wind, pathogens, physio-logical disorders

Source: Franklin et al. (1987).

Diseases constitute a major disturbance factor in natural forests. They result in habitat for wildlife and contribute to species diversity. Wildlife habitat is created through tree mortality resulting in standing dead snags and down logs. In addition, cavities can be easily excavated by animals in living trees with rot. Decay in tree tops also may cause tops to fall during wind storms, creating nest sites. Furthermore, parasites such as dwarf mistletoes create witches' brooms and other abnormal branching patterns that also may be suitable nest sites for owls. Dwarf mistletoe-infected trees may be extremely important sites for spotted owls in the East Cascades subregion. In the West Cascades subregion spotted owls may utilize dwarf mistletoe-infected trees as well as trees with cavities created by disease organisms. Dwarf mistletoes also may affect fire behavior and species succession in some drier ecosystems (Wicker and Leaphart 1976).

As a result of tree mortality, gaps are commonly created in forests. These gaps provide more light to the forest floor and encourage light-loving understory plants. Thus, species and structural diversity is increased and the rate of forest succession is increased. Generally, the scale of disease disturbance, e.g., infection centers in stands, is considerably smaller than the landscape-size disturbances created by bark beetles or defoliators. Most of the fungi causing diseases are decomposer organisms in natural ecosystems. In this role they decompose organic matter, including woody debris, and cycle nutrients (Waring et al. 1987).

III. Forest Protection in the West Cascades Subregion

A. The Natural History of Disturbance

Fire

In the moist Douglas-fir forests of the Coast Range of Oregon, the Washington Cascades, and the Olympics, fire return intervals are long (Fahnestock and Agee 1983) and most forests are first-generation post-fire forests less than 750 years old. This would suggest a fire return interval somewhat less than 750 years. The fire cycle model of Agee and Flewelling (1983), which is based on climate, could not reproduce a natural fire rotation (essentially a fire cycle) less than 3,500 years using 20th Century climate patterns, and even with significant alteration in climate input to the model, fire return intervals could only be brought down to about 900 years. They suggest that perhaps much larger than average events may have occurred in the past (also suggested by Henderson and Peter 1981, for the southeastern Olympics) as a result of short-term but very extreme changes in two or more of the climate parameters that drive the model.

Large fires have occurred in the historic past (Morris 1934) but our knowledge of old-growth forest establishment dates is so weak as to preclude firm hypotheses about disturbance pulses of the presettlement past. The forests around Mt. Rainier appear to have had a major fire event about 750 years ago (Hemstrom and Franklin 1982) and similar aged stands have been identified in the southern and western Olympics (Agee pers. observ.). A series of about 650-year-old and/or 450- to 500-year-old fires is apparent from the data of Henderson and Peter (1981) in the southern Olympics; Franklin and Hemstrom (1981) and Yamaguchi (1986) in the southern Washington Cascades; and Huff (1984) and legend (Quinault Natural Resources 1983) in the western Olympics. Although forest age-class data are sparse, these are also times of sunspot minima identified by Stuiver and Quay (1980), using tree-ring analysis of carbon-14 activity. If large fire events are associated with these periods of general global cooling, they may represent periods where altered synoptic weather patterns, particularly during the growing season, contained higher lightning frequency and foehn (east) wind patterns.

In moist Douglas-fir forests, long early seral tree recruitment (e.g., 75 to 100 years for Douglas-fir) has been documented after disturbance by fire (Franklin and Hemstrom 1981). This pattern is not characteristic of all prehistoric fires. For example, Huff (1984) showed a 60-year recruitment interval for a ca. 1465 fire in the western Olympics, while Yamaguchi (1986) showed that about 95 percent of Douglas-fir was recruited within 40 years after a fire in ca. 1300 near Mount St. Helens. However, even on these sites the regeneration period is decades long and probably represents some regeneration from trees that initially colonized the burn and grew large enough to produce viable seed to help completely restock the stand. Lack of seed source, brush competition, and/or reburns have been identified as factors delaying regeneration on such sites (Franklin and Hemstrom 1981). Patterns of reburns on the Tillamook fire of 1933 at 6-year intervals (1939, 1945, 1951) (Pyne 1982), at Mt. Rainier in the late 19th Century, and at the southern Washington Yacolt burn of 1902 (Gray 1990) are evidence these sites will reburn. High surface fire potential during early succession in Douglas-fir forest was identified by Isaac (1940) as a "vicious cycle" of positive feedback, encouraging rhizomatous bracken fern (*Pteridium aquilinum*); this pattern was quantified by Agee and Huff (1987). Given sufficient sources for reignition (e.g., the original Yacolt and Tillamook burns and all reburns are thought to have been human-ignited), the reburn hypothesis is likely to be true in certain areas. However, it is not clear whether reburns were a common event prior to European settlement in the moist portion of the Douglas-fir region.

After crown closure, potential surface fire behavior declines, and then gradually increases in the old-growth seral stage (Agee and Huff 1987). Reburns in roughly 100-year-old stands during the late 1400s (Henderson and Peter 1981) may suggest that crown fire behavior independent of surface fuels in these thick-canopied stands may be an additional significant type of fire. Current knowledge is insufficient to tell.

For many years, the pattern of stand replacement fire summarized above was a paradigm of fire for the west side Douglas-fir region. Recent work, particularly in the Oregon Cascades in drier western hemlock plant associations, suggests a higher fire frequency and different ecological role for fire in mesic to dry Douglas-fir forest, reinforcing the output of the climate-based fire cycle model (Agee 1991a). A site in the western Oregon Cascades (Stewart 1986) near the H. J. Andrews Experimental Forest regenerated after a stand replacement fire in ca. 1530, but had experienced three partial mortality fires since then, in ca. 1660, 1860, and 1890. Some of these were in the settlement period and probably reflect human-caused fires of that period, but the partial mortality associated with them is significant. Over a broader area several miles to the southeast encompassing similar forest types, Morrison and Swanson (1990) suggest a natural fire rotation of 95 to 145 years during the last five centuries, well below that of the moist Douglas-fir forests of Washington. The patchiness of at least some of the fires is illustrated by the fire severity maps in Morrison and Swanson (1990). A similar fire regime was noted by Means (1982) on dry Douglas-fir sites in the western Oregon Cascades and by Agee and Dunwiddie (1984) for dry Douglas-fir forests in Washington's San Juan Islands. Another fire history analysis was completed by Teensma (1987) near the area studied by Morrison and Swanson. Using conservative methods that did not recognize underburns with no resulting regeneration or substantial fire-scarring of trees, Teensma estimated a natural fire rotation of 100 years during the last five centuries. If fires of moderate severity are removed from the analysis, a stand-replacement mean fire return interval is 130 to 150 years, suggesting that intense fires are a significant part of the natural fire regime in this area, but that fires of lower severity also occur. Other stands of 500 years age or older exist without much evidence of recurrent fire.

These studies indicate that a variable fire regime with shorter fire return intervals than moist Washington Douglas-fir forests occurs in the central Oregon Cascades, and in other mesic to dry Douglas-fir forests. It is, in a sense, a transitional area to the Klamath subregion in terms of fire history.

Huff (1984) summarized the species response to disturbance regimes for moist Douglas-fir forests. If fire is absent for 700 to 1,000 years on wet sites, Douglas-fir will drop out of the stand, and western hemlock, Pacific silver fir, or western red cedar will be the primary seed source for post-fire regeneration. On sites with fire return intervals in the 300- to 600-year range, well within the longevity of individual Douglas-fir trees, mixed dominance of Douglas-fir and western hemlock or Pacific silver fir will result from a typically severe stand replacement fire (Figure E.4). By age 200+ years, the characteristics of old-growth are almost always present. The Douglas-fir component, having developed after the previous centuries-old fire, provides the large live tree criterion. Both Douglas-fir and the more dense western hemlock begin to supply the large log component as they begin to die from suppression, diseases, or windthrow.

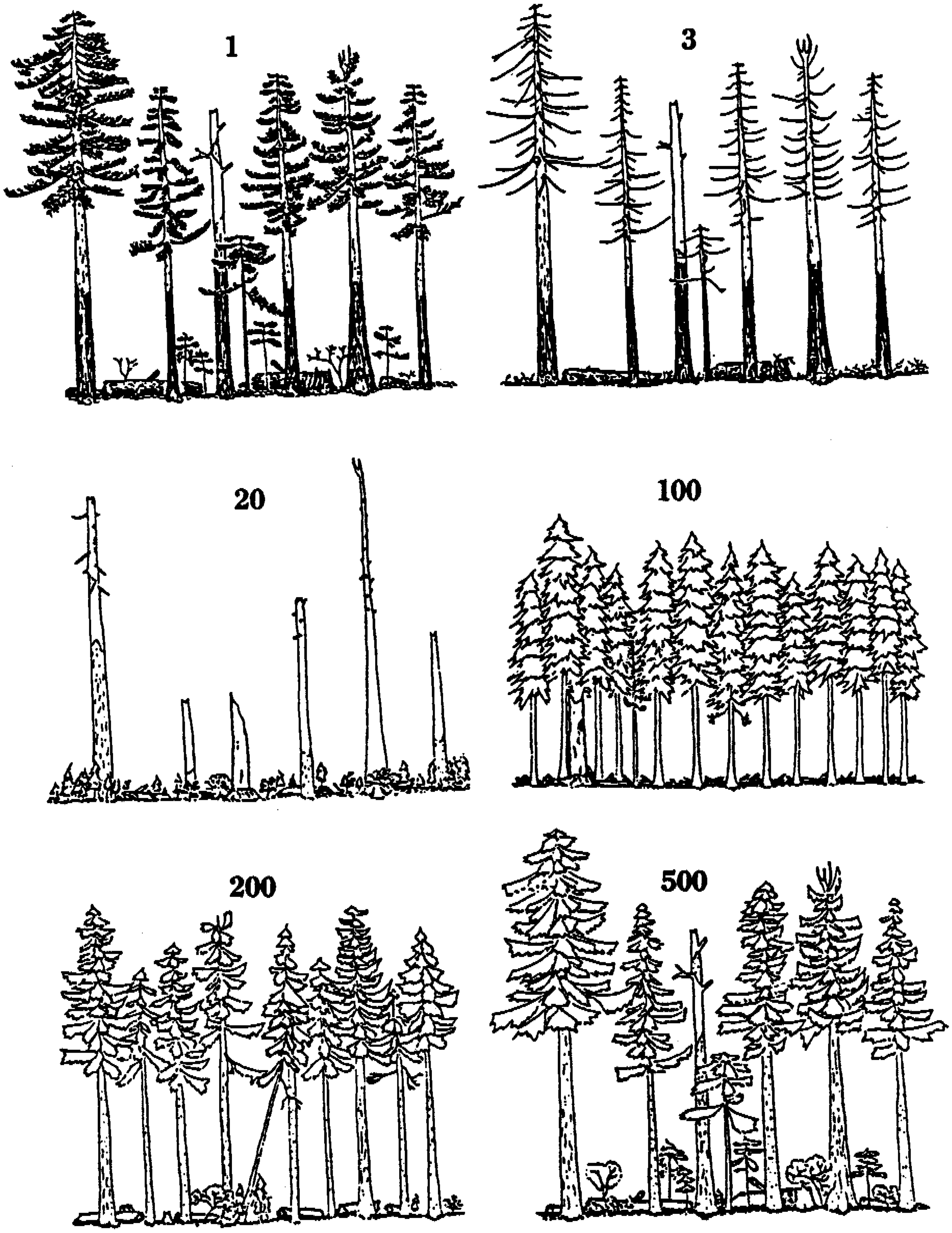


Figure E.4. A stand development sequence for the moist western hemlock/Douglas-fir type. Stand age is shown above each stage, and begins after a total crown scorch fire event. Old-growth character begins between 100 and 200 years and is maximized in the 500-year stand.

Local situations away from the coast may be associated with substantial wind damage during time. Forests on the lee side of Mt. Rainier, for example, in the White River drainage, appear to have been damaged by winds over past centuries. Trees in the Columbia River gorge area north to at least Mount St. Helens and south to Mt. Hood are "flagged" because of strong easterly winds which desiccate foliage on the upriver sides of the trees. North or east winds, such as occurred in Puget Sound during December 1990, occasionally are associated with substantial windthrow.

At Cascade Head, an exposed headland near Otis, Oregon, Harcombe (1986) found that small-scale events have a larger impact on the forest than large-scale blowdowns, comparing the canopy turnover time of 119 years from small-scale events to 384 years for blowdown from large-scale events (i.e., time for an area equal to the forest area to blow down from either type of disturbance). In fact, small- and large-scale blowdown can occur. Basing long-term windthrow return intervals on 50 years of record, as Harcombe does, is not a very reliable method of prediction for such an episodic disturbance.

In the Olympic Mountains, Henderson et al. (1989) suggest that wind is most important in the coastal zones (Figure E.5). Substantial blowdowns occurred in 1979 (Hood Canal storm), 1962 (Columbus Day storm), and 1921 (Boyce 1929). Stand-level information from ridgeline stands in the western Olympics suggests other wind-associated events in the late 1880s and early 1850s (Agee, unpublished data). Although each event did not affect the

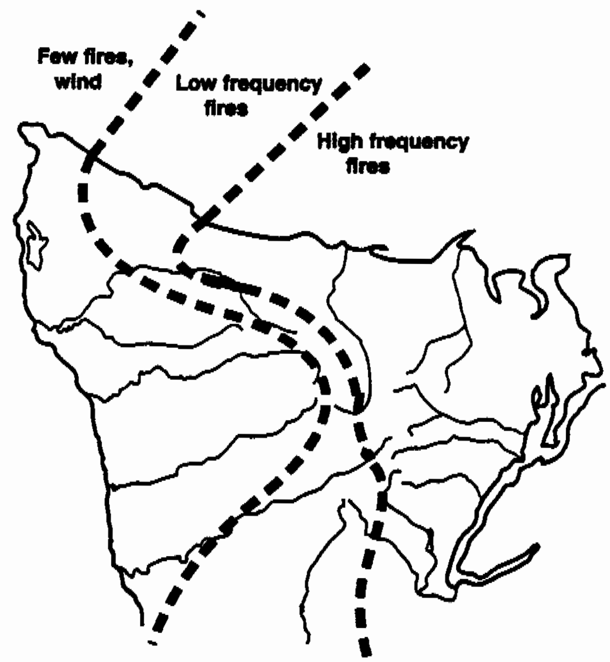


Figure E.5. *Map of Olympic Peninsula showing the relationship between groups of environmental zones and forest fire frequency.*

entire area, a return interval of about 30 years for major wind disturbances seems to be operating in this area. The Columbus Day storm also affected other stands throughout the subregion but to a lesser extent and generally in sensitive topographic situations (such as saddles).

Insects

Insects in this subregion usually act as secondary agents of disturbance after major disturbances caused by fire and wind. Insects tend to have less influence in this subregion because physiological stress from drought and other causes is relatively low.

After fire Douglas-fir beetles will attack weakened trees and freshly down trees. Ambrosia beetles will also attack boles of standing dead and down conifers. Trees weakened by root diseases, particularly by *Phellinus weirii*, are very susceptible to Douglas-fir beetle attack.

Occasional outbreaks of the western hemlock looper in extensive old-growth hemlock stands have occurred every 15 to 20 years from the 1890s to the 1960s, but no other insects have caused large-scale defoliation. Sitka spruce weevil causes leader deformation in young trees (Furniss and Carolin 1977). Sitka spruce tends to be least impacted by weevils in the fog zone along the coast and up major river valleys. Outside this zone it is commonly attacked by the Sitka spruce weevil.

Diseases

Diseases, especially root rots, stem decays, and dwarf mistletoes, in the West Cascades subregion appear to be a greater agent of disturbance than insects. Foliage diseases, stem cankers, and rusts play a minor role. Diseases appear to occur in a relatively random pattern across the landscape, although some site factors such as moisture no doubt influence disease expression. They have considerable influence on forest succession and biodiversity. Many diseases have specific hosts such as Douglas-fir. Thus, diseases can change species composition in affected stands.

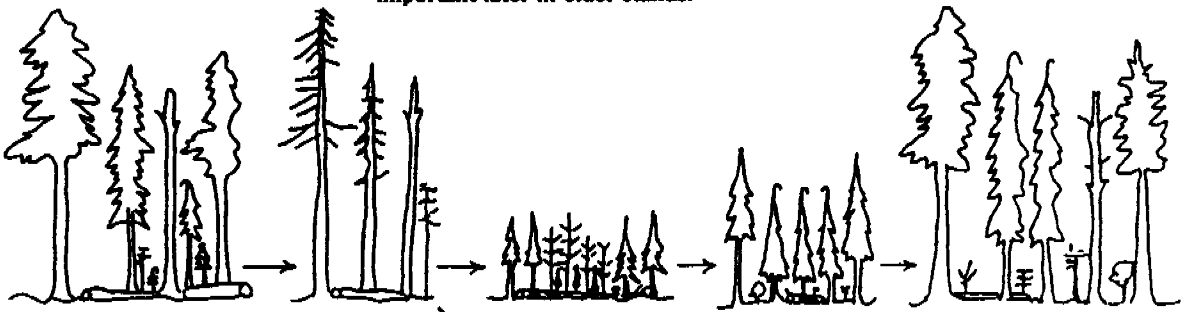
After a large-scale stand-replacement fire (Figure E.6, A-C) Douglas-fir tends to invade sites except in wetter areas near the coast. In the early stages of succession where Douglas-fir dominates, root diseases are important causes of mortality. Rhizina root rot can be important in the seedling stage. *Phellinus weirii* is important from about age 15 to 125 years (Childs 1970) while *Armillaria ostoyae* is most important from about age 5 to 25 years (Hadfield et al. 1986). These ages are relative since in many cases the actual establishment period in natural stands may be as long as 20 years. In old-growth forests, butt and bole decay fungi dominate although root rots are still present and can contribute to mortality. Dwarf mistletoes are not important in forests dominated by Douglas-fir because it is rarely attacked west of the Cascade crest (Bega 1979). As the hemlock component increases with succession, dwarf mistletoes also increase.

In drier areas of the West Cascades subregion away from the coast, fires are not always of stand-replacement intensity. Such fires may not kill large, old Douglas-fir trees, and these fires typically create uneven-aged stands.

Rhizina undulata is a fire-loving fungus. Dormant spores in the soil germinate only in the presence of heat from fires. The fungus is only active for a few years after fire then it once again goes dormant (Morgan and Driver 1972).

Inland Douglas-fir/western hemlock

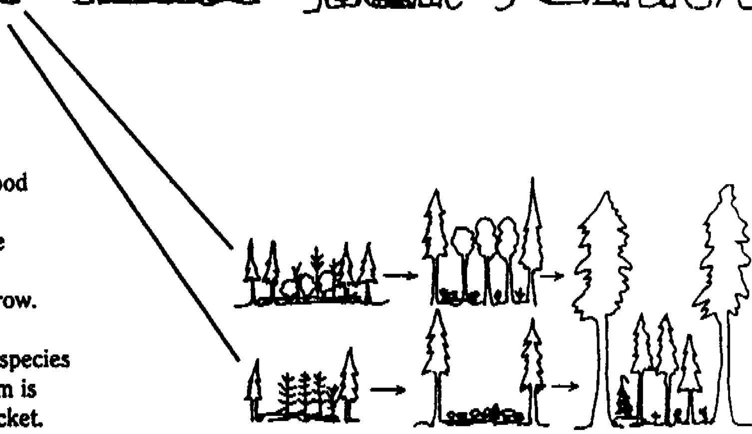
A. Root rots, especially caused by *Phelinus weirii*, kill young Douglas-fir allowing shade tolerant and less disease susceptible western hemlock and western redcedar in the understory to grow in disease pocket. Decay fungi become important later in older stands.



Stand replacement fire

B. Root rots kill young Douglas-fir. Hardwood species, such as red alder, vine maple, and bigleaf maple occupy the pocket. As disease inoculum is reduced Douglas-fir can grow in the pocket. Western hemlock also will grow.

C. Root rots kill young Douglas-fir. Brush species occupy pocket for many years until inoculum is reduced and Douglas-fir can grow in the pocket. Western hemlock also will grow.



Coastal western hemlock

D. Wind is a major factor. Dwarf mistletoes and decay fungi (butt and stem decay) strongly influence forest structure.

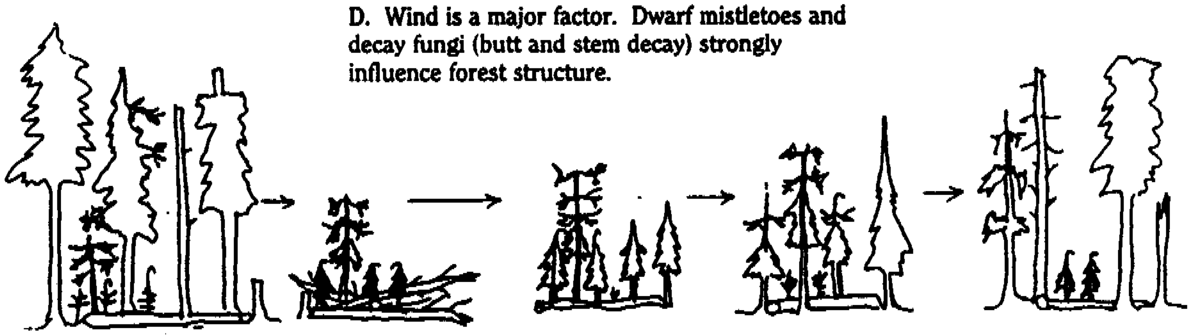


Figure E.6. *Typical theoretical successional sequences involving fire (A-C), wind (D), and diseases in the West Cascades subregion.*

Phellinus weirii tends to create large, expanding root rot centers. Northwestern conifers appear to vary in their susceptibility to *P. weirii* (Hadfield et al. 1986). Douglas-fir and true firs are highly susceptible. Western hemlock and Sitka spruce are intermediately susceptible (infected but seldom killed). Western white pine (*Pinus monticola*) and western red cedar are tolerant or resistant. All hardwoods are immune. Shade tolerant species in the understory which are less susceptible to *P. weirii*, such as western hemlock, are usually favored thus speeding up succession (Figure E.6.A). In some cases, especially in very young stands, hardwoods such as vine maple (*Acer circinatum*), big leaf maple (*Acer macrophyllum*), and red alder may establish in *P. weirii* pockets (Figure E.6B). These species are immune to *P. weirii* and this process effectively sets succession back in time. Brush species also may establish in disease pockets devoid of trees (Figure E.6.C). Thus *P. weirii* can create significant species and structural diversity at the landscape level.

The spread of *P.weirii* is almost exclusively by vegetative growth along root contacts between neighboring trees. Spread by spores is rare (Hadfield et al. 1986). Clones of *P. weirii* can occupy the same relative location on the landscape for 1,000 or more years moving very slowly (12 inches per year; Dickman 1984). Tree species change is associated with spread of the infection center. The fungal clone usually is not destroyed by fire since it resides in large woody roots and the base of trees. It also infects old-growth trees, but large, old trees often survive infection for many years. Production of adventitious roots assists this process. In an old-growth stand dominated by Douglas-fir in the Oregon Coast Range, Tkacz and Hansen (1982) estimated that 19 percent of the susceptible species were healthy, 30 percent were live and infected, 36 percent were killed by the fungus, and 15 percent were killed by other causes. There is no doubt some degree of genetic resistance to the fungus exists and some clones appear more pathogenic than others (Driver et al. 1982). After fire, *P. weirii* can stay alive in large woody root systems for as long as 100 years, thus influencing the structure of the post-fire stand.

The area of western Oregon and Washington heavily infected by *P. weirii* is estimated to be about 10 percent (Hansen and Goheen 1989). Clones of *P. weirii*, however, are not distributed evenly across the landscape. The incidence of *P. weirii* seems to be higher on moisture and/or nutrient stressed sites. Incidence appears to be higher in sites with dry gravelly soils and or lower rainfall and ridges and upper slopes (Kastner 1991). Disease incidence is not strongly related to aspect. *P. weirii* incidence seems to be particularly high in the Puget Sound region, the Cascade Mountains foothills, the Oregon Coast Range, and mountain hemlock (*Tsuga mertensiana*) forests of the Oregon Cascades.

Armillaria ostoyae attacks a wider range of conifers than *P. weirii*, but in this subregion it is not thought to be as important as *P. weirii*. It usually does not occur in large pockets but attacks individual or small clusters of trees. These trees are usually under environmental or competitive stress. Mortality caused by *Armillaria* seldom occurs in stands older than 25 years west of the Cascade crest unless the trees are undergoing extreme stress. Occasionally trees on very moist sites are attacked. *Armillaria* also may attack Douglas-fir already stressed by *P. weirii*.

Black stain root disease has become important in young-growth managed stands in southern Oregon, but the role of this disease in older forests and forest succession is not known at this stage. In later stages of succession, butt rot and bole decay become increasingly important as shown in Figure E.6.A-C. Dwarf mistletoe is also important in areas with a lot of western hemlock.

In coastal areas where western hemlock and Sitka spruce dominate, and where wind is the primary disturbance rather than fire, root rots do not seem to be as important as they are in Douglas-fir dominated forests (Figure E.6.D). In coastal forests decay fungi tend to be the dominant disturbance agents along with hemlock dwarf mistletoe. *Heterobasidion* *annosum* is the dominant disease organism in western hemlock, and commonly acts as butt and root rot. Trees do not seem to develop significant butt rot until they are more than 100 years old. A successional sequence involving dwarf mistletoes and decay fungi in coastal western hemlock forest is shown in Figure E.6.D. Dwarf mistletoes strongly affect tree growth and branch habit, but usually do not cause much mortality. Trees in the coastal area tend to grow to large sizes and ages, especially in areas protected from high winds. They typically have considerable defect caused by diseases; large and irregular branches, dead tops and branches, broken tops and snags created by wind, butt rot, and decay fungi. *Armillaria* root rot may contribute to whole tree blowdown in old-growth forests.

B. Management Effects on Stands

Stand manipulation in the West Cascades subregion has occurred since the 1850s, when the first extensive logging began in the Douglas-fir region (Ficken 1987). Management effects on stands still in a "natural" condition include fire suppression effects, cutting pattern on adjacent stands, and the spread of insect and disease problems.

Fire protection in most areas became effective only after 1910. With natural fire return intervals in the hundreds of years, the effect of 80 years of successful fire exclusion has been minimal. In the remote and rugged Olympic Mountains, Agee and Flewelling (1983) estimated that fire protection this century had "saved" only several thousand acres. Many of the stands in the subregion would not have burned even if fire protection had not been in place, but protection has had subtle effects on the mosaic of age classes present. This subtle effect on the landscape has been overwhelmed by the effects of clear-cutting in the subregion.

Escaped slash fires have been an important component of recent wildfire acreage in the West Cascades subregion. For example, of the 14 major fires in the Mt. Hood National Forest in 1960-75, all started or gained momentum in logging slash (Dell 1977, Deeming 1990). Debris burning was responsible for about 15 percent of wildfire acreage in Oregon and Washington in 1960-80 (Agee 1989). Recent declines in the total area that is slash burned, due to air quality restrictions, as well as very large fires from other causes in the 1980s, may likely reduce these percentages in the future.

The management of stands has accelerated windthrow along susceptible edges where clear-cuts border protected forest. For example, Ruediger (1985) noted that blowdown adversely affected small owl management areas in the Gifford Pinchot National Forest, particularly in locations where the forest was fragmented by timber harvesting. In the Bull Run watershed near Portland, Oregon, 43 percent of large blowdown areas after a 1973 storm and 81 percent after a 1983 storm were associated with boundaries of existing clear-cuts and roads (Franklin and Forman 1987).

Management of stands in the West Cascades subregion has had considerable influence on diseases and a lesser influence on insect populations. The Sitka spruce weevil strongly influences the successful establishment of Sitka spruce plantations. Populations of the Douglas-fir beetle probably have increased slightly as a result of logging but not usually to epidemic proportions. However, root diseases, especially *Phellinus* root rot, appear to have increased considerably as more and more of the landscape has been converted to young-growth Douglas-fir forests. Stumps created by logging harbor the fungus, allowing it to remain viable (Tkacz and Hansen 1982, Thies 1984). Many young plantations of Douglas-fir are now at risk. Management activities such as thinning seem to have increased the incidence of *Armillaria* and black stain root disease. Reducing the variety of tree species in forests tends to promote pests (Schowalter 1988). Black stain disease has spread dramatically in Douglas-fir monocultures where nonhost trees are not available to interrupt transmission of the pathogen. Fertilization has been practiced widely but as yet the impact on root diseases seems small. Foliage diseases also appear to have increased but not to epidemic proportions.

C. Likely Outcome of a Total Protection Strategy During the Next Century

Total protection in the context of this section is defined as "hands-off" management within DCAs for the next 100 years.

Fire

The West Cascades subregion has the highest probability of a successful fire suppression strategy for DCAs. Mature to old-growth forests have a low surface fire behavior potential (Agee and Huff 1987). Severe fire weather is usually short-lived (Pickford et al. 1980, Huff and Agee 1980). The area of greatest concern is the Columbia Gorge area, where severe east winds can cause fires to move rapidly. DCAs in this area (Gifford Pinchot and Mt. Hood National Forests) still have a high probability of successful protection, but the area has a history of large fires (Gray 1990). While the chance of protection is high, and the probability of a large fire in a DCA is low, during the next 50 to 100 years portions of some DCAs are likely to burn. There remains the possibility that a large fire complex caused by extremely unusual lightning or east wind events could occur, but the probability of this occurring in the next 50 to 100 years is unknown and likely beyond management control. Global climate change, if it creates more ignition or increases fire behavior potential, may alter fire disturbance patterns.

Wind

Within the coastal Sitka Spruce Zone, large-scale windthrow events are likely to occur several times a century. Within exposed areas (Figure E.5) substantial blowdown potential exists. The "biological legacy" of green trees left by the 1921 windstorm on the western Olympic Peninsula has allowed rapid habitat recovery to the point that spotted owls now inhabit these stands (North pers. comm.). It is not clear whether such habitation by owls is recent, or whether it continued through and after the blowdown event, or recovered decades later. In the transitional areas between primarily wind-dominated and primarily fire-dominated areas (Figure E.5, the Olympic Peninsula), similar windthrow events are likely in forests at the edge of cleared forest or in forest patches interspersed with clear-cut patches. In more inland areas, more localized impacts from wind are likely. Large, unbroken old-growth forests are not likely to suffer severe impacts from wind, while more fragmented areas may suffer severe blowdown (Ruediger 1985, Franklin and Forman 1987).

Insects

Insects have not proved to be a major problem in the West Cascades subregion. The chance of protection from catastrophic insect attacks in DCAs is high except for the occasional outbreaks of defoliators such as the western hemlock looper. Large hemlock looper outbreaks probably will not occur until large areas of older hemlock forests are restored. Other insects such as the Douglas-fir beetle may increase if large fires or large areas of blowdown occur.

Diseases

It will be difficult to completely protect DCAs from diseases. Many diseases, especially decay organisms and dwarf mistletoes, are desirable in terms of creating owl habitat. While removal of infected western hemlock trees is desirable for timber production, retention of some infected trees in managed stands will allow development of dwarf mistletoe trees in the future. Young trees may be protected from wounding to prevent entry of decay organisms, but eventually most trees will develop decay if they are left for more than 100 years. Older trees are much more likely to have substantial decay columns, especially white wood species like western hemlock, Sitka spruce, and true firs.

D. Forest Protection Guidelines

Fire

Intensive presuppression, detection, and initial attack, with high priority for suppression forces, are the most prudent course in the West Cascades subregion. This region is moist, and severe fire weather usually persists only for several days at a time. Fire suppression records in 1950-80 (Hardy 1983) show that the average size of Class E and larger fires (300+ acres) was relatively small in national forests primarily in this subregion: Olympic (897 acres), Mt. Baker-Snoqualmie (458 acres), Gifford Pinchot (1,458 acres), Mt. Hood (2,423 acres), and Siuslaw (none), in contrast to east side national forests, which averaged more than 2,500 acres for Class E+ fires. The Gifford Pinchot and Mt. Hood forests, with the largest averages in the subregion, have east side acreage and have the Columbia Gorge wind influence. Of course, larger fires have occurred within historical time in the subregion, and there is a chance of a series of large fires in this subregion similar to what apparently occurred in the past. Nevertheless, an aggressive fire control strategy appears to have a high chance of success here.

The primary fire severity level in this subregion is high (Huff 1984, Yamaguchi 1986, Gray 1990) so that stands burned are likely to be unsuitable for owls for decades to a century, assuming that snags and any residuals are not salvaged. In wilderness areas and national parks, a prescribed natural fire policy may be in place. If owl habitat is a primary management constraint, prescribed natural fire zones should exclude DCAs and should include an intervening buffer between the DCA and the prescribed natural fire zone.

If manipulation of stands is mandated (some portion clear-cut or partial cut), the use of fire to reduce hazard should be considered in a minority of cases, generally on the drier, more fire-prone sites. First, the risk of escaped fires exists (Dell 1977), although fire behavior usually is reduced once the fire enters adjacent uncut stands. Secondly, fuel hazards in untreated slash decline to levels similar to treated slash over a short time frame. Burning slash in these moist west side conditions may reduce fire hazard up to 15 years (Morris 1970) compared to untreated slash. Fine fuels fall to background levels for both precommercial thinning and blowdown within 2 to 4 years (Christensen and Pickford 1991). This is a temporal risk which is probably acceptable as long as contiguous slash is not present over thousands of acres.

From a fire protection standpoint, stand manipulation directed toward reduction of fire hazard in natural stands should be avoided. Instead, an aggressive fire control strategy should be implemented, with concentration on fire detection and initial attack. If manipulation is contemplated (for salvage, thinning), slash treatment should be considered on a minority of sites.

Wind

Most potential DCAs already have some clear-cut units within them. From a wind protection standpoint, adjacent areas are at risk. One option is to simply leave the existing units alone and accept the windthrow risk in the hope that additional damage will be limited to a couple of tree lengths into the stand. Another option is to enter adjacent stands along susceptible edges and "feather" the edges. The objective of feathering is to divert or break up the flow pattern of wind so it is not continually encountering a "wall" of trees. For a several-tree length reach, susceptible species or crown classes of trees can be thinned out. Residuals can be mechanically pruned; those on the leading edge can be pruned on alternate whorls to reduce wind pressure in the crown. All these techniques open the stands and reduce owl habitat for perhaps decades, but may stop an otherwise decades-long advancing wall of windthrow. Most stands affected by wind tend to rebuild wind resistance in this same manner. Such intensive management to build wind resistance has not generally been practiced in the Pacific Northwest, and its economics are unknown, but such management may be useful in areas bordering DCAs. Local expertise will be invaluable in designing wind-protected units.

Partial cutting may be employed in intervening areas between DCAs or potentially within a DCA (management directives not available as of the date of this report). Coastal areas (see Figure E.5), particularly the western Olympic Peninsula, are at greatest risk for accelerated windthrow. Recent experience is lacking in the Pacific Northwest, but guidelines from southeast Alaska (Harris 1989) may be relevant until more local experience is available: 1) stay out of areas with evidence of past blowdown; 2) avoid those stands exposed to storm winds (usually from southwest in our area); 3) avoid thinning more than 30 percent of the basal area of closed-canopy, even-aged stands; 4) thin from below and concentrate on trees with stilt roots, decay, or lean; 5) avoid damage to the residual stand; and 6) thin heavily at an early age to provide good rooting opportunity for residuals. Western red cedar seems to be relatively windfirm along the coastal margin (Harris 1989; Franklin, pers. comm.).

Windthrown areas have increased fuel hazards and higher potential fire behavior. The guidelines for slash treatment after partial cutting, summarized in the previous section, should be implemented in windthrown areas; treat slash in a minority of areas.

Insects

Under most conditions, active management for control of insect populations will not be necessary in DCAs. In the event of major windthrow where access is possible, some down timber should be removed to prevent large buildups of Douglas-fir beetle and ambrosia beetle populations. Salvage could be done without negative impacts on fire hazard, but must be weighed against other habitat values of the windthrown trees.

Diseases

Foliage diseases are not likely to be epidemic. No sprays are recommended. It may be desirable to control root rots in some areas to prevent tree death and rapid stand succession. In some areas with good access, stump removal has been employed to maintain a relatively healthy stand, especially in areas with high *Phellinus* incidence. In most DCAs, access for stump removal will not be good, and little active management of root rots will be feasible. Young stands should be protected against the spread of black stain root disease which can be devastating. There is some evidence that thinning during summer may reduce infection. The usual timber management practice for controlling western hemlock dwarf mistletoe is to remove all infected trees. An alternative strategy, if timber management is to be practiced in DCAs, might be to leave a few mistletoe-infected trees so that the habitat values produced by mistletoe will continue to be present into the future. There is concern that mistletoe infection will significantly reduce timber yields, and providing nesting platforms and nest boxes might be considered. Wounding of younger trees may be desirable to create entry columns for decay organisms at an earlier age than would occur naturally. This would be helpful for cavity-nesting birds.

IV. Forest Protection in the Klamath Subregion

A. The Natural History of Disturbance

Fire

The Douglas-fir forests of the Klamath subregion are among the driest forest types in which Douglas-fir is a dominant and where Douglas-fir old-growth is recognized (Old-Growth Definition Task Group 1986). The complex geology, land use history, steep environmental gradients, and variable fire history of this area have prevented generalizations about fire history and its ecological effects. Indians may have had significant ignition effects in these drier Douglas-fir forests (Lewis 1973, Boyd 1986). Miners, settlers, and trappers altered the patterns of burning in the 19th Century, and fire suppression has altered burn patterns in the 20th Century (Atzet and Wheeler 1982, Atzet et al. 1988). From the coastal forests of southwest Oregon to the crest of the Coast Range inland, fire frequency decreases from perhaps 90 to 150 years to about 50 years. Frequencies averaging 20 years have been found in the eastern Siskiyou Mountains (Atzet et al. 1988), and Agee (1991b) has documented a similar fire return interval in the eastern Siskiyous between 1740 and 1860 before significant European settlement. In the Salmon River watershed in northern California, Wills (1991) found presettlement mean fire return intervals of 10 to 15 years for Douglas-fir/hardwood forests.

When fire return intervals are reduced to 50 years or less in these drier and warmer environments, a stand development sequence similar to that shown in Figure E.7 may occur (Agee 1991a). Beginning after a stand-replacement fire, the Douglas-fir regenerating on the site may survive several low to moderate severity fires that thin the Douglas-fir ("resisters"), remove the understory white or grand fir ("avoiders"), and topkill the associated hardwoods such as madrone, oaks, and tanoak ("endurers"). Several recurrences of such fires will create a stand with several age classes of Douglas-fir (some of which are large), and an age class of Douglas-fir and hardwoods representing regeneration after the last disturbance. Not every fire will result in Douglas-fir regeneration, suggesting many fires had little effect on the overstory canopy (Thornburgh 1982, Wills 1991). Understory-tolerant conifers of other species may be represented in post-fire regeneration. Large logs may be provided by residual Douglas-fir (or ponderosa or sugar pine where they are present) that have died from insects, diseases, or the last fire, or have blown over. In presettlement time, the log and snag density was likely lower than at present because of frequent fires. At age 250+ years, the structure of this stand may meet the old-growth criteria, having developed in a very different way than wet site Douglas-fir stands. Such stands usually will be intermixed with others that have experienced a stand-replacement event during one of the intermediate fires, so that the landscape is more patchy than in wetter Douglas-fir forests.

Along the coast, redwood forest exists along a fog belt and may extend up valleys with slopes dominated by Douglas-fir/hardwood forests. Veirs (1980) suggests fire return intervals in the northern redwood forests at 50 to 500 years, but other investigators working to the south suggest more frequent fire return intervals: 31 years at Humboldt Redwoods State Park (Stuart 1987), 20 to 29 years at Salt Point (Finney and Martin 1989), and 22 to 27 years at Muir Woods (Jacobs et al. 1985). The pattern of fairly frequent presettlement fire and moderate fire severity apparently existed almost to the coast in areas south of Eureka.

Wind

Wind appears to be an important disturbance factor primarily along the coast in the Klamath subregion. In coastal Humboldt County, average timber losses from windthrow exceeded the combined losses from fire, insects, and diseases (Oswald 1968), and Zinke (1988) noted wind-flagging along the coastal rivers in the redwood belt. Further inland, wind is not mentioned in a discussion of Douglas-fir/hardwood and mixed-hardwood forests (Thornburgh 1982, Sawyer et al. 1988). Whittaker (1960), in his extensive monograph on these forests, did not include discussion of wind, although he recognized the importance of fire. However, in ridgeline areas within the White Fir Zone of the Siskiyou Mountains, wind was implied to be an important disturbance factor (Agee 1991b).

Insects

Insects have historically caused disturbances in this subregion in association with fire. In natural forests insect populations were probably higher than those in the West Cascades subregion because of higher stress. However, there is a great deal of ecosystem variability

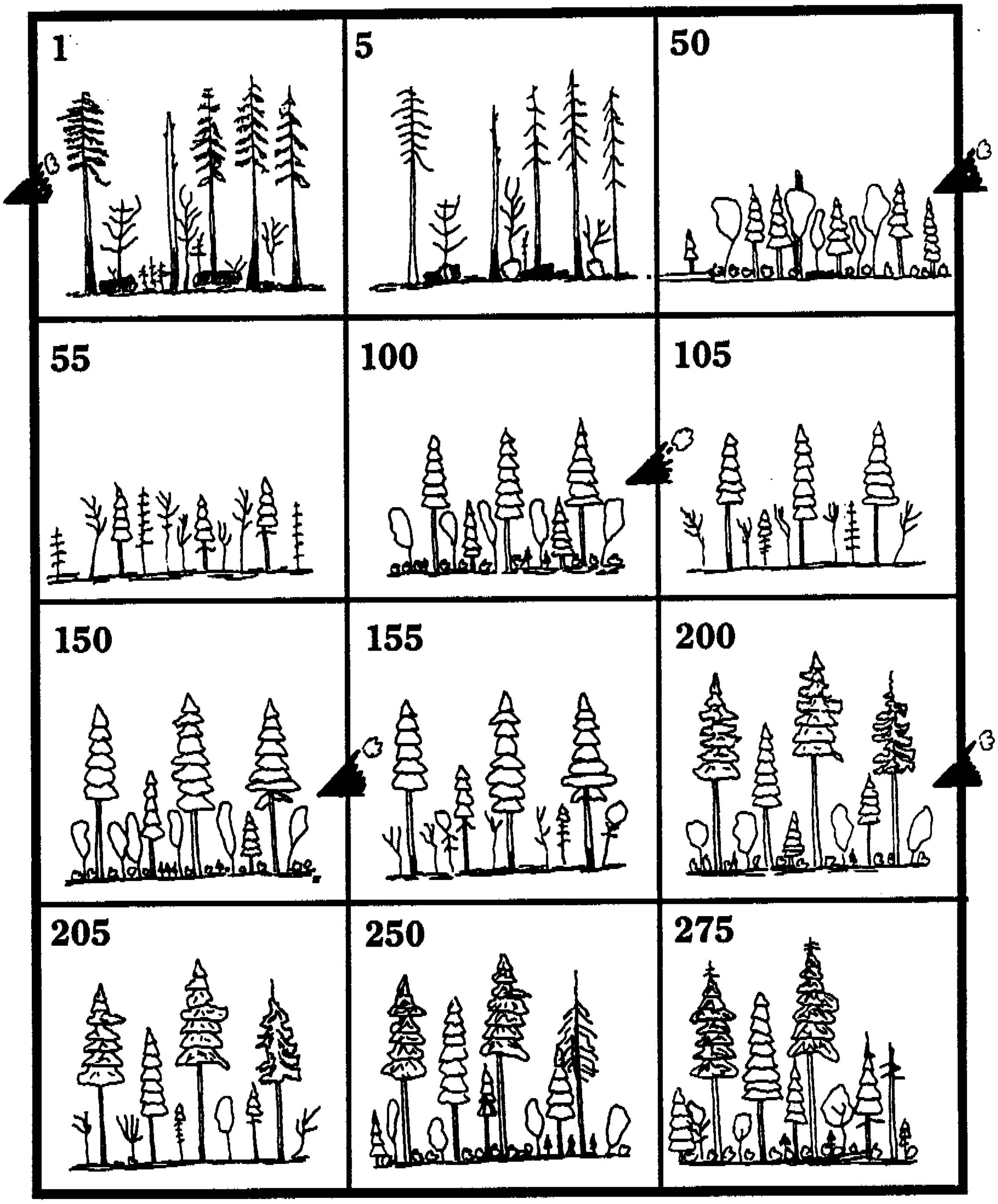


Figure E.7. *A stand development sequence for Douglas-fir/hardwood forest. After a stand replacement event, fires occur at return intervals of 50 years or less (indicated above at 0, 50, 100, 150, and 200 years). Conifers are thinned/pruned while hardwoods are top-killed. Old-growth character develops, but through quite a different process than in the moist western hemlock/Douglas-fir type (see Figure E.4).*

across the landscape and the mixed-species nature of the forests may have kept defoliator and bark beetle populations lower than anticipated. There is also a great deal of variability in the fire regime in this subregion.

Diseases

Root diseases were probably important agents of disturbance in this subregion. *Armillaria* probably killed stressed pines but wide tree spacing may have reduced its rate of spread through the soil. *Phellinus weirii* and *Heterobasidion annosum* incidences would have been related to development of susceptible Douglas-fir and true firs. *Heterobasidion annosum*, although capable of causing root rot of pines, probably only attacked the most stressed individuals.

Dwarf mistletoe infections would have been lower in areas with frequent fires and slightly higher in areas with lower fire frequency. Natural rust populations, especially western gall rust, were lower and of course white pine blister rust was absent. Foliage diseases also would have been low. Butt rot and bole decay would have been important disturbance agents in older forests.

B. Management Effects on Stands

Management effects on fire in the Klamath subregion are complex. Historical fire return intervals varied considerably, and the fire severity associated with these historical events was also quite variable. Fire suppression has been a policy since early in the 20th Century, and for the most part it has been a successful strategy. The effect of fire management can perhaps be broken into two periods: the 1900 to 1980 period, and the period 1980 to present and the future.

In the beginning of the former period, large fires occurred in the subregion (179,000 acres in 1907; 152,000 acres in 1918 in the Siskiyou National Forest; Atzet et al. 1988). The effect of fire management up into the 1980s was to suppress all fires except those burning under the most severe conditions. Total burn acreage declined, although the acres that did burn usually were scorched more heavily than in prehistoric fires. The average size of the "large fire" (Class E+: more than 300 acres) between 1950 and 1980 in the Siskiyou and Rogue River National Forests was 747 and 327 acres, respectively (Hardy 1983). This average has ballooned since then in the Siskiyou National Forest with the 1987 fires (Helgerson 1988). In the Klamath National Forest in northern California, a U-shaped distribution of average total area burned exists from 1950 to 1988 (Perkins unpublished data). The 1950-60 annual average was 11,605 acres, which dipped to 4,862 acres in 1960-80; the large 1987 fires (more than 275,000 acres in the Klamath National Forest) increased the average for the decade 1980-88 to 31,140 acres.

The success of the fire suppression policy allowed fuels to build in remaining protected forests. The patchiness of variable fire severity was removed, and fuels became more continuous, both horizontally and vertically. Thick understories of conifers and/or hardwoods developed. Slash left after timber cutting often was treated by broadcast burning, and yarding of unmerchantable material (YUM yarding) also was done in some locations to reduce fuel hazard potential (Hardy 1983).

The recent period has been characterized by a trend toward larger fires. A more continuous fuel complex over the landscape is at least partially responsible, fuels have increased within protected stands, and clear-cut stands have exposed slash, not all of which has been fuel treated. In 1987, an extensive lightning storm set off more than 600 fires in southern Oregon, including 19 which reached more than 1,000 acres in size (Helgerson 1988). Fire suppression forces were overwhelmed, and some fires burned for months over rough, semiaccessible terrain. Fires burned at night, during cool days, on hot days, up and down slopes, essentially spreading over a wide variety of burning conditions. The 1987 fires burned 190,000 acres in southern Oregon, more than half were in the Siskiyou National Forest. About 775,000 acres in northern California burned during the same time, mostly on national forest land (Atzet et al. 1988).

A mosaic of fire severity resulted. Less than half of the area of most of the southern Oregon fires burned with high intensity, with the remainder burning at moderate and low intensity (Gross et al. 1989). In northern California on the Hayfork District of the Shasta-Trinity National Forest, burned stands had about 5 percent of the area burned with crown fire consuming more than 50 percent of the crown; with another 25 percent of the area more than 50 percent scorched; about 32 percent was 10 to 50 percent scorched; while the remaining 38 percent was less than 10 percent crown scorched (Weatherspoon and Skinner unpublished manuscript). It is not possible to reconstruct what those percentages would have been historically, but it is expected that they might have been even more biased toward the lower damage classes.

The effects of fire management in the Klamath subregion was then a 70-year period of declining fire acreage, with burned areas probably biased to the high scorch level, followed by recent experience with larger fires of more variable severity, due to their simultaneous occurrence and lack of fire control forces to immediately control them.

Management effects on wind are similar in type to the West Cascades subregion but less extensive due to dissected terrain. The forest landscape has been fragmented by clear-cutting, and loss to windthrow occurs around uncut edges (Stone et al. 1969). However, because of dissected terrain of the subregion and the inland nature of much of it, windthrow owing to management activities has been relatively limited.

In the Klamath subregion forest management, including clear-cutting and fire suppression, has had a major impact on insects and diseases. Defoliator and bark beetle populations have increased. *Armillaria*, *P. weirii* and *H. annosum* also have increased. Specific diseases such as *Phytophthora lateralis* root rot of Port Orford cedar and black stain root disease of Douglas-fir have been dramatically increased by forest management (Baker 1988). Infections appear to be worse along roads for both of these diseases. It is suspected that road machinery carries spores of *P. lateralis* from infected to noninfected areas where they spread in runoff and soil water. Thinning has caused an increase in black stain root disease.

C. Likely Outcome of a Total Protection Strategy in DCAs During the Next Century

Total protection in the context of this section of the report is defined as "hands-off" management within DCAs for the next 100 years.

Fire

The recent experience in this subregion with large, uncontrolled fire events is likely to continue with a total protection strategy for DCAs. Fuels will only become more continuous with successful protection, and multiple fires are likely to recur because of the nature of lightning events in the subregion. Total protection should result in 1) a continued occurrence of isolated fires which burn with relative high severity, being controlled when fire weather shifts toward more moderate conditions, and 2) continued large fire "events" with multiple fires of many thousands of acres. These fires will overwhelm control forces and exhibit variable severity, with a skew over time toward the higher damage classes. A total fire protection strategy is likely to be unsuccessful, during the next 50 to 100 years, in providing protection against catastrophic disturbance in DCAs.

If timber harvest activity is undertaken in DCAs, fire management simulations (Hardy 1983) suggest that fuel treatment will be effective in reducing future burned area, although it may be cost-inefficient. Hardy's fuel treatment options were YUM yarding (8 inches x 10 feet or 6 inches x 6 feet), and his "base case" for wildfire size distributions (1950-80) did not include either the early 1907-18 fires or the 1987 fires, making fuel treatment compared to the "base case" hard to justify economically. A survey of partial-cut and uncut stands burned by the northern California fires of 1987 suggests that cutting was associated with increased fire severity levels, but fuel treatment within cut units (underburning or lop/scatter) was effective in reducing damage compared to no treatment within cut units (Weatherspoon and Skinner unpublished manuscript).

Wind

Wind effects should not be exacerbated by total protection of DCAs. Continued limited blowdown should occur around the margins of currently clear-cut areas within DCAs. Unusual storms may accelerate this damage, but it is highly unlikely that a single storm or series of storms will cause massive blowdown within the DCAs of this subregion. This conclusion becomes more tempered toward the coastal edge of the subregion.

Total fire protection in this region usually will result in more insect and disease outbreaks because of increased stress. However, because of the patchy nature of the forest types and the fact that large landscape areas are not covered by a single species, insect outbreaks over extensive areas probably are not as likely as they are in the East Cascades subregion. Fire exclusion, however, will cause an increase in the Douglas-fir and true fir components of stands growing on dry, lower elevation sites. During drought periods the flatheaded fir borer and fir engraver beetle will cause extensive mortality in these stands; resulting fuels could cause increased fire problems. Root diseases, especially *Armillaria* root disease, and dwarf mistletoes are likely to increase.

D. Forest Protection Guidelines

Fire

There is likely to be a wide variety of opinion regarding the optimum fire management strategy for DCAs in the Klamath subregion during the next century. This variety would be partly due to the fact that a total protection strategy, if successful, would produce the most acres of owl habitat. It would be partly due to the uncertainty associated with global change; disturbance regimes are likely to be affected and may drive many of the vegetation changes projected under various global change scenarios. The range of opinions also would be caused by a lack of consensus about how effective fire suppression alone may be, and what would be gained by treating fuels in unmanipulated stands.

In our opinion, a total fire protection strategy has a fairly low probability of protecting owl habitat during the next century in most DCAs in the Klamath subregion. There is substantial reason to believe the trend toward large fires will continue, and fire severity will become skewed toward higher severity levels. Damage to understory and overstory will reduce or eliminate owl habitat in burned areas. Therefore, some type of fuel management program is recommended. Available data suggest that stands manipulated primarily for timber production will have increased fire severity levels. The fire management manipulations suggested below are specifically recommended for owl habitat objectives, not for timber production. There are probably ways the two could be integrated if timber management occurs within the DCA system.

Fuel and fire specialists in the vicinity of each DCA are the best qualified to develop the fuel management strategies. There is no reason to expect strategy to be the same in each DCA. The expected result of any strategy will be a temporary to permanent reduction in preferred owl habitat within the manipulated area, with a higher probability of control of potentially catastrophic wildfires over the larger area. Two types of fuel management strategies are described, and an innovative fire management program will make use of both of them plus additional measures. The first is underburning, and the second is fuelbreaks; each addresses different objectives.

Underburning is an area treatment which eventually reduces total dead fuel loads and vertical fuel continuity. Wildfires entering such stands under most conditions have less severe overstory scorch and allow direct control of the fire. To be effective, underburning must be implemented over wide areas. For example, at Yosemite National Park, some stands that had been underburned twice experienced crown fire behavior from a wildfire that developed momentum as it crowned through adjacent brush and untreated stands (van Wagtendonk pers. comm.). A first fire will consume much dead fuel, but also will create a lot (Thomas and Agee 1986). A second fire within the decade will consume the created fuel and maintain low fuel hazard for a longer period. Opening the understory reduces the protection offered owls and at least temporarily (1 to 2 decades?) provides less optimum habitat. Therefore, underburning should not be done over a wide area of any DCA within one decade.

The main objective of a fuelbreak is to compartmentalize units by creating a zone of reduced fuel between them, which allows safe access for fire suppression forces during wildfires and a reasonable control location (Green 1977). Fuelbreaks generally are placed along ridgelines where continuous fuels exist. Stands are manipulated to have discontinuous tree canopies, pruned boles on residual trees, and substantial understory removal (leaving a few clumps here and there). Some removed fuels can be utilized if good access is present; fine fuels are often pile-burned at the site. From a distance the fuelbreak need not be a visual eyesore and can be quite visually pleasing even at close range. A fuel manipulation in mixed-evergreen forest below the developed area at Oregon Caves National Monument in the early 1980s is a good example of the visual advantages of understory thinning and fuel reduction. Indefinite maintenance of the fuelbreak in low fuel condition is essential. In the Klamath subregion, the occurrence of sprouting hardwoods with substantial regrowth potential (Tappeiner et al. 1984) suggests maintenance intervals of a decade or less for fuelbreaks.

Underburn sites can be keyed into fuelbreaks to expand fuel-reduced areas. The under-burning need not be done at historic return intervals. Monitoring of burned areas where owls exist should be done to determine what effects underburning has and how long they last.

If these fuel strategies are implemented over wide areas, conflicts with existing air quality guidelines are likely. The choice to be made is planned emissions or unplanned ones; absence of emissions is not a realistic option. An additional constraint on fuel management activities is that some DCAs may be partially within designated wilderness. Prescribed fire has been used in national park wilderness (van Wagtendonk 1985, Agee et al. 1981), but not to our knowledge in Forest Service wilderness (although policy now allows such use), which would be the primary management agency for wilderness in the Klamath subregion. Fuelbreaks have not been used in either type of wilderness, and increased use of prescribed fire might help to avoid placing fuelbreaks in wilderness. Consideration of fire management strategies in wilderness where DCAs exist should be done on a regional basis, but applied using local expertise. There will be some risk of escaped prescribed fires, some portions of which may be of high severity, even though they will be burning in early or late season. This risk cannot be eliminated, but it can be reduced with crew training, good ignition patterns, and patience. When compared to the alternative of attempted full suppression, the risk of escaped prescribed fires is reasonable to assume.

In the higher elevation White Fir and Red Fir Zones, where cooler climate and often lush herbaceous understories exist, fuelbreak and underburning activities probably are not needed specifically for owl habitat protection. A quick-response fire suppression strategy should be sufficient protection in these areas. Wilderness fire plans should be designed to mesh with the larger DCA fire management plans, and may consider either prescribed or prescribed natural fire as deemed appropriate by local fire management personnel.

Wind

Guidelines similar to those for the West Cascades subregion are applicable to the Klamath subregion. The zone of highest susceptibility is along the coast, but since this subregion is relatively mountainous right to the edge of the sea, the guidelines for the inland area of the West Cascades subregion are applicable. Along the coast, dominant coast redwood trees are relatively windfirm (Boe 1965) and should be favored in any stand manipulations such as thinnings or feathering operations.

Insects

Insect behavior will be largely controlled by fire frequency. There should be no need for spraying defoliators, but this option should not be ruled out if needed. Fuel treatment after harvest activity should keep the populations of Douglas-fir beetle and ambrosia beetles relatively low. Keeping stands in as low a stress condition as possible should reduce bark beetle attacks.

Diseases

Total fire suppression increases root diseases, dwarf mistletoe infections, and decay fungi. However, it will be difficult to totally suppress fires and it is anticipated that diseases will not increase dramatically if fires occur.

V. Forest Protection in the East Cascades Subregion

A. The Natural History of Disturbance

Fire

Historical fire return intervals in the East Cascades subregion tend to be shortest in areas lower in elevation than what appears to be the better owl habitat. Moving from the sage steppe to ponderosa pine forests, neither of which is prime owl habitat, presettlement fire return intervals may be as low as 5 to 10 years (Bork 1985) in low severity fire regimes. As elevation increases, a more mixed-conifer forest emerges, grading from the Douglas-fir series to the grand fir series of plant associations. Douglas-fir and ponderosa pine are dominant at the lower elevations and at higher elevations on ridges, while western larch, grand fir, and other conifers are found in addition on the more mesic or higher elevation sites (Sudworth 1908).

Stand replacement fires are not the most common fire severity that occurred in the Douglas-fir and grand fir series of plant associations (Keane et al. 1990). However, higher intensity fires are an important process for natural stand regeneration of western larch, lodgepole pine, and Douglas-fir, and have occurred in these areas at centuries-long intervals (Antos and Habeck 1981). Many intermediate fires of lower intensity and severity occur at a more frequent interval. In Montana, on a grand fir habitat type, the intermediate interval was about 17 years (Arno 1976). In the eastern Washington Cascades and Okanogan highlands, the intermediate fire interval was estimated at 22 years (Finch 1984), with a range of 12 to 52 years. Fires of low to moderate severity are the most common types in the moderate severity fire regime.

Unusual stand conditions created by a long fire-free interval or severe fire weather can result in a crown fire. Fuel conditions also can affect the probability of crown fire behavior. Pole-sized, heavily stocked stands have a high crown fire potential (Davis et al. 1980). If a young stand survives an initial light burn, perhaps due to its burning under average to moist weather conditions, subsequent underburns act as a negative feedback mechanism for crown fires by reducing fuels that might encourage crown fire spread. A long interval between underburns allows a tall understory to develop, which has a higher probability of crowning (Davis et al. 1980).

The successional dynamics of forests in the East Cascades subregion depend on the intensity of the fire as well as the species composition and structure of the vegetation at the time of the fire. Low intensity surface fires encourage western larch and ponderosa pine canopy dominance (Arno et al. 1985), as they are *fire resisters*. Their thick bark insulates the cambium against damage better than any of their associates, and in mature stands they are usually the taller trees, which helps them avoid crown scorch. The deciduous habit of larch may make crown scorch less important, especially for late season fires (Davis et al. 1980). Peterson and Ryan (1986) modeled the relative survival of a mixed-conifer stand after a fire under moderate fuel moisture conditions with a scorch height of 30 feet. Mature western larch and ponderosa pine suffered no mortality in the simulation, while the basal area of other species, including Douglas-fir, declined 75 to 100 percent. After such fires, western larch radial growth often increases (Reinhardt and Ryan 1988), while residual Douglas-fir may show no change in radial growth increment.

If a crown fire does occur, it kills all the trees in the stand. Herbs and shrubs may dominate the floristics of early succession, with some herbs (e.g., *Epilobium angustifolium*) peaking and declining within the same decade (Stickney 1986). Western larch has light-winged seeds, which can blow onto a burned site from adjacent stands or from lightly scorched cones in the fire-killed stand (Haig et al. 1941). Lodgepole pine, if present on the site, will establish from serotinous cones in the area. If the crown fires have been spaced more than 150 years apart, western larch is the most probable tree dominant at the time of disturbance, because lodgepole pine, the other early seral species with fast growth, is short-lived and may have been killed by mountain pine beetles (Haig et al. 1941). Where the crown fire interval is shorter than 150 years, lodgepole pine will at least share dominance in the post-fire tree cohort (Gabriel 1976, Antos 1977, Antos and Habeck 1981). However, if the stand is repeatedly underburned after lodgepole pine establishment, lodgepole pine will be eliminated because of its thin bark in favor of western larch, ponderosa pine, and Douglas-fir.

If two crown fires occur in quick succession, the site may revert to a brushfield (Antos and Habeck 1981), as neither western larch nor lodgepole pine survives such fires in the pole stage (Davis et al. 1980). Where a single crown fire occurs, stand establishment usually includes individuals of other species as well as lodgepole pine and larch. On dry sites, ponderosa pine may be included. On average sites, Douglas-fir and grand fir are normally present, and on moist sites western white pine may be a codominant. None of the associated species typically grows as fast as western larch and lodgepole pine (Haig et al. 1941, Cobb 1988). Individual species create different strata over time, although all may establish in the same time period. On a series of even-aged stands in eastern Washington that regenerated after crown fires, Cobb (1988; Figure E.8) found western larch to be a consistent dominant, with lodgepole pine sharing dominance on some sites. Douglas-fir and grand fir showed a variety of stratification patterns but always in intermediate or suppressed crown positions.

Low intensity fires in these stands increase the relative dominance of western larch, ponderosa pine, and/or Douglas-fir over their associates because of their crown position relative to grand fir, and thicker bark than lodgepole pine on dominant trees. Substantial understory development, perhaps after the breakup of lodgepole pine in the canopy, will encourage an understory reinitiation stage in stand development (Oliver 1981) which may be associated with increased crown fire potential and another set of multiple successional post-fire pathways.

A successional model of western larch/Douglas-fir forests, including fire dynamics was developed by Keane et al. (1990) for the Douglas-fir series in Montana. The model outputs generated by fire return intervals of 10, 20, and 50 years, and a no-fire situation are shown in Figure E.9. Ponderosa pine is most dominant in the more frequent fire return interval simulations. In the Douglas-fir series simulation, Douglas-fir is the most shade-tolerant species included and dominates the no-fire scenario. In the East Cascades subregion, the Douglas-fir series has little larch, and the fire scenarios would favor ponderosa pine with some Douglas-fir. The grand fir series is more common where larch is found; Douglas-fir in this series behaves more like larch while grand fir is the most shade-tolerant species. Substituting those species in the graphs gives a general idea of this alternative succession scenario: for example, in the no-fire scenario, larch, ponderosa pine, and Douglas-fir would decline and grand fir would increase.

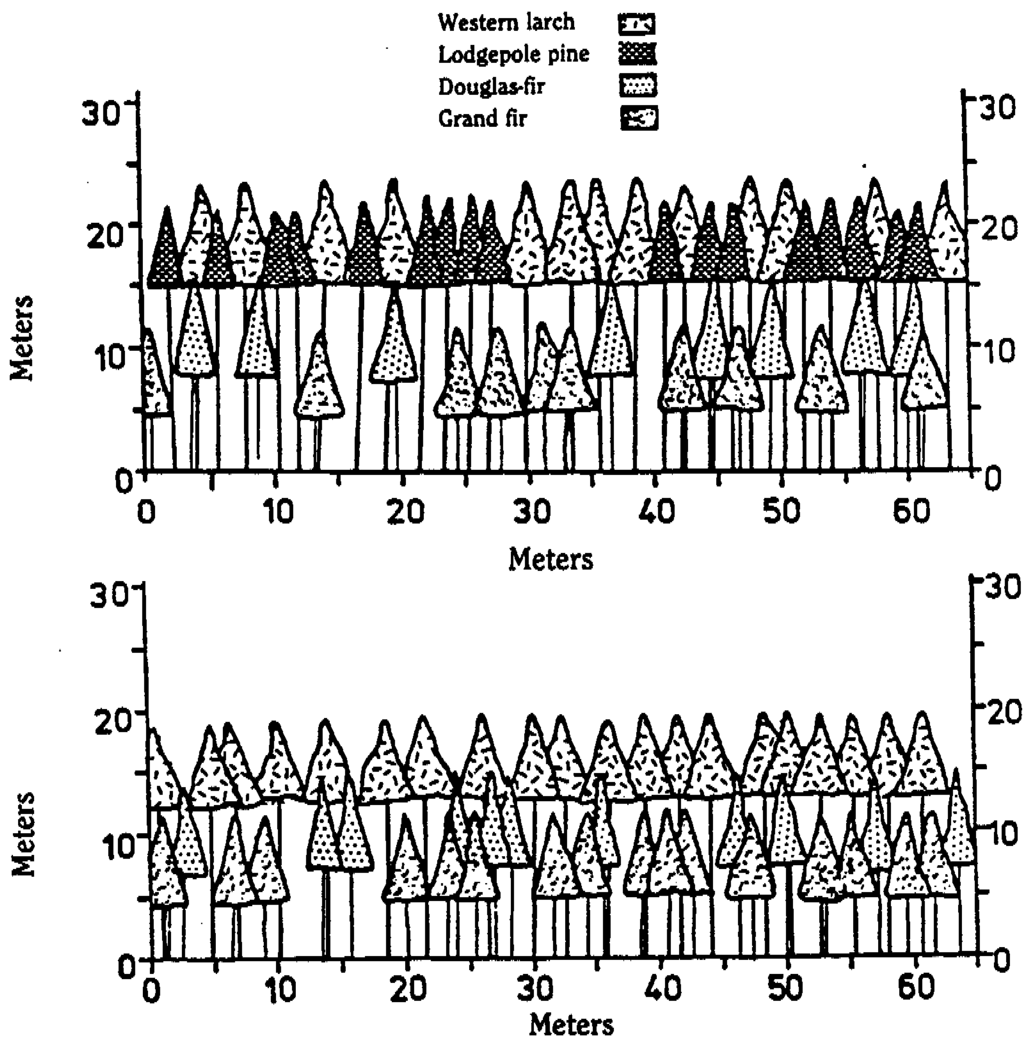


Figure E.8. *In these mixed-conifer forests of the eastern Cascades, multiple canopy levels can be found in young stands (Cobb 1988). These stands are even-aged, both developing after a stand replacement disturbance. Larch and lodgepole pine dominate these young stands (100 years old) while Douglas-fir and grand fir are relegated to subcanopy positions.*

Wind

There is no known published information concerning wind in the East Cascades subregion. This is likely because it is an intermittent and rarely extensive disturbance factor here. Our experience suggests that most natural stands and partial cuttings are relatively windfirm. Wind does not appear to be a factor of significant concern in designing a forest protection scheme for spotted owl DCAs in the East Cascades subregion.

Insects

Insects in this subregion historically have caused large disturbances. The frequent natural fire frequency on the eastern side of the subregion, however, probably did not allow

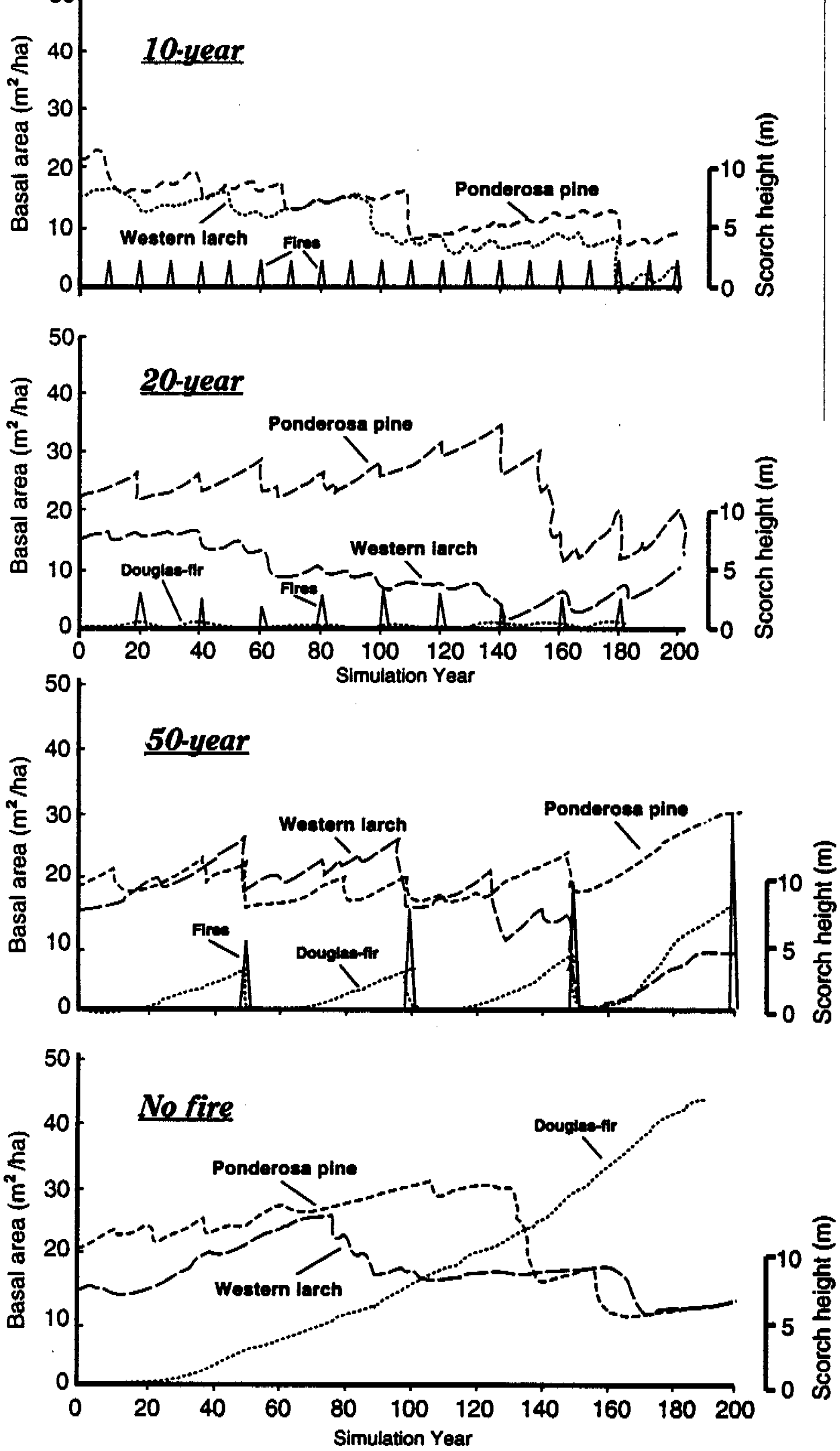


Figure E.9. *Simulations of relative basal area of species in mixed-conifer forest under varying disturbance regimes (Keane and others 1990). As fire return intervals lengthen, ponderosa pine decreases in importance relative to Douglas-fir. Where grand fir is present, its response would be similar to that shown for Douglas-fir in these figures.*

populations to build frequently to the epidemic levels currently observed in this area. Insects probably acted as agents of stabilization in these ecosystems, similar to fire. Endemic populations of defoliators (Douglas-fir tussock moth and spruce budworm), which tend to attack Douglas-fir and true firs, could not easily build up in areas with frequent natural fire regimes because succession to the shade tolerant Douglas-fir and true firs did not proceed and stands were typically dominated by pine species. On the western edge of the subregion, where fires are less frequent, and Douglas-fir and true firs were more dominant, insect populations were historically higher.

Douglas-fir beetle, fir engraver beetle, and Cooley spruce gall aphid populations were generally low in areas with high fire frequency. Frequent fires also kept populations of mountain pine beetle, red turpentine beetle, and pine engraver beetles at low levels because tree density was low and trees were under relatively low stress. In areas with less frequent fires beetle populations would have been larger.

Diseases

Like insects, diseases in this area also acted as an agent of stabilization in natural forests. Root diseases such as *Armillaria* probably removed stressed pines. *Phellinus weirii* and *Heterobasidion annosum* incidences were also lower because of lower populations of susceptible Douglas-fir and true firs. More root diseases probably occurred on the western than eastern edge of the subregion.

Dwarf mistletoe infections were also lower in areas with frequent fires and slightly higher in areas with lower fire frequency. Natural rust populations were lower and white pine blister rust was absent. Foliage diseases also would have been low. Decay fungi would have been present, but pines tend to have less butt rot and bole decay than later successional species such as Douglas-fir and true firs. In older stands butt rots and decay fungi would increase in importance.

B. Management Effects on Stands

An extensive summary of forest health problems created by management (or lack of it) during this century is contained in the Blue Mountains Forest Health Report "New Perspectives in Forest Health" (Gast et al. 1991). Although the Blue Mountains report was prepared for two national forests east of the East Cascades subregion, its summary of management impacts is applicable to this subregion. The report has garnered wide regional publicity.

Fires were once common in the subregion, but effective fire suppression has allowed the development under an overstory of larch, ponderosa pine, and Douglas-fir a thick understory of shade-tolerant grand fir (Figure E.10). Fire hazard increases, and fires which were once likely to be benign understory fires of low severity become high severity stand-replacement fires. High severity fires did occur in these low severity regimes (Figure 3) but not at the scale they now do. Where protection is successful, the moisture stress experienced by the dense overstocked stands encourages spruce budworm attacks on the firs. Although seldom fatal, such attacks weaken trees during several years and increase the probability of successful attacks by bark beetles or root rots. The Blue Mountains report recommended a large increase in prescribed underburning to remove vulnerable species and reduce fire hazards (Gast et al. 1991).

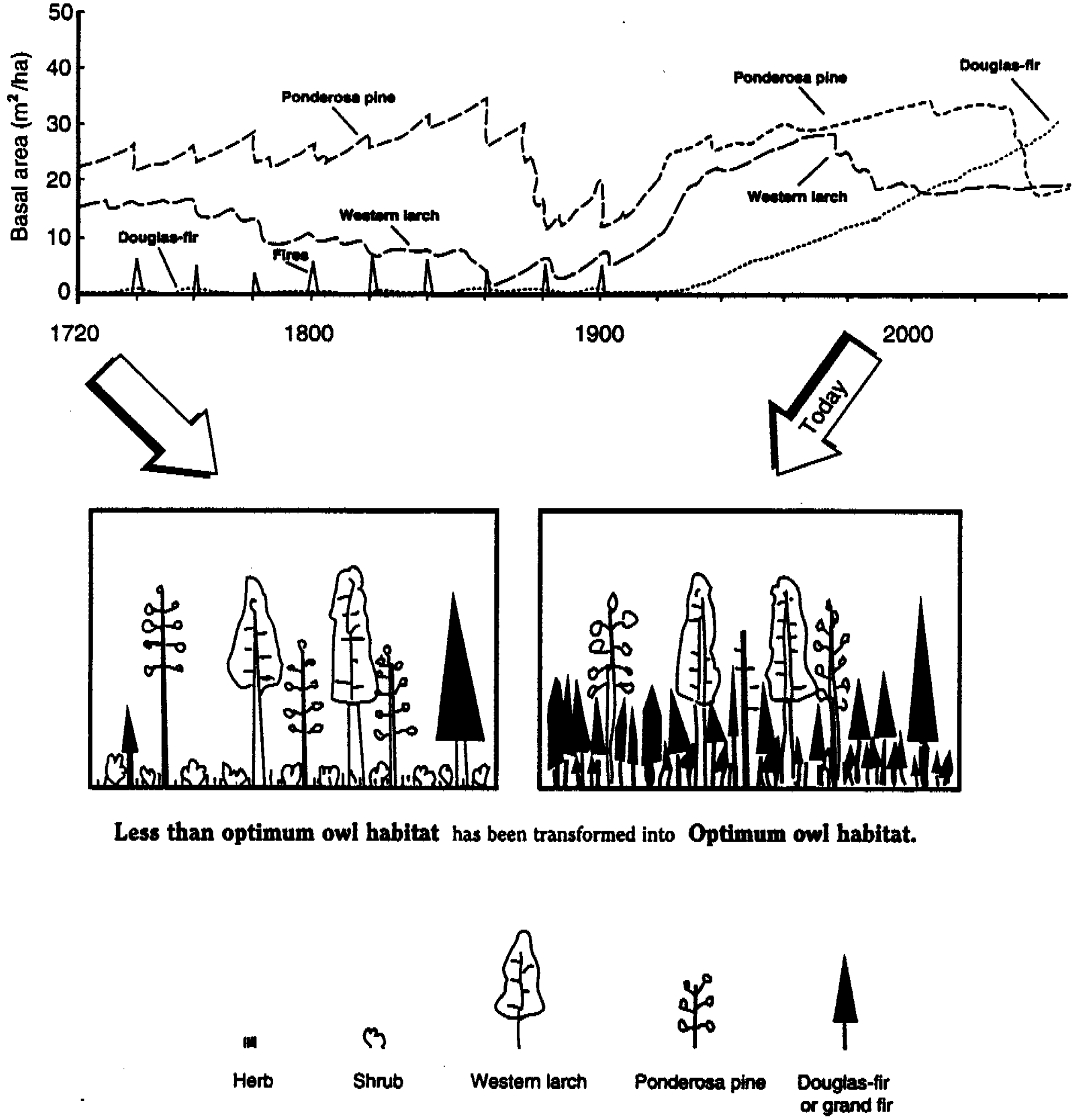


***Figure E.10.** A simulation of ecological changes in East Cascades subregion forests due to successful fire exclusion. This graph was constructed by combining from Figure E.9 the 20-year fire return interval simulation up to 1900 with the no-fire simulation after 1900. Shade-tolerant understory trees now choke the forest. Although such conditions may be conducive to owl habitat, there appears to be little historic precedent for current forest structure, and these habitats are likely to be significantly altered in the next several decades.*

With the exception of increased windthrow potential around edges of clear-cut, forest management has had little effect on wind effects in the East Cascades subregion.

In the East Cascades subregion forest management, especially high-grading and fire suppression, has had a major impact on insects and diseases. Fire suppression and removal of desirable shade intolerant species, such as ponderosa pine, have favored shade tolerant Douglas-fir and true firs with very high stand densities. As a result insect and disease incidence in this subregion increased dramatically in the last 50 to 100 years.

Outbreaks of Douglas-fir tussock moth and spruce budworm occurred naturally but it is thought that management has increased outbreak severity. Such outbreaks can cover hundreds of square miles.

Swetnam and Lynch (1989) reconstructed the history of spruce budworm outbreaks in the southern Rocky Mountains from 1700 to 1983 using tree ring analysis and identified at least nine outbreaks. Severity and timing were highly variable. The average period of reduced growth was 12.9 years and ranged from 5 to 26 years. The average interval between initial years of successive outbreaks was 34.9 years and ranged from 14 to 58 years. There was a relatively long period of reduced budworm activity in the first decades of the 20th Century but since then outbreaks have been more severe. Current outbreaks may be more severe than outbreaks occurring under natural conditions. However, current outbreaks were not clearly less or more frequent than those during the previous two centuries. This change in severity was related to changes in age structure and species composition following harvesting and fire suppression in the late 19th and 20th Centuries.

Douglas-fir tussock moths also seem to have increased in severity. Although native to North America, tussock moths were not reported defoliating stands until 1908. Since that time infestations have occurred synchronously every 8 to 10 years over wide geographic areas (Brubaker 1978).

Spraying epidemic defoliator populations with chemicals and *Bacillus thuringiensis* has had little impact.

Douglas-fir beetle and pine bark beetle populations have increased resulting in widespread tree mortality across the landscape. Pine tip moth problems also have increased, especially in young plantations.

Fire suppression, high-grading and changes in species succession also have changed the disease situation; root rot diseases are now extremely damaging, especially *weirii* and *Armillaria ostoyae* (Baker 1988). *Armillaria* has become extremely damaging in the more stressful environment created by fire suppression. It kills all conifer species and all ages of trees in this subregion. It has increased dramatically as stumps have been created in managed forests with the subsequent increase in inoculum potential. Mixed-conifer forests are often more severely damaged by root diseases after logging than before logging (Filip 1990, Filip and Goheen 1984). *Heterobasidion annosum* also has increased. It now causes considerable mortality in pine stands as well as root and butt rot in true firs. It may even occur in Douglas-fir. Some foliage diseases seem to have increased with management, and larch needle blight is currently active over a wide area in eastern Washington.

Dwarf mistletoes also have increased in managed stands. Fire typically cleanses forest stands of dwarf mistletoe (Baker 1988). Douglas-fir, true firs, ponderosa pine, and lodgepole pine have become easily infected and now many of these trees have reached canopy dominance capable of infecting new trees in the understory. Interestingly, half of the owl nesting sites in the Wenatchee area of the East Cascades subregion are in dwarf mistletoe-infected Douglas-fir trees. Few of these trees would have existed in natural forests. Forsman et al. (1990) noted that owls utilize north-slope, closed-canopy forests more than the south-slope ponderosa pine forests. These mixed-coniferous stands retain characteristics of mature and old-growth stands, such as snags and down trees, a moderate to strongly multilayered canopy, and heavy infestation of Douglas-fir dwarf mistletoe. In the Wenatchee National Forest spotted owls were noted to nest in more or less even-aged mixed-conifer stands 90 to 130 years old with a high proportion of Douglas-fir (Buchanan pers. comm.). These stands were infected with dwarf mistletoe and more than half the owl nests were in mistletoe brooms.

The introduced disease, white pine blister rust, has been particularly devastating to western white pine and sugar pine. Native western gall rust has increased in plantations of lodgepole pine and also occurs in ponderosa pine.

C. Likely Outcome of a Total Protection Strategy During the Next Century

Total protection in the context of this section of the report is defined as "hands-off" management within DCAs for the next 100 years.

Fire

A total fire suppression strategy has created the multilayered yet unstable forest structure present on the landscape today. There is a very low probability that any DCA created in the East Cascades subregion will avoid catastrophic wildfires over a significant portion of its landscape during the next century. Most DCAs will exhibit landscape effects of fire similar to those in the Entiat River watershed. Fires of high severity and wide extent (with little overlap) have burned in 1970, 1974, 1976, and 1988 in areas once capable of supporting owls. In the 1970 fire area, many midslope and ridge areas exhibited a presettlement pattern of low intensity fires, with even-aged lodgepole pine stands in valley bottoms, suggesting longer interval, higher severity fires in the valleys. With the more continuous fuels provided by successful fire protection, the 1970 fires were more uniformly stand replacement in nature. One stump bared by salvage in a burned area of the 1988 fire showed a fire-free period of 99 years over which a dense, stagnated understory developed (a 60-year-old ponderosa pine was 2 inches in diameter). Before that, the tree survived underburns in 1870, 1860, 1850, 1830, and 1817, with earlier fire scars erased by the later burns.

Wind

If fires can be suppressed, root rots are likely to spread faster. These trees significantly infected by root rots have an increased probability of windthrow. Such windthrow pockets begin as small circles and eventually widen as the root rots spread laterally to susceptible tree species. Resistant species will regenerate or be released in the openings, creating a younger, all-sized stand of primarily shade tolerant species. These are likely to be affected by other pathogens or insects and be heavily damaged by wildfires.

Insects

Fire exclusion, coupled with natural mortality factors, gradually reduce the pine and larch components of mixed-conifer stands. Insect outbreaks associated with these seral species should show a gradual reduction in severity. However, the resulting multistoried stands of Douglas-fir and true fir create conditions for the buildup of defoliators. Douglas-fir tussock moth and western spruce budworm populations will increase, with frequent outbreaks. Episodes of tree defoliation and/or drought in east side stands will result in severe outbreaks of the Douglas-fir beetle and fir engraver beetle. Accumulations of heavy fuels within stands will make total fire protection very difficult. Large, fire-damaged Douglas-fir trees are susceptible to bark beetle attack.

Diseases

Total fire protection will continue to increase foliage diseases, such as larch needle blight, root rots, especially *Armillaria* root disease, heart rots (especially of true firs), and true fir and Douglas-fir dwarf mistletoes. As mentioned earlier, however, total fire protection in this subregion will be difficult to attain. Fires may reduce certain diseases, such as dwarf mistletoes, depending on fire intensity. They also cause wounding of some tree species, thus providing entry courts for fungi, especially bole decay organisms.

D. Forest Protection Guidelines

There are no forest protection options to maintain owl habitat at its current level in the East Cascades subregion. As noted, the current extensive habitat is likely a result of an historical anomaly: successful fire protection. The structure resulting from this anomaly is inherently unstable, subject to increased fire, wind, disease, and insect damage. Any stand manipulation which will significantly increase resistance to these disturbance factors apparently will result in decreased owl habitat, through reduction of thick understory conditions. However, there should be experiments to test the effect such manipulations will have on owl populations. Through the process of adaptive management (Walters 1986) future management direction will depend on the results of initial management efforts.

Fire

Many valley stands have longer fire return intervals than associated slopes. A prescribed burning program might be implemented on slopes while excluding toe slopes and valley bottoms. Such a program might protect nesting habitat in valley locations for a significant number of owls, while providing much more fire-resistant foraging areas on the slopes. Since north aspects appear to have more owl nesting sites (Buchanan pers. comm.), these aspects might be protected more often than south aspects. Wildfire control would have much more success if stands with thick understories were isolated and in riparian, north-aspect locations. Possible effects of fragmenting owl populations will have to be weighed against the benefits of hazard reduction. Effects of the burning on other wildlife and fish populations also might be more positive than negative if selected areas were excluded from the burning programs.

As in the Klamath subregion, tying in prescribed burning areas with fuelbreaks will increase the suppression capability when wildfires occur and aid in the implementation of a successful prescribed fire program with fewer escape fires.

Insects

In the absence of fire, spraying the forest with Sevin or *B. thuringiensis* has been recommended in some areas to reduce population levels of defoliating insects. This can also reduce tree mortality and lower the fire danger temporarily. However, such treatment is not likely to be very effective in DCAs or elsewhere and is not recommended as a DCA protection strategy. Stands may need to be thinned to keep them in a condition with less moisture stress to reduce the possibility of bark beetle attack and increased mortality. Thinning, however, may increase the incidence of root diseases such as *Armillaria* root rot.

Diseases

In the absence of fire, *Armillaria* root disease will continue to increase. Thinning to control bark beetles probably will increase the rate of spread. More mortality will result and stands will become particularly vulnerable to fire because of heavy fuel loadings. Dwarf mistletoes will continue to increase in the absence of fire, particularly on Douglas-fir. With underburning, mistletoe-infected trees in the understory will be killed. Heart rots will also continue to increase in the absence of fire in older stands.

VI. Conclusions

Forest ecosystems are dynamic. They change with or without active management. In the case of unmanaged stands within the range of the northern spotted owl, such temporal change has been different within the three subregions defined in this report: the West Cascades, Klamath, and East Cascades subregions. Such change and the likelihood of successful protection of owl habitat by subregion is summarized in Table E.7, Klamath subregion. Clearly, active management is recommended for a majority of the land area occupied by the northern spotted owl, and within areas such as the Klamath subregion where the highest densities of owls exist.

A recommendation to implement a strategy that in fact reduces optimum owl habitat may seem a paradox. We believe that such implementation will in the long run better protect owl habitat than a more short-sighted attempt to continue total protection. Total protection would have been a viable 50-year strategy in 1910, but it is not viable in the 1990s. Active management of habitat in the Klamath and East Cascades subregions, through protection strategies designed to prevent large-scale catastrophic events, is the most rational management direction. In the West Cascades subregion, while we recognize that large-scale catastrophic disturbance is historically important, future occurrence is not predictable, and an aggressive fire control strategy is recommended. While these strategies are by no means perfected, they will help us learn through implementation, and hopefully ensure the long-term viability of the northern spotted owl.

Table E.7. A comparison by subregion of changes in forest structure since active forest protection began, the probability of continued successful protection, and needs for innovative management.

Category	Subregion		
	West Cascades	**Klamath**	**East Cascades**
Change in Unmanaged Stands with Protection	Low	High	Very high
Probability of Continued Successful Protection During the Next Century	High	Very low	Very low
Need for Innovative Future Forest Protection	Low	High	High

Literature Cited

Agee, J.K.; Personal Observation and Unpublished Data, University of Washington, Seattle, WA.

Agee, J.K. 1981. Fire effects on Pacific Northwest forests: flora, fuel, and fauna. Pages 54-66 in: Proceedings of the Northwest Fire Council; 1992; Portland, OR.

Agee, J.K. 1989. A history of fire and slash burning in western Oregon and Washington. Pages 3-20 in: Hanley, D., [and others], eds. The burning decision: regional perspectives on slash. Seattle, WA: University of Washington, Institute of Forest Resources Contribution 66.

Agee, J.K. 1990. The historical role of fire in Pacific Northwest forests. Chapter 3 in: Walstad, J.D.; Radosevich, S.R.; Sandberg, D.V., eds. Natural and Prescribed Fire in Pacific Northwest Forests. Corvallis, OR: Oregon State University Press. 317 p.

Agee, J.K. 1991a. Fire history of Douglas-fir forests in the Pacific Northwest. Pages 25-33 in: Ruggiero, L., [and others], eds. Wildlife and vegetation of unmanaged Douglas-fir forests. General Technical Report PNW-GTR-185. Portland, OR: U.S. Department of Agriculture, Forest Service.

Agee, J.K. 1991b. Fire history along an elevational gradient in the Siskiyou Mountains, Oregon. Northwest Science. 65:188-199.

Agee, J.K.; Flewelling, R. 1983. A fire cycle model based on climate for the Olympic Mountains, Washington. Proceedings of the fire and forest meteorology conference 7; 1992; 32-37 p.

Agee, J.K.; Dunwiddie, P. 1984. Recent forest development on Yellow Island, San Juan county, Washington. Canadian Journal of Botany. 62:2074-2080.

Agee, J.K.; Huff, M.H. 1987. Fuel succession in a western hemlock/Douglas-fir forest. Canadian Journal of Forest Research. 17:697-704.

Agee, J.K.; Clark, L.D.; Broyles, R.P.; Rose, L. 1981. Wilderness fire management at Pinnacles National Monument. Fire Management Notes. 42(1):10-12.

Alexander, W.H. 1924. The distribution of thunderstorms in the United States. Monthly Weather Review. 52:337-343.

Antos, J.A. 1977. Grand fir (*Abies grandis* [Douglas] Forbes) forests of the Swan Valley, Montana. Missoula, MT: University of Montana. M.S. thesis.

Antos, J.A.; Habeck, J.R. 1981. Successional development in *Abies grandis* (Douglas) Forbes forests in the Swan Valley, western Montana. Northwest Science. 55:26-39.

Arno, S.F. 1976. The historical role of fire on the Bitterroot National Forest. Forest Service Research Paper INT-187. Ogden, UT: U.S. Department of Agriculture.

Arno, S.F.; Simmerman, D.G.; Keane, R.E. 1985. Forest succession on four habitat types in western Montana. Forest Service General Technical Report INT-177. Ogden, UT: U.S. Department of Agriculture.

Atzet, T.; Wheeler, D. 1982. Historical and ecological perspectives on fire activity in the Klamath Geological Province of the Rogue River and Siskiyou National Forests. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Atzet, T.; Wheeler, T.D.; Gripp, R. 1988. Fire and forestry in southwest Oregon. FIR Report. 9(4):4-7.

Baker, F.A. 1988. The influence of forest management on pathogens. Northwest Environmental Journal. 4:229-246.

Barrett, S.; Arno, S. 1982. Indian fires as an ecological influence in the northern Rockies. Journal of Forestry. 80:647-651.

Bega, R.V. 1979. Diseases of Pacific coast conifers. Handbook Number 521. U.S. Department of Agriculture.

Boe, K.N. 1965. Windfall after experimental cuttings in old-growth redwood: Proceedings of Society of American Foresters; 1965; 59-65 p.

Bork, J. 1985. Fire history in three vegetation types on the eastern side of the Oregon Cascades. Corvallis, OR: Oregon State University. Ph.D. dissertation.

Boyce, J.S. 1929. Deterioration of wind-thrown timber on the Olympic Peninsula, Washington. Technical Bulletin 104. Portland, OR: U.S. Department of Agriculture.

Boyce, J.S. 1961. Forest pathology. New York, NY: McGraw-Hill.

Boyd, R. 1986. Strategies of Indian burning in the Willamette Valley. Canadian Journal of Anthropology. 5:65-86.

Brubaker, L.B. 1978. Effects of defoliation by Douglas-fir tussock moth on ring sequences of Douglas-fir and grand fir. Tree Ring Bulletin. 38:49-60.

Buchanan, J., Personal Communication, Washington Department of Wildlife, Olympia, WA.

Childs, T.W. 1970. Laminated root rot of Douglas-fir in western Oregon and Washington. Forest Service Research Paper PNW-102. Portland, OR: U.S. Department of Agriculture.

Christiansen, E.C.; Pickford, S.G. 1991. Natural abatement of fire hazard in Douglas-fir blowdown and thinning fuelbeds. Northwest Science. 65:[In press].

Cobb, D.F. 1988. Development of mixed western larch, lodgepole pine, Douglas-fir, and grand fir stands in eastern Washington. Seattle, WA: University of Washington. M.S thesis.

Davis, K.M.; Clayton, B.D.; Fischer, W.C. 1980. Fire ecology of Lolo National Forest habitat types. Forest Service General Technical Report INT-79. Ogden, UT: U.S. Department of Agriculture.

Deeming, J. 1990. Effects of prescribed fire on wildfire occurrence and severity. Pages 95-104 in: Walstad, J.D., [and others], eds. Natural and prescribed fire in Pacific Northwest forests. Corvallis, OR: Oregon State University Press.

Dell, J. 1977. Some implications of eliminating prescribed burning as a treatment option in managing forest vegetation and fuels in the Pacific Northwest. R-6 Fuel Management Notes 5:1-10. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Dickman, A.W. 1984. Fire and *Phellinus weirii* in a mountain hemlock (*Tsuga mertensiana*) forest; postfire succession and the persistence, distribution, and spread of a root-rot fungus. Eugene, OR: University of Oregon. Ph.D. dissertation.

Driver, C.H.; Morse, D.R.; Edmonds, R.L. 1982. Detection of disease resistance in Douglas-fir seedlings and variation in pathogeneity in *Phellinus weirii* by monitoring water stress after inoculation. Pages 275-282 in: Heybrock, H.M., [and others], eds. Resistance to disease and pests in forest trees. Wageningen, The Netherlands: Centre for Agricultural Publishing and Documentation (Poduc).

Fahnestock, G.R.; Agee, J.K. 1983. Biomass consumption and smoke production by prehistoric and modern forest fires in western Washington. Journal of Forestry. 81:653-657.

Ficken, R.E. 1987. The Forested Land: A History of Lumbering in Western Washington. Seattle, WA: University of Washington Press. 324 p.

Filip, G.M. 1990. Effect of tree harvesting on Armillaria root diseases in an old-growth mixed-conifer stand in northeastern Oregon. Northwest Environmental Journal. 6:412-413.

Filip, G.M.; Goheen, D.J. 1984. Root diseases cause severe mortality in white and grand fir stands of the Pacific Northwest. Forest Science. 30:138-142.

Finch, R.B. 1984. Fire history of selected sites on the Okanogan National Forest. Okanogan, WA: U.S. Department of Agriculture, Forest Service, Okanogan National Forest.

Finney, M.A.; Martin, R.E. 1989. Fire history in a *Sequoia sempervirens* forest at Salt Point State Park, California. Canadian Journal of Forest Research. 19:1451-1457.

Forsman, E.D.; Sovern, S.C.; Taylor, M., [and others]. 1990. Home range and habitat of northern spotted owls on the east slope of the Cascade Mountains. Northwest Environmental Journal. 6:430-431.

Franklin, A., Personal Communication and Personal Observation, U.S. Department of the Interior, Fish and Wildlife Service, Fort Collins, CO.

Franklin, J.F.; Dyrness, C.T. 1973. Natural vegetation of Oregon and Washington. Forest Service General Technical Report PNW-8. Portland, OR: U.S. Department of Agriculture.

Franklin, J.F.; Hemstrom, M.A. 1981. Aspects of succession in the coniferous forests of the Pacific Northwest. In: West, D.C., [and others], eds. Forest Succession. New York, NY:Springer-Verlag.

Franklin, J.F.; Forman, R.T.T. 1987. Creating landscape patterns by forest cutting: ecological consequences and principles. Landscape Ecology. 1:5-18.

Franklin, J.F.; Shugart, H.H.; Harmon, M.E. 1987. Tree death as an ecological process. BioScience. 37:550-556.

Furniss, R.L.; Carolin, V.M. 1977. Western forest insects. Forest Service Miscellaneous Publication Number 1339. U.S. Department of Agriculture.

Gabriel, H.W. 1976. Wilderness ecology: the Danaher Creek drainage, Bob Marshall Wilderness, Montana. Missoula, MT: University of Montana. Ph.D. dissertation.

Gast, W.R.; Scott, D.W.; Schmitt, C., [and others]. 1991. Blue Mountains forest health report: "New perspectives in forest health". Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Malheur, Umatilla, and the Wallowa-Whitman National Forests.

Gordon, D.T. 1973. Damage from wind and other causes in mixed white fir - red fir stands adjacent to clear-cuttings. Forest Service Resource Paper PSW-90. Berkeley, CA: U.S. Department of Agriculture.

Gratkowski, H. 1956. Windthrow around staggered settings in old-growth Douglas-fir. Forest Science. 2:60-74.

Gray, A. 1990. Forest structure on the Siouxon burn, southern Washington Cascades: Comparison of single and multiple burns. Seattle, WA: University of Washington. M.S. thesis.

Green, L. 1977. Fuelbreaks and other fuel modification for wildland fire control. Handbook number 499. U.S. Department of Agriculture.

Gross, E.; Steinblums I.; Ralston, C.; Jubas, H. 1989. Emergency watershed treatments on burned lands in southwestern Oregon. Pages 109-114 in: Berg, N., ed. Proceedings of the symposium on fire and watershed management. Forest Service General Technical Report PSW-109. Berkeley, CA: U.S. Department of Agriculture.

Habeck, J.R. 1990. Old-growth ponderosa pine-western larch forests in western Montana: ecology and management. Northwest Environmental Journal. 6:271-292.

Hadfield, F.S.; Goheen, D.J.; Filip, G.M., [and others]. 1986. Root diseases in Oregon and Washington conifers. R6-FPM-250-86. Portland, OR: U.S. Department of Agriculture, Forest Service, State and Private Forestry, Forest Pest Management.

Hagle, S.K.; Tunnock, S.; Gibson, K.E.; Gilligan, C.J. 1987. Field guide to diseases and insect pests of Idaho and Montana forests. Missoula, MT: U.S. Department of Agriculture, Forest Service, State and Private Forestry.

Haig, I.T.; Davis, K.P.; Weidman, R.H. 1941. Natural regeneration in the western white pine type. Technical Bulletin 767. U.S. Department of Agriculture.

Hansen, E.M.; Goheen, D.J. 1989. Root disease complexes in the Pacific Northwest. Pages 129-141 in: Morrison, D.J., ed: Proceedings of the 7th International Conference on Root and Butt Rots; 1992; Victoria, B.C.: Pacific Forestry Centre.

Harcombe, P.A. 1986. Stand development in a 130-year old spruce-hemlock forest based on age structure and 50 years of mortality data. Forest Ecology Management. 14:41-58.

Hardy, C.C. 1983. An evaluation of alternative fuel treatments on the Siskiyou National Forest, southwest Oregon. Master of Forest Resources Professional Paper. Seattle, WA: University of Washington. 110 p.

Harris, A.S. 1989. Wind in the forests of southeast Alaska and guides for reducing damage. Forest Service General Technical Report PNW-GTR-244. Portland, OR: U.S. Department of Agriculture.

Hawksworth, F.G.; Wiens, D. 1972. Biology and management of dwarf mistletoes. Handbook number 401. U.S. Department of Agriculture.

Heinselman, M. 1981. Fire intensity and frequency as factors in the distribution and structure of northern ecosystems. Pages 7-57 in: Mooney, H.A., [and others], eds. Fire Regimes and Ecosystem Properties. Forest Service General Technical Report WO-26. Washington, D.C.: U.S. Department of Agriculture.

Helgerson, O. 1988. Historic fire year for Oregon and California. FIR Notes. 9 (4):2-4.

Hemstrom, M.A.; Franklin, J.F. 1982. Fire and other disturbances of the forest in Mount Rainier National Park. Quaternary Research. 18:32-51.

Henderson, J.A.; Peter, D. 1981. Preliminary plant associations and habitat types of the Shelton Ranger District, Olympic National Forest. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Henderson, J.A.; Peter, D.H.; Lesher, R.D.; Shaw, D.C. 1989. Forested plant associations of the Olympic National Forest. R-6 Ecology Technical Paper 001-88. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Hepting, G. 1971. Diseases of forest and shade trees of the United States. Agriculture Handbook Number 386. U.S. Department of Agriculture, Forest Service.

Hines, W.W. 1971. Plant communities in the old-growth forests of north coastal Oregon. Corvallis, OR: Oregon State University. M.S. thesis.

Holsten, E.H.; Hennon, P.E.; Werner, R.A. 1985. Insects and diseases of Alaskan forests. Alaska Region Report Number 181. U.S. Department of Agriculture, Forest Service, State and Private Forestry, Forest Pest Management.

Huff, M.H. 1984. Post-fire succession in the Olympic Mountains, Washington: forest vegetation, fuels, and avifauna. Seattle, WA: University of Washington. Ph.D. dissertation.

Huff, M.H.; Agee, J.K. 1980. Characteristics of large lightning fires in the Olympic Mountains, Washington: Proceedings of Fire and Forest Meteorology Conference 6; 1992; Portland, OR. 117-123p.

Isaac, L.A. 1940. Vegetation succession following logging in the Douglas-fir region with special reference to fire. Journal of Forestry. 38:716-721.

Jacobs, D.F.; Cole, D.W.; McBride, J.R. 1985. Fire history and perpetuation of natural coast redwood ecosystems. Journal of Forestry. 83:494-497.

Johnson, W.T.; Lyon, H.H. 1988. Insects that feed on trees and shrubs. Ithaca, NY: Cornell University Press.

Kastner, W.W. 1991. Relationship between occurrence of laminated root rot and site characteristics and its impacts in Douglas-fir forests of the northern Oregon Coast Range. Professional Paper, Master of Forest Resources. Seattle, WA: University of Washington.

Keane, R.E.; Arno, S.F.; Brown, J.K. 1990. Simulating cumulative fire effects in ponderosa pine/Douglas-fir forests. Ecology. 71:189-203.

Lewis, H. 1973. Patterns of Indian burning in California: ecology and ethnohistory. In: Bean, L., ed. Anthropological Paper 1. Ramona, CA: Ballena Press.

Means, J.E. 1982. Developmental history of dry coniferous forests in the central western Cascade Range of Oregon. Pages 142-158 in: Means, J.E., ed. Forest succession and stand development research in the Northwest. Corvallis, OR: Forest Research Laboratory.

Moore, K.; MacDonald, B. 1974. Final report of the fringe-strip study team. Nanaimo, British Columbia: British Columbia Fish and Wildlife Branch. 19 p. Unpublished report.

Morgan, P.D.; Driver, C.H. 1972. Rhizina root rot of Douglas-fir seedlings planted on burned sites in Washington. Plant Disease Reporter. 56:407-409.

Morris, W.G. 1934. Forest fires in western Oregon and Washington. Oregon History Quarterly. 35:313-339.

Morris, W.G. 1970. Effects of slash burning in overmature stands of the Douglas-fir region. Forest Science. 16:258-270.

Morrison, P.; Swanson, F. 1990. Fire history and pattern in a Cascade Range landscape. Forest Service General Technical Report PNW-254. Portland, OR: U.S. Department of Agriculture.

North, M., Personal Communication, University of Washington, Seattle, WA.

Norton, H. 1979. The association between anthropogenic prairies and important food plants in western Washington. Northwest Anthropological Research Notes. 13:175-200.

Old-growth Definition Task Group. 1986. Interim definitions for old-growth Douglas-fir and mixed-conifer forests in the Pacific Northwest and California. Forest Service Resource Note PNW-447. Portland, OR: U.S. Department of Agriculture.

Oliver, C.D. 1981. Forest development in North America following major disturbances. Forest Ecology Management. 3:153-168.

Oswald, D.D. 1968. The timber resources of Humboldt County, California. Forest Service Resource Bulletin PNW-26. Portland, OR: U.S. Department of Agriculture.

Partridge, A.D.; Canfield, E.R.; Chacko, R.J., [and others]. Undated. Keys to major disease insect and related problems of forests in northern Idaho. Forest, Wildlife, and Range Experiment Station Contribution Number 27. Moscow, ID: University of Idaho.

Perkins, J.,Personal Communication, U.S. Department of Agriculture, Forest Service, Yreka, CA.

Perry, D.A.; Borchers, J.G. 1990. Climate change and ecosystem response. Northwest Environmental Journal. 6:293-313.

Peterson, D.L.; Ryan, K.C. 1986. Modeling post-fire conifer mortality for long-range planning. Environmental Management. 10:797-808.

Pettinger, L.F.; Goheen, D.J. 1972. A field guide to important forest insects and diseases of Oregon and Washington. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Division of Timber Management.

Pickford, S.G.; Fahnestock, G.; Ottmar, R. 1980. Weather, fuels, and lightning fires in Olympic National Park. Northwest Science. 54:92-105.

Pyne, S.J. 1982. Fire in America: a cultural history of wildland and rural fire in America. Princeton University Press.

Quinault Natural Resources. 1983. The great fire of 500 years ago. Quinault Natural Resources IV. 5:23.

Reinhardt, E.D.; Ryan, K.C. 1988. Eight-year tree growth following prescribed underburning in a western Montana Douglas-fir/western larch stand. Forest Service Resource Note INT-387. Ogden, UT: U.S. Department of Agriculture.

Ruediger, W.C. 1985. Implementing a spotted owl plan: the Gifford Pinchot National Forest experience. Pages 10-13 in: Gutierrez, R.J.; Carey, A.B., eds. Ecology and management of the spotted owl in the Pacific Northwest. Forest Service General Technical Report PNW-185. Portland, OR: U.S. Department of Agriculture.

Ruth, R.H.; Harris, A.S. 1979. Management of western hemlock - Sitka spruce forests for timber production. Forest Service General Technical Report PNW-88. Portland, OR: U.S. Department of Agriculture.

Ruth, R.H. Yoder, R.A. 1953. Reducing wind damage in the forests of the Oregon Coast Range. Northwest Forest and Range Experiment Station Resource Paper 7. Portland, OR: U.S. Department of Agriculture, Forest Service.

Sawyer, J.O.; Thornburgh, D.A.; Griffin, J.R. 1988. Mixed-evergreen forest. Pages 359-381 in: Barbour, M.G.; Major, J., eds. Terrestrial vegetation of California. California Native Plant Society Special Publication 9.

Schowalter, T.D. 1988. Forest pest management: a synopsis. Northwest Environmental Journal. 4:313-318.

Shinn, D. 1980. Historical perspectives on range burning in the inland Pacific Northwest. Journal of Range Management. 33:415-422.

Sinclair, W.A.; Lyon, H.H.; Johnson, W.T. 1987. Diseases of trees and shrubs. Ithaca, NY: Cornell University Press.

Steinbrenner, E.C.; Gessel, S.P. 1956. Windthrow along cutlines in relation to physiography on the McDonald Tree Farm. Weyerhaeuser Forestry Resource Notes 15. Centralia, WA.

Stewart, G.H. 1986. Population dynamics of a montane conifer forest, western Cascade Range, Oregon, USA. Ecology. 67:534-544.

Stickney, P. 1986. First decade plant successional following the Sundance forest fire, northern Idaho. Forest Service General Technical Report INT-197. U.S. Department of Agriculture.

Stone, E.C.; Grah, R.F.; Zinke, P.J. 1969. An analysis of the buffers and watershed management required to preserve the redwood forest and associated streams in the Redwood National Park. Mimeo Report. Berkeley, CA: Stone and Associates. 106 p.

Stoszek, K.J. 1988. Forests under stress and insect outbreaks. Northwest Environmental Journal. 4:247-261.

Stuart, J.D. 1987. Fire history of an old-growth forest of *Sequoia sempervirens* (Taxodiaceae) forest in Humboldt Redwoods State Park, California. Madrono. 43:128-141.

Stuiver, M.; Quay, P. 1980. Changes in atmospheric carbon-14 attributed to a variable sun. Science. 207:11-19.

Sudworth, G. 1908. Forest trees of the Pacific slope. Washington, D.C.: U.S. Department of Agriculture, Forest Service.

Swetnam, T.W.; Lynch, A.M. 1989. A tree ring reconstruction of western spruce budworm history in the southern Rocky Mountains. Forest Science. 35:962-986.

Tappeiner, J.C.; Harrington, T.B.; Walstad, J.D. 1984. Predicting recovery of tanoak (*Lithocarpus densiflorus*) and Pacific madrone (*Arbutus menziesii*) after cutting or burning. Weed Science. 32:413-417.

Taylor, A.R. 1974. Ecological aspects of lightning in forests: Proceedings of the Tall Timbers Fire Ecology Conference 13; 1992. 455-482 p.

Teensma, P. 1987. Fire history and fire regimes of the central western Cascades of Oregon. Eugene, OR: University of Oregon. Ph.D. dissertation.

Thies, W.G. 1984. Laminated root rot: the quest for control. Journal of Forestry. 82:345-356.

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, T.; Agee, J.K. 1986. Prescribed fire effects on mixed-conifer forest structure at Crater Lake, Oregon. Canadian Journal of Forest Resources. 16:1082-1087.

Thornburgh, D.A. 1982. Succession in the mixed-evergreen forests of northwestern California. Pages 87-91 in: Means, J.E., ed. Forest succession and stand development research in the Northwest. Corvallis, OR: Forest Research Laboratory Oregon State University.

Thwaites, R.G., ed. 1905. Original journals of the Lewis and Clark expedition 1804-06. Dodd, Mead. New York.

Tkacz, B.M. and E.M. Hansen. 1982. Damage by laminated root rot in two succeeding stands of Douglas-fir. Journal of Forestry. 80:788-791.

Trewartha, G.T. 1968. An introduction to climate. Fourth edition. New York, NY: McGraw-Hill Book Company.

USDA Forest Service. 1983. Forest disease management notes. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Forest Pest Management.

van Wagtendonk, J.W., Personal Communication, U.S. Department of the Interior, National Park Service, El Portal, CA.

van Wagtendonk, J.W. 1985. Fire suppression effects on fuels and succession in short-fire-interval wilderness ecosystems. Pages 119-126 in: Lotan, J., [and others], eds. Proceedings - symposium and workshop on wilderness fire. Forest Service General Technical Report INT-182. Ogden, UT: U.S. Department of Agriculture.

Veirs, S. 1980. The influence of fire in coast redwood forests. Pages 93-95 in: Stokes, M.A.; Dieterich, J.H., eds. Proceedings of the fire history workshop. Forest Service General Technical Report RM-81. Ft. Collins, CO: U.S. Department of Agriculture.

Walters, C. 1986. Adaptive management of renewable resources. New York, NY: Macmillan.

Waring, R.H.; Cromack, K. Jr.; Matson, P.A., [and others]. 1987. Responses to pathogen-induced disturbance: decomposition, nutrient availability and tree vigor. Forestry. 60:219-228.

Weatherspoon, P., Unpublished Data, U.S. Department of Agriculture, Forest Service, Redding, CA.

Weatherspoon, C.P.; Skinner, C.N. No date. An assessment of factors associated with damage from the 1987 wildfires in northern California. Redding, CA: U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station. 27 p. plus tables and figures. Unpublished manuscript. On File with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

White, P.S. 1979. Pattern, process, and natural disturbance in vegetation. Botanical Review. 45:229-299.

White, P.S.; Pickett, S.T.A. 1985. Natural disturbance and patch dynamics: an introduction. Chapter 1 in: Pickett, S.T.A.; White, P., eds. The ecology of natural disturbance and patch dynamics. New York, NY: Academic Press. 472 p.

White, R. 1980. Land use, environment, and social change: the shaping of Island County, Washington. Seattle, WA: University of Washington Press.

Whittaker, R.H. 1960. Vegetation of the Siskiyou Mountains, Oregon and California. Ecological Monographs. 30:279-338.

Wicker, E.F.; Leaphart, C.D. 1976. Fire and dwarf mistletoes (*Arceuthobium* spp.) relationships in the northern Rocky Mountains. Pages 279-298 in: Proceedings of the Tall Timbers Fire Ecology Conference 14; 1992.

Wickman, B.G. 1990 Old-growth forests and history of insect outbreaks. Northwest Environmental Journal. 6:401-403.

Wills, R. 1991. Fire history and stand development of Douglas-fir/hardwood forests in northern California. Arcata, CA: Humboldt State University. M.S. thesis.

Yamaguchi, D.K. 1986. The development of old-growth Douglas-fir forests northeast of Mount St. Helens, Washington, following an A.D. 1480 eruption. Seattle, WA: University of Washington. Ph.D. dissertation.

Zinke, P. 1988. The redwood forest and associated north coast forests. Pages 679-698 in: Barbour, M.G.; Major, J., eds. Terrestrial vegetation of California. California Native Plant Society Special Publication 9.

Appendix F

Managing Stands for Northern Spotted Owl Habitat

This report was prepared by Dr. John Tappeiner and the following scientists:

Northern California – Southern Oregon
Rob Lewis – U.S. Bureau of Land Management, Medford District
Dr. Steve Tesch – College of Forestry, Oregon State University
Dr. Dale Thornburgh – Department of Forestry, Humboldt State University
Dr. Phil Weatherspoon – U.S. Forest Service, Pacific Southwest Experiment Station, Redding, California

Oregon Cascades and Coast Range
Kevin Birch – Oregon Department of Forestry
Walt Knapp – U.S. Forest Service, Portland, Oregon
Dr. Bill McComb – College of Forestry, Oregon State University
Bob Saunders – U.S. Forest Service, Willamette National Forest
Dr. Tom Spies – U.S. Forest Service, Research Lab, Corvallis, Oregon
Dr. John Zasada – U.S. Forest Service, Research Lab, Corvallis, Oregon

Western Washington and East Cascades
Monte Bickford – U.S. Forest Service, Wenatchee National Forest
Dr. Bob Gara – University of Washington
Dr. Connie Harrington – U.S. Forest Service, Research Lab, Olympia, Washington
Dr. Lorin Hicks – Plum Creek Timber Company, Seattle, Washington
Dr. Jerry Hoyer – Washington Department of Natural Resources
George Leitner – U.S. Forest Service, Region 6, Portland, Oregon
Dr. Sandy Martin – U.S. Forest Service, Research Lab, Wenatchee, Washington
Dr. Chad Oliver – College of Forest Resources, University of Washington
Terry Raettig – Washington Governor's Timber Team

Contents

I. Summary of Literature Review and Experience

Northern spotted owl habitat generally occurs as mature and/or old-growth forests of the Pacific Northwest. This report discusses management of forest stands for owl habitat including examples of silvicultural systems and treatments which resemble natural forest disturbances. These systems can be used to accelerate the development of stand structures used by owls and to grow habitat in stands where it is not likely to occur through natural stand development. Stand structure characteristics (density, stocking by tree species and size class, snags, logs on the forest floor) of stands that contain owl nest sites were used as goals (or desired future conditions) for these silvicultural systems. Data from actual stands were used to develop examples of silvicultural systems which are expected to produce owl habitat.

A silvicultural system is a series of treatments to trees, shrubs, and other plants designed to produce a desired stand through time–in this case, a structure that provides habitat for northern spotted owls. The treatments and techniques employed necessarily will vary throughout the range of northern spotted owls. For example, in some forests in northern California and the eastern Washington Cascades where there is a history of harvesting individual trees or small groups of trees, there are mixed-species stands composed of trees of various sizes or ages. In these forests, silvicultural systems should maintain this diverse structure, while ensuring that there will be large trees in the future and protecting stands against fire, insects, and disease. In these forests, mimicking natural disturbance (i.e., fire) too closely may reduce owl habitat. In other forests of California, Oregon, and Washington, stands are composed of trees of relatively uniform sizes and ages. Here, silvicultural systems that attempt to mimic natural, small-scale disturbances and increase understory tree regeneration to develop multilayered stands seem appropriate. In many of these forests, windthrow and the regeneration of trees in dense understories of shrubs are probably of more concern than fire.

Not all these stands "need" to be treated to develop into suitable habitat. Some stands already provide habitat or were expected to provide it in a short time without intervention. However, many other stands have been managed for wood production, not for owl habitat, and they will not readily produce multistoried stands without treatment. Thus, there are many stands in which treatment may hasten development of habitat, and other stands in which maintenance of habitat and wood production may occur simultaneously. The potential for a stand to produce owl habitat varies from stand to stand and depends on variables such as tree and shrub species composition; site productivity; and the age, size, number, and spatial distribution of trees. For example, stands with a high stocking of conifers will not quickly produce large trees with deep crowns or develop a multistoried structure. Stands with a dense understory of shrubs may not produce additional layers of trees because regeneration of trees cannot occur under the shrubs. Stands must be evaluated individually to determine their potential for producing habitat and which silviculture system to apply, if any. The possibilities for managing stands for owls are considerable. For example, it is estimated that within the habitat conservation areas (HCAs) proposed by the Interagency Scientific Committee (Thomas et al. 1990) there are more than 2 million acres in stands on federal lands in Oregon and Washington that are not suitable nesting habitat.

Planning for silviculture systems to provide owl habitat must be done at the landscape and stand levels. Landscape variables to evaluate include: location of owls; habitat for owl prey; types of stands not providing habitat- including area, structure, ages, location; need for fire protection and fuel breaks; disease and insect occurance; access, and other uses.

When thinning stands, for example, activities probably should be spread over time and space to avoid having large contiguous areas of temporarily open canopy, and to avoid nesting owls. Similarly, treatments such as prescribed burning to reduce fire hazard should be scheduled with regard to stand structure, owl use, fuel concentrations, fire control strategies, and other considerations.

A. Stand Structure and Owl Habitat

Owl habitat as used in this report is defined as the stand structures that northern spotted owls use for nesting. This type of habitat is apparently the most critical for survival and recovery of owls. The structure has been quantified (see Appendix B) by studies in which tree diameter and heights as well as snags, logs, and other vegetation were inventoried in stands used for nesting. The structures of stands used for nesting are consistently multistoried with many small trees and fewer large trees per area (Figure F.1). They are typically mixed species with two or more age classes that have developed following one or more disturbances such as low intensity fire, windthrow, and root diseases. Species in the overstory are generally redwood, ponderosa pine, sugar pine, western hemlock, and Douglas-fir, while the understory may include western hemlock, western red cedar, white fir, tanoak, bigleaf maple, and Douglas-fir on dry sites. There are often large dead trees and logs on the forest floor. The structures resemble those of old-growth stands (Spies and Franklin 1991).

B. Producing Stand Structure for Northern Spotted Owls

Actual examples of thinning show that reducing the density of overstory trees allows space for trees to produce large crowns and stems, and for trees and shrubs to be established in the understory (Figures F.2 and F.3). If stocking is not controlled, dense stands may develop (Figure F.4), and it would take many years for these stands to produce owl habitat.

The following key points emerge from the review of stand development history and literature and from developing silviculture prescriptions:

1. Disturbances of various sizes and intensities are a natural part of long-term forest stand development.
2. Many stands within the range of the owl are growing at high densities (many trees per acre). Thinning these stands will increase growth rates, sizes of crowns, and diameters of remaining trees.
3. Mortality caused by suppression and crowding among trees is not likely to provide large snags or logs on the forest floor because only the smaller trees die. Thinning of stands will result in larger snags and down logs. After small trees are harvested, only larger trees will remain to succumb to diseases, insects, fire, and other causes.
4. To provide large snags and logs on the forest floor in young (30 to 80+ years) conifer stands, it often may be necessary to kill some of the larger trees in the stand. This is particularly true for stands regenerated after harvesting or reforestation following a fire.
5. Development of a multistoried stand from single-story conifer stands generally will require thinning, small openings in the canopy, or some other disturbance to reduce overstory density. If a dense layer of shrubs is present, disturbance or control of this layer likely will be required to establish conifers or hardwoods which can form the additional layers.

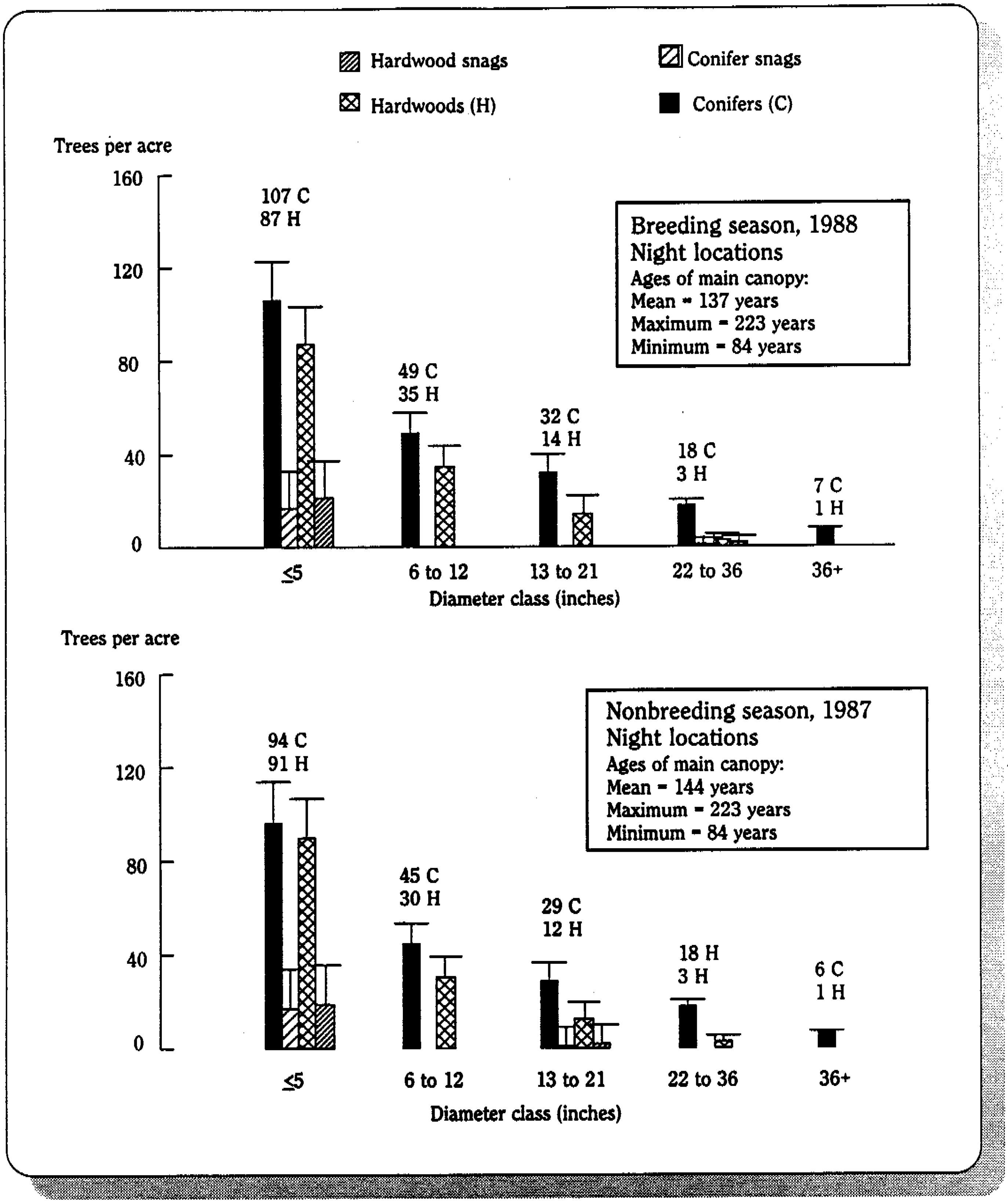
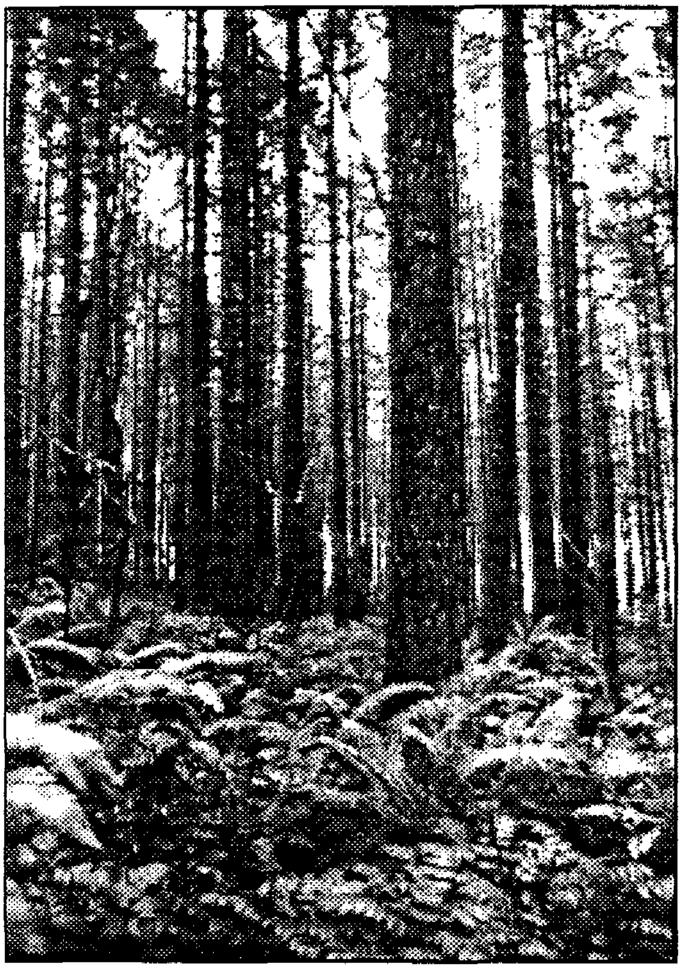


Figure F.1. *Examples of stand structure (numbers of trees and snags by diameter class) from stands used by spotted owls in northern California (Bingham pers. comm..). The same multilayer structure (many trees in small diameter classes and progressively fewer trees in larger classes) was similar for stands with nest sites throughout the range of the spotted owl. Vertical bars represent standard errors.*

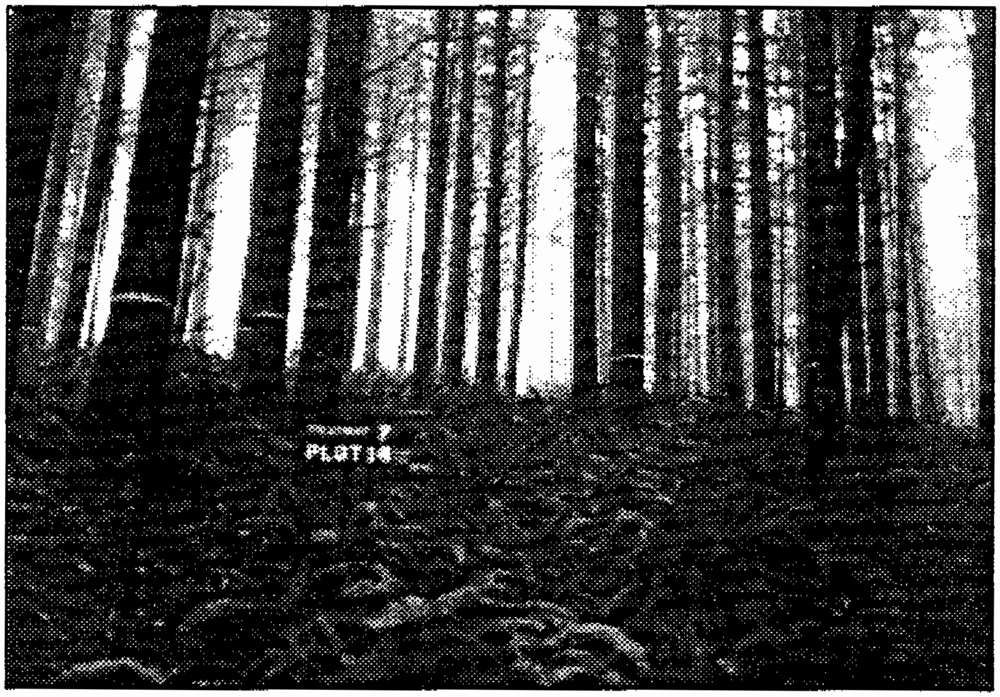
Stand A



Stand B

Figure F.2. *A–unthinned Douglas-fir stand 65 years old; average diameter at 4.5 feet is about 15 inches. Salal, Oregon grape, and swordfern understory will likely preclude the establishment of species which would form a multistoried stand.* ***B***–*a 65-year-old stand thinned to 50 trees per acre at age 45 years, and planted with western hemlock; Douglas-fir diameter averages about 29 inches. Stand B is likely to produce suitable habitat more quickly for spotted owls than stand A. Photographs taken near Falls City, Oregon.*

***Figure F.3.** Effects of thinning Douglas-fir. Stands are about 40 years old. Photograph taken near Hoskins, Oregon (Curtis and Marshall 1986).*
***F.3.A.** (treatment 9) = no thinning. No understory; average tree diameter at 4.5 feet is about 12 inches.*



***F.3.B.** (treatment 7) = lightly thinned. Some understory development; average diameter is about 18 inches.*

F.3.C. *(treatment 1) - heavy thinning. Considerable understory; average diameter about 20 inches.* *See Figure F.5 and F.6.*

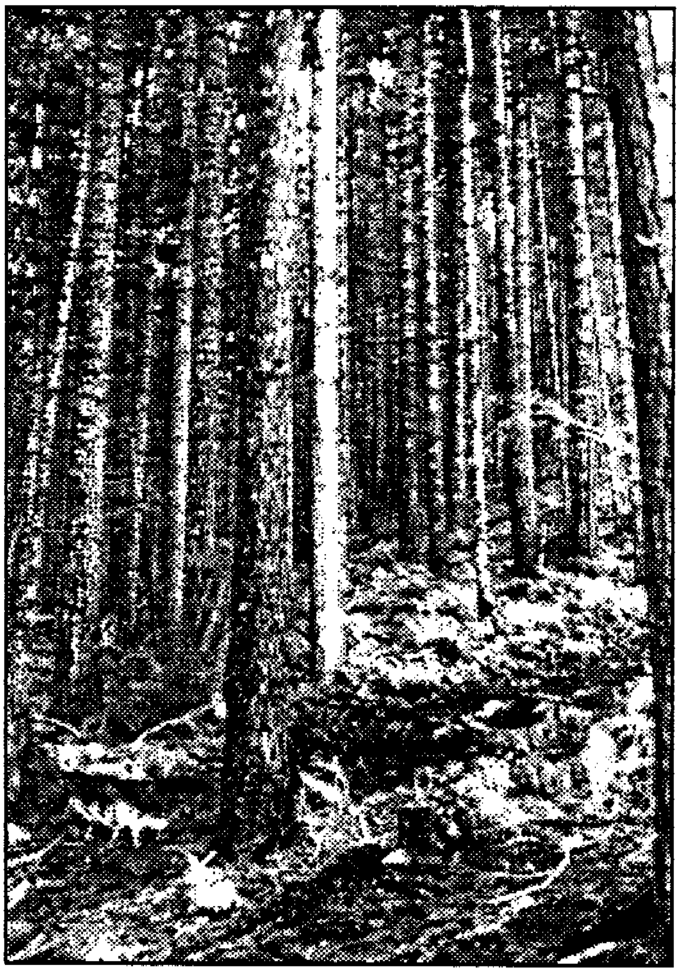


Figure F.4. *An unthinned, dense Douglas-fir stand about 70 years old, with no understory. Careful thinning and making small openings, followed by establishing shade-tolerant tree species, would aid the development of a multistoried stand and owl habitat. Thinnings at earlier ages would have resulted in trees with larger diameter stems, longer crowns, development of an understory, as well as commercial wood production.*

6. Young stands (10 to 80+ years) on productive sites develop quite rapidly. To treat them most effectively, treatment should begin early in the life of the stand when they are most "plastic," before crowns become short and stands become susceptible to wind damage, insects, and diseases. Failure to treat stands before they become too dense will reduce options for future treatments and will substantially delay the development of stand structures used by owls.
7. To maintain uneven-size/age stand structure in many northern California and eastern Cascades forests and to keep ponderosa pine in these forests, it will be necessary to make openings and to thin dense stands or parts of stands. Thinning also will help relieve disease and insect problems in these forests.
8. In fire-prone areas in northern California, southern Oregon, and the eastern Cascades, where natural fire has been excluded, there may be short-term habitat improvement. However, in the long term these stands may be destroyed by fire if fuel loading and the potential for severe wildfires are not reduced.
9. Seedlings and saplings of shade-tolerant conifers and hardwoods needed to form multistory stands will be present in some stands as advanced regeneration. In other stands, it will be necessary to control dense shrub/hardwood understories to attain regeneration by planting or seeding.

II. Review of Natural Vegetation and Stand Development — History of Forest Management

A. Coastal Forests and Western Cascades of Oregon and Washington

Forests on federal lands in the western Cascades and Coast Range mountains of Oregon generally are classified in the Western Hemlock and Silver Fir Zones by Franklin and Dyrness (1973). There is plentiful moisture throughout these zones, and plant associations range from oxalis and sword fern on moist sites to Douglas-fir, ocean spray, vine maple, and salal on drier sites. Older stands in these forests often have a well-developed understory of shrubs and hardwoods such as vine maple, yew, bigleaf maple, salal, salmonberry, rhododendron, hazel, ocean spray, and huckleberry. Conifers in the understory are primarily western hemlock and western red cedar on moist sites. Grand fir and Douglas-fir may occur on dry sites, and silver and noble fir at upper elevations.

1. Natural Forest Development

Natural disturbances in these forests occur over a range of sites, frequencies, intensities, and patterns. Under natural conditions, stand replacement fires occurred at intervals of about 95 years to more than 500 years (Appendix E) with the longer intervals on moist sites. These fires often burned many thousands of acres. The mortality of the overstory within these extensive burns varied considerably (Spies and Franklin 1991, Morrison and Swanson 1990). Groups of trees and scattered individual trees often survived more than one fire. Thus, the Douglas-fir overstory in old-growth forests is often multi-aged (Franklin and Hemstrom 1981). Even with fire suppression, large fires can occur, for example, the Tillamook burn in the 1930s and the Oxbow fire in the 1960s.

Wind effects are most severe on ridge tops and near the coast and Columbia Gorge, although severe storms like the Columbus Day storm of 1961 caused major disturbances on a wide range of sites (Ruth and Harris 1979). Wind effects are often small-scale, blowing down small groups (less than one acre) and individual trees and breaking tops; although entire stands (more than 20 acres) may be blown down. Insect populations (bark beetles) often increase after fire or blowdown.

Root and stem diseases are widespread, but generally occur on a smaller scale than wind and fire. They slowly kill groups of trees. Over extensive areas, root disease may affect more than 10 percent of the entire area. Other agents of disturbance include ice storms, which mostly break the tops of stands of young trees, and mass movement such as landslides, which are important locally.

Individual trees also die because of competition among trees (Drew and Flewelling 1979). Self-thinning is a natural part of stand development and occurs much more quickly on more productive sites than on poor sites. Rate of self-thinning is dependent on species composition and stand density.

These factors affect the rate and course of stand development (Spies et al. 1991). For example, natural succession after fire would likely result in a variety of young stands irregularly stocked with conifers, shrubs, and hardwoods, some large trees not killed by the fire, and often large accumulations of snags and down logs from the previous stand (Spies et al. 1988). As stand development continued, conifers would dominate parts of stands and if they were dense enough, shrubs and hardwoods would be excluded (Oliver 1981). In other parts of the stand, conifers would grow in the open and develop large crowns and branches, and patches of shrubs and hardwoods would remain. After about 80 years, wind, pathogens, and self-thinning would kill individual overstory conifers and groups of conifers producing openings, snags, and down logs. Patches of shade-tolerant conifers, hardwoods, and shrubs would grow in the openings (Alaback and Tappeiner 1991). Where shrub layers were dense, tree regeneration would be excluded or time for its establishment greatly extended. This process of disturbances at irregular intervals would continue producing waves of tree and shrub regeneration, snags, and down logs and providing a diverse stand structure (Spies and Franklin 1991, Spies et al. 1988, Spies et al. 1990).

Natural disturbances to forest stands vary in intensity, distribution, frequency, and size. Viewed in the context of the home range of an owl (about 3,000 acres) these disturbances may be extremely small (a 0.05-acre opening, less than 0.0002 percent of a home range) or they could include the entire home ranges of one to many spotted owls.

2. Forest Management and Stand Development

While timber harvest on private lands began in the late 1800s, major timber harvest programs by the U.S. Forest Service and U.S. Bureau of Land management started about 1945 to 1950. Due to concerns for road access, logging methods, watershed impacts, and providing edge for elk and deer, "patch cutting" (usually more than 20 acres) was used; that is, stands scattered throughout a watershed were clear-cut and planted. Since harvesting on federal lands began about 40 years ago, today in most watersheds young stands are usually 0 to 40 years of age, and there are natural stands of large old trees. Thus, today there is a strongly bimodal age distribution between managed and unmanaged stands. In addition, there are some natural stands of intermediate ages resulting from fire, wind, and earlier harvesting. Harvest by thinning in some areas also has occurred in the last 20 to 30 years.

Treatments to establish plantations following clear-cutting or fire have tended to alter secondary succession to ensure well-stocked conifer stands. The course of forest succession following fire or harvesting of mature or old forests varies depending upon severity of disturbance, composition of preharvest vegetation, site conditions, availability of conifer seeds, and animal population levels. In most situations, if Douglas-fir seed is not available in sufficient quantities immediately after harvest, tree regeneration is slow and irregular and generally unacceptable in meeting wood production objectives. Because of this long, natural regeneration period, most sites are planted as soon after harvest as possible. To reduce growth of broad-leaved trees, shrubs, and herbs, some type of site preparation (fire, mechanical, chemical) is done after harvesting and before planting. Planting often is followed by some treatment that reduces density and vigor of nonconiferous vegetation. The purpose of these practices is to obtain a uniform conifer stand and quickly achieve conifer crown closure thereby shortening the period of dominance by nonconifers. Stocking control is important for obtaining correct stand structure. Precommercial thinning is done often in 10- to 20-year-old stands to ensure uniform conifer spacing and control density of conifers and hardwoods. This is especially necessary on coastal sites where natural regeneration of western hemlock, and sometimes other conifers, occurs among planted seedlings and dramatically increases stocking (700 + trees per acre). Forest stands, especially plantations established for timber production, often will proceed through a stem exclusion stage (Oliver 1981) in which shrubs and hardwoods die or become substantially suppressed by a dense conifer overstory. Most of the understory plants likely will die if hemlock is the main overstory tree (Alaback 1982), because its foliage is denser (high leaf area index) compared to Douglas-fir (Waring et al. 1978). Thus, plantations, because of their lack of large trees and snags from the previous stand, and regular, close spacing, may develop stands that are quite different from young natural stands (Spies et al. 1988).

On coastal sites, red alder stands frequently have become established. These stands often have salmonberry or salmonberry-sword fern understories which prevent conifer establishment. Shade from salmonberry and browsing by mountain beaver in salmonberry-dominated areas prevent conifer regeneration. Alder stands with salmonberry in the understory, unless treated to establish conifers, are unlikely to produce conifer stands capable of developing owl habitat because the salmonberry will form a dense, persistent shrub layer as the alder dies and will prevent establishment of conifers or retard it for many years (Tappeiner et al. 1991).

B. Northern California and Southwestern Oregon

1. Natural Forest Development

The vegetation comprising owl habitat in southwestern Oregon and northern California is quite diverse. It includes redwood forests (Zinke 1977), mixed-evergreen forests (both hardwood and conifers) (Sawyer and Thornburgh 1977a) and mixed-conifer forests (Sawyer and Thornburgh 1977b). Atzet et al. (1992) have classified the vegetation of southwestern Oregon into 16 series and each series usually is subdivided into several plant associations (more than 200 total). The most common series are white fir, western hemlock, Douglas-fir, tanoak, and mountain hemlock. These vegetation series and their included associations vary by elevation and aspect and occur on a variety of soil types, including soils of volcanic and metasedimentary material. There is generally less precipitation in this area, except near the coast, than there is in the western Cascades and northern coastal forests. Climate is Mediterranean, with strong coastal and continental influences. In northern California, the most common vegetation series include redwood, Douglas-fir, tanoak, and white fir.

Fire occurs in forests of all vegetation series. Natural fire return intervals vary from 20 to 200 years (Atzet and Wheeler 1982) (Appendix E). More frequent and less intense fires generally occur on drier sites at lower elevation, with less frequent stand-replacement fires at higher elevations or near the coast. See Walstad (1992) for a discussion of recent fire history. Accidental ignition and purposeful use of fire by Indians and European settlers also has had a major impact on the forests.

Factors affecting natural succession and management of landscapes and individual stands in this region include fire, wind, insects, pathogens, and browsing by animals. Chance of ignition is high on interior sites due to lightning and human causes. Fires are likely to be intense because of the summer drought, steep terrain, and accumulation of fuels due to fire suppression and logging slash. The likelihood of fire and its effects vary by forest type. Fire is not expected to be a severe problem in most of the redwood forests or coastal Douglas-fir forests. Fire (or some other disturbance) is, however, important to help conifers maintain dominance over hardwoods in mixed-evergreen forests (Thornburgh 1981, Hoover 1988).

Pathogens (such as black stain and annosus root rot) and insects (such as western and mountain pine beetle, fir engraver beetle) are most likely to cause conifer mortality on dry interior sites. Insects are particularly likely to affect dense stands where poor tree vigor may predispose stands to attack, especially in periods of drought. Root disease also may make stands susceptible to insects. Ice storms and wet snow can uproot large, broad-leaved evergreen trees in mixed-evergreen forests.

Wind can be a major factor on coastal sites, especially when large individual trees are left in shelterwoods. Hemlock, Douglas-fir, redwood, sugar pine, and ponderosa pine are susceptible to windthrow, which is locally important on interior sites and most likely to occur on ridge tops, saddles, and in conifer stands on shallow soils or infected with root diseases. Pocket gophers and browsing deer and livestock, which are important factors in the establishment and growth of planted and natural conifers, may have major effects on reforestation in some areas.

Four to five decades of fire suppression and timber harvesting have influenced today's forests. Fire suppression likely has favored the development of the understory of tanoak, a shade-tolerant hardwood which is a climax species in the tanoak association and an important component of the Douglas-fir, white fir, and western hemlock associations. Fire exclusion also has favored the development of hemlock and white fir understories on some mesic sites, Douglas-fir understory on dry sites, and a tanoak understory beneath redwood. To the extent that a well-developed understory is important for owl habitat, fire exclusion probably has improved owl habitat. Recent large, variable-intensity fires have increased the structural and species diversity of mixed-evergreen and mixed-conifer forests in northwestern California (Thornburgh 1991).

2. Forest Management and Stand Development

Logging in this area began about 1830. Large-scale commercial harvesting began about 1915, but was confined to gentle terrain (Walstad 1992). Cutting rapidly increased after 1945. Effects of logging varied tremendously. In some cases, only certain species were cut and large trees of nonmerchantable species were left (partial cutting). Also, shelterwood methods and, more recently, clear-cutting were employed. Partial cutting and shelterwood regeneration method probably have favored the establishment and growth of Pacific madrone and white fir and the growth of established tanoak. In general, the types of stands present today include: a) old-growth stands undisturbed, except for fire suppression;

b) stands composed of varying numbers and species of conifers and hardwoods released by logging, residual old-growth trees, and natural regeneration of conifers, hardwoods, and shrubs following logging; and c) relatively uniform young stands that contain shrubs, hardwoods, and other conifers that have been established by natural seeding and planting.

C. Eastern Cascades of Oregon and Washington

The forests in the eastern Cascades inhabited by northern spotted owls generally are composed of mixed-conifer stands in the Douglas-fir and grand fir plant associations. Under natural fire regimes these forests had intense fire, at possibly centuries-long intervals, and light underburns at about 10- to 20-year intervals (Appendix E). With the reduction of fire during the last 6 to 10 decades, forests have become quite dense and multistoried, primarily from the invasion of more shade-tolerant grand fir, Douglas-fir, and Englemann spruce. Lack of fire has likely resulted in better owl habitat.

Insects and diseases are of major concern in many of these forests. Defoliators and bark beetles are common, as are root diseases (*Armillaria, Phellinus,* and *H. annosum*). Insects and diseases probably have increased as shade-tolerant conifers invaded after fire suppression (Appendix E). These forests frequently have been managed by individual tree selection with the goal of salvaging larger dead or diseased trees. This practice, along with fire exclusion, has contributed to today's mixed-species, multistoried stands. Fire hazard is high due to the dry climate, fuels from dead trees, and the multistory structure (Appendix E).

III. Stand Development and Management

The studies and models discussed here were designed to understand and predict the effects of thinning and regulating stand density on forest stand growth, development, and yield. They were not designed specifically to determine how to provide owl habitat. For example, they do not provide information on snag production from mortality of larger trees or the development of large limbs or cavities which may be used as nest sites. Nevertheless, these studies are valuable background for developing silvicultural systems to provide habitat. They show that tree size and stand structure can be regulated by careful management of stand density. There are growth models, applicable to the forests used by owls, which can be used to predict trends in stand development, tree size, crown cover, mortality, and other factors. Background information and techniques are available that can be applied to stands of various ages, structures, species composition, and sites to grow stands for owl habitat. There is a large body of literature on stand growth and development dating to Europe in the 19th Century (Assmann 1970) and it includes many studies in North America. However, only information developed from studies in forests within the range of the northern spotted owl will be discussed.

A. Stand Manipulation and Thinning

Numerous studies have shown that regulation of stand density affects individual tree and stand characteristics such as crown length and width, branch and stem size, leaf area index, vigor, and wind stability. Effects are apparent in young and old stands. Reukema (1975) summarized information from replicated spacing studies, established 50 years earlier at Wind River Experimental Forest. On these dry sites, high stocking reduced height and diameter growth rates and resulted in stands of poor vigor. Eversole (1955) recognized these trends when the stands were 25 years old, and there was no reversal of trends in height and diameter growth rates during the intervening 25 years.

The most thorough study on the effects of management on young Douglas-fir is the regionwide "levels of growing stock study" (Marshall 1990, Curtis and Marshall 1986, Williamson and Curtis 1984, Tappeiner et al. 1982). The study is being conducted on five study sites with each of nine treatments replicated three times at each site. Treatments

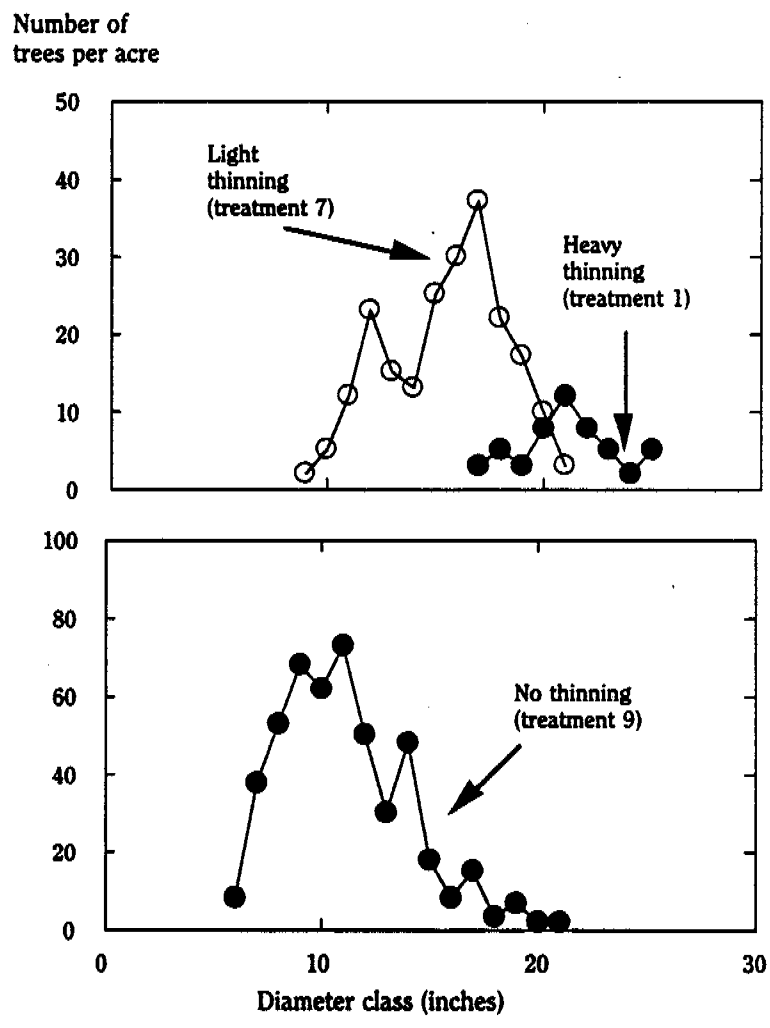


***Figure F.5.** Number of trees per acre by diameter class at age 45 years; 20 years after thinning. Hoskins, Oregon, level of growing stock study (Marshall 1990).*

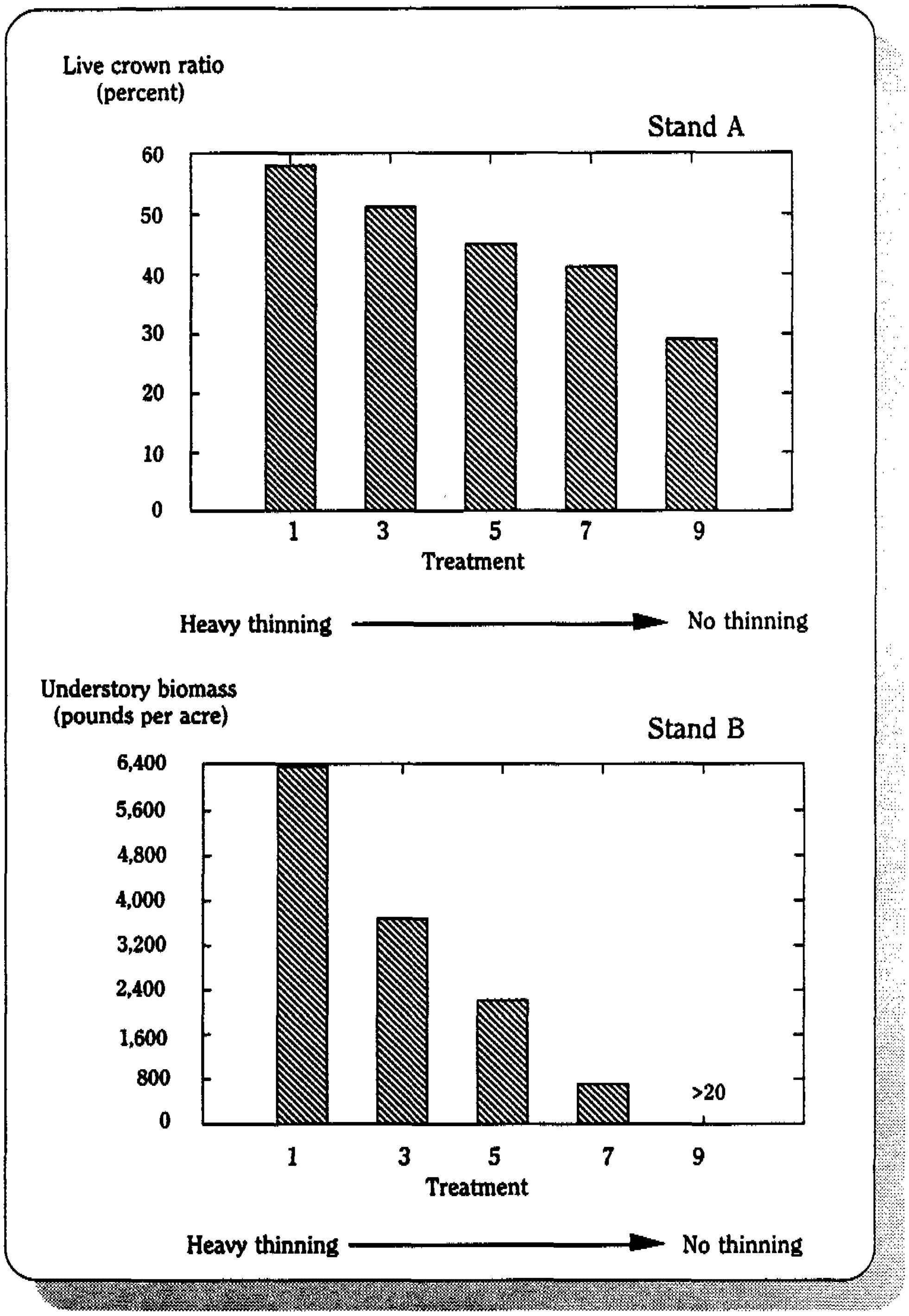


Figure F.6. *Effect of thinning intensity on: average live crown ratios of Douglas-fir trees (Stand A) and understory shrub biomass (Stand B). Hoskins, Oregon, levels of growing stock study (Marshall 1990), Sutliff (unpublished data).*

range from no thinning to intensive thinning, with only about 50 trees per acre remaining at age 40 years. This study shows that in stands on a wide range of site productivity, frequent thinning has substantially altered stand structure and tree growth. For example, after 25 years at the Hoskins, Oregon, study site, diameter distributions, crown length, wood volume, and basal area growth were altered by thinning (Marshall 1990). The average diameter of the stands, especially the numbers of trees in the larger size classes, increased following thinning (Figure F.5). For example, after heavy thinning, diameters

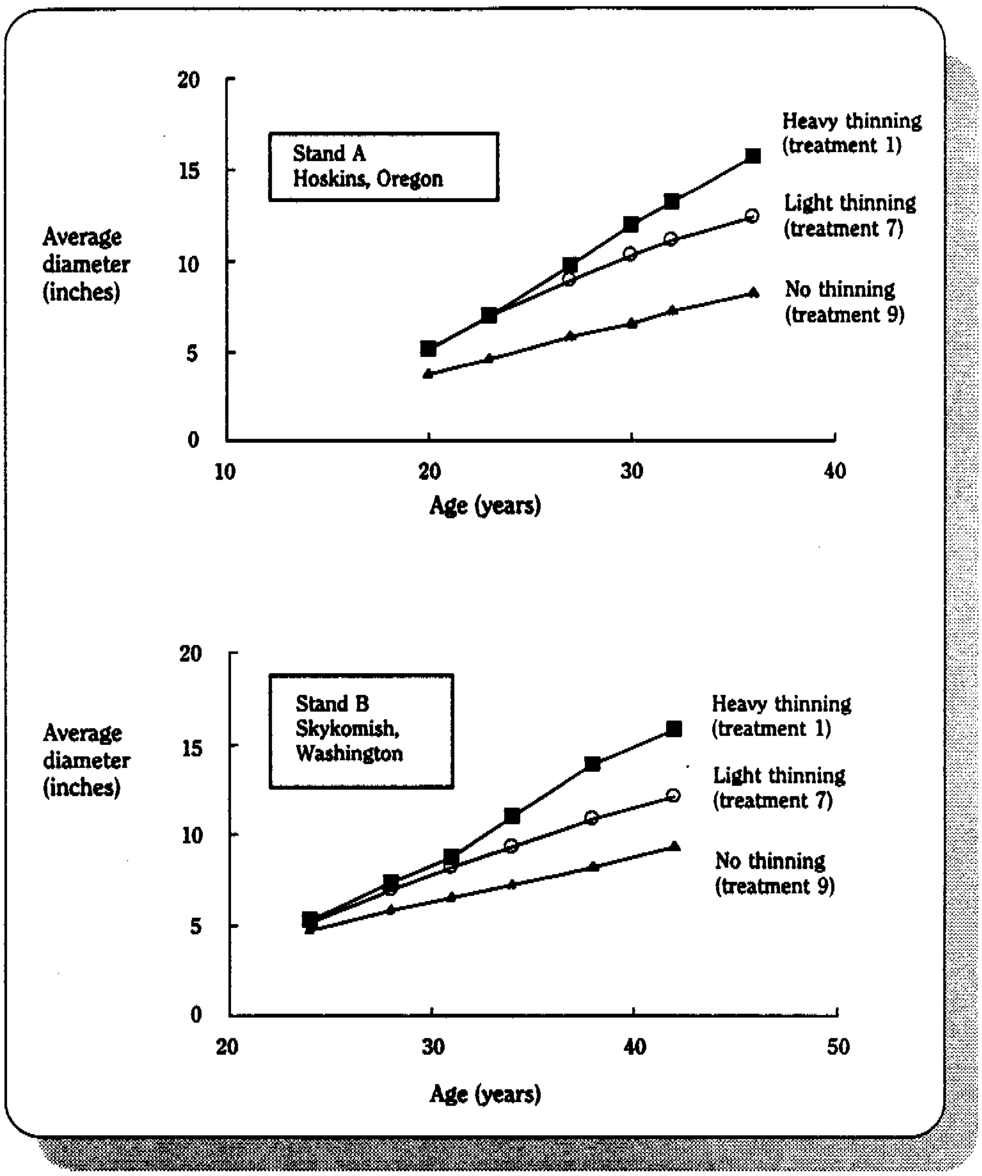


***Figure F.7.* Average diameter following three intensities of thinning in two levels of growing stock studies (Curtis and Marshall 1986).**

ranged from 16 to 24 inches; after light thinning they ranged from about 4 to 20 inches. The crown size of individual trees and understory development increased as thinning intensity increased (Figure F.6). Understory biomass increased from about 9 pounds per acre in unthinned plots to more than 6,300 pounds per acre with heavy thinning. The trends and actual values for diameter (Figure F.7) and other parameters at the other sites were quite similar to those at the Hoskins, Oregon, study site (Curtis and Marshall 1986).

Thinning regimes can be flexible and Douglas-fir stands can respond equally well to different intensities and timing of thinnings (Reukema 1972). Stands 38 years old were thinned: a) lightly (12 percent volume removed) at 3-year intervals, b) moderately (22 percent volume removed) at 6-year intervals, and c) heavily (31 percent volume removed) at 9-year intervals. About the same amount of volume was removed in all three treatments. After 18 years, there was no difference in net volume growth compared to the controls, indicating that young stands can respond positively to a range of thinning regimes. Studies by Dilworth (1980), Nystrom et al. (1984), and Greene and Emmingham (1986) suggesting that the effects of density on the development of young western hemlock and western red cedar stands are similar to effects on Douglas-fir (King 1986).

Other work has shown that development of older Douglas-fir and western hemlock stands can be regulated by stand density control and careful thinning. Williamson and Price (1971) summarize information collected 5 to 38 years after thinning in 70-to 150-year-old Douglas-fir. Thinning intensity ranged from a control with no thinning to 55 percent of total basal area removed, and included both crown thinning (removing large trees) and low thinnings (removing small trees). Thinning reduced mortality caused by bark beetles, indicating that stand vigor was improved. Similarly, Williamson (1966 and 1982) studied growth response after thinning in a 110-year-old stand of Douglas-fir. Nineteen years after light and heavy thinnings, volume growth was nearly equal that of the control, suggesting that stands this age can be vigorous and are able rather quickly to occupy space made available by thinning. Newton and Cole (1987) reconstructed stand development to provide further evidence of the ability of thinned Douglas-fir stands to produce large trees. Stands 50 and 70 years old were thinned to less than 40 trees per acre. At time of thinning, trees were about 14 to 24 inches in diameter. Seventy years later, diameters ranged from 24 to 50 inches (average 35 to 40 inches). Basal area growth continued to increase for 70 years, indicating that trees were vigorous and continued to respond to the growing space provided by the low stocking. An understory of bigleaf maple, grand fir, and shrubs (e.g., hazel and oceanspray) had developed in these stands.

Windthrow is a natural part of stand development which will occur in thinned and unthinned stands. It is not necessarily a concern after thinning, even in older stands. Graham et al. (1985) recorded windthrow on 400 acres of thinned 100-year-old Sitka spruce-western hemlock stands near the coast at Cascade Head, Oregon, from which 0 to 25 percent of the basal area was removed. Windthrow was variable and occurred in thinned and unthinned sites. For example, all windthrow in one tract occurred on half the plots, and tracts which had heavy windthrow during some storms had only very light losses during others. Overall volume of windthrown trees was nearly twice as great in unthinned stands as it was in thinned stands, possibly because trees prone to wind damage were removed in thinning. Total mortality from all causes, but not including thinned volume, was somewhat less on thinned sites (225 cubic feet per acre) than on unthinned sites (300 cubic feet per acre); this amounts to about only one year's volume growth. Similarly, Williamson and Price (1971), after studying 70- to 150-year-old stands 18 years after thinning, concluded that windthrow was related to factors such as soil depth and topographic position and wind patterns rather than thinning.

Ruth and Harris (1979) discussed the problems of wind and thinning in western hemlock-Sitka spruce forests. They concluded that site (topography, soil depth, soil drainage), root disease, type of thinning, and age at thinning (or other disturbance) are variables that determine the windthrow potential for a stand. Thinning old, dense stands will likely increase risk of damage on windy sites, while thinning younger stands may decrease the risk at later stages of development. Leaving wind firm edges that do not channel wind and unthinned buffers is important on exposed sites because they are likely to decrease the risk of blowdown progressing throughout a stand. Thinning also lowers height to diameter ratios of trees by increasing stem diameter growth relative to height growth and by lowering the center of gravity of the crown. Based on European experience, height to diameter ratios of 100 or more in Douglas-fir indicate susceptibility to damage (Worthington and Staebler 1961). Thinning would decrease this ratio because tree diameter growth usually is increased by thinning more than height growth is increased.

B. Understory Vegetation and Advanced Regeneration

Regulating stand density affects understory vegetation. As the overstory becomes less dense from thinning or natural disturbance, an understory of shrubs, hardwoods, conifers, and other species develops. Conifer and hardwood seedlings and saplings will grow to provide the multilayered stands used by owls. Alaback and Herman (1988) reported the development of a two-layered conifer stand 17 years following thinning in western hemlock and spruce stands. However, development of too dense an understory of hemlock may inhibit development of shrub or forb layers. After disturbance to the overstory (release), conifer seedlings and saplings increase their growth, and it appears that in open conditions the rate of growth following release is related to the size of their crowns and rates of prerelease height growth (Helms and Standiford 1985, Gordon 1973, Stein 1986). Careful removal of overstory trees is needed to ensure release of advanced regeneration; however, Douglas-fir seedlings can recover from damage by overstory removal (Tesch et al. 1990). Growth of western hemlock and western red cedar present in the understory of a recently thinned 110-year-old Douglas-fir stand was increased by fertilization or thinning (Harrington and Wierman 1990).

Thinning or other disturbance also aids the development of shrubs (Long and Turner 1975) (Figure F.3). Vine maple clones spread by layering as they are pinned to the ground by falling trees (O'Dea 1991). Shrubs like salmonberry and salal spread from increased rhizome extension and seedling establishment in thinned stands (Tappeiner et al. 1991, Huffman 1991). Too dense a layer of shrubs or forbs will prevent the establishment of conifers and hardwoods in the understory (Isaac 1938). Bigleaf maple seedlings become established as the overstory is thinned to about 70 to 80 percent cover or less, but before a layer of shrubs or forbs is formed (Fried et al. 1988). Where layers of shrubs occur in the understory, some treatment to reduce their density may be needed to establish trees to provide owl habitat.

C. Fertilization

Fertilization has been shown to increase the rate of stand development in stands 15 to 110 years old. For example, 80-year-old (Miller and Harrington 1979) and 110-year-old (Harrington and Miller 1979) Douglas-fir stands increased basal area and diameter growth rates following application of nitrogen fertilizer as urea or ammonia nitrate. Increased growth occurred in thinned and unthinned stands and on a range of sites and stand ages less than 90 years (Miller et al. 1979, Miller and Tarrant 1983). Fertilization also increased diameter and height growth in thinned and unthinned 15-year-old western red cedar stands (Harrington and Wierman 1990).

D. Historical Stand Management Practices

The primary silvicultural system for Douglas-fir and western hemlock forests in the coastal forests and western Cascades of Oregon and Washington has been even-age management. This is an efficient way to manage these forests for timber production primarily because a) the major conifers can be regenerated in open conditions following disturbance, b) steep topography on many sites precludes tractor logging or makes it prohibitively expensive and likely to cause serious soil erosion, and c) cost of setting up cable logging equipment and road building in steep terrain makes it most efficient and least expensive to clear-cut. Under the even-age system, stands most often are regenerated using the clear-cutting method, followed by site preparation, planting nursery-grown seedlings, and some level of control of herbs, shrubs, or hardwoods. The shelterwood method also has been used on some sites where wind is not a serious problem (Williamson 1973).

Early in the development of silvicultural practices in this region, Kirkland and Brandstrom (1936) recommended partial cutting and group selection as a way to manage Douglas-fir. Isaac (1956) reviewed the early trials of this type of "selection management" in old-growth forests and recommended that Douglas-fir forests be managed under even-age systems. His recommendations were based on observations that a) little natural regeneration occurred after selection cutting, b) understory trees were damaged by logging, c) there was blowdown (few trees, but lots of volume), and d) the old trees generally did not increase their growth rates after cutting. Isaac (1956) recognized several cases where selection cutting (uneven-age management) appeared to be reasonable: a) dry sites with more open stands, b) stands with a high proportion of young trees, and c) salvage. It is important to note that his recommendations were based mainly on experience in old stands, not young stands (less than 100 to 120 years). These recommendations considered only natural regeneration without well-planned site preparation prior to planting or natural seeding, followed by vegetation control. Also, advances in logging technology probably will allow somewhat more intricate treatments. Therefore, because of new information on harvesting and reforestation methods, Kirkland and Brandstrom's (1936) ideas of group selection, and group shelterwood and irregular shelterwood (Smith 1986, Troup 1928) should be reviewed. They can be considered for use on certain sites in young and mature forests along with green tree retention and other "new perspective" practices.

E. Stand Simulators and Growth Models

Growth models can be used to predict the development, growth, and yield of forest stands with and without treatments. These models will predict average tree diameter, height, total stand basal area, volume, and mortality. Simulators such as DFSIM (Curtis et al. 1981), CRYPTOS (Krumland and Wensel 1980), ORGANON (Hester et al. 1989), and PROGNOSIS (Stage 1973) predict these variables for entire stands and/or by tree size classes within stands. The trends in simulated stand growth and development are consistent among these models. They were used in this report to project the effects of different silvicultural systems on stand growth for owl habitat. When compared with data from actual stands, DFSIM and ORGANON predict trends in stand growth quite accurately (Hann 1991, Stere 1991).

The snag recruitment simulator provides a means to predict snag longevity by diameter and decay class for natural snags or those created by management. This program was developed by Bruce Marcot (U.S. Forest Service, PNW Research Station, Portland, Oregon) based on information in Neitro et al. (1985).

IV. Examples of Silviculture Prescriptions

Following are silviculture systems for different types of stands common throughout the range of northern spotted owls. Data were used from actual stands and simulated the development of structures following treatments to grow large trees and produce multilayered stands. When actually implementing these systems the following points should be evaluated to see if they apply to the stand in question. They are suggestions which will help ensure that silviculture systems "mimic" natural disturbance and stand development. The list is not exhaustive; other ideas will be appropriate on a stand by stand basis:

- Favor some large trees with many limbs for potential nest sites.
- Use hardwoods to help develop a multilayered stand.
- Encourage the growth of advanced regeneration of shade-tolerant conifer and hardwood species, even in young (30 to 50+ years old) stands.
- Establish new regeneration by planting or seeding in young (50+ year-old) stands after making small openings or reducing overstory density in parts of a stand.
- Consider varying the distribution of overstory trees when thinning. Vary spacing and tree density, make openings for new regeneration and release advanced regeneration.
- When thinning, leave some trees in the smaller crown size classes (intermediate and suppressed) to help promote a layered stand.
- In stands with irregularly spaced trees, consider a crown thinning to release individual trees while maintaining the irregular spacing.

A. Douglas-fir and Western Hemlock Stands (Oliver et al. 1991)

The following examples from Douglas-fir and western hemlock stands 30 to 70 years old (Oliver et al. 1991) show trends of stand development under different densities. Diagrams are drawn to scale using information from stand simulators. Stands are projected with no treatment (Figures F.8, F.9, F.10). In addition, the 30-year-old stand (Figure F.8) is projected with two thinning regimes (low and moderate density); the 70-year-old stand is projected with a thinning regime (moderate density) and a treatment to produce a multiple-canopy stand (Figure F.9). In these stands, the second story would result from release of conifers and hardwoods, or planting and seeding of conifers following thinning. Development of a young plantation is shown in Figure F.10. Here, too, thinnings stimulate large tree and early understory development. These simulations indicate that there are several advantages of manipulating overstory density to produce owl habitat:

a) The size of the average tree, and the size of the largest 5 percent of the trees in the stands, are increased. For example, the 30-year-old stand (Stand B, Figure F.8) under a low density thinning regime is simulated at age 90 (year 2050) to have an average diameter of 36 inches and the largest 5 percent of the trees have diameters of about 44 inches; while Stand A, with no activity, has trees of 18-inch average diameter and the largest 5 percent of the trees have 27-inch diameters.
b) In stands which have been thinned, the canopy is "deeper," and trees have larger crowns. For example, stands managed under the low-density thinning regime at age 90 years (year 2050) have crowns estimated from 60 to 140 feet above ground

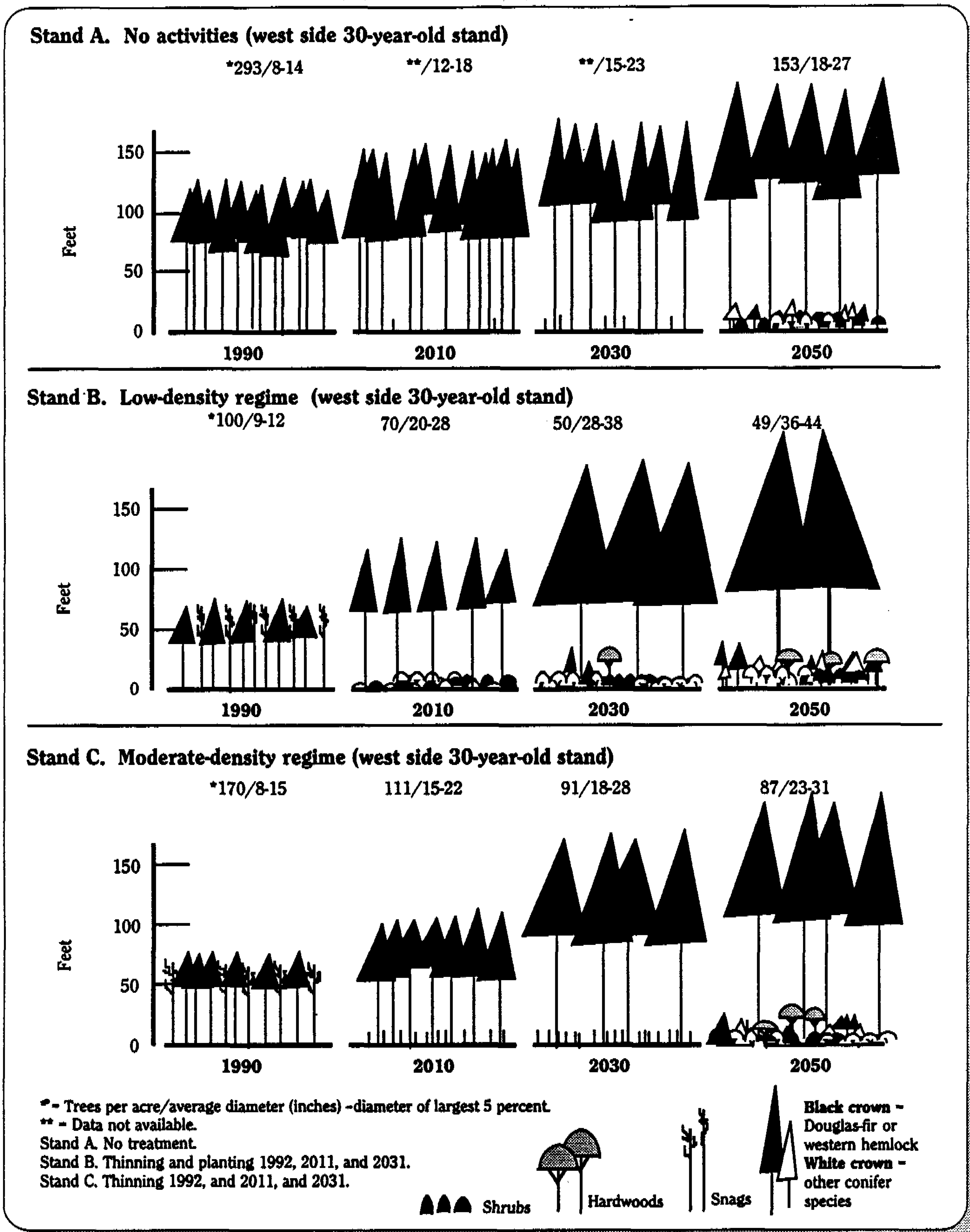


Figure F.8. A 30-year-old Douglas-fir/western hemlock stand simulated with no treatments and with development under low-density and moderate-density regimes. Numbers of trees per acre, average diameter, and diameter of the largest 5 percent of the trees are shown at each year. Note the increased crown and understory development as overstory tree density decreases (Oliver et al. 1991).

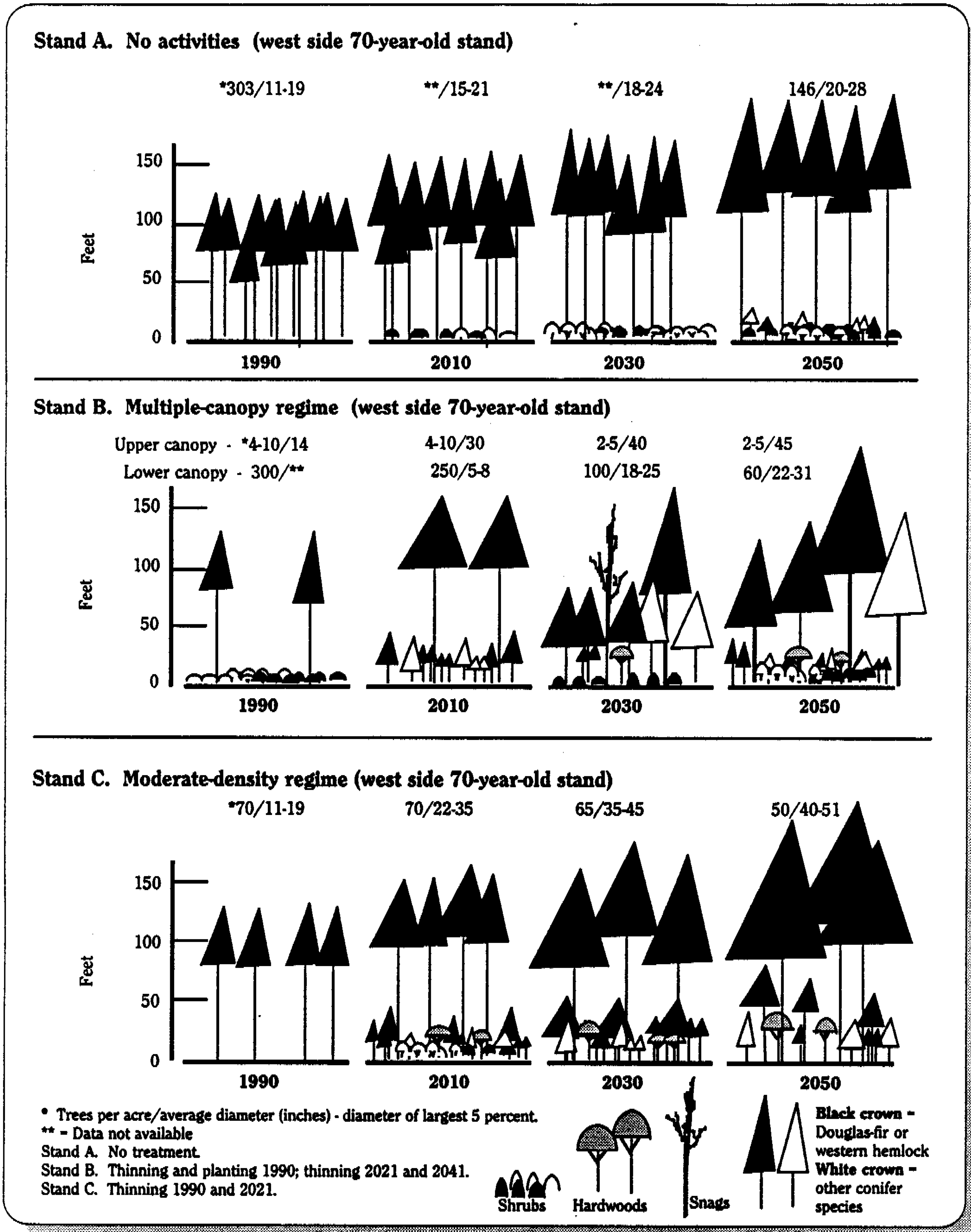


Figure F.9. *A 70-year-old Douglas-fir/western hemlock stand simulated with no treatments and with development of multiple-canopy and moderate-density regimes. Number of trees per acre, average diameter, and diameter of the largest 5 percent of the trees are shown at each year. Note the increased crown and understory development as overstory tree density decreases (Oliver et al. 1991).*

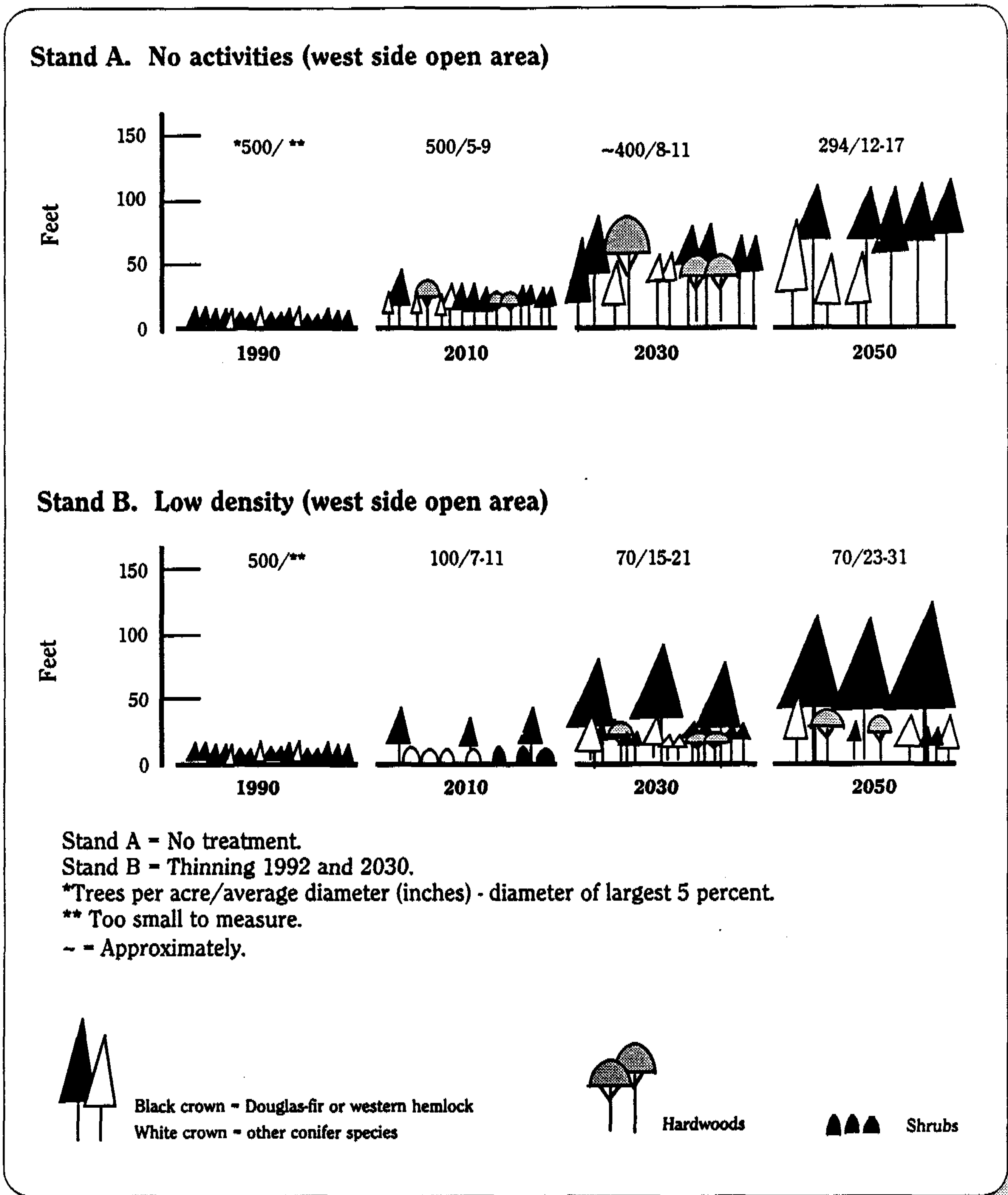


Figure F.10. *A plantation of Douglas-fir and western hemlock simulated with no thinning and with thinning of small trees at ages 20 and 40 years. Numbers of trees per acre, average diameter, and diameter of the largest 5 percent of the trees are shown at each year. Note the increased crown and understory development as overstory tree density decreases (Oliver et al. 1991).*

Table F.1. Costs per acre or return per acre over 60 years for each silvicultural system on each stand (Oliver et al. 1991). Costs assume no timber removal is done and no risk reduction measures are taken. Returns assume all timber killed is removed (none is left to create snags and logs). Part of the cost of creating spotted owl habitat, as well as reducing the risk of fires and insects, may be defrayed by selling some of killed trees in each stand. Where some trees are left and others removed, costs (or returns) would be between values shown here.

	Cost No Removal (in dollars)	Returns Full Removal (in dollars)
West side 30-year-old stands		
No activities system:	$ 0	$ 0
Low density system:	$ 340	$ 7,165
High density system:	$ 337	$ 7,900
West side 70-year-old stands		
No activities system:	$ 0	$ 0
Multiple canopy strata system:	$ 1,390	$ 14,042
Moderate density system:	$ 771	$ 4,866
West side open areas		
No activities system:	$ 0	$ 0
Maintain opening system	$ 310	$ 0
Low density system:	$ 422	$ 1,000
East side multiple canopy strata stands		
No activities system:	$ 0	$ 0
Low density system:	$ 1,030	$ 2,129
High density system:	$ 742	$ 1,215
East side pole stands		
No activities system:	$ 0	$ 0
Multiple canopy strata system:	$ 2,822	$ 1,777
High density system:	$ 1,515	$ 1,862
East side open areas		
No activities system:	$ 0	$ 0
Maintain opening system:	$ 350	$ 0
Low density system:	$ 150	$ 0

(i.e., more than 60 percent of the length of the tree will contain live crown); while untreated stand crowns will be 110 to 140 feet above ground (see Figure F.8).

c) Reducing overstory density will enhance development of an understory and encourage the development of multilayered stands typical of those used by owls (Figure F.1). Without thinning, stands may be either too dense for tree and shrub seedlings to become established, or those that are present will grow very slowly.

These stands are not likely to produce large snags or logs on the forest floor naturally. Mortality due to crowding will kill trees less than 11 inches in diameter. However, stands at low density will have trees 25 inches in diameter breast height (dbh) and larger, some of which will be killed by pathogens and insects, or which can be girdled or topped to make snags.

Oliver et al. (1991) predicted that the risk of wind damage to unmanaged stands is greatest when they are about 30 to 70 years old (Ruth and Harris 1979). After about 70 years, the larger trees in the stand are likely to become stable.

The maximum possible costs and maximum possible returns for these scenarios have been estimated (Table F.1).

B. Douglas-fir from Oregon Coast Range (Birch 1991)

Example 1: A 60-year-old Douglas-fir and western hemlock stand on a productive site (site index 130 feet at 50 years) with 280 trees per acre. The goal of the simulation was to produce a multilayered stand structure (similar to Stand A in Figure F.11) as quickly as possible.

- At 60 years the stand was thinned leaving a) the largest 10 trees per acre (26 to 30 inches in diameter), b) trees in the smaller sizes (48 trees per acre, 4 to 12 inches in diameter), and c) 10 percent of the trees 12 to 26 inches in diameter.
- Space created by tree removal was regenerated at a density of about 200 trees per acre by planting or releasing advanced regeneration.
- By age 120 years, this stand was projected to have a diameter distribution resembling those around owl nest sites (Figure F.11 Stand A). The largest trees were more than 44 inches dbh. There were more than 150 trees per acre less than 12 inches in diameter in the understory. Estimated understory height ranged from 45 feet to more than 120 feet; estimated canopy cover was 100 percent.
- Snags and down logs might not occur naturally with this system, and may have to be made by killing trees.

Note that the untreated stand was not projected to have developed multiple layers or have the desired structure by age 120 years.

Example 2: A Douglas-fir, grand fir, bigleaf maple stand (site index 120 feet at 50 years) with an initial density of 881 stems per acre. Since stocking was so high, this stand was simulated to have three thinnings (Figure F.11, Stand B). Hardwoods were left to develop a multilayered structure.

- At age 40 years, 50 percent of the conifers in the 10- to 16-inch diameter classes were thinned. There were 362 conifers and 114 hardwoods per acre left; 100 conifers per acre were planted.
- At age 60 years, 50 percent of the trees in the 10- to 22-inch diameter class were made to snags and down logs, or harvested. There were 275 conifers and 70 hardwoods per acre left; 100 conifers per acre were planted.
- At age 80 years, 60 percent of the conifers 8- to 22-inches in diameter were made into snags and down logs or harvested. There were 224 conifers and 70 hardwoods per acre left.

Removing trees or killing them for snags or down logs allowed space for development of large trees (42+ inches in diameter) and establishment and growth of an understory. No trees more than 22 inches in diameter were removed or killed for snags or down logs. At

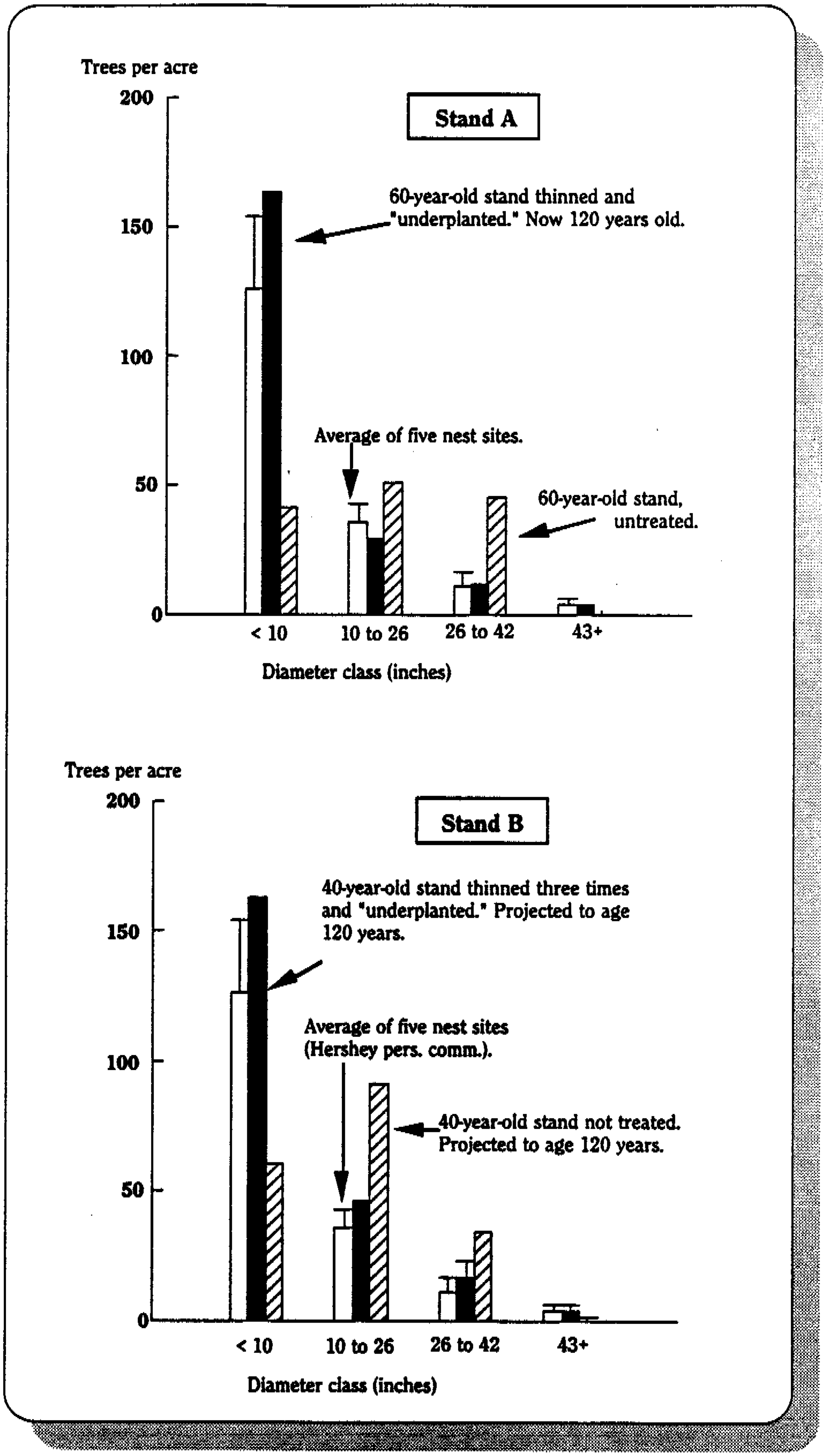


Figure F.11.* *Diameter distributions for spotted owl nest sites (Hershey pers. comm.) and simulations of two stands managed to produce spotted owl habitat, and two unmanaged stands (Birch 1991).

age 120 years, the treated stand was projected to have the required structure (Figure F.11, Stand B); simulated understory height ranged from 30 feet to 110 feet; canopy cover was 53 percent. Without treatment, the stand would not have a multilayered structure; understory was projected to be about 22 percent.

Example 3: Two young stands were simulated to grow without treatment until age 120 years. Stand A, which had about 230 bigleaf maple stems per acre, developed a second layer as the conifers overtopped the maple (Figure F.12). However, the understory was not nearly as well developed as the stand used for nest sites (or the managed stands in examples 1 and 2), since the second layer had fewer, shorter trees than stands used for nesting. Stand B, which had no maple, would not likely form a second story.

C. Redwood and Mixed-Conifer from Northwestern California (Thornburgh 1991)

This is a simulation of a redwood and Douglas-fir plantation on a productive site (site index 200 feet at 100 years). At 15 years, there were 78 redwood sprout clumps per acre (4 to 12 sprouts per clump). The rest of the stand was planted to redwood and Douglas-fir and there are natural saplings and seedlings of grand fir, western hemlock, Sitka spruce, and tanoak (Figure F.13). Also present were salal, ceanothus, huckleberry, and red alder. The goal was to allow redwood sprout clumps maximum development to form an upper canopy and to produce a mixed, layered stand with the other species.

- At 15 years, four to five sprout clumps per acre were selected and all large saplings were removed within a 16- to 20-foot radius. Shorter seedling grand fir, western hemlock, and Sitka spruce were allowed to grow in the shade of the large sprout clumps. The rest of the stand was thinned at an irregular spacing, 9 to 18 feet (average about 13 feet).
- At 25 years, there was 100 percent cover within the sprout clumps, and about 95 percent cover within the remainder of the stand with some gaps in the canopy. At this age, the stand may provide cover for dispersal, roosting, and foraging. Large redwood trees in sprout clumps could be topped to begin to produce potential nest sites.
- At 40 years, the stand was multilayered within the redwood sprout clumps. It was thinned to 135 trees per acre. Two to four large trees per sprout clump were girdled for snags and logs on the forest floor.
- At 40 to 50 years, this stand was multilayered, with a structure typical of stands used by owls for nesting.

Without management, this stand would not have a well-developed understory. This type of prescription could be started in older stands using the principles of thinning around large trees to favor their development and keeping smaller trees of tolerant species in the understory to form a multilayered stand.

D. Douglas-fir and Tanoak from Southwestern Oregon (Lewis and Haske 1991)

A 20-year-old Douglas-fir stand was modeled with treatments to produce a multilayered stand and without treatments. An old multilayered stand similar to stands used by owls for

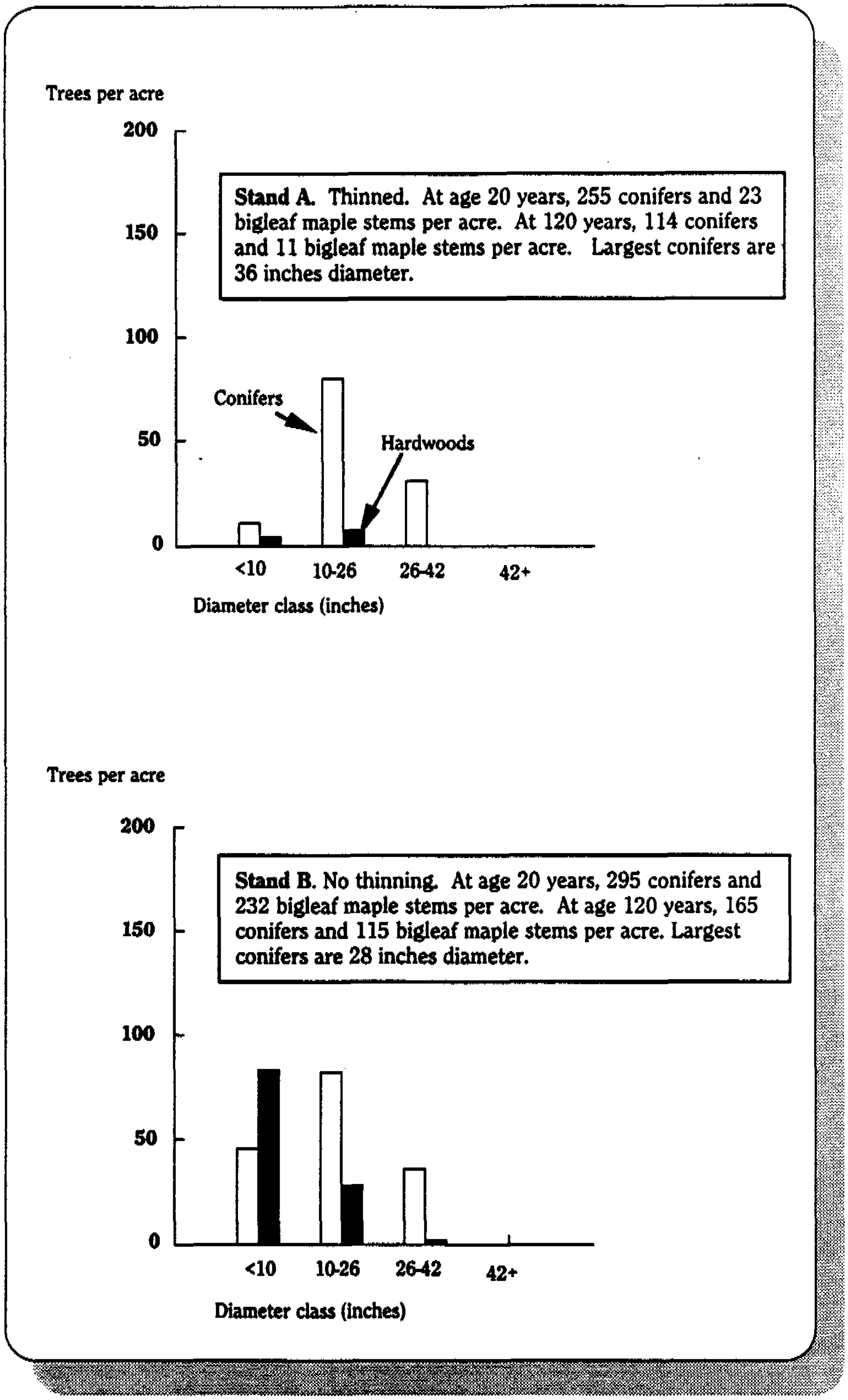
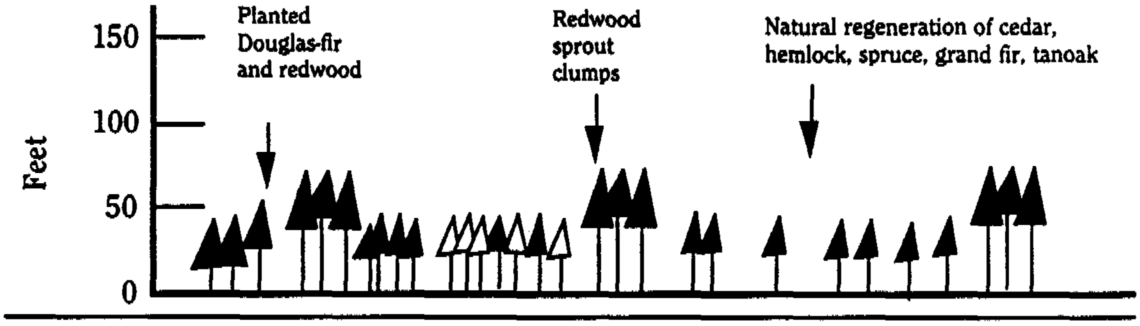
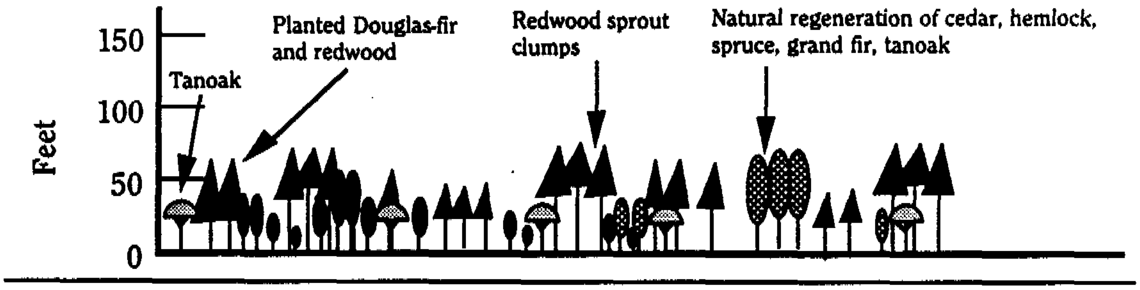


Figure F.12. *Simulated diameter distributions of two stands at 120 years of age after thinning (Stand A) and no thinning (Stand B) (Birch 1991). Compare diameter distibutions with stands thinned at later ages to obtain large trees and understory layers (see Figure F.4).*

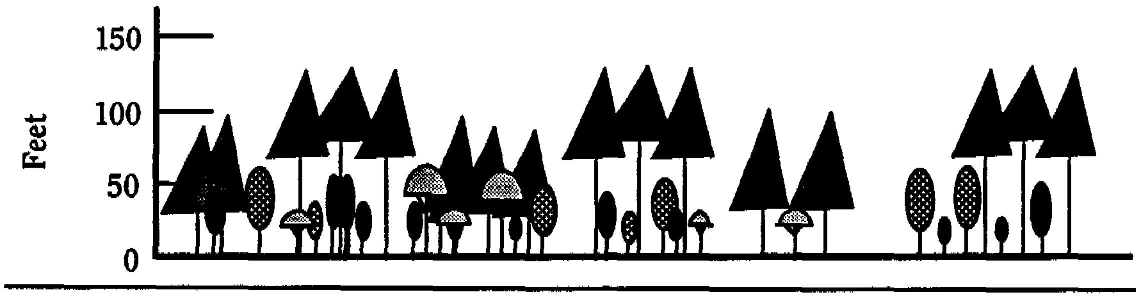
Age 15 years - 511 trees per acre, 78 sprout clumps per acre. Treatment: thin four to five sprout clumps (~16-X-17 feet) to maintain large live crowns and accelerate diameter growth, thin rest of stand at an irregular spacing (average ~13-X-13 feet). Maintain species mix; leave trees beneath crowns of sprout clumps to encourage development of layers.



Age 25 years - Sprout clumps average 65 feet tall, 19.2 inches diameter. Other trees average 60 feet tall, 16 inches diameter; smaller understory rees at edges of taller redwood clumps. Possibly take out tops of two to three large redwoods per acre to form multiple-top trees for possible future nest sites.



Age 40 years - Sprout clumps average 110 feet tall, 30.2 inches diameter. Other trees average 100 to 105 feet tall, 24 inches diameter; 250 to 270 trees per acre. Treatment: girdle two or more dominant trees per sprout clump for own logs and snag (~30 inches). Thin the rest of stand (16 to 30 inches diameter) to 135 trees per acre.



Age 50 years - Sprout clumps average 140 feet tall, 37.6 inches diameter. Other trees average 130 feet tall, 29.5 inches diameter.

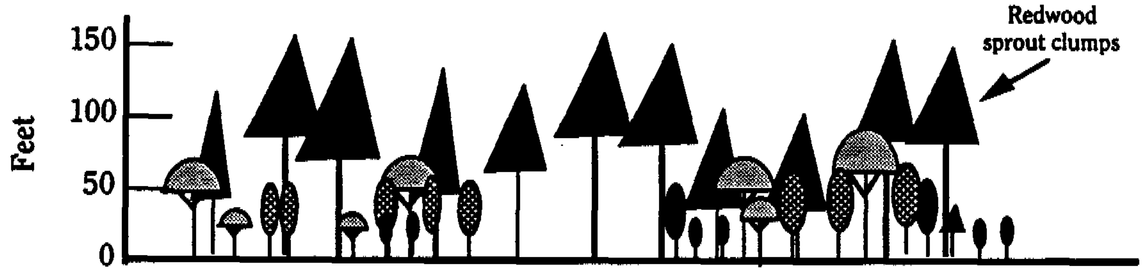


Figure F.13. *Silviculture system for producing spotted owl habitat in young-growth redwood stands (Thornburg 1991)* nesting was used as a goal. Figure F.14 compares the structure of the natural old-growth stand to the structure of the two modeled stands at age 135 years.

- At age 2- years, the managed stand was thinned to 200 trees per acre.
- At age 50 years, the stand was thinned to about 80 trees per acre. Tanoak were controlled to establish Douglas-fir in the openings created by thinning. These treatments minimized the establishment of openings created by a moderately intense fire.
- At age 80 years, the stand was thinned again, removing about 30 trees per acre. In practice, underburning might be considered to reduce fire hazard and duplicate the presettlement fire return interval.
- By 135 years of age, a multilayered stand was achieved which resembled the old stand used as a goal (Figure F.14, Stand C). Maximum tree diameters were 40 inches compared to 52 inches in the old stand. Heights of trees in the lower layers were predicted to range from about 20 feet to 80 feet. Projected crown closure was more than 70 percent. If burning were done, there likely would be fewer conifers in the 10- to 16-inch diameter classes in the managed stand at 135 years. The unmanaged stand was not projected to have a multilayered structure, and maximum diameter was predicted to be about 34 inches.

E. Uneven-age Management in Mixed-Conifer Forests in Northern California (Weatherspoon and Ritchie 1991)

In this case, the stand was multistoried, and it was simulated under uneven-age management and use of prescribed fire for 240 years (Figure F.15). This example illustrates that uneven-age management in mixed-conifer forests can be used to maintain a structure like that used by owls. However, if prescribed fire were used to reduce fuel accumulation and risk of an intense wildfire, then it likely would be difficult to maintain a suitable structure in all parts of a stand for long periods of time.

- The stand was multistoried, but probably had many more small trees 1 to 10 inches in diameter than would be present without fire prevention.
- Two systems were used: 1) group selection to make small openings up to about 1 acre, plus thinning among groups, and 2) small (1 to 2 acres) irregular shelterwood units to obtain regeneration and to keep large trees in the stand.
- Regeneration and thinning were done every 20 years.
- Prescribed underburning was used about every 40 years to reduce fuel loads and to make the stand less susceptible to a severe wildfire. Underburning was estimated to cause a reduction in numbers of trees in the understory, but it would aid establishment of new seedlings.
- The unmanaged stand lost its layered structure. Since there was no disturbance to the overstory, large trees were projected to increase their density (basal area) to more than 300 square feet per acre (Figures F.15 and F.16), and to form a dense canopy which would inhibit growth of trees into size classes larger than 41 inches in diameter.

This example shows that uneven-age management can be used to maintain multilayered stands. Without disturbance to the overstory, the understory layers would be greatly reduced over time. In these forests with a low intensity high frequency natural fire regime, prescribed burning is desirable to reduce fuels and the chances of an intense fire which would kill all the trees. However, if fire were used, understory density would likely decrease for a number of years. These multistoried stands probably were not common before fire suppression and logging. Controlling stand density and obtaining regeneration,

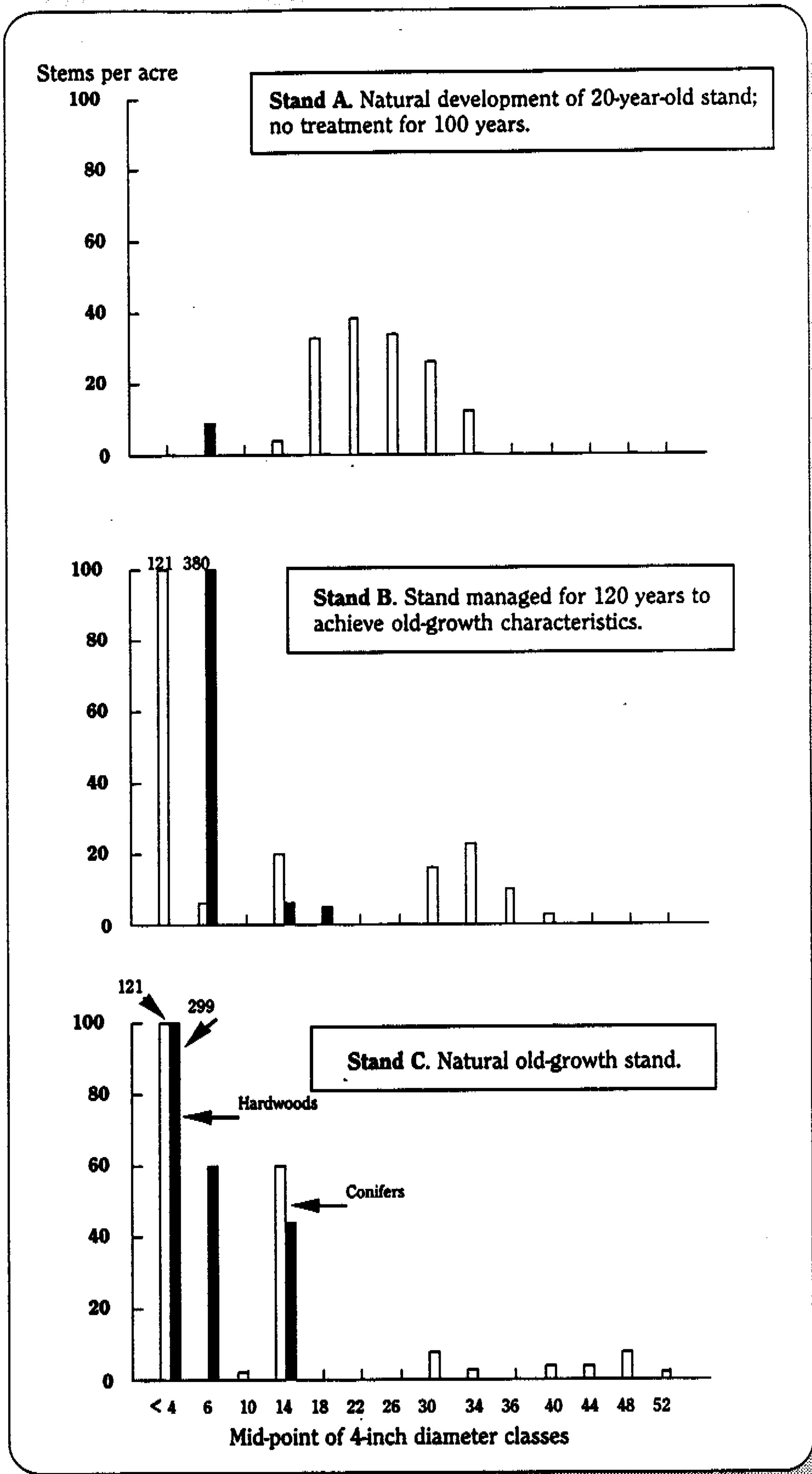


Figure F.14. *A. 20-year-old stand modeled with treatments to produce old-growth characteristics at 100 years (Stand B), and at 100 years with no treatments (Stand A). Stand C is the desired stand structure (Lewis and Haske 1991).*

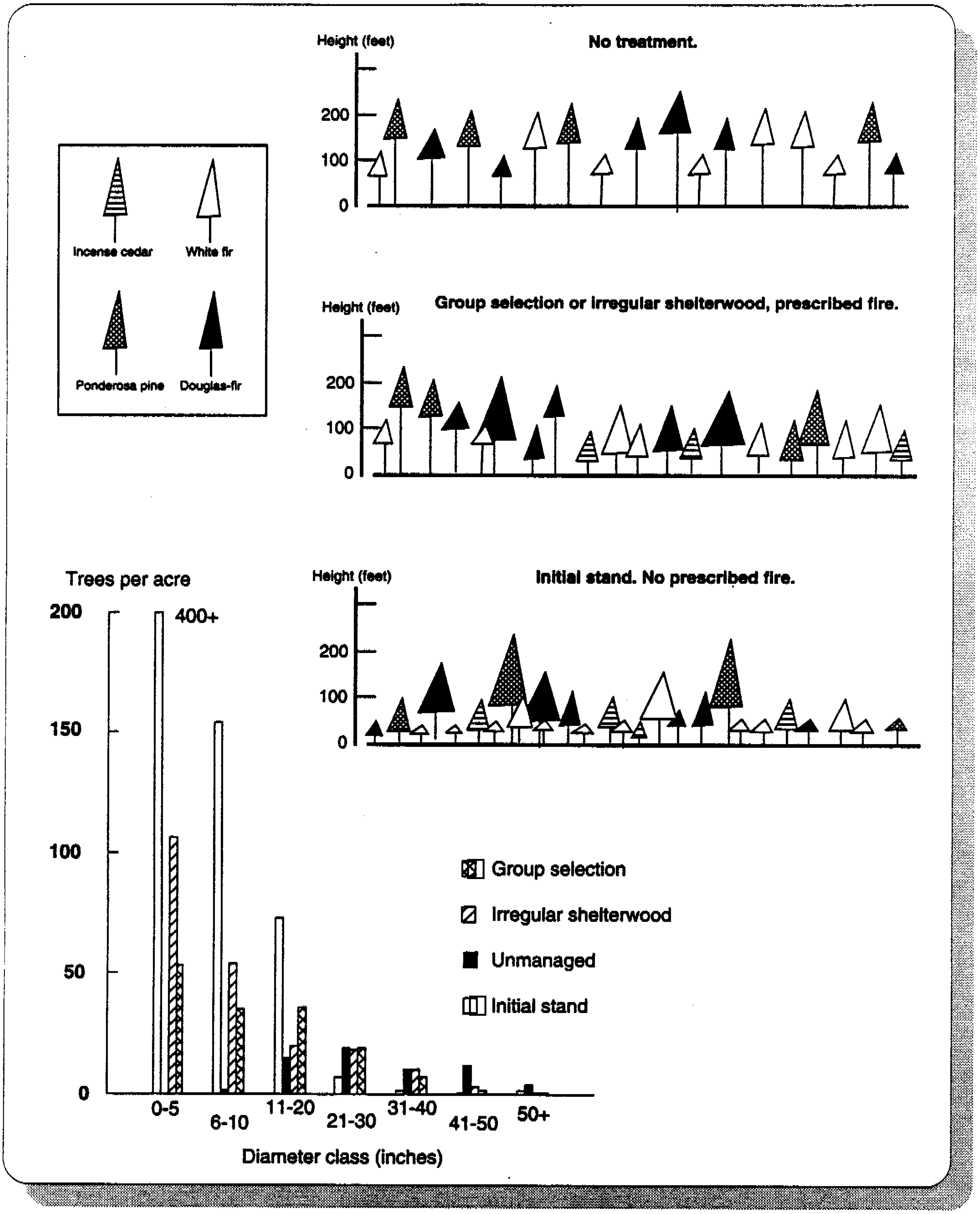


Figure F.15. Simulations of a mixed-conifer stand before management, after 240 years with no management and with uneven-age management using irregular shelterwood and group selection methods. Prescribed fires were used to reduce fire hazard in the managed stands. Drawings of stand structures above and diameter distributions below (Weatherspoon and Ritchie 1991).

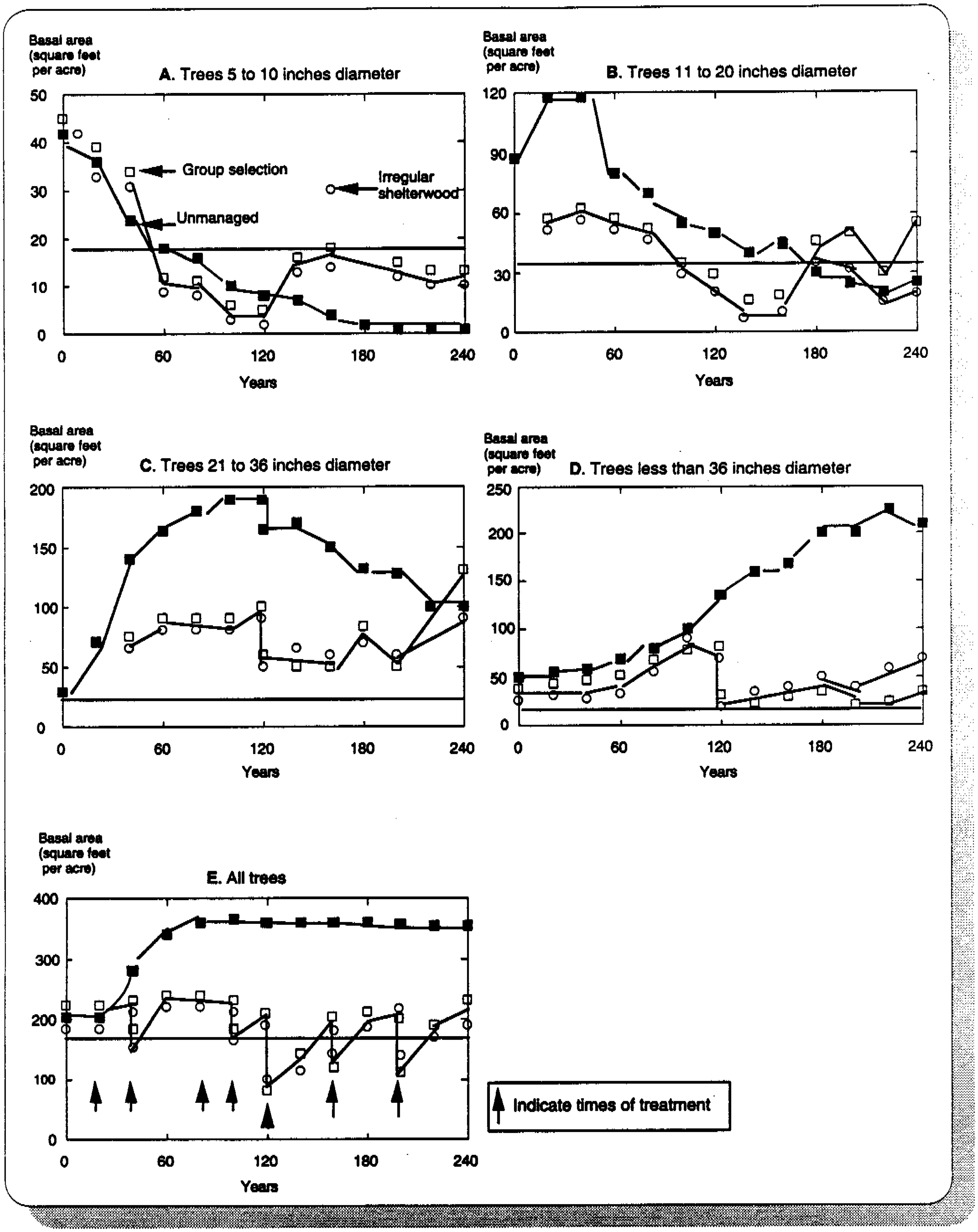


Figure F.16. A mixed-conifer stand simulated to maintain a multilayered structure through 240 years by two types of uneven-age management and prescribed fire. Diagrams show the basal area by four size classes in Stands A, B, C, and D, and for the entire Stand E. Horizontal lines indicate minimal level of basal area needed to maintain structure (Weatherspoon and Ritchie1991).

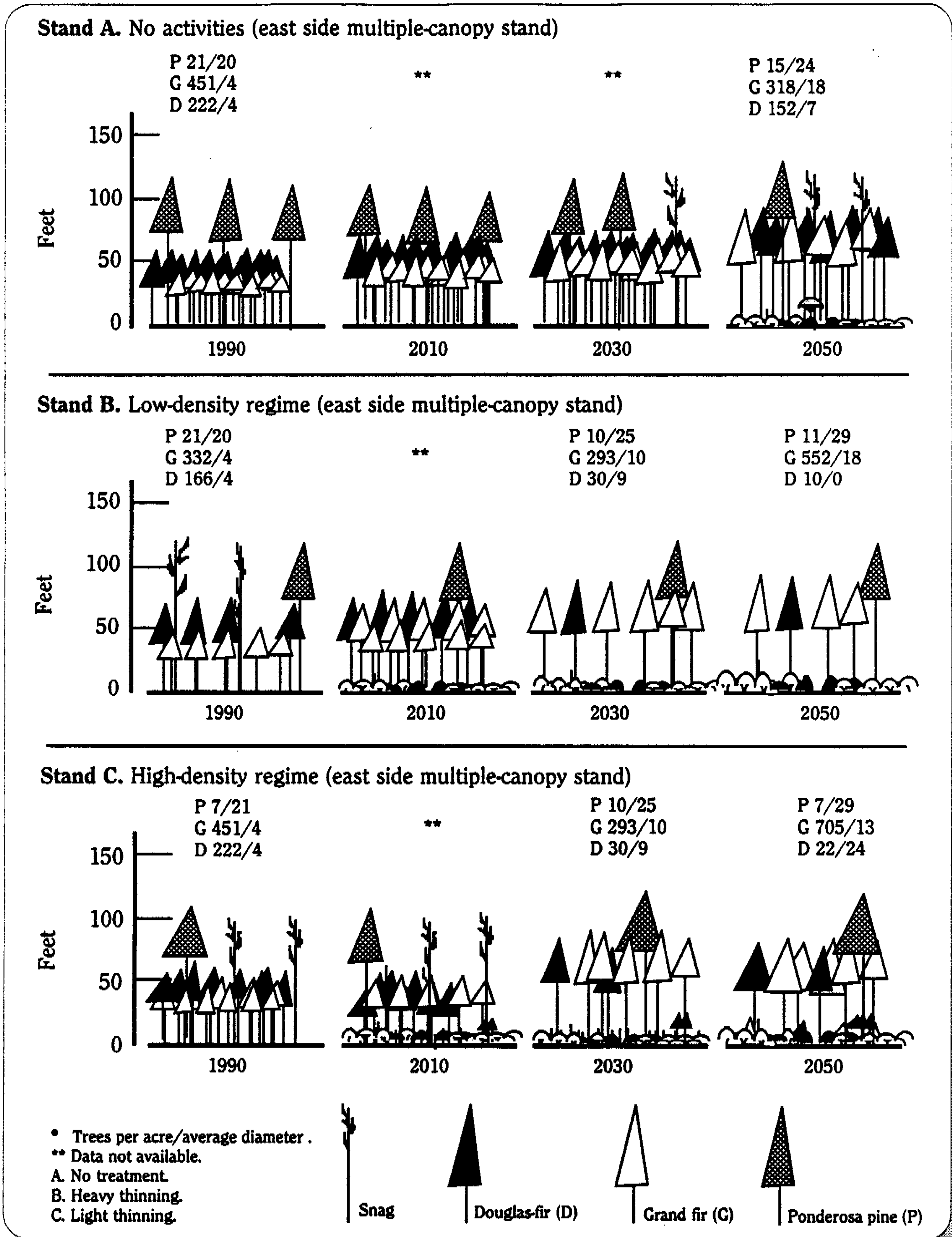


Figure F.17. *Development of a mixed-conifer, multiaged stand, eastern Cascades, at different densities. Number of trees per acre and the average diameter are shown for the principal species (Oliver et al. 1991).*

as well as fire control, will be needed to maintain these structures. If prescribed fire were used to reduce fuels and the likelihood of an intense wildfire, it might not be possible to maintain an ideal structure for owls in all parts of a stand over time. Use of prescribed fire should be implemented on a landscape basis with burning varied over space and time.

F. Multilayer and Mixed-Species, Eastern Side Cascades

Typical eastern Cascades multilayered, mixed-species stands of ponderosa pine, larch, lodgepole pine, Douglas-fir, and grand fir are projected: a) with no treatment of a stand originated by wildfire about 80 to 100 years ago, b) with heavy thinning applied to a stand which resulted from partial cutting during the past 80 to 90 years, and c) with light thinning applied to high density stands which resulted after fire suppression but no partial cutting. Under natural fire regimes, these stands would tend to be more open and probably less suitable habitat for owls (Oliver et al. 1991).

- With no activity, a stand formed a very dense layer of grand fir and Douglas-fir beneath a sparse canopy of ponderosa pine (Figure F.17, Stand A).
- Thinning (Figure F.17, Stands B and C) followed by natural regeneration changed the understory to primarily grand fir and decreased ponderosa pine in the overstory. This trend probably could be reversed with heavy thinning and/or planting of pine. Trees with mistletoe brooms can be left for owl nest sites.
- Risk of severe fire was high in all three systems due to slash after treatment or self-thinning due to crowding. Fuel management and fire suppression likely will be needed to maintain these structures (Appendix E).
- Pathogens and insects killed trees of all species, added to fuel loading, and decreased the density of the overstory. Thinning and salvage under a low density scenario would help reduce effects of pathogens and insects.
- Opening the canopy in small patches and preparing the site for seeding or planting probably will be needed to maintain ponderosa pine and Douglas-fir in the forests, if fire is to be excluded to provide owl habitat.

Summary

These silvicultural systems, developed for common types of stands throughout the range of the owl, indicate that multilayered stands can be developed or maintained. Where stands are well stocked with young conifers, thinning these stands provides space for development of large trees with full crowns, while providing light and moisture for growth of understory trees into multiple layers. The structure and species composition of multistoried stands can be developed and maintained by opening the overstory to favor established seedlings and saplings or to establish new ones.

Fire, wind, insects, pathogens, soils, and other environmental variables are important within forests throughout the owl's range. They must be evaluated on a stand by stand basis to determine how they affect stand development. Their potential effects often will be a key in selecting a silviculture system. Also, the structure of stands must be considered. Are there hardwoods or conifers present in the understory which will form multiple layers? Are there shrubs which will prevent or delay the establishment of trees needed to form multilayers? Will the stand produce large snags or only small ones? What will costs or returns be? Therefore, the cases presented are examples of systems which might be used to produce owl habitat. In practice, multidisciplinary professional input is needed on the ground to develop and implement silvicultural systems.

Careful implementation, monitoring, and evaluation of treatment effects are also essential. They indicate the willingness and commitment to ensure that the system will produce the desired structure and habitat.

As with all silviculture activities, there is an important link between planning and implementation. Silviculture systems and practices that are feasible ecologically may be difficult and expensive to carry out. The prescriptions outlined here call for thinning, encouraging the growth of advance regeneration of hardwoods and conifers, and establishment of regeneration during the course of stand development. All of these practices require care and need to be closely monitored during and after implementation. Natural disturbances such as fire, insect outbreaks, and windthrow affect managed and unmanaged stands. These events occur at random, and the timing and nature of their effects cannot be predicted. After such events occur, managed and unmanaged stands must be evaluated to determine their effects on stand development. In some stands, the effects might be beneficial, in that they would aid stand development toward old-growth characteristics. In other cases, disturbance might prevent or delay development of desired stand structures.

Literature Cited

Agee, J.K. 1990. The historical role of fire in the Pacific Northwest forests. Pages 25-38 in: Walstad, [and others], eds. Prescribed and natural fires in Pacific Northwest forests. Corvallis, OR: Oregon State University Press. 316 p.

Alaback, P.A. 1982. Dynamics of understory biomass in Sitka spruce-western hemlock forests of southeast Alaska. Ecology. 63:1932-1948.

Alaback, P.A.; Herman, F.R. 1988. Long-term response of understory vegetation to stand density in *Picea-Tsuga*. Canadian Journal of Forest Research. 18:1522-1530.

Alaback, P.A.; Tappeiner, J.C. 1991. Response of western hamlock and early huckleberry seedlings to forest windthrow. Canadian Journal of Forest Research. 21:534-539.

Assmann, E. 1970. Principles of forest yield study. New York, NY: Pergammon. 506 p.

Atzet, T.; Wheeler, D.L. 1982. Historical and ecological perspectives of fire activity in the Klamath Geological Province of the Rogue River and Siskiyou National Forests. Region 6 - Range 102. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. 16 p.

Atzet, T.; Wheeler, D.L.; Smith, B., [and others]. 1992. Vegetation. Pages 92-113 in: Hobbs, [and others], eds. Reforestation practices in southwestern Oregon and northern California. Corvallis, OR: Forest Research Laboratory, Oregon State University.

Baker, F.S. 1953. Stand density and growth. Journal of Forestry. 51:95-97.

Bingham, B., Personal Communication, U.S.Department of Agriculture, Forest Service, Arcata, CA.

Birch, K. 1991. Examples of manipulating stand structure to obtain characteristics preferred by spotted owls. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181. 35 p.

Brieglieb, P.A. 1952. An approach to density management in Douglas-fir. Journal of Forestry. 50:529-536.

Curtis, R.O.; Clendenen, G.W.; DeMars, D.J. 1981. A new stand simulator for coastal Douglas-fir: DF SIM: a user's guide. Forest Service General Technical Report PNW-128. Portland, OR: U.S. Department of Agriculture. 79 p.

Curtis, R.O.; Marshall, D.D. 1986. Levels-of-growing-stock cooperative study in Douglas-fir. Forest Service Research Paper PNW-356. Portland, OR: U.S. Department of Agriculture. 113 p.

Curtis, R.O. 1987. Levels-of-growing-stock cooperative study report number 9 - some comparisons of DFSIM estimates with growth in the levels-of-growing-stock study. Forest Service Research Paper PNW-376. Portland, OR: U.S. Department of Agriculture. 34 p.

Del Rio, E.; Berg, A.B. 1979. Growth of Douglas-fir reproduction in the shade of a managed forest. Research Paper 40. Corvallis, OR: Forest Research Laboratory, Oregon State University. 14 p.

Dilworth, J.R. 1980. Growth of western hemlock stands after precommercial thinning. Research Bulletin 33. Corvallis, OR: Forest Research Laboratory, Oregon State University. 16 p.

Drew, T.J.; Flewelling, J.W. 1979. Stand density management: an alternative approach and its application to Douglas-fir plantations. Forest Science. 25:518-532.

Eversole, K.R. 1955. Spacing tests in a Douglas-fir plantation. Forest Science. 1:14-18.

Franklin, J.; Dyrness, C.T. 1973. Natural vegetation of Oregon and Washington. Corvallis, OR: Oregon State University Press. 417 p.

Franklin, J.F.; Hemstrom, M.A. 1981. Aspects of succession in coniferous forests in the Pacific Northwest. Pages 212-229 in: West, O.C.; Shugart, H.H.; Botkin, D.B., eds. Forest succession: concepts and application. New York, NY: Springer-Verlag.

Fried, J.S.; Tappeiner, J.C.; Hibbs, D.E. 1988. Bigleaf maple seedling establishment and early growth in Douglas-fir forests. Canadian Journal of Forest Research. 18:1226-1233.

Gordon, D.T. 1973. Released advance reproduction of white and red fir. . . growth, damage, mortality. Forest Service Research Paper PSW-95. Berkeley, CA: U.S. Department of Agriculture. 22 p.

Graham, J.N.; Bell, J.F.; Herman, F.R. 1985. Response of Sitka spruce and western hemlock to commercial thinning. Research Paper PNW-334. Portland, OR: U.S. Department of Agriculture. 17 p.

Greene, S.E.; Emmingham, W.H. 1986. Early lessons from commercial thinning in a 30-year old Sitka spruce, western hemlock forest. Forest Service Research Note PNW-448. Portland, OR: U.S. Department of Agriculture. 15 p. ?6

Gutierrez, R.J.; Carey, A.B., eds. 1985. Ecology and management of the spotted owl in the Pacific Northwest. Forest Service General Technical Report PNW 185. Portland, OR: U.S. Department of Agriculture. 119 p.

Hadfield, J.S.; Goheen, D.J.; Filip, G.M., [and others]. Root diseases in Oregon and Washington conifers. Portland, OR: U.S. Department of Agriculture, Forest Service Region 6. 27 p.

Hann, D.W. 1991. Subject: validation of ORGANON. Corvallis, OR: College of Forestry, Oregon State University. 16 p. Memo. On File with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Harrington, C.A.; Miller, R.E. 1979. Response of a 110-year old Douglas-fir stand to urea and ammonia nitrate fertilizer. Forest Service Research Note PNW-336. Portland, OR: U.S. Department of Agriculture. 7 p.

Harrington, C.A.; Wierman, C.A. 1990. Growth and foliar nutrient response to fertilization and precommercial thinning in a coastal western red cedar stand. Canadian Journal of Forest Research. 20:764-773

Helms, J.A.; Standiford, R.B. 1985. Predicting release of advance reproduction of mixed conifer species in California following overstroy removal. Forest Science. 31:3-15.

Hershey, K., Personal Communication, Oregon State University, Corvallis, OR.

Hester, A.S.; Hann, D.W.; Larsen, D.R. 1989. Organon: Southwest Oregon growth and yield model user manual, version 2. Corvallis, OR: Forest Research Laboratory, Oregon State University. 59 p.

Hoover, L.D. 1988. Gap regeneration in old-growth Douglas-fir hardwood forests of northwestern California. Arcata, CA: Humboldt State University. 68 p. M.S. thesis.

Huffman, D. 1991. Salal seedling establishment and clonal development in young growth Douglas-fir stands. Corvallis, OR: College of Forestry, Oregon State University. 96 p. M.S. thesis.

Hunter, M.L. 1990. Wildlife forests and forestry. Englewood Cliffs, NJ: Prentice Hall. 370 p.

Isaac, L.A. 1938. Factors affecting the establishment of Douglas-fir seedlings. U.S. Forest Service Circular number 486. Washington, D.C.: U.S. Department of Agriculture. 45 p.

Isaac, L.A. 1956. Place of partial cutting in old-growth stands of the Douglas-fir region. Forest Service Pacific Northwest Forest and Range Experiment Station Research Paper 16. Portland, OR: U.S. Department of Agriculture. 148 p.

King, J.E. 1986. Review of Douglas-fir thinning treatments. Pages 258-280 in: Oliver, [and others], eds. Douglas-fir stand management for the future. Proceedings of a Symposium; 1985 University of Washington, College of Forest Resources Contribution 55. Seattle, WA. 388 p.

Kirkland, B.P.; Brandstrom, A.J.F. 1936. Selective timber management in the Douglas-fir region. Washington, D.C.: Charles Lathrop Park Forestry Foundation. 172 p.

Krumland, B.; Wensel, L.D. 1980. CRYPTOS(1) - user's guide. Cooperative redwood yield research project, Research Note 16. Berkeley, CA: University of California, Berkeley, College of Natural Resources. 41 p.

Lewis, R.; Haske, M. 1991. Development of biological diversity based silvicultural regimes for Tanoak series forests of the Klamath mountains province. 40 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.

Lindquist, J.L.; Palley, M.N. 1963. Empirical yield tables for young growth redwood. California Agriculture Experiment Station Bulletin 796. Berkeley, CA: University of California. 47 p.

Long, J.N. 1977. Trends in plant species diversity associated with development in a series of *Pseudotsuga menziesii/Gaultheria shallon* stands. Northwest Science. 51:119-130.

Long, J.N.; Turner, J. 1975. Above-ground biomass of understory and overstory in an age sequence of four Douglas-fir stands. Journal of Applied Ecology. 12:179-188.

Marshall, D.D. 1990. The effects of thinning on stand and tree growth in a young high site of Douglas-fir in western Oregon. Corvallis, OR: Oregon State University. 189 p. Ph.D. dissertation.

McCreary, D.D.; Perry, D.A. 1983. Strip thinning and selective thinning in Douglas-fir. Journal of Forestry. 81:375-377.

Miller, R.E.; Harrington, C.A. 1979. Response to urea and ammonia nitrate fertilizer in an 80-year old Douglas-fir stand. Forest Service Research Note PNW-330. Portland, OR: U.S. Department of Agriculture. 5 p.

Miller, R.E.; Reukema, D.L.; Williams, R.L. 1979. Response to fertilization in thinned and unthinned Douglas-fir stands: Proceedings of the forest fertilization conference. Pages 150-157, In Gessel, Kenady, Atkinson, eds; 1976 September 25-27; Union, WA: College of Forest Research, University of Washington, Institute of Forest Resources Contribution No. 40. 275 p.

Miller, R.E.; Tarrant, R.F. 1983. Long-term growth response of Douglas-fir to ammonia nitrate fertilizer. Forest Science. 29:127-137.

Morrison, P.H.; Swanson, F.J. 1990. Fire history and pattern in Cascade Range landscape. Forest Service General Technical Report PNW-254. Portland, OR: U.S. Department of Agriculture. 77 p.

Neitro, W.A.; Binkley, V.N.; Cline, S.P., [and others]. 1985. Snags (wildlife trees). Pages 129-169 in: Brown, E.R., ed. Management of wildlife and fish habitats in forests of western Oregon and Washington. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Region.

Newton, M.; Cole, E.C. 1987. A sustained yield scheme for old-growth Douglas-fir. Western Journal of Applied Forestry. 2:22-25.

Nystrom, M.N.; Bell, D.S.; Oliver, C.D. 1984. Development of young growth western red cedar stands. Forest Service Reserach Paper PNW-324. Portland, OR: U.S. Department of Agriculture. 9 p.

O'Dea, M. 1991. Vine maple clonal development in Douglas-fir forests. Corvallis, OR: Oregon State University College of Forestry. 121 p. M.S. thesis.

Oliver, C.D. 1981. Forest development in North America following major disturbances. Forest Eclolgy and Management. 3:153-168.

Oliver, C.D.; Larson, B.C. 1990. Forest stand dynamics. New York, NY: McGraw-Hill Incorporated. 467 p.

Oliver, C.D.; Harrington, C.W., [and others]. 1991. Northern spotted owl habitat in previously managed forests in western and eastern Washington with and without further management systems for Douglas-fir/western hemlock and other mixed-conifer stands. 72 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.

Reukema, D.L. 1972. Twenty-one-year development of Douglas-fir stands repeatedly thinned at varying intervals. Forest Service Research Paper PNW-141. Portland, OR: U.S. Department of Agriculture. 23 p.

Reukema, D.L. 1975. Fifty-year development of Douglas-fir stands planted at various spacings. Forest Service Research Paper PNW-253. Portland, OR: U.S. Department of Agriculture. 19 p.

Rosenberg, K.V.; Raphael, M.G. 1986. Effects of forest fragmentation on vertebrates in Douglas-fir forests. Pages 263-272 in: Verner, J.; Morrison, M.L.; Ralph, C.J., eds. Wildlife 2000, modeling habitat relationships of terrestrial vertebrates. Madison, WI: University of Wisconsin Press, University of Wisconsin.

Ruth, R.H.; Harris, A.S. 1979. Management of western hemlock Sitka spruce forests for timber production. Forest Service General Technical Report PNW-88. Portland, OR: U.S. Department of Agriculture. 197 p.

Sawyer, J.O.; Thornburgh, D.A. 1977a. Mixed-evergreen forests in: Barbour, M.G.; Major, J., eds. Terrestrial vegetation of California. New York, NY: Wiley and Sons. 359-381 p.

Sawyer, J.O.; Thornburgh, D.A. 1977b. Montane and subalpine vegetation of the Klamath Mountains. Pages 699-732 in: Barbour, M.G.; Major, J., eds. Terrestrial vegetation of California. New York, NY: Wiley and Sons.

Smith, D.M. 1986. The practice of silviculture. New York, NY: John Wiley and Sons. 527 p.

Spies, T.A.; Franklin, J.F. 1988. Old-growth and forest dynamics in the Douglas-fir. Natural Areas Journal. 8:190-210.

Spies, T.A.; Franklin, J.F.; Thomas, T.B. 1988. Coarse woody debris in Douglas-fir forests of western Oregon and Washington. Ecology. 69:1689-1702.

Spies, T.A.; Franklin, J.F.; Klopsch, M. 1990. Canopy gaps in Douglas-fir forests of the Cascade mountains. Canadian Journal of Forest Research. 20:649-658.

Spies, T.A. 1991. [In press]. Plant species diversity and occurrence in young, mature, and old-growth Douglas-fir stands in western Oregon and Washington. Symposium material. Portland, OR: U.S. Department of Agriculture, Forest Service, Old-growth symposium.

Spies, T.A.; Franklin, J.F. 1991. The structure of natural young, mature, and old-growth Douglas-fir forests in Oregon and Washington. In Ruggiero, [and others] eds. Wildlife and vegetation of unmanaged Douglas-fir forests. Portland,OR: U.S. Forest Service, General Technical Report PNW GTR 285. Pages 91-110.

Spies, T.A.; Tappeiner, J.; Pojar, J.; Coates,D. 1991. Trends in ecosystem management at the stand level. Transactions 56th North American Wildlife and Natural Resource Conference. 56:628-639.

Staebler, G.R. 1956. Evidence of shock following thinning of young Douglas-fir. Journal of Forestry. 54:339.

Staebler, G.R. 1956. Effect of controlled release on growth of individual Douglas-fir trees. Journal of Forestry. 54:567-568.

Stage, A.R. 1973. Prognosis model for stand development. Forest Service Research Paper INT-164. Ogden, Utah: U.S. Department of Agriculture. 32 p.

Stein, W.I. 1986. Regeneration outlook on BLM lands in the Siskiyou Mountains. Forest Service Research Paper PNW-349. Portland, OR: U.S. Department of Agriculture. 104 p.

Stere, D.H. 1991. A discussion of forest stand simulators. Portland, OR: Oregon Department of Forestry. 15 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.

Sutliff, M., Personal Communication, Department of Forest Resources, Oregon State University, Corvallis, OR.

Tappeiner, J.C.; Bell, J.F.; Brodie, J.D. 1982. Response of young Douglas-fir to 16 years of intensive thinning. Research Bulletin 38. Corvallis, OR: Forest Research Laboratory, Oregon State University. 17 p.

Tappeiner, J.C.; McDonald, P.M. 1984. Development of tanoak understories in conifer stands. Canadian Journal of Forest Research. 14:271-277.

Tappeiner, J.C.; Knapp, W.H.; Wierman, C.A., [and others]. 1986. Silviculture on the Pacific Coast - the past 30 years and the next 30 years. Journal of Forestry. 84(5):37-46.

Tappeiner, J.C.; McDonald, P.M.; Hughes, T.F. 1986. Establishment of tanoak and Pacific madrone in conifer forests of southwestern Oregon. New Forests. 1:43-55.

Tappeiner, J.C.; Zasada, J.; Ryan, R.B.; Newton, M. 1991. Salmonberry clonal and population structure: the basis for persistent cover. Ecology. 72(2):609-618.

Tesch, S.D.; Crawford, M.S.; Baker-Katz, K.; Mann, J.W. 1990. Recovery of Douglas-fir seedlings from logging damage in southwestern Oregon: preliminary evidence. Northwest Science. 64:131-139.

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, B.R.; Verner, J. 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.

Thornburgh, D.A. 1981. Succession in mixed evergreen forests in northwestern California. In: Forest succession and stand development research in the Pacific Northwest. Proceedings of a symposium; 1981 March 26; College of Forestry, Oregon State University, Corvallis, OR. Forest Research Laboratory, Oregon State University. 87-91 p.

Thornburgh, D.A. 1991. Vegetation of northern California as viewed by the northern spotted ow. 12 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.

Troup, R.S. 1928. Silvicultural systems. Oxford: Clarendon Press. 216 p.

Turner, J. 1979. Effects of fertilization on understory vegetation: Proceedings of forest fertilization conference; Gessel, Kenady, Atkinson, eds; Pages 168-173; 1992 September 25-27; Union, WA. Institute of Forest Resources Contribution Number 40. Seattle, WA: College of Forest Resources, University of Washington. 275 p.

U.S. Department of Agriculture, Forest Service. 1979. Shelterwood cutting in Region 6. Miscellaneous publication. Forest Service task force report, Division of Timber Management. Portland, OR: U.S. Department of Agriculture. 55 p.

Walstad, J.D. 1992. [In press]. A history of the development, use, and management of resources in southwestern Oregon and Northern California. Pages 26-47 in: Hobbs, S.A. [and others], eds. Reforestation practices in southwestern Oregon and Northern California. Portland, OR: Forest Research Laboratory, Oregon State University. 465 p.

Waring, R.H.; Emmingham, W.H.; Gholz, H.L.; Grier, C.C. 1978. Variation in maximum leaf area of coniferous forests in Oregon and its ecological significance. Forest Science. 24:131-140.

Weatherspoon, P.; Ritchie, M. 1991. Modeling of stand management alternatives for northern spotted owl habitat in the mixed-conifer type of northern California. 36. p. Unpbulished manuscript. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Wensel, L.C.; Koehler, J.R. 1985. A tree growth projection system for northern California coniferous forests. Research Note 10. Berkeley, CA: University of California, Berkeley, Department of Forestry and Resource Management, Northern California Forest Yield Cooperative. 30 p.

Williamson, R.L. 1966. Thinning response in 110-year old Douglas-fir. Forest Service Research Note PNW-36. Portland, OR: U.S. Department of Agriculture. 7 p.

Williamson, R.L.; Price, F. 1971. Initial thinning effects in 70- to 150-year old Douglas-fir - western Oregon and Washington. Forest Service Research Paper PNW-117. Portland, OR: U.S. Department of Agriculture. 15 p.

Williamson, R.L. 1973. Results of shelterwood harvesting of Douglas-fir in the Cascades of western Oregon. Forest Service Research Paper PNW-161. Portland, OR: U.S. Department of Agriculture. 13 p.

Williamson, R.L. 1982. Response to commercial thinning in a 110-year old Douglas-fir stand. Forest Service Research Paper PNW-296. Portland, OR: U.S. Department of Agriculture. 16 p.

Williamson, R.L.; Twombly, A.D. 1983. Pacific Douglas-fir. Pages 9-12 in: In silviculture systems for the major forest types of the United States. Agriculture Handbook 445. Washington, D.C.: U.S. Department of Agriculture, Forest Service. 191 p.

Williamson, R.L.; Curtis, R.O. 1984. Levels-of-growing-stock cooperative study in Douglas-fir: Report number 7 - preliminary results, Stampede Creek, and some comparisons with Iron Creek and Hoskins. Forest Service Research Paper PNW-323. Portland, OR: U.S. Department of Agriculture. 42 p.

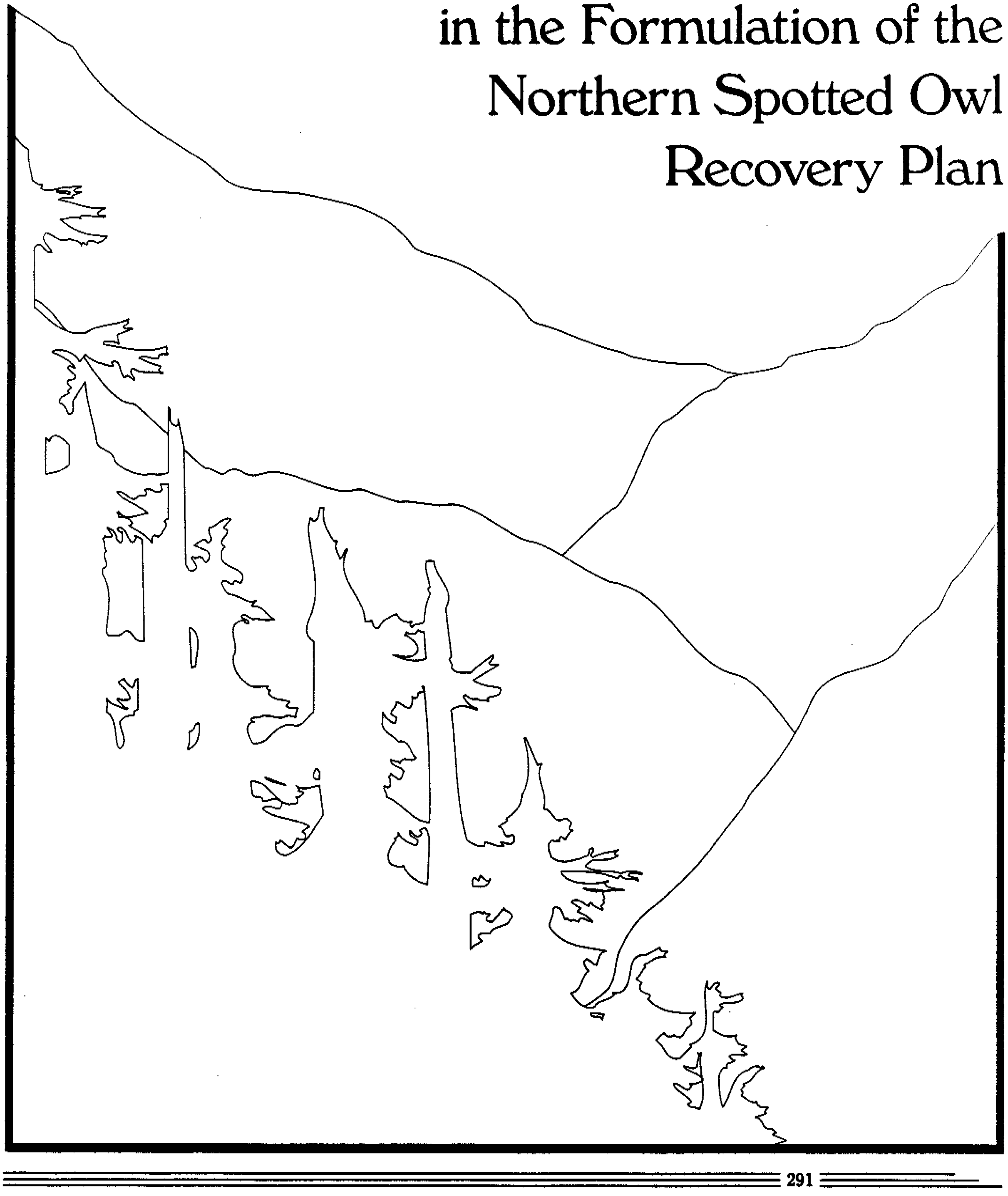
Worthington, N.P.; Staebler, G.R. 1961. Commercial thinning of Douglas-fir in the Pacific Northwest. U.S. Department of Agriculture, Forest Service Technical Bulletin Number 1230. Washington, D.C.: Publisher. 124 p.

Yerkes, V.P. 1960. Growth after thinning in 110-year old Douglas-fir. Pacific Northwest Forest and Range Experiment Station Research Note 189. Portland, OR: U.S. Department of Agriculture, Forest Service. 3 p.

Zinke, P.J. 1977. The redwood forest and associated north coast forests. Pages 359-381 in: Barbour; Major, J., eds. Terrestrial vegetation of California. New York, NY: Wiley and Sons.

Appendix G

Economic and Social Considerations in the Formulation of the Northern Spotted Owl Recovery Plan



Contents

I. Introduction and Summary

A. Requirements of the Endangered Species Act

The Endangered Species Act establishes a biological imperative that governs the formulation of the recovery plan for the northern spotted owl, a species that was placed on the list of threatened species on June 26, 1990. The biological imperative requires that the recovery plan provide for the management of the owl and its habitat in a manner that will result in the conditions necessary for its long-term survival without the protection of the Endangered Species Act. If this is achieved, the species can be removed from the list. Clearly, biological principles and information will form the primary basis for designing and evaluating the management actions for recovery of the spotted owl.

B. The Problem

Formulation of a recovery plan for the northern spotted owl encounters many of the fundamental conflicts that generally arise between efforts to promote economic growth and productivity and efforts to protect environmental quality. The range and habitat of the owl are extensive and largely coincide with the remaining old-growth forests if the Pacific Northwest and other valuable timberlands with similar characteristics. Many of the recovery plan's recommendations to protect the owl population would substantially restrict timber harvest in these forests and would prevent harvest in some younger forestlands so that they can become owl habitat in the future. Although the preservation of owl habitat will yield a variety of benefits to wildlife and recreation, substantial social and economic costs will be caused by the reductions in timber harvest that will result from implementing such measures during several decades.

U.S. Forest Service and U.S. Bureau of Land Management (BLM) estimates indicate that planned timber sales in federal forests in the 1990s would have yielded annual timber harvests of 3 to 4 billion board feet per year, generating more than $1 billion dollars annually in economic benefits and supporting nearly 70,000 jobs in the Pacific Northwest. Projections for some owl preservation plans show that they would cause a substantial decline in production and employment in the timber and wood products industries in the Pacific Northwest. Timber harvest from federal lands would be cut nearly in half. Cost estimates of such proposals have ranged as high as $25 billion over 50 years (Mead et al. 1990) and 40,000 jobs (Beuter 1990). The threat of such economic effects has made the preservation of the owl controversial.

C. The Role of Economic Considerations

Secretary of the Interior Manuel Lujan Jr., asked the Northern Spotted Owl Recovery Team to consider economic effects to the extent consistent with its legal mandate in formulating a recovery plan for the owl. The decision to consider economic effects in formulating a recovery plan represents a significant departure from past practice. Recovery plans prepared for other species have not formally used economic analysis, although the costs of management actions such as acquisition of habitat have been considered.

Several unique challenges confronted the Recovery Team because of the precedent-setting nature of this effort. Advocates of forest preservation and owl conservation expressed concerns that the consideration of economic effects would prevent the recovery plan from being based on scientifically credible biological principles and information. Moreover, in their comments on other owl conservation proposals, forest preservation advocates emphasized the ecological and economic benefits of owl conservation. Advocates of timber harvest have expressed concerns about the substantial economic costs of owl conservation and have sought ways of reducing restrictions on timber harvest. The Recovery Team needed to develop an approach that would be responsive to the Secretary's directive while also addressing concerns on both sides of the spotted owl controversy.

In comments on other owl conservation proposals, many people emphasized the environmental and economic benefits of owl conservation and forest preservation. These benefits arise from effects of reduced timber harvest such as greater abundance of other species that depend on older forests, improved water quality in streams and rivers, greater abundance of fishes, and increased recreation and tourism values. It was recommended that, if an economic analysis were to be used, it should include a full evaluation of the benefits as well as the costs of protecting habitat for the spotted owl population.

In contrast, others expressed concerns about the substantial economic costs of owl conservation. They recommended that the formulation of the recovery plan be based on a systematic analysis of the economic costs and the risks to the owl population under a variety of options. The final recovery plan, they suggested, should be the option having the least costs.

In early discussions of its task, the Recovery Team developed a conceptual approach for considering economic effects. The Recovery Team agreed that consideration of economic effects would be done in a manner that would not diminish the primacy of the biological imperative. The Recovery Team would use the best available biological information to set recovery objectives and to devise management actions to achieve recovery of the owl. Because recovery of the species is the goal of a recovery plan under the Endangered Species Act, the Recovery Team decided not to consider whether, in light of the costs and benefits of achieving recovery, a less costly goal should be pursued.

The Recovery Team recognized, however, that different combinations of management actions could satisfy the biological imperative to provide for the long-term survival and recovery of the owl. Because different management actions have different costs, it should be possible, at least in principle, to find a combination of management actions that would satisfy the biological imperative at least cost. It was appropriate to make a concerted effort to reduce the costs of achieving recovery because of the substantial costs of protecting the owl and the anticipated effects on people economically dependent on timber harvest in the Pacific Northwest.

Biological principles and information were used to design management actions that would contribute to achieving recovery. Economic principles and information were used to identify ways to achieve recovery at lower costs. This common sense approach is like the efforts of a family to decide what sorts of products meet their needs and then to shop for the lowest prices on those products. It is also consistent with generally accepted principles of public policy for the development of programs in which the result to be achieved has already been specified.

The approach used by the Recovery Team also was designed to meet the needs of the biologists on the Recovery Team who were responsible for formulating the owl conservation measures in the recovery plan. Decisions regarding owl conservation options to be considered and the design criteria for those options were based on biological considerations. The economic information developed for use by the biologists and other Recovery Team members was limited to fundamental economic principles and simple indicators of the most important economic effects. This economic information was designed to be understandable to biologists and other Recovery Team members with little or no training in economics.

This approach differs in several ways from a comprehensive, systematic cost-benefit study of options for achieving recovery. First, it was designed primarily to facilitate design of a recovery plan rather than to provide information about costs and benefits that could be used to decide whether to implement the resulting plan. Second, it did not involve the design and evaluation of a wide variety of options.

The Recovery Team decided not to conduct a full evaluation of the economic benefits of the recovery plan for several reasons. It was not appropriate, under the Endangered Species Act, to consider whether the benefits were sufficient to justify incurring the costs of achieving recovery. Any decision to pursue a goal short of recovery would require an act of Congress and was not within the purview of the Recovery Team.

Furthermore, evaluation of the benefits of particular owl conservation plans is costly and difficult. Whereas the economic benefits of timber harvest are indicated by purchases of timber, most of the beneficial effects of owl habitat protection are not bought and sold in markets. Existing information and analytical methods regarding such nonmarket benefits are generally not sufficient to show how a recovery plan design should be refined in order to enhance these benefits.

In summary, the Recovery Team did not have the charter or the means to determine whether the economic benefits of recovery outweigh the costs. For these reasons the Recovery Team chose not to devote its resources to a full assessment of the benefits. The Recovery Team recognizes, however, that such benefits may be substantial. A qualitative summary is included later in this appendix.

Although the Recovery Team tried to find ways to reduce the cost of achieving recovery, it was not able to design and evaluate a wide variety of options. Existing biological models were not adequate to give credible estimates of trends in the owl population for widely different options. In addition, new forest management practices, which could be an important component of less costly options, have not been tested sufficiently to estimate their long-term effects on the owl population or timber harvest. Instead of designing and comparing options, the Recovery Team sought ways to reduce the costs of the recovery plan as it produced the detailed design of the plan.

The economic analysis used in formulating the recovery plan was not intended to provide a precise and comprehensive enumeration of all of the economic effects of owl conservation measures. The approach was selective and "economical." Analysis was limited to key indicators of the costs of owl conservation that would be understandable and helpful to the Recovery Team's biologists in their efforts to find ways to reduce the costs of achieving recovery.

D. Summary of Features to Reduce Costs

Part of the process of formulating a cost-effective recovery plan is to consider a wide variety of ways to reduce costs without undercutting the effectiveness of the plan. This appendix outlines economic principles and information suggesting several cost-reducing measures that the Recovery Team considered. Some were rejected for biological reasons, others for lack of demonstrated application and lack of data needed to implement them.

Several features were included in the recovery plan as a result of efforts to reduce the costs of achieving recovery. These include:

- Designated conservation areas (DCAs) were designed to a) make use of areas that have relatively high-quality owl habitat, b) use forestlands that have been reserved for other purposes where possible, and c) reduce the use of forestlands with high potential for timber harvest.

- To promote greater efficiency, the DCA boundaries were refined in formulating the final recovery plan based on the site-specific data available to the federal forest management agencies.

- The DCA management guidelines allow limited salvage and silvicultural treatment of areas not suitable for owl habitat to promote more rapid development of suitable habitat and to provide timber.

- The management guidelines for federal lands outside of the DCAs were tailored to local conditions so that the resulting timber harvest restrictions will better assure the habitat conditions in each area that are needed for recovery without incurring unnecessary costs.

- Recommendations for management of nonfederal lands are intended to increase the efficiency of the nonfederal contribution to recovery by integrating state authorities and existing programs into a coordinated strategy.

- A monitoring and research program and a process for adaptive management are proposed to provide information about habitat conditions that are most productive for owls and data about forest management practices that are most compatible with production and maintenance of owl habitat. They provide a basis for improving the cost-effectiveness of the recovery plan.

E. Summary of Preliminary Estimates of the Economic Effects of Implementing the Recovery Plan

Estimates of the economic effects of the recovery plan are included in this appendix. They were developed to provide a basis for comparison between the draft recovery plan and other owl conservation and forest preservation proposals. To provide a consistent basis for such comparisons, the estimates were developed using the same estimation methods applied by the U.S. Fish and Wildlife Service (FWS) in evaluating the effects of the critical habitat designation for the northern spotted owl. These estimation methods are summarized in section IV of this appendix, and are described in more detail in *Economic Analysis of Critical Habitat Designation Effects for the Northern Spotted Owl* published by the FWS at the time of the critical habitat designation (USDI 1992a).

Implementation of the recovery plan would result in lower annual timber harvest in the federal forests of the Pacific Northwest than would occur under the forest plans that were in effect for Forest Service and BLM lands before the owl was federally listed. Lower timber harvests would also result from implementation of the Interagency Scientific Committee

(ISC) strategy under plans proposed by the Forest Service and the BLM management plans, as well as from the current designation of critical habitat and compliance with section 7 of the Endangered Species Act. The estimated timber harvests under the recovery plan would be slightly less than would result from continuing these plans and policies, but the estimated employment effects would be about the same.

It is estimated that the recovery plan would reduce the mid-1990s timber harvest on federal forestlands by 2.36 billion board feet in comparison to the levels that would occur under the federal agencies' earlier plans. Lower timber harvest on federal forestlands is expected to reduce economic benefits by about $830 million per year. Federal revenues are estimated to be about $740 million per year lower while the counties' share of the $740 million would be about $280 million lower (see Table G.1.).

In comparison to the mid-1990s employment levels that would result from the federal agencies' earlier plans, the employment level with the recovery plan is estimated to be lower by about 32,000 jobs.

Several features of the recovery plan will tend to offset the economic effects of restrictions on timber harvest on federal lands. First, the recovery plan would allow silvicultural treatments in DCAs if they are designed to promote development of habitat conditions suitable for owls in areas that are not currently suitable. Rough estimates of the possible effects of these activities show that treatment of 50,000 acres per year could support about 600 jobs and yield about 100 million board feet of timber per year.

The second feature that will tend to offset the effects of timber restrictions will be to allow limited timber salvage in DCAs. Timber salvage in federal forests averaged more than 650 million board feet per year during the 1980s. DCAs contain a bit less than half of the forestlands available for timber harvest. Salvage of 10 to 20 percent of the salvageable timber in DCAs could yield, on average, 20 to 40 million board feet per year, supporting about 315 to 630 jobs.

Other sources of timber supply, including private forestlands in the Pacific Northwest, may increase production in response to higher timber prices. Although the response in the Pacific Northwest is likely to be limited and probably could not be sustained more than a few years, it would slow the rate of job displacement in the early years of recovery plan implementation.

Table G.1. Summary of Economic Effects of the Northern Spotted Owl Recovery Plan.

Lower timber harvest on federal lands	2.36 billion board feet per year
Lower timber employment levels	32,000 jobs
Wage losses	$1.6 billion to $1.8 billion over 20 years
Foregone timber value	$830 million per year
Lower federal revenue	$740 million per year
Lower county revenue share of federal revenue	$280 million per year
Offsetting gains from salvage and silviculture:	
Timber harvest	120 to 140 million board feet per year
Employment	915 to 1,230 jobs

In reviewing these estimates of the economic effects of implementing the recovery plan, it is important to note that they reflect all owl conservation on federal lands. The estimates were prepared in this way because the recovery plan will provide a comprehensive basis for all owl conservation efforts. Thus, these estimates attribute to the recovery plan all of the economic effects of owl conservation on federal lands that would occur after implementation of the plan.

II. General Economic Principles for Reducing the Cost of Spotted Owl Recovery

The Recovery Team began its efforts to find ways of achieving recovery at lower costs by reviewing general principles of economics that deal with costs and efficiency. To identify a wide range of possibilities for reducing costs, the Recovery Team considered the application of these principles to a variety of owl conservation measures. This section summarizes the principles and applications that the Recovery Team considered. The recovery plan includes some, but not all, of the possible applications of these principles.

A. The Efficiency Principle

The efficiency principle can be simply stated: people in the United States will have higher incomes and a higher standard of living if the goods and services they want, including environmental quality and the preservation of species and ecosystems, are produced more efficiently.

The American people want many things. Most consumers recognize that they can get more from their family budgets by shopping to find lower prices for the things they want. Business managers know that they can make higher profits by reducing the costs of their business operations or by increasing the total value of their output without proportionally increasing costs. Though imperfect, market-based economic systems have proven capable of providing people with more of what they want than other economic systems. An important reason for this success is the incentives the market creates to reduce costs. Reducing costs is one way that our economic system resolves conflicts among the many different opportunities to use each resource.

Our desire for secure and increasing incomes and material well-being often appear to be in conflict with our desire to protect the environment. Economists do not see this conflict as inherently different from the conflict between, say, using iron to construct office buildings and using iron to manufacture cars. More buildings and cars can be produced if proper care is taken to reduce the costs of the iron used in building construction and auto manufacturing. Similarly, higher environmental quality and greater material well-being can be produced if proper care is taken to reduce the costs of environmental protection as well as the environmental costs of economic production.

One important difference between environmental resources, such as wildlife, and economic resources, such as iron, is that environmental resources are not easily made a part of market transactions. Although the price of iron provides an incentive to economize its use, there is no similar incentive for a resource such as owl habitat. Governmental protection of environmental resources is often justified by such market failures.

The efficiency principle applies to governmental protection of environmental quality just as it does to private production of consumer goods. We can have more of both if we use resources more efficiently to produce both. In the case of achieving recovery for the spotted owl, we can meet recovery goals and have more timber and wood products if the recovery measures we implement are more efficient.

The conflict between achieving recovery for the owl and realizing the economic and social benefits from a greater and less costly supply of timber can be reduced by implementing forestland and habitat management practices that yield a viable owl population at lower total cost.

In general, achieving recovery of the owl requires the preservation and development of owl habitat that will support an owl population of sufficient number and appropriate spatial distribution to survive despite random catastrophic events such as fire and disease. Much of the existing owl habitat is old-growth forests that are prime for timber harvest. Additional owl habitat can be grown by letting younger forests continue to grow and age. The preservation and development of habitat will require restrictions on timber harvest from forestlands that are now suitable owl habitat as well as from forestlands that are likely to develop into suitable owl habitat.

The primary economic costs of achieving recovery result from the loss of the economic benefits from the timber that otherwise would be harvested and, to a lesser extent, from the resulting increases in the prices of goods that are produced from timber. Economic benefits arise from timber harvest because logs have a higher economic value than the costs of producing them. The economic benefits from harvesting timber are mostly captured by the owners of forestlands. For federal lands, the profits are captured by the Forest Service and the BLM and are shared with states and local communities.

The primary social cost of owl conservation measures is the decline in the quality of peoples' lives that results from unemployment and reduced income caused by foregone timber harvest. These social costs are generally most severe in small, isolated communities where a large portion of the population is employed in the timber and wood products industries. Small businesses such as sawmills and supply businesses may fail, causing loss of assets and income. People in these communities have less opportunity to find new jobs at similar wages than people living in areas with a more diversified economic structure.

The general principle for reducing the economic and social costs of owl recovery is to employ management actions that will produce a higher "yield" of owls (the number of owls supported) per unit of foregone timber production and its benefits, particularly near communities where timber workers are less able to shift to other employment.

B. The Importance of Owl Habitat Productivity

A recovery plan that uses habitat having higher productivity for owls should be able to achieve recovery using less habitat (assuming other biological requirements for recovery are met). Identifying the characteristics of habitat that are best for owls and finding ways to enhance owl habitat productivity, especially in areas that currently are not suitable habitat, may help to reduce the costs of recovery.

The high cost of owl preservation results from the large area of forestlands with old-growth characteristics that are needed to provide sufficient habitat to support a viable owl population. The productivity of owl habitat is measured by the density, reproductive success, and individual survival rates of the owl population that it is capable of supporting. Owl habitat productivity varies substantially and depends highly on local conditions as well as the general structure of the forest landscape. Other things being equal, the costs of achieving recovery of the owl will be lower if the areas used as owl habitat are capable of supporting more owls per acre.

Measures that increase owl habitat productivity also may help reduce recovery costs. For the overall cost of recovery to be reduced, the costs of implementing measures to increase owl habitat productivity must be less than the economic benefits gained from the additional timber that can be harvested because of the increased owl habitat productivity.

If ways can be found to improve the capability of existing and newly developed owl habitat to support the owl population, then less forestland will be needed to sustain the population and more forestland can be used for timber production. This may reduce the long-term costs of achieving recovery of the owl.

Research on owl ecology may help to identify environmental conditions that promote higher owl productivity. Experimentation with various silvicultural practices may be able to show how such conditions can be created or improved in the forestlands reserved for owl habitat. Each measure for increasing owl habitat productivity should be evaluated to determine whether it would cost less than the economic benefits from the additional timber harvest that could be allowed if it were implemented. If measures that cost less are implemented, the total cost of achieving recovery will be reduced.

It appears that the total area and connectivity of owl habitat will need to be increased to achieve recovery. Some younger forestlands that do not currently provide suitable owl habitat will need to be added to the overall landscape devoted to the owl. Measures that accelerate the development of younger forestlands into good owl habitat may be able to promote more rapid recovery and reduce the amount of forestlands that must be reserved to achieve recovery.

It also may be possible that, as new habitat is added, some areas of old-growth devoted to supporting the owl population early in the recovery process can be harvested, perhaps by using selective harvest techniques instead of clear-cutting. As younger forests develop into suitable habitat, they could be substituted for equivalent old-growth areas previously reserved for the owl. Timber harvest could then occur in the old-growth areas that had been replaced instead of in younger forests with lower timber yields. To the extent that the economic benefits from harvesting timber in the younger forests would have been lower than in the old-growth that could be harvested, this process would reduce the total cost of recovery.

C. Joint Production Possibilities

A recovery plan may be able to achieve recovery at lower cost by preserving or producing owl habitat areas that also contribute to the preservation of other species that are candidates for federal listing as threatened or endangered and need similar conservation measures. If timber harvest will need to be restricted to preserve other species as well as the owl, there may be opportunities to reduce the total cost of wildlife conservation by using areas capable of supporting a variety of species rather than using separate habitat areas for each species. Economists regard such opportunities as joint production possibilities.

A recovery plan also may be able to achieve recovery at lower costs by preserving or producing owl habitat areas that contribute to the provision of valuable services, such as recreation. Recreation is an important use of forestlands, and has brought increasing demand for restrictions on timber harvest. There may be opportunities to reduce the total cost of providing forestlands for habitat and recreation by identifying areas where the opportunities for joint production are greatest.

In the long run, it may be possible to provide owl habitat using measures that also provide for timber growth and harvest in the same areas. Although much attention has been focused by previous owl preservation plans that would prohibit timber harvest in owl habitat areas, selective timber harvest in existing suitable habitat may provide timber while also preserving essential habitat conditions. If the effectiveness of these harvest practices can be demonstrated, they can be used to reduce the economic and social costs of achieving recovery. Such possibilities need to be identified and tested to determine the extent they can be used to reduce the total cost of owl recovery.

D. The Importance of Timber Productivity

To the extent that a recovery plan uses forestlands of lower timber productivity for owl habitat, it can achieve recovery at lower costs. Ideally, the total cost of a recovery plan would be minimized by selecting owl habitat areas with the highest ratio of owl habitat productivity to timber productivity as long as those areas also met the recovery objectives. Northern spotted owl conservation proposals have become controversial because of the unfortunate coincidence of owl habitat and high-value timber occurring in old-growth forests. Nevertheless, there are variations in the value of the timber inventory and in the future timber growth that can be achieved on different sites. Location and slope as well as the timber inventory affect the value of the existing timber in a stand. Soil conditions and rainfall affect the rate of regeneration and regrowth of timber once a stand has been harvested. In principle, use of areas with lower value timber and lower quality stands as owl habitat would reduce the costs of achieving recovery, assuming that such areas provide appropriate and sufficient habitat for owl recovery.

E. Institutional Principles for Promoting Efficiency

Economists have been able to identify the characteristics of institutions that tend to achieve high efficiency. The Recovery Team considered several of such principles in formulating the recovery plan.

Institutions tend to achieve higher efficiency when they:

- Use incentives to reward performance that improves the achievement of objectives,
- Achieve an effective balance between central guidance on goals and objectives and decentralized decision-making,
- Allow a diversity of approaches reflecting differences in local conditions,
- Provide flexibility to adapt to changing conditions and to improve quality and efficiency by responding to information about the effectiveness and costs of various actions,
- Specialize in closely related activities,
- Participate in trading or market transactions that promote the highest value use of resources.

Experience with market mechanisms shows that resource managers respond more efficiently to incentives than to directives and restrictions. The Recovery Team looked for opportunities to create incentives for improving owl productivity within each of the ownership and management regimes with jurisdiction over owl habitat.

Field-level forest managers and biologists often have knowledge of local conditions that is not reflected in formal data available to their headquarters' organizations. Using this local knowledge and information about the effectiveness of various forest management practices, they may be able to identify the most productive owl habitat and make significant increases in habitat productivity and timber harvest on the lands in their jurisdictions.

Allowing greater diversity in designating and managing owl habitat also may increase the chances of finding new, innovative measures for increasing owl habitat productivity.

Economic patterns show the efficiency of specialized organizations. In the case of owl conservation, specialization may facilitate increases in owl productivity. It may be possible to create specialized elements within existing organizations for the express purpose of managing owl habitat. In some cases, changes in land ownership may be needed. Because protection of the owl population is a public good, not a market good, it would be reasonable to rely more on public than private institutions for the provision of owl habitat.

Management systems that allow trading of resources among managers of competing uses have proven to be more effective at allocating resources among those competing uses in a cost minimizing way. This principle has gained wider recognition in environmental policy in recent years. For example, applications of trading processes are being developed for air emission reduction as well as wetlands preservation and restoration. Similar trading mechanisms may be able to contribute to reducing the costs of allocating forestlands to owl recovery. For example, government agencies might be allowed to trade forestlands outside of areas designated for owl habitat for forestlands in designated areas if they can show that there will be gains in the support of owls and timber harvest.

F. Equity and Distributional Principles

In its efforts to gather information about the costs of owl recovery, the Recovery Team learned of the strong concerns in timber-dependent communities about the unfairness of the burden they may be forced bear so that the owl can be preserved to the benefit of all. As a result, the Recovery Team developed a number of principles dealing with equity and distributional issues.

It may be possible to reduce the social costs of achieving owl recovery by slowing the rate of decline in timber harvest near the most isolated, timber-dependent communities. The job losses that result from restricting timber harvest cause more severe wage losses and other social costs in these communities. If ways can be found to lessen the reduction in timber harvest near these communities, especially in the near term, the social costs of owl recovery may be lower. It also may be more equitable to compensate individuals who bear the cost of owl conservation measures by shifting more of the cost to the general public. Compensation has the added advantage of reducing the social costs by offsetting income losses that often cause socially damaging behavior without causing similar costs among the broader population from which the compensation is drawn.

G. Dealing with Uncertainty and Risk

Policy uncertainties and scientific uncertainties affect the costs of owl conservation measures. Policy uncertainty increases costs by encouraging harvesting of timber before timber is at the age at which it would yield the greatest profit. Policy uncertainty also is likely to dampen investments in increased forestlands productivity. Scientific uncertainty about owl ecology and the effects of various forest management practices increases costs by requiring habitat protection measures in the short term that may be more restrictive than are needed in light of subsequent research. However, past experience shows that it also can be costly when research shows that greater protection is needed because past forest management practices did not provide adequately for the owl.

Investments that would improve the timber productivity of forestlands are discouraged by the uncertainty regarding whether the additional timber supply that results will be available for harvest or whether it will be unavailable because of future owl conservation measures. One aspect of providing incentives to increase timber growth, especially on private lands, is to reduce this uncertainty. Policies that make clear which forestlands can be harvested and when they can be harvested will reduce the uncertainty that impedes investment.

Various forest management practices have the potential to increase owl habitat productivity or to allow some timber harvest in owl habitat with less damage to its value as habitat. Uncertainty about the effects of such practices prevents their use and increases the costs of owl conservation.

III. Relationship Between Spotted Owl Habitat and the Timber Resource Base

The high costs of protecting northern spotted owl habitat result from the fact that the owl's range largely coincides with the most valuable timber resources in the Pacific Northwest. Spotted owls concentrate their activities in old-growth stands or in mixed-age stands containing old-growth and mature trees. Recent owl surveys have located owls in a wide variety of habitat conditions. However, until research shows that owl populations can thrive in areas that do not have classic old-growth characteristics, old-growth stands will be needed as the primary source of the owl habitat.

Northern spotted owls not only prefer old-growth and mature forestlands, but they use a great deal of them. Studies of the home ranges of owl pairs in various physiographic provinces showed that owl pairs use areas as small as 1,000 acres and as large as 27,000 acres. Median home ranges of 3,000 to 7,000 acres were typical. A further factor that accounts for the large amount of habitat needed to support owl populations is the need for numbers of owl pairs and individual owls to occupy a contiguous habitat area within which they can interact. The long-term survival of a species depends not just on the survival of individuals but also on successful mating, raising of young, and dispersal of juveniles.

The need to preserve large areas of old-growth and mature forestlands brings owl conservation into direct conflict with timber harvest. For decades, old-growth timber has been the primary source of logs for the timber and wood products industries in the Pacific Northwest. Stands of large trees provide a larger volume of high-quality wood at lower cost than do younger stands.

Unfortunately, many of the forest management practices that have been used to increase the returns from timber harvest have been detrimental to owl habitat. Not only does the practice of clear-cutting remove old-growth trees, but the regenerated forests are often even-aged, single-species stands with little habitat value for owls. The patchwork of regenerated clear-cuts distributed throughout the landscape after decades of timber harvest breaks up the continuity of the habitat available for owls. Although owls are often found in young or mature stands, their success in mating and raising young appears to be reduced by habitat fragmentation.

The sustainable yield concept that underlies most modern forest management relies in part on the fact that regenerated forests grow more rapidly than the old-growth they replace. The harvest of old-growth allows cleared land to be used to grow new trees. From the standpoint of long-term timber supply, the more rapid growth in younger stands helps to support higher levels of sustainable timber harvest. Simply stated, sustainable yield harvest limits the removal of timber to the rate at which timber can be regrown within the management area. The growth in regenerated forests is considered in setting the rate of cutting old-growth.

There has been considerable debate about whether the past level of federal timber harvest in the Pacific Northwest is sustainable. This is a complex issue and its resolution is beyond the scope of the Recovery Team's responsibility. The level of future timber harvest that would occur if there were no owl conservation is the baseline for the analysis of the economic effects of the recovery plan. If harvest levels in the future are lower than they were during the 1980s or are lower than indicated by current forest plans, then timber industry employment and timber revenues also will be lower, even without owl conservation. The economic losses resulting from a lower baseline harvest should not be attributed to owl conservation measures.

However, it is important to recognize that economic losses resulting from other declines in timber harvest will be exacerbated by the costs of protecting owl habitat. Removal of forestlands from the timber base to protect owl habitat may have spillover effects on the rate of timber sales in federal forests. Furthermore, timber-dependent communities may be less able to adapt to the effects of owl conservation because of the effects of other declines in timber harvest. For the purposes of this analysis, however, the costs attributable to the need to protect owl habitat were treated as independent from costs associated with reductions in the baseline harvest level.

The problem posed by the owl's need for extensive areas of commercially valuable old-growth and mature forest is evident in a few statistics. Although the variety of definitions of old-growth makes assessment of trends somewhat confusing, it is clear that the trend has been sharply downward. For example, Booth (1991) estimated the amount of prelogging old-growth (200 years or older) at 19.8 million acres in western Oregon and Washington. By the early 1980s, more that 80 percent of this original old-growth had disappeared, with federal lands containing most of the residual old-growth (Booth 1991). Haynes (1986) estimated that about 3.5 million acres of old-growth forests (200 years or older) remained on nonwilderness lands. Another source, the ISC report (Thomas et al. 1990), cited an estimate that 17.5 million acres of suitable habitat were available for owls in 1800. By the end of the 1980s, only about 7.1 million acres were available. The Forest Service recently produced estimates of old-growth by gathering information from a wide range of forest landowners, however, the landowners used different definitions of old-growth. This survey estimated that there currently are 10.4 million acres of old-growth, of which 8.8 million acres are on federal lands, including wilderness areas and national parks.

In the 1980s, old-growth harvest on federal lands proceeded at about 3 to 4 billion board feet per year, mostly by clear-cutting. Although inventories of spotted owl habitat are not available to measure its decline during this period, habitat would have continued to decline steeply because of this rate of harvest.

On the economic side of the balance, old-growth harvest from federal lands was worth more than $1 billion per year, providing substantial revenue that was shared by the U.S. Treasury and the state and county governments. Direct employment in the timber and wood products industries that depends on the supply of logs from old-growth harvest on federal lands has provided jobs for about 30,000 people.

In general, the timber harvest in the Pacific Northwest has occurred earlier and more rapidly on private forestlands than on public forestlands. Significant timber harvest in the national forests did not begin until after World War II. Several consequences of this pattern affect the preservation of owl habitat and its economic effects. First, because most of the private old-growth forestlands have been harvested, most of the remaining forestlands that provide the best owl habitat are in federal forests. Second, it was expected that the total timber harvest in the Pacific Northwest in the next few decades (while the regrowth on private lands matured) would be sustained by harvest from federal forests. Sustained yield or nondeclining flow concepts being used in setting the rate of timber sales from federal forests were applied to the substantial areas of old-growth timber in these forests. The removal of a substantial portion of this timber inventory from the timber resource base will reduce the federal harvest level during a period when the private forests in the region are not capable of sustaining a significant increase in harvest.

IV. Economic and Social Cost Information Considered in the Formation of the Recovery Plan

In addition to the economic principles discussed earlier, the Recovery Team considered several types of economic information. These included:

- The estimated costs of previous owl conservation proposals,
- Indicators of the dependency and sensitivity of local economies to timber harvest,
- Indicators of the effects of various elements of the recovery plan and other owl conservation proposals on timber harvest, revenues, and employment,
- Estimates of the costs and returns of various silvicultural practices.

The first two categories of information were used to provide a context that would facilitate the design of lower-cost options for consideration. The third category was used in the assessment of the various management actions the Recovery Team considered for inclusion in the recovery plan. Most of the evaluation criteria were intended to help the Recovery Team evaluate the likely contribution of various options toward recovery. Harvest and employment effects were included to show whether various options were substantially different in their costs. The Recovery Team also reviewed estimates of the costs and revenues from silvicultural practices that might be used to promote development of owl habitat.

The Recovery Team also considered information about the social costs of implementing owl conservation measures from several sociological studies.

When the Recovery Team completed formulation of the recovery plan, it prepared estimates of the economic costs of implementation. These are described in this section of the appendix. This section also provides a discussion of the concepts and analytical methods used to estimate the indicators of employment and revenue effects.

A. Previously Estimated Economic Costs of Owl Conservation Proposals

The Recovery Team reviewed six major studies of the economic effects of owl conservation[1]. This was done to gain a better understanding of the factors that contribute to the high cost of protecting the owl and to identify analytic methods, assumptions, and data that could be used in producing economic information about the recovery plan. These studies are summarized briefly here and in Table G.2.

1. The Economic Consequences of Preserving Old-Growth Timber for Spotted Owls in Oregon and Washington (Walter J. Mead et al., University of California, Santa Barbara. October 1990).

This study provided a comprehensive analysis of the economic effects of preserving the remaining old-growth forests in Oregon and Washington to provide habitat for the owl. In addition to the nearly 2 million acres of old-growth set aside in preserves, such as national parks and wilderness areas, the proposal would protect from timber harvest all other old-growth, estimated here to be more than 4 million acres. A harvest reduction of 2,257 million board feet on federal lands is estimated to be partially offset in early years by increased harvest from younger forests on private lands.

The estimated net cost of this proposal during the next 50 years is $24.5 billion (discounted to present value at 4 percent). Total job losses are estimated to be as high as 18,000.

The Mead study provided estimates of the following economic effects:

- The value of foregone old-growth timber harvest,
- The value of foregone second-growth timber harvest that would have been grown on lands from which old-growth is cut,
- The loss in the value of capital equipment, primarily sawmills,
- The loss in the value of labor due to unemployment and reemployment at lower wages,
- The increased value of recreation in old-growth forests.

2. Social and Economic Impacts of Spotted Owl Conservation Strategy (John H. Beuter, for the American Forest Resource Alliance, 1990).

The Beuter study examined the economic, social, and cultural effects of the conservation strategy for the northern spotted owl prepared by the ISC (Thomas et al. 1990). The ISC strategy proposed a network of habitat conservation areas (HCAs) encompassing about 5

[1]Since the completion of the Recovery Team's review, a more detailed somparison of thes six studies has been prepared by the Congressional Research Service. See *Economic Impacts of Protecting Spotted Owls: A Comparison and Analysis of Existing Studies.* Ross W. Gorte, Congressional Research Service, December 7, 1992.

million acres of forestlands managed by the Forest Service and the BLM. Significant portions of the HCAs are not currently old-growth, but under the prohibition on timber harvest in HCAs, these portions would become owl habitat in future decades. Significant amounts of old-growth forests were not included in the HCAs, but were to be partly protected under a rule requiring 50 percent of each quarter-township of federal forests outside of the HCAs to be left with trees averaging at least 11 inches in diameter and providing 40 percent canopy closure (the 50-11-40 rule).

The estimated annual timber harvest on federal lands in the Pacific Northwest during 1991-2000 would be reduced by 1.6 billion board feet. Federal forestlands in Oregon and Washington would experience an estimated reduction of 1.4 billion board feet per year.

The Beuter study estimated that implementation of the ISC strategy on public lands would cause direct job losses of 17,133 and total job losses of 40,321. Income losses are estimated to be $1 billion. In making these estimates, adjustments were made for job and income losses caused by other reductions in timber harvest plans and technological changes.

The Beuter study provided estimates of the following economic effects:

- Changes in employment,
- Changes in income and gross state product,
- Changes in tax receipts,
- Changes in revenues to local governments from federal timber sales,
- Social and cultural changes in timber-dependent communities.

3. Economic Effects of Implementing a Conservation Strategy for the Northern Spotted Owl (Tom Hamilton et al., Forest Service and BLM, May 1990).

This study was performed by the Forest Service and the BLM to assess the effects of implementing the ISC strategy. It estimated that federal timber sales would be reduced from the planned 1995 level of 4.4 billion board feet to 2.6 billion board feet, a reduction of 1.8 billion board feet. The reduction in total employment resulting from these restrictions was estimated to be 25,409 jobs. The value of the foregone timber harvest was estimated to be $392 million in 1995. An analysis of the potential market response estimated that timber prices would be about 30 percent higher in 1995 if the ISC strategy were implemented and that private timber harvest would be 1.1 billion board feet greater. The higher prices and private timber harvest would partially offset the revenue and employment effects of the foregone federal timber sales, but could not be sustained because of inadequate private timber inventories.

4. Three-State Impact of Spotted Owl Conservation and Other Timber Harvest Reductions (Bruce R. Lippke et al., Center for International Trade in Forest Products, University of Washington, September 1990).

The Lippke study also estimated the impacts of implementing the ISC strategy. It estimated that timber harvest on federal lands would be reduced by 1.7 billion board feet per year and that harvest on state and private lands could be reduced by 1 billion board feet. The

Lippke study estimated that implementation of the ISC strategy on public lands would cause direct job losses of 22,919 and total job losses of 48,130. Income losses are estimated to be $530 million per year if there is no reemployment. In making these estimates, adjustments were made for job and income losses caused by other reductions in timber harvest plans.

The Lippke study provided estimates of the following economic effects:

- Changes in employment,
- Changes in income,
- Changes in tax receipts,
- Changes in federal revenues from timber sales,
- Changes in revenues to local governments from federal timber sales,
- Capital asset losses suffered by mill owners and homeowners,
- Gains to other U.S. and foreign timber producers and,
- Social impacts in timber-dependent communities.

5. Conservation Plans for the Northern Spotted Owl and Other Forest Management Proposals in Oregon: Economic Implications of Changing Timber Availability. (Brian J. Greber et al., Oregon State University, July 1990)

This study estimated the effects of the ISC strategy on timber harvest, employment, wage and salary losses, and local government funding in Oregon. It estimated that the ISC strategy would reduce federal and state timber harvest in Oregon by 1.154 billion board feet per year in the 1990s, displacing 16,000 workers by 1995 and causing wage and salary losses of $682 million per year. County receipts were estimated to decline by about $14 million or about 3.8 percent. These estimates reflect the assumption that there would be no change in private timber harvest.

The study also estimated the effects of private industry conservation efforts similar to the ISC policies and of private harvest increase in response to the higher timber prices that would result from federal conservation efforts. Private conservation was estimated to increase total job displacement to 42,100 jobs and income losses to $1.8 billion per year. An increase in private timber harvest, while not sustainable over the long run, would reduce job displacement in the 1990s to 4,700 jobs and the income losses to $199 million per year. These effects would be higher, however, in the next decade when private harvest would be lower than the sustainable level.

6. Economic Analysis of Critical Habitat Designation Effects for the Northern Spotted Owl (USDI January 1992a).

The FWS prepared this analysis to accompany its January 1992 rulemaking to designate critical habitat for the northern spotted owl. The critical habitat includes most of the acreage in the ISC's HCAs plus about 1.7 million acres of federal forestlands that were not included in HCAs. The FWS used estimates provided by the Forest Service and the BLM on the effects on federal timber harvest attributed to various efforts to protect owl habitat. This study provided estimates of timber harvest for Forest Service and BLM forestlands according to the agencies' latest plans, under announced policies for implementation of the ISC strategy, and under the FWS determinations of whether timber sales would jeopardize the continued existence of the owl or adversely modify the designated critical habitat.

The FWS study estimated that Forest Service and BLM implementation of the ISC strategy would reduce federal timber harvests in 1995 by 1.7 billion board feet per year. It estimated that Forest Service and BLM implementation of the ISC strategy would cause total job losses of 27,705. The further protection provided by the FWS under the Endangered Species Act would reduce timber harvests by an additional 236 million board feet and total employment by an additional 3,311 jobs. The imposition of the prohibition on adverse modification of the critical habitat is estimated to cause additional reductions of 102 million board feet in the 1995 timber harvest and an additional loss of 1,420 jobs. The wage losses due to critical habitat designation were estimated to be $65 million in present value (discounted at 10 percent).

The FWS study also provided estimates of the following economic effects:

- Federal revenue from timber sales and the net loss to the U.S. Treasury,
- Changes in employment by county,
- Changes in revenues to counties from federal timber sales.

Although these studies analyzed somewhat different proposals using different methods and assumptions, they produced comparable estimates. Table G.2 summarizes selected estimates from the studies to facilitate comparison. It is clear that the costs of owl habitat protection are substantial at the national and regional levels. Nationally, the value of foregone timber harvest is the most significant cost. This cost is borne primarily by federal taxpayers. The counties that share federal timber receipts also are hurt by the loss of timber revenues. Employment and wage losses and asset losses also hit timber-dependent communities hard.

B. Potential Social Costs of Owl Conservation Measures

There is substantial literature about the social effects of economic changes in rural communities. Research on timber-dependent communities has been used in several studies to assess the social effects of the timber harvest reductions that might result from owl conservation measures. This literature was reviewed and discussed by the Recovery Team. Existing sociologic studies do not provide a basis for quantitative estimates of the social effects that would result from implementation of the recovery plan or other owl conservation plans. Such studies do, however, allow an assessment that is useful in judging the types of social effects that are likely and in planning programs to mitigate such effects.

It appears likely that success of the recovery plan in the long run may depend substantially on how its social effects are handled. The support and cooperation of local communities has proven to be important in the success of many wildlife conservation programs. Experience with other large-scale wildlife conservation programs has shown that it is difficult to sustain a healthy and diverse ecosystem unless the human communities that depend on it are also healthy. It appears likely that, if people in timber-dependent communities are to support efforts to protect the owl, substantial efforts will be needed to reduce the social costs they bear.

The work of Robert G. Lee of the University of Washington provides a good synthesis of studies of the social effects of owl conservation programs in Washington and Oregon (Lee 1990, Lee et al. 1991a, Lee et al. 1991b). Louise Fortmann of the University of California,

Table G.2. Summary of previous studies of economic effects of northern spotted own conservation.

	Mead	Beuter	Hamilton	Lippke	FWS[8]	
					ISC	ESA
Reductions in federal timber harvest *(millions of board feet)*	2,257[1]	1,800[2]	1,800	1,700[2]	1,682[3]	338[3]
Job loss						
Direct	7,225	17,133	NA	22,919	NA	NA
Total	18,000	40,321	25,409	48,130	27,705	4,731
Wage losses *(millions of dollars)*	1,049[4]	625[5]	NA	4,600[6]	NA	65[7]
Timber value losses (net) *(millions of dollars)*	23,371[4]	NA	500[5]	NA	NA	NA

[1]In Washington and Oregon only, estimate for the first year reflects offset by increased private harvest.
[2]On public lands in all three states.
[3]FS and BLM lands in three states.
[4]Total present value over 50 years, discounted at 4 percent.
[5]Annually.
[6]Total present value.
[7]Present value discounted at 10 percent. Estimated only for the 1,690,000 acres of federal forestlands that the critical habitat designation adds to the ISC's habitat conservation areas.
[8]FWS included analysis of both the effects of the ISC plan andthe separate effects of the listing of the spotted owl.
Sources: Mead et al. 1990, Beuter 1990, Lippke et al. 1990, Hamilton et al. 1990, USDI 1992a.
FWS - U.S. Fish and Wildlife Service.
ISC - Interagency Scientific Committee.
ESA - Endangered Species Act.
FS - U.S. Forest Service.
BLM - U.S. Bureau of Land Management.
NA - Not applicable.

Berkeley, has studied similar effects in California (Fortmann et al. 1990). This work supports the use of employment and revenue estimates as indicators of economic and social effects. More importantly, it suggests that other factors may have an equally important bearing on the way people in timber-dependent communities respond to the resulting changes in their lives.

Lee (1990 and 1991) identified four factors that are likely to exacerbate the social effects of owl conservation: 1) an apparent shift from decentralized, participatory forestland management that is oriented toward community stability to centralized command and control regulation to protect owl habitat; 2) the perception that the federal government has reneged on its commitment to maintain a nondeclining even flow of timber from federal forests, a commitment on which many people based a lifelong commitment of their own resources; 3) a social structure that is less likely to adapt to permanently decreased employment and loss of personal and business assets in timber-dependent communities than is assumed; 4) the potential emergence of conflict among different groups of people in which timber workers are stereotyped and stigmatized.

Lee's work suggests that these factors may create a situation that inhibits the adaptiveness of people in timber-dependent communities and increases the undesirable social effects of reductions in federal timber harvest.

Research in timber-dependent communities suggests that the shift from decentralized forest management to centralized species preservation policy causes increased opposition to owl conservation measures. As a result, implementation of owl conservation plans is likely to require greater use of enforcement measures and greater short-term exploitation of the forests may occur. Accelerated liquidation of private forestlands may offset economic losses for some people in the short run, but also may have undesirable ecological effects and exacerbate the decline in timber harvests in coming decades.

The removal of forestlands from the timber base to protect owl habitat will cause a permanent decrease in timber harvest levels. This is perceived by people in timber-dependent communities as a betrayal. Many people in these communities have committed their personal energies and financial resources in response to the government's assurance of a nondeclining flow of timber from federal forests. Many regarded this policy as a promise on the part of the government. The federal timber harvest was expected to play a particularly important role in the next decade or two because of the inadequacy of the timber inventory on private lands to sustain harvest levels during that period.

People in these communities have developed ways of adapting to the cyclical unemployment that results from changes in the demand for timber that have been induced by national economic cycles. These adaptations depend in part on the assurance that the timber supply would be adequate to support recovery as soon as the demand for timber rebounded. As Lee reported, these adaptations are not well suited for coping with permanent reductions in timber harvest levels, the resulting permanent reductions in timber industry employment and the resulting effects on peoples' income.

Sociological research in timber-dependent communities has shown that people developed shared values and behavior patterns that allowed them to cope with cyclical changes in timber demand. People share a commitment to hard work, individualism, and self-reliance. While these values often are regarded as the bedrock of American culture, they may inhibit the development of cohesiveness and adaptability needed to make the changes in careers and economic structure to respond to a permanent decline in timber harvest.

As Lee reported, loggers have relied on their reputation as skilled woods workers and their mobility to find work. A logger has been able to improve his economic security by developing a reputation as a "good worker." Loggers appear to have developed a sense of occupational community, a commitment to logging as a way of life that may inhibit adaptation to permanent reduction in timber employment through career change. Many mill workers are less mobile than loggers and tend to be dependent on a single mill. Small business owners have committed their life's savings to investment in their enterprises, knowing that they would have some hard times during down-cycles, but expecting that, over the long run, the timber supply would provide support for their businesses.

The controversy about protection of the owl appears to have elements of an emerging conflict between urban populations wanting increased protection of environmental resources and rural populations that have worked in extractive industries. According to Lee, people in timber-dependent communities fear the dominance of the urban majority and feel manipulated by the apparent expectation that they will adapt to the change in the timber supply. Moreover, this conflict is exacerbated by the attempt to exclude timber and wood products workers from the larger community of people regarded as deserving sympathy and fair treatment (Lee 1991).

Sociologic research indicates that the social costs in timber-dependent communities may be heightened by the stereotyping and stigmatizing methods that some groups advocating preservation of owl habitat have employed, particularly against loggers. From their studies of behavior in other communities, sociologists know that the resulting dehumanization can make victimization more likely and can cause maladaptive behavior among victims. The combination of economic stress and stigmatization can lead to increased loss of self-esteem, depression and passivity, drug and alcohol abuse, violence, and family dysfunction. Sociologists regard such situations as life-threatening traumas that can cause maladaptive behavior patterns that can be transmitted through families for generations.

The contrast between the behavior described by sociologists and the behavior described by economists is worth noting. Economic models are based on the assumption that economic behavior is "rational." It is assumed, for example, that people are able to figure out and take the actions that would best improve their situations. Displaced workers, in this model, seek new training or move to new locations with better employment opportunities. Sociologic models, in contrast, recognize that people respond to some traumatic experiences in ways that prevent such economic adaptation. The resulting individual and community behavior patterns may inhibit people's recovery from traumatic changes in their situation.

Lee and other sociologists suggested that programs to protect the owl be accompanied by efforts to draw on the strengths of the people in timber-dependent communities. Lee recommended, for example, that their entrepreneurial lifestyle and inventiveness be used to develop and implement silvicultural methods that would promote the growth of owl habitat and increase the value of timber that can be harvested.

Lee's work also pointed out the difficulties imposed on state and local governments by the combined effects of the unemployment and social effects resulting from owl habitat conservation and the decline in revenues received by counties from federal timber sales (Lee et al. 1991b, Bray and Lee 1991). Just as the demand for social services increases, the financial resources available to local governments will decrease because of the decline in federal timber receipts in which they share. Counties with a high dependency on federal timber and an above average proportion of protected owl habitat will suffer disproportionately.

Studies of this problem concluded that severely affected counties could have difficulty maintaining essential services and meeting the additional needs caused by economic dislocation. Many counties, particularly in Oregon, have received more than 50 percent of their revenues from federal timber receipts (Bray and Lee 1991). Federal receipts have been allocated primarily to schools and roads but support other programs as well. Reductions in funds from federal timber receipts would force cuts in services that are not mandated by law such as preventive health care; social services such as counseling and youth programs; parks; and libraries. The reduction in such services is expected to heighten the social costs in communities hit by permanent reductions in employment opportunities and other effects of owl conservation policies.

C. Indicators of the Timber Dependency of Local Economies

One of the opportunities to reduce the economic and social costs of achieving recovery for the owl is to reduce the amount of habitat preservation in areas where it causes the highest cost. It is useful to identify those communities where people's incomes are most directly tied to timber harvest that might be affected by owl conservation. A closely related factor is the extent to which people will be able to find employment in other sectors because of the proximity to more diverse urban economies or local opportunities for economic diversification. Several of the studies reviewed by the Recovery Team included efforts to measure timber dependency. Instead of developing new indicators, the Recovery Team drew upon these efforts. They are summarized here.

The Beuter study included a substantial effort by Douglas C. Olson to assess the timber dependency of various multicounty regions in the three-state area. Table G.3, taken from the Beuter study, summarizes the results of that effort, and shows that the highest dependency on timber occurs in southwestern Washington and southwestern Oregon. West-central Oregon, the Olympic Peninsula, and western Oregon fall into a second tier of high dependency.

The FWS study developed job response coefficients for the 50 counties affected by owl conservation efforts. These coefficients reflect the flow of logs from harvest sites to mills and the direct and total employment that results in each county per million board feet of timber harvest. Table G.4 shows the job response coefficients for the 50 counties from the FWS study.

The FWS study also examined a variety of other economic indicators at the county level including unemployment, per capita income, percentage of employment in the timber and wood products industries, percentage of federally owned land and dependence on federal timber harvest, and the effect of reductions in timber harvest on county revenues. These statistics are summarized in Table G.5.

Trends in economic development and population growth provide an important indicator of recent diversification in county economic structure. Counties that have experienced rapid population and income growth are participating in the general diversification of the economic structure in the Pacific Northwest, primarily through growth in service sectors and light industry. Data about changes in employment in timber and manufacturing assembled by the FWS for the 50 counties that may be affected by owl conservation also are included in Table G.5.

Table G.3. Economic dependency indexes for wood products and other selected industrial sectors, by economic area and region, 1985.

Economic Area/Region	Dependency Indexes: Estimated Percent of Area's Economic Base in Each Sector						
	Wood Products		Other Manufacturing	Agriculture, Forestry, and Fisheries	Services	Other	Total
	Primary	Secondary					
Washington							
Puget Sound	7	2	31	16	14	30	100.0
Olympic Peninsula	40	5	0	9	19	27	100.0
Southwestern	55	4	9	13	9	10	100.0
Western	13	0	40	7	13	27	100.0
Central	10	0	9	72	4	5	100.0
Oregon							
Northwestern	23	3	10	44	8	12	100.0
West-Central	45	6	2	21	13	13	100.0
Southwestern	52	6	0	23	7	12	100.0
Western	40	5	4	22	6	23	100.0
Central	28	18	0	18	9	27	100.0
California							
North Coast	15	4	9	24	28	20	100.0
North Interior	17	5	0	17	23	38	100.0
Sacramento	2	3	6	44	21	24	100.0
Northern	5	3	3	22	27	40	100.0
3-State Owl Region	20	4	16	14	17	29	100.0

Dependency indexes in this table were determined exclusive of the government and household sectors. See Table A-2 in Beuter (1990) for indexes determined with all sectors included. Also, see Table A-1 in Beuter (1990) for more sector detail regarding indexes in this table.

Metropolitan areas are included in the economic areas as well as the regions in this table.

Source: Olson in Beuter 1990.

The FWS considered these factors in designing a process for deciding whether to exclude areas from the designation of critical habitat (USDI 1992). It used the effects on county budgets and timber-based employment to identify 13 counties on which to focus exclusion decisions. These counties are:

Washington	Oregon	California
Chelan	Curry	Trinity
Clallam	Douglas	
Lewis	Hood River	
Skamania	Jackson	
	Josephine	
	Lane	
	Tillamook	
	Wasco	

Table G.4. Job response coefficients for affected counties.*

Washington County	Jobs/ mmbf	Oregon County	Jobs/ mmbf	California County	Jobs/ mmbf
Chelan	11.81	Benton	17.11	Colusa	8.01
Clallam	12.46	Clackamas	9.88	Del Norte	12.51
Clark	10.40	Columbia	10.79	Glenn	8.0
Cowlitz	11.58	Coos	14.47	Humboldt	14.29
Grays Harbor	12.46	Curry	13.92	Lake	12.51
Jefferson	10.30	Deschutes	15.58	Mendocino	12.51
King	12.00	Douglas	13.87	Shasta	9.63
Kittitas	15.08	Hood River	8.51	Siskiyou	9.63
Klickitat	10.40	Jackson	13.92	Tehama	8.36
Lewis	10.40	Jefferson	14.17	Trinity	10.03
Mason	10.72	Josephine	13.92		
Okanogan	10.40	Klamath	15.74		
Pierce	10.30	Lane	17.11		
Skagit	9.63	Lincoln	17.11		
Skamania	10.40	Linn	17.11		
Snohomish	10.41	Marion	14.02		
Whatcom	9.63	Multnomah	11.05		
Yakima	15.08	Polk	14.02		
		Tillamook	9.46		
		Wasco	8.51		
		Washington	9.88		
		Yamhill	10.79		

*Includes direct, indirect, and induced jobs.
mmbf = million board feet
Source: USDI 1992a.

Table G.5. Economic characteristics of counties affected by critical habitat designation.

State/County	(1990) Unemployment Rate	1989 Per Capita Income	1990 population per Square Mile	Timber and Wood Products Employment (%)	Percent Employment Changes 1980-1989: Change in Timber Jobs	Percent Employment Changes 1980-1989: Change in Manufacturing Jobs	Percent Federally Owned Land in County	Percent Dependence on Federal Timber	Percent* Reduction in County Revenue
Washington									
Chelan	8.0	$17,335	18	1.3	-34	20	75	39.8	18
Clallam	7.0	$14,942	32	10.3	-33	12	46	60.6	8
Clark	4.9	$15,379	380	4.2	5	43	1	60.3	0
Cowlitz	6.9	$15,276	72	19.5	-36	7	3	5.1	1
Grays Harbor	9.1	$14,772	33	17.8	-35	12	13	38.9	5
Jefferson	4.8	$15,378	11	1.3	-51	28	61	1.6	13
King	3.4	$22,125	708	1.1	4	30	24	24.8	0
Kittitas	7.1	$14,035	12	1.7	-6	8	29	**	10
Klickitat	11.4	$15,270	9	13.4	10	10	3	50.1	2
Lewis	7.9	$13,920	25	11.2	-22	12	30	55.9	17
Mason	6.1	$13,072	40	10.6	-21	18	27	6.3	6
Okanogan	9.9	$15,163	6	8.0	15	19	46	45.3	3
Pierce	4.8	$15,546	350	1.8	-10	30	31	46.1	0
Skagit	6.7	$16,163	46	3.1	-8	29	46	40.9	4
Skamania	16.0	$14,225	5	29.1	-21	-46	75	50.1	109
Snohomish	3.9	$17,832	222	2.2	-4	48	47	52.5	2
Whatcom	4.9	$15,457	60	3.1	61	35	61	39.0	3
Yakima	9.7	$14,494	44	2.3	10	22	19	NA	5
Oregon									
Benton	3.8	$16,687	104	4.0	127	16	5	57.5	16
Clackamas	3.5	$18,191	140	2.4	-14	40	43	63.9	7
Columbia	7.4	$13,891	58	11.5	-2	15	0	6.8	0
Coos	8.9	$13,608	38	10.2	-36	-5	7	24.5	42
Curry	5.8	$13,799	17	10.1	-4	16	57	87.6	59
Deschutes	5.9	$15,836	25	8.7	47	41	75	10.5	3
Douglas	8.4	$13,353	19	19.6	8	9	29	81.6	62
Hood River	7.8	$15,438	32	5.7	7	18	63	52.7	18
Jackson	6.8	$14,046	53	9.0	18	22	26	76.1	45
Jefferson	6.3	$13,880	9	14.8	79	36	25	10.5	3
Josephine	8.0	$11,438	38	9.0	-3	20	33	94.2	49
Klamath	9.3	$13,540	10	16.0	-14	6	56	51.1	14
Lane	5.9	$15,049	62	8.1	-11	14	47	60.4	30
Lincoln	5.9	$14,722	40	2.7	-39	14	29	57.5	30
Linn	7.8	$13,059	40	13.7	-18	9	33	41.2	30

continues-

continued

State/County	(1990) Unemployment Rate	1989 Per Capita Income	1990 population per Square Mile	Timber and Wood Products Employment (%)	Percent Employment Changes 1980-1989: Change in Timber Jobs	Percent Employment Changes 1980-1989: Change in Manufacturing Jobs	Percent Federally Owned Land in County	Percent Dependence on Federal Timber	Percent* Reduction in County Revenue
Marion	5.4	$14,957	193	3.1	47	29	27	81.4	5
Multnomah	4.9	$18,308	1,355	1.3	-28	10	26	52.7	1
Polk	5.5	$13,582	67	3.8	-37	5	0	70.3	12
Tillamook	6.1	$13,360	20	4.8	-62	0	15	32.8	28
Wasco	7.8	$16,672	9	4.8	-9	-1	13	67.0	8
Washington	3.4	$18,596	430	1.1	29	35	1	18.9	0
Yamhill	5.3	$14,585	92	5.5	-6	25	6	58.5	6
California									
Colusa	**	**	**	**	**	**	**	**	**
Del Norte	12.6	$12,139	24	6.5	-68	-14	72	13.5	15
Glenn	12.5	$16,185	19	0.5	-69	-9	24	75.5	3
Humboldt	7.7	$15,546	33	9.9	-18	6	20	1.8	5
Lake	9.4	$14,166	**	0.2	**	**	**	**	2
Mendocino	8.1	$15,856	23	9.3	-4	10	14	14.9	1
Shasta	8.6	$15,567	39	4.0	1	29	40	41.7	2
Siskiyou	11.6	$14,300	7	9.7	-5	-2	62	71.7	8
Tehama	10.7	$12,471	17	11.3	7	9	23	24.4	3
Trinity	12.2	$12,495	4	**	4	-8	74	76.0	32

*Revenue reductions estimated for effects of U.S. Forest Service and U.S. Bureau of Land Management implementation of the Interagency Scientific Committee strategy, the prohibition against federal actions that would jeopardize a threatened species and the designation of critical habitat.

** = Data not available.

Source: USDI 1992.

The State of Washington has completed an evaluation of the potential jobs lost due to efforts to conserve the northern spotted owl. Using ISC recommendations as a benchmark and recent harvest levels as a base, 8,200 jobs in the timber and wood products industries are considered to be at risk. These are distributed as follows:

Olympic Peninsula	1,161
Northwestern Washington	1,849
Southwestern Washington	1,964
Central Washington	855
Puget Sound	2,234
Eastern Washington	136

When indirect employment is considered in addition to direct employment in the timber and wood products industries, the total potential job loss in Washington is 20,800. These estimates reflect the actual harvest in recent years rather than timber sale plans and include indirect employment impacts for the entire state.

An analysis completed by the State of Washington identified the relative economic risk of 100 communities in areas affected by the reductions in federal timber harvest. Communities were designated as either high-risk, at risk, low-risk, or uncertain on the basis of a number of criteria. The criteria included absolute and relative dependency on timber-based employment, dependency on federal timber supplies that are being reduced, and an assessment of the local industry.

The following factors were used to designate a community as high-risk:

- More than 20 percent of the population is employed in the timber and wood products industries.
- Significant portions of the local timber and wood products industries are dependent on national forest timber where harvest reductions are planned.

Table G.6 shows the results of this analysis.

The State of Oregon performed a similar analysis to identify severely affected timber-dependent communities that would receive services under the Oregon Economic Development Department's (OEDD) Timber Response Program. A community is considered to be severely affected if:

- It has had a 4 percent decline in employment in the timber and wood products industries since 1989 compared to the total 1990 workforce,
- Its annual average unemployment rate exceeds the state's annual average rate by more than 50 percent, or
- The OEDD director determines that the community has suffered or is likely to suffer a severe economic decline.

The communities shown in Table G.7 are affected by both timber supply and cyclical problems. While the spotted owl most directly affects western Oregon communities, eastern Oregon communities feel the pressure on log supply. Eastern Oregon communities primarily are affected by timber supply declines, particularly ponderosa pine, in the new federal forest plans. As a result, these communities also are shown to be severely affected.

Table G.7 lists the Oregon communities declared to be severely affected as of November 19, 1991.

Table G.6. High-risk communities in Washington.

East Skagit County/East Snohomish County:	Sedro Woolly Rockport Darrington Gold Bar Sultan
Western Clallam County:	Forks Beaver
East Lewis County:	Morton Glenoma Randle Packwood
Okanogan County:	Okanogan Omak Tonasket
Grays Harbor County:	Aberdeen Amanda Park Copalis Crossing Hoquiam Humptulips Montesano Pacific Beach Carlisle Neilton
Skamania County and Klickitat County:	Stevenson Carson Bingen White Salmon
Yakima County:	Naches

Source: Governor's Timber Team, Washington.

Table G.7. Severely affected communities and counties in Oregon* (updated November 19, 1991).

Communities			
Astoria	Dillard	Marcola	Selma
Beavercreek	Elmira	Maupin	Spray
Blodgett	Estacada	Medford	Springfield
Brownsville	Foster	Central Point	Thurston
Camas Valley	Garibaldi	White City	Sutherlin
Camp Sherman	Gilchrist	Merlin	Sweet Home
Cascadia	Glide	Mill City	Swisshome
Cave Junction	Gold Beach	Gates	Tenmile
Kerby	Halfway	Molalla	Tidewater
Chemult	Harrisburg	Monmouth	Tiller
Cheshire	Hines	Monument	Tygh Valley
Chiloquin	Jefferson	Myrtle Point	Ukiah
Crater Lake	Marion	New Pine Creek	Union
Sprague River	John Day	North Bend	Vernonia
Clatskanie	Lakeside	North Powder	Walton
Coquille	Lakeview	Noti	Warm Springs
Cottage Grove	Lebanon	Oakridge	Warrenton
Saginaw	Lorane	Philomath	Wilbur
Crabtree	Lostine	Powell Butte	Willamina
Culp Creek	Lowell	Prospect	Williams
Curtin	Fall Creek	Reedsport	Yoncalla
Days Creek	Lyons	Riddle	
Deadwood	Mapleton	Ritter	
Dexter			
Counties			
Grant**	Lake**	Wheeler*	
Coos	Harney**	Morrow*	
Douglas	Klamath	Umatilla*	

Source: Oregon Timber Response Program Status Report, November 1991.
*Affected by declines in log supply.
**Counties outside of the rangte of the northern spotted owl.

V. Preliminary Evaluation of the Economic Effects of Implementing the Northern Spotted Owl Recovery Plan

A. Economic Effects Covered by Preliminary Estimates

The Recovery Team drew upon the studies summarized in section IV of this appendix, particularly the FWS analysis, to develop estimates of the economic costs of implementing the recovery plan. Estimates of the following indicators of economic costs were made:

- Reduction in federal timber sale volumes and revenues and the resulting effects on U.S. Treasury and county budgets.
- Reduction in employment levels.
- Reduction in wage and salary income due to unemployment and reemployment at lower wages.

Estimates were not made of other economic effects such as capital asset losses; recreation or the other benefits of forest conservation; and increased profits or harvest by private forest landowners. Quantitative estimates of social costs of implementing the recovery plan were not made.

This section summarizes the basic analytical concepts needed to estimate and properly account for the economic effects of reduced federal timber harvests. Next it summarizes the estimation methods and assumptions used for the preliminary estimates and presents the resulting estimates.

B. Analytical Concepts

This section provides an economic framework within which the various factors that affect the costs of achieving recovery can be related. The discussion is presented in qualitative, nonmathematical terms to facilitate a broader understanding and use of the concepts. The basic concepts are presented in a single period, comparative static analysis for the sake of simplicity. For a comprehensive analysis of long-term effects, the concepts would be extended to deal with many time periods. This would reflect the effects of timber growth and the concept that resource values realized sooner are worth more than the same values if realized later. It also would deal more explicitly with the dynamic processes through which local and regional economies adjust to the kind of structural economic change caused by policies restricting timber harvest. The following discussion takes a static approach to provide a more easily understandable analytical framework.

1. The Supply Curve.

The supply curve for a commodity is one of the fundamental concepts of economic analysis. It represents the rate of production for a commodity or good that is achievable at various costs. For timber, the supply curve reflects the costs that would be incurred by firms in all the activities needed to grow trees, harvest timber, and bring logs to the mills to be sawed into lumber. Such costs include forest management, road construction, cutting and loading, and transportation. It does not reflect the costs experienced by society as a result of the environmental effects of timber production because firms generally do not pay for such costs. It does, however, include the costs of complying with regulations designed to reduce the environmental effects of these activities.

As is the general case with supply curves, the timber supply curve slopes upward as shown in Figure G.1. At any given time, there are numerous sites that could be harvested at various costs. When prices are higher, it is worthwhile incurring greater costs to harvest additional timber. The upward sloping supply curve reflects the economic diversity of the existing forestlands. It results from a mixture of stands of timber, some with relatively low costs per board foot, some with relatively high costs.

The supply curve can be derived from a table listing the annual amount of timber that could be harvested at each cost from each site in the inventory. The total amount that could be produced at each cost is the sum of the annual harvest at that cost from all the sites. The supply curve shows the annual production at each price which is the sum of the potential annual harvest at all costs less than or equal to the price. Table G.8 provides an example of this way of deriving a supply curve. Figure G.2 shows the supply curve derived from Table G.8.

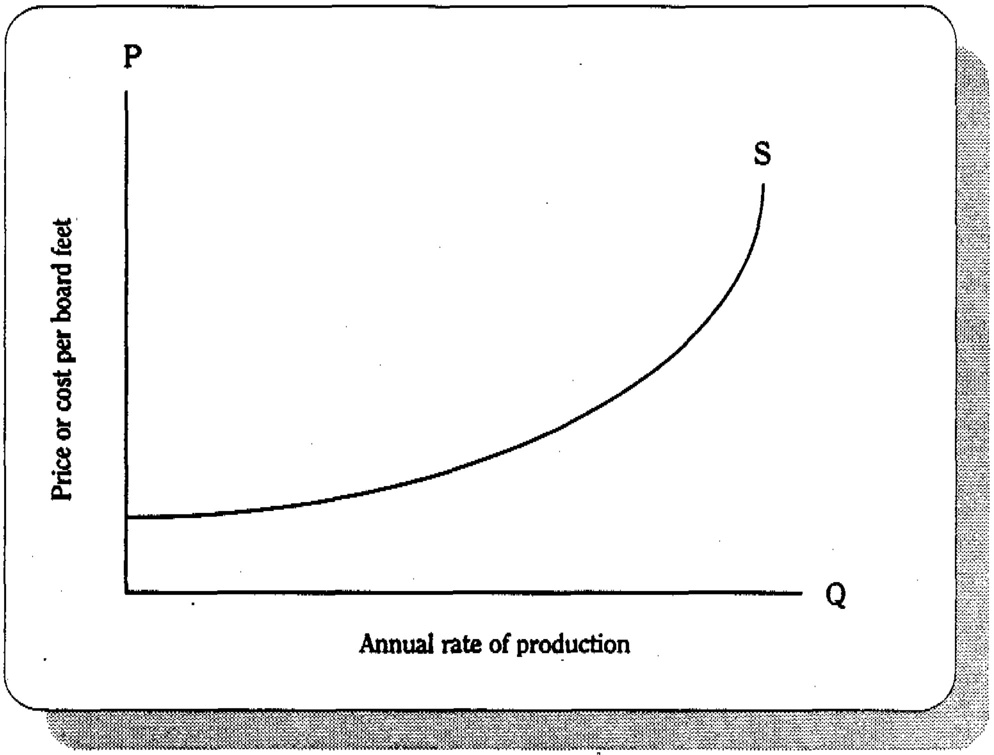


Figure G.1. Timber supply curve.

A region's timber supply curve reflects the condition of its current inventory of standing timber. For example, Figure G.3 shows two supply curves, one that would yield high levels of production over a broad range of timber prices (s_1) and a second (s_2) that yields relatively little production at low prices, moderate production at midrange prices and not much increase in production even at fairly high prices. The first (s_1) would characterize production from the forestlands in a region that has a substantial inventory of mature standing timber, the second (s_2) from a region with limited forestlands or forestlands where the lower-cost timber already has been harvested.

The second supply curve also could represent the supply curve in a region in which lands with low-cost timber were held off the market. Prohibiting timber harvests on sites with relatively low costs shifts the supply curve to the left for all higher costs. Table G.9 shows the supply schedule from Table G.8 recalculated to reflect the removal of sites 1 and 2. Figure G.4 shows the supply curve derived from Table G.9. As a comparison of Figures G.2 and G.4 shows, policies that remove harvestable timber from the timber resource base generally can be represented by a leftward shift in the supply curve from S_0 to S_1 as shown in Figure G.5. This is particularly true if low-cost sources of timber are made unavailable for harvest.

2. The Fundamental Economic Benefits of Timber Production.

The market for lumber is national. Lumber and wood products are shipped long distances and can be imported, primarily from Canada. Because of the available supply of lumber from timber grown in other regions and the flexibility in substitution of other materials for

Table G.8. Example of the derivation of timber supply curve (illustrated in Figure G.2).

Potential Timber Production by Site and Cost

Site	Cost (dollars per unit)	Production (units)
1	5	200
	10	110
	15	50
	20	0
	25	0
2	5	0
	10	0
	15	275
	20	50
	25	20
3	5	0
	10	0
	15	0
	20	100
	25	50
4	5	250
	10	400
	15	150
	20	50
	25	20
5	5	0
	10	0
	15	0
	20	100
	25	50

Potential Timber Production by Cost

Cost (dollars per unit)	Production (units)
5	450
10	510
15	475
20	300
25	140

Supply Schedule

Price (dollars per unit)	Production (units per year)
5	450
10	960
15	1,435
20	1,735
25	1,875

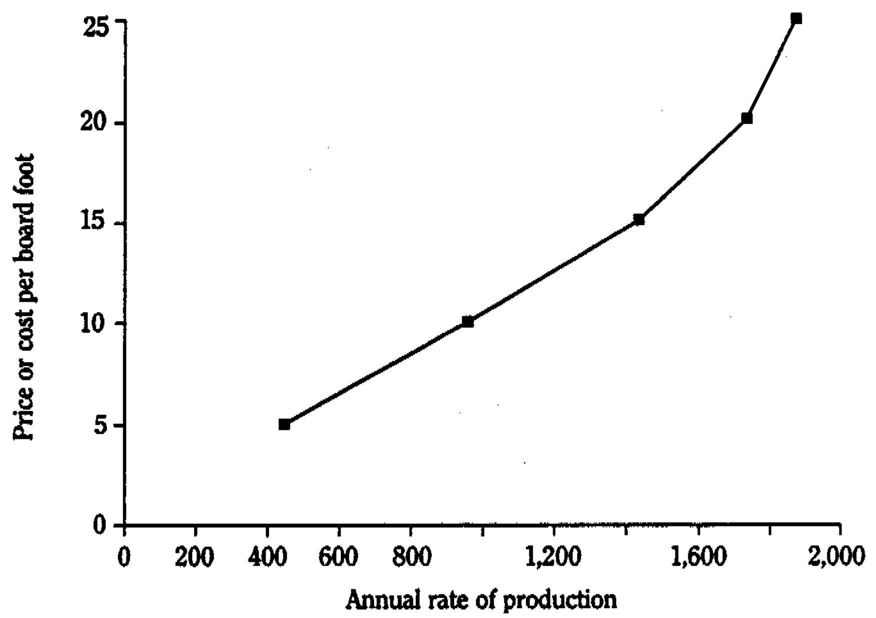


Figure G.2. *Timber supply curve derived from Table G.8.*

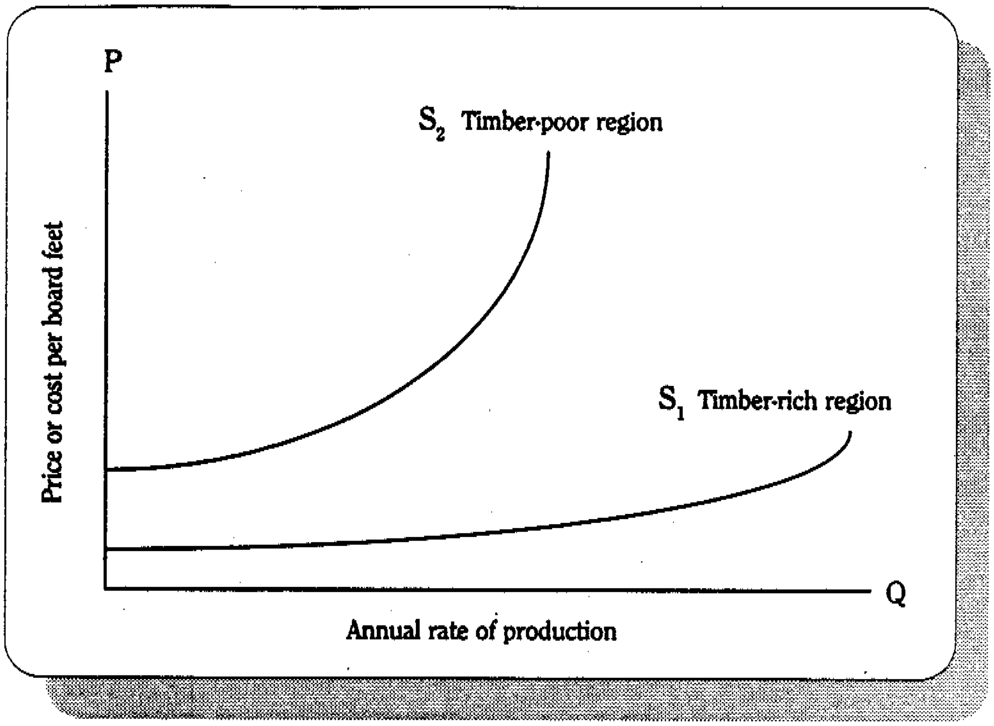


Figure G.3. *Theoretical timber supply curves.*

Table G.9. Recalculation of example to show effect of restricted timber availability on derivation of timber supply curve (illustrated in Figure G.4).

Potential Timber Production by Site and Cost			Potential Timber Production by Cost		Supply Schedule	
Site	Cost (dollars per unit)	Production (units)	Cost (dollars per unit)	Production (units)	Price (dollars per unit)	Production (units per year)
1	5	0				
	10	0	5	250	5	250
	15	0	10	400	10	650
	20	0	15	150	15	800
	25	0	20	250	20	1,050
2	5	0	25	120	25	1,170
	10	0				
	15	0				
	20	0				
	25	0				
3	5	0				
	10	0				
	15	0				
	20	100				
	25	50				
4	5	250				
	10	400				
	15	150				
	20	50				
	25	20				
5	5	0				
	10	0				
	15	0				
	20	100				
	25	50				

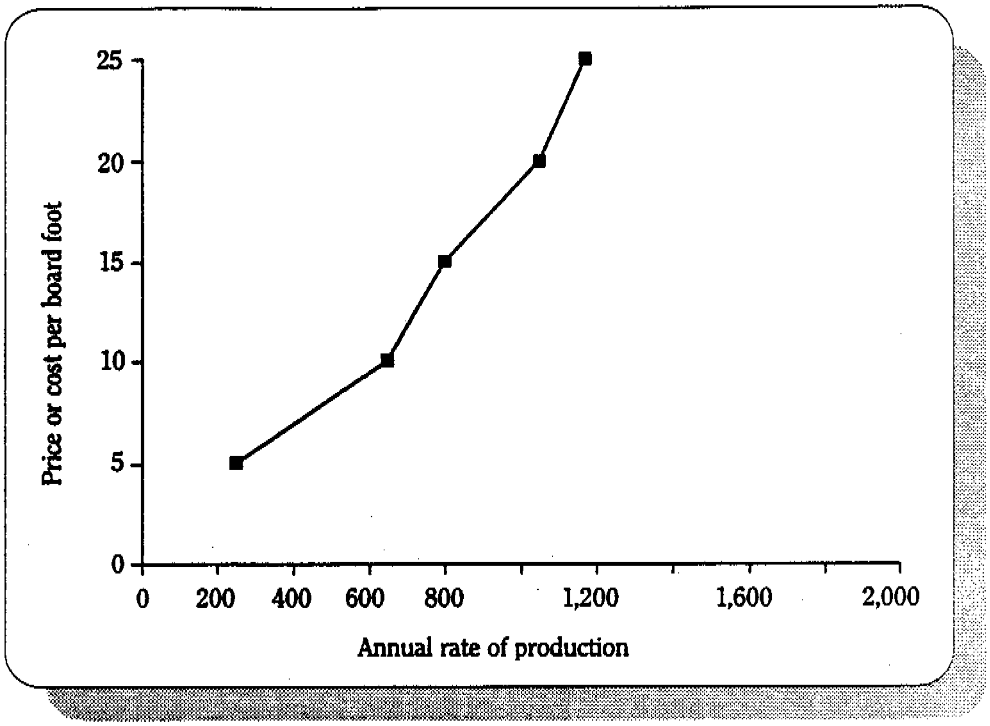


Figure G.4. *Timber supply curve derived from Table G.9.*

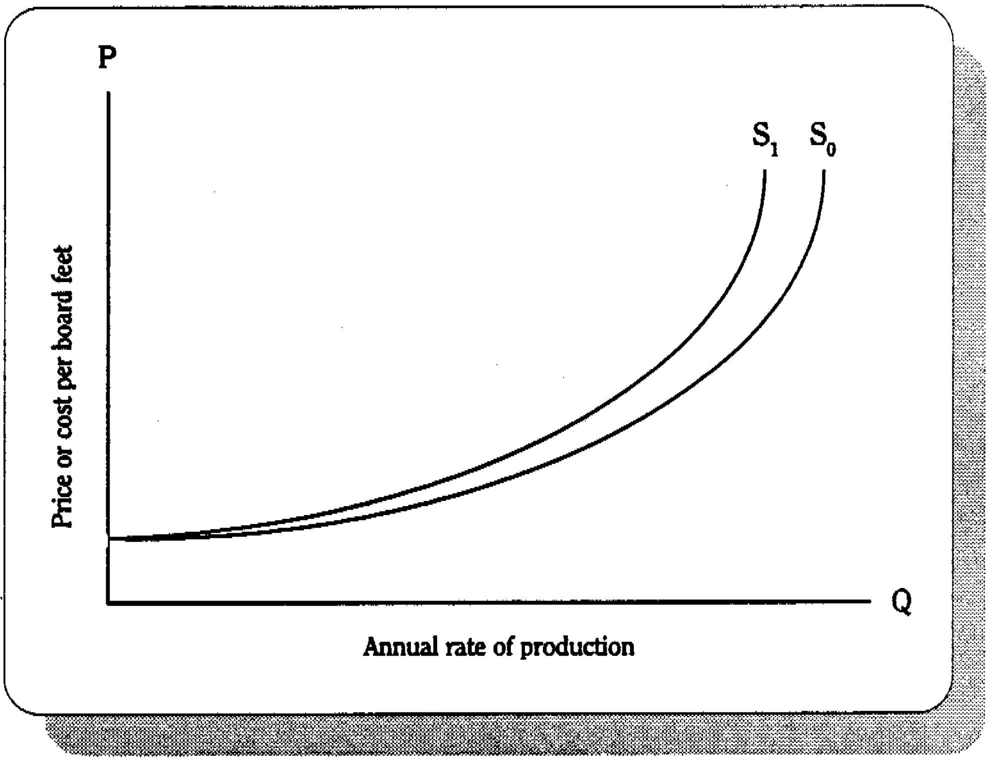


Figure G.5. *Effect of removing low cost timber from timber supply curve.*

lumber, the level of timber production in the Pacific Northwest has only a small effect on lumber prices. If the rate of timber harvest in the Pacific Northwest does not have much affect national lumber prices or consumption, it will not substantially effect on the rate of consumption or the benefits that consumers experience from using lumber.

If lumber prices and consumption are not affected much by changes in Pacific Northwest timber production, what then is its benefit? Economists define the economic rent as the fundamental economic benefit from development of natural resources. The economic rent from harvesting a stand of timber is the difference between the revenues from the sale of the timber harvested and the costs of all the various resources–labor, materials, energy, capital–used in harvesting and transporting them. As Figure G.6 shows, the price of timber, P_T, is determined by the intersection of the supply curve (S) and the demand curve (D) for timber. This intersection represents the market equilibrium between supply and demand.

In Figure G.6, the economic rent from the harvesting of Q_T board feet per year sold at P_T, the price of timber, is the hatched area between the price line and the supply curve. The hatched area is what is left when the costs of production, which is represented by the area under the supply curve from the origin to QT_T, is subtracted from the rectangle that represents the production revenues, $P_T \times Q_T$.

A good measure of the direct economic benefit of producing timber is the gains the economy realizes by incurring less cost in harvesting and transporting logs than the price paid for the logs. These benefits are captured in a variety of forms: stumpage fees paid to landowners including the federal government and state governments, lumber company profits, federal income taxes, and state taxes. Stumpage prices are the best indicators of the economic benefit of the timber that is cut because competitive bidding for timber harvest contracts forces firms to bid away most of the difference between the value of the logs at the millgate and the costs of harvest and transportation.

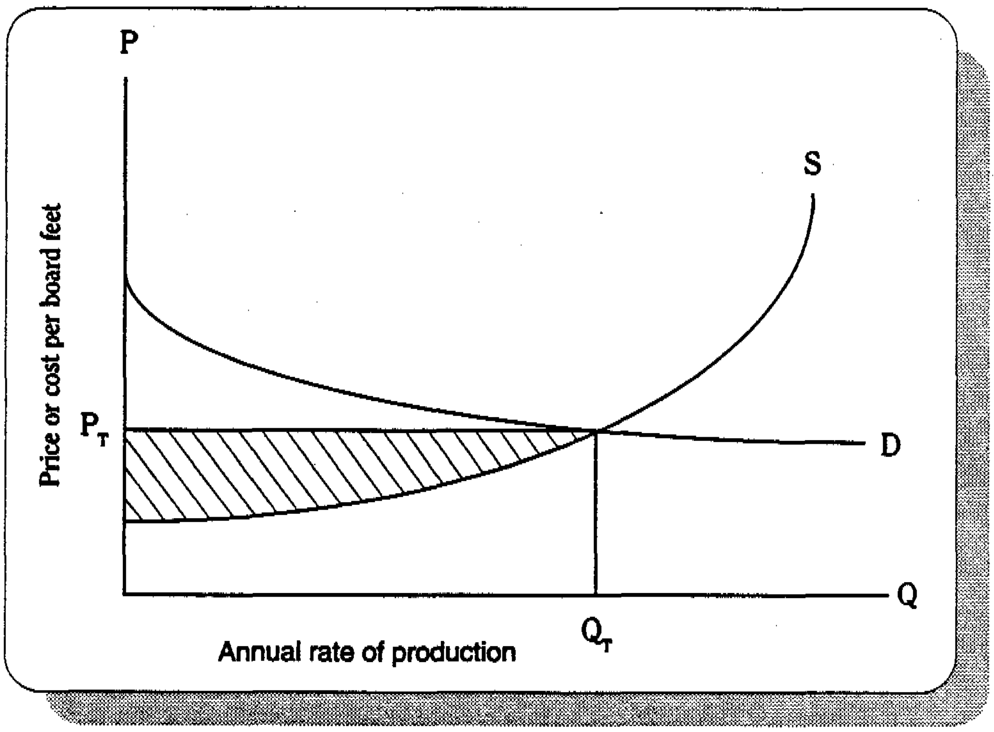


Figure G.6.* *Timber supply curve and economic rent.

The timber supply curve in Figure G.6 shows the economic benefit that can be realized from harvesting various portions of the timber resources in a region's forestlands. The costs of production reflect technologies currently available and the current prices of the resources used to harvest and transport timber. Under ideal market conditions, the portion of the timber inventory that is brought into production would be the portion that yields economic rent at prevailing prices, thus contributing direct benefits to the economy. If timber prices are low, only the lower-cost stands are brought into production. If timber prices are higher, then higher-cost stands can be brought into production as well, increasing the total rate of production and the economic rent. The total economic rent realized from the timber produced is equal to the sum of the economic rent realized from each of the stands contributing to production.

Timber consumers, such as sawmills, plywood mills, and pulp mills, also benefit from the production of timber. The extent of such benefits depends on the prices at which they sell their products, the other costs they incur in processing wood, and the price they pay for timber.

Figure G.7 shows the same supply and demand curves as Figure G.6. The demand curve for *timber shows the prices that timber buyers would be willing to pay for timber at different rates of timber consumption. The prices that mills would pay depend on wood product* prices and other mill operating costs. More efficient mills with lower operating costs can pay higher prices for timber and still make profits. Less efficient mills close when timber prices are high, reducing the rate of timber consumption. The substantial profits that can be made by most efficient mills during periods when timber prices are relatively low are represented by the difference between the highest prices on the demand curve and the prices set by the market when timber supplies are abundant. The hatched area in Figure G.7 represents the benefits to timber consumers, called the consumers' surplus by economists. In this case, it represents the sum of the profits made by mill operators at the timber price set by the market.

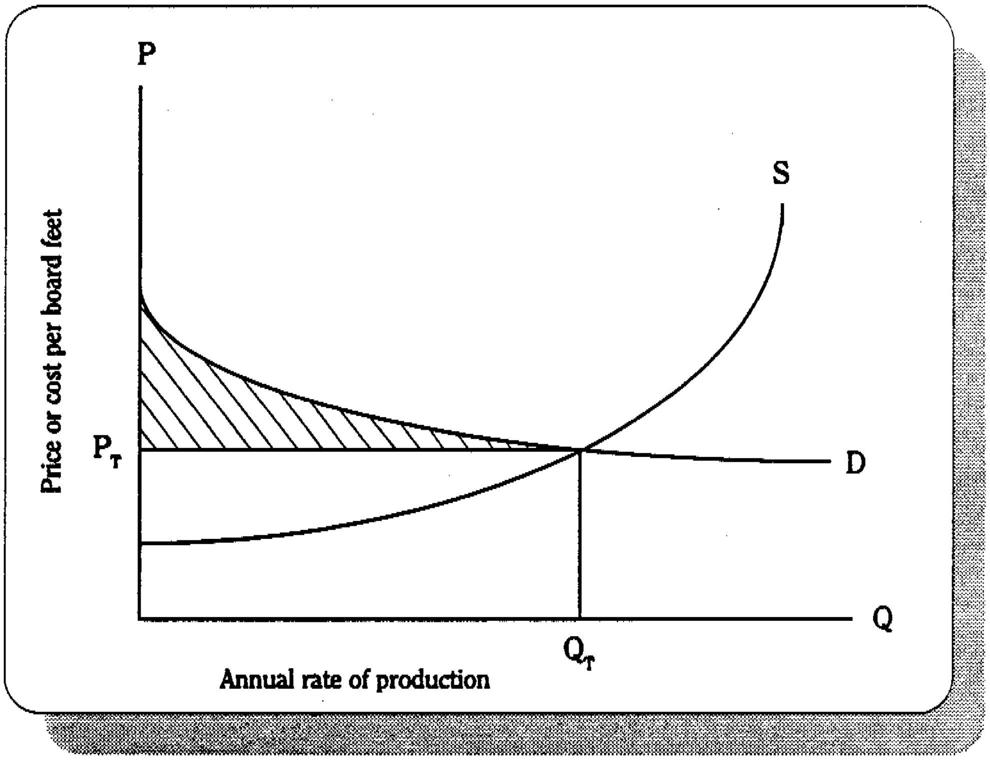


***Figure G.7.** Timber supply curve and consumers' surplus.*

3. Economic Effects of Owl Habitat Protection.

a. Costs

The dedication of substantial areas of federal forestlands to provide owl habitat will remove substantial amounts of land suitable for timber harvest from the federal timber base. What is the economic response and the effect on the various elements of the economy directly affected by this difference in the timber supply? In general, the following differences would be expected in future timber markets:

- The rate of federal timber harvest will be lower in future years than it would be without owl habitat protection.
- The rate of production from private lands will be somewhat higher.
- The price of timber will be somewhat higher.
- Federal revenues will be lower because of the foregone harvest, but will be higher on the remaining harvest because of the price increase.
- Private timber profits will be higher because of higher production and higher timber prices.
- Timber consumers, such as sawmills and plywood mills, will have lower profits because they must pay higher timber prices without receiving more for their lumber.

To estimate the extent of these effects, economists use the basic analytical concepts of supply and demand curves discussed earlier. Their application to the analysis of the effects of owl habitat protection is shown in Figure G.8. Without owl conservation measures, the total timber harvest would be Q_o, and the timber price would be P_o. The federal harvest, Q_{fed}, is shown as if it were the lowest cost source of supply, having cost approximately equal to C_o. Federal forests have most of the remaining old-growth timber that has the lowest cost per unit in the timber resource base. It is assumed that the rate of federal timber harvest would be lower by Q' because of the establishment of owl habitat conservation areas. In Figure G.8, the effect of the lower federal harvest is shown by a leftward shift in the timber supply curve (from S_o to S_f) that results from deletion of the segment of the original supply curve from the origin to Q'.

In Figure G.8, the equilibrium between the supply curve with owl habitat conservation, S_f, and the demand curve, D, is shown at E_f with the timber price, P_f, higher than P_o. With owl conservation, the harvest rate, Q_f, is less than Q_o but greater than Q_1, the harvest rate equal to (Q_o - Q') that would occur if there were no increase in the private harvest rate in response to the restriction in federal harvest. These features of Figure G.8 can be used to estimate the direct economic effects of the removal of forestlands from the timber base to protect the owl.

The basic concepts for analysis of the economic effects caused by owl habitat conservation are the economic rent realized from timber harvest and the consumers' surplus. The graphic representation of economic rent is shown in Figure G.6. The hatched area represents the sum of the profits that landowners would realize from harvest on all of the forestlands contributing to the annual harvest. These lands range from those with low costs that yield high profits to others with costs nearly equal to the price which logs bring that yield almost no profit. The graphic representation of the consumers' surplus is shown in Figure G.7. The hatched area represents the sum of mill profits ranging from the high profits earned by the most efficient mills to nearly zero profits earned by economically marginal mills with high costs.

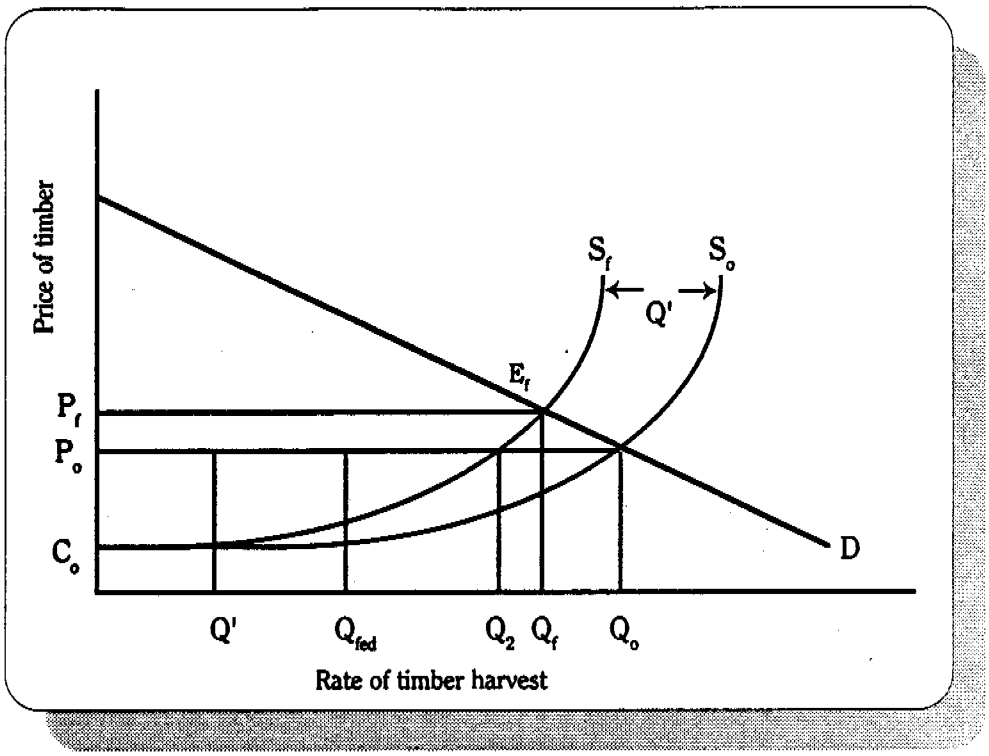


Figure G.8. *Effects of removal of timberland on regional timber market.*

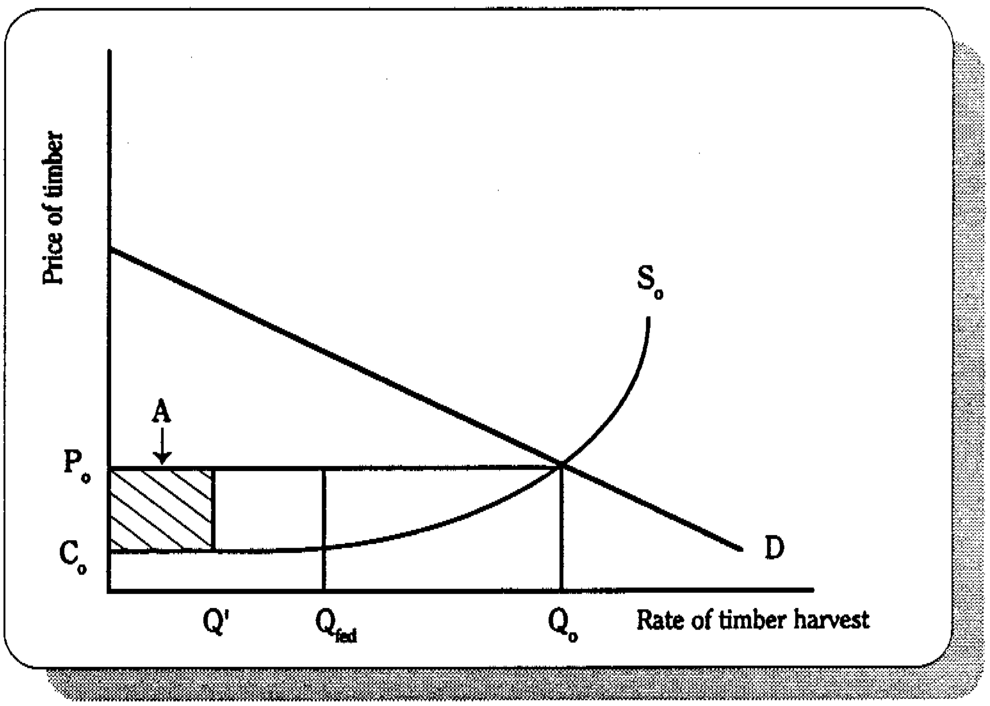


Figure G.9. *Economic benefit foregone by reduction in federal timber harvest.*

The federal government will not, of course, produce economic benefits or receive revenues for the portion of federal timber that is in forestlands reserved for owl habitat and must remain unharvested. The economic benefit that would result from this harvest is equal to the difference between the value of the logs that would be produced and the cost of harvest. This benefit is represented by Area A approximately equal to $(P_o - C_o) \times Q'$ in Figure G.9. The removal of federal forestlands from the timber base to provide owl habitat causes economic losses equal to this unrealized portion of the economic benefit.

The economic benefits from the federal timber harvest that continues despite protection of owl habitat would be higher because of the higher price of timber. The gain resulting from the higher timber price is shown in Figure G.10 by Area B equal to $(P_f - P_o) \times (Q_{fed} - Q')$. As we shall see, these gains to the federal government are offset by losses to timber consumers.

To compute the effects of owl habitat conservation on the benefits and revenues from federal timber harvest, we must know the relationship between the analytical concepts shown in Figures G.9 and G.10, and 1) the way costs are incurred by federal agencies and the timber buyers and 2) the receipts from these sales. The BLM and Forest Service incur different costs and structure bids for timber differently. These differences will affect the receipts that are foregone and the way they will save costs by not preparing for timber sales on the lands reserved for owl conservation.

Private timber producers also would benefit from receiving a higher price for the timber they would harvest even if there is no owl conservation. In Figure G.11, this is represented by Area C equal to $(P_f - P_o) \times (Q_1 - (Q_{fed} + Q'))$. As is the case for federal timber, this gain is offset by losses to timber consumers.

Private producers would also harvest at a higher rate in the case with federal owl habitat conservation in response to the higher price, P_f. The additional harvest is shown in Figure G.11 as $(Q_f - Q_1)$. This harvest is achieved at higher cost, however, as represented by the

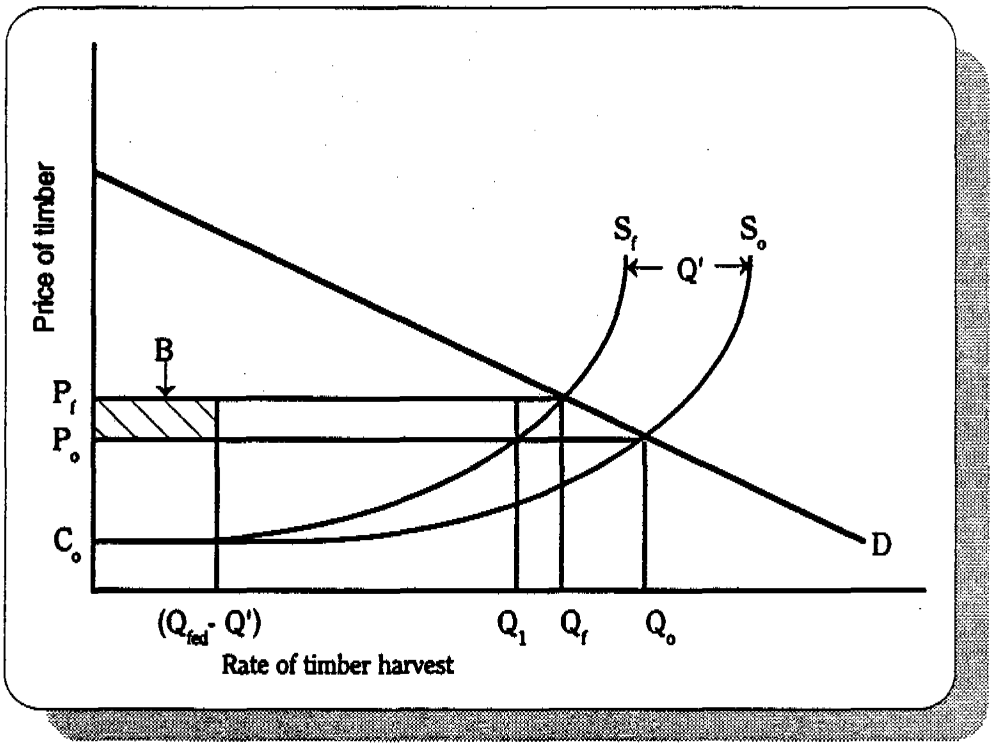


Figure G.10. Price-induced gains in economic benefits from federal timber harvest.

area under the supply curve, S_f from Q_1 to Q_f. The profit on this additional production is relatively small because of its high cost. It is equal to the area representing the additional revenues, $P_f x (Q_f - Q_1)$ less the area representing the additional costs. The profit on the additional private production is shown in Figure G.11 as the small triangular Area D under price line P_f but above S_f.

Although the federal government and private timber owners benefit from the price increase, consumers of timber, such as sawmills and plywood mills, lose. To determine the total effect on the economy, we must estimate the effects on timber consumers as well as producers. Mills lose because the higher price of logs that results if timber harvest on federal lands is restricted by protection of owl habitat causes lower profits.

The graphic analysis of the effects on timber consumers is shown in Figure G.12. If there were no owl conservation, the timber buyers' benefits are represented by the roughly triangular area with corners at P_o, I_D, and E_o. If owl conservation restricts timber supply, the timber buyers' benefits are represented by the roughly triangular area with corners at P_f, I_D, and E_f. The losses experienced by timber buyers are represented by the difference between the two triangles, shown as hatched Area E.

Careful analysis of the computations for the areas representing price-induced gains to the federal government (Area B in Figure G.10) and the private timber producers (Areas C and D in Figure G.11) shows that they are all included in Area E in Figure G.12 representing losses to timber buyers. Thus, the price-induced gains to timber owners are achieved at the expense of timber buyers. Moreover, the losses to timber buyers exceed the price-induced gains to timber producers by Area F shown in Figure G.13.

Figure G.13 shows the graphical representation of the total cost from loss in timber production due to habitat conservation. The total cost is the sum of Area A, the loss of economic benefits on the federal timber that will not be harvested, and Area F, the net loss caused by timber price increases. These costs reflect all of the effects on the national economy that occur in timber markets. If all of the costs of harvesting timber, including all

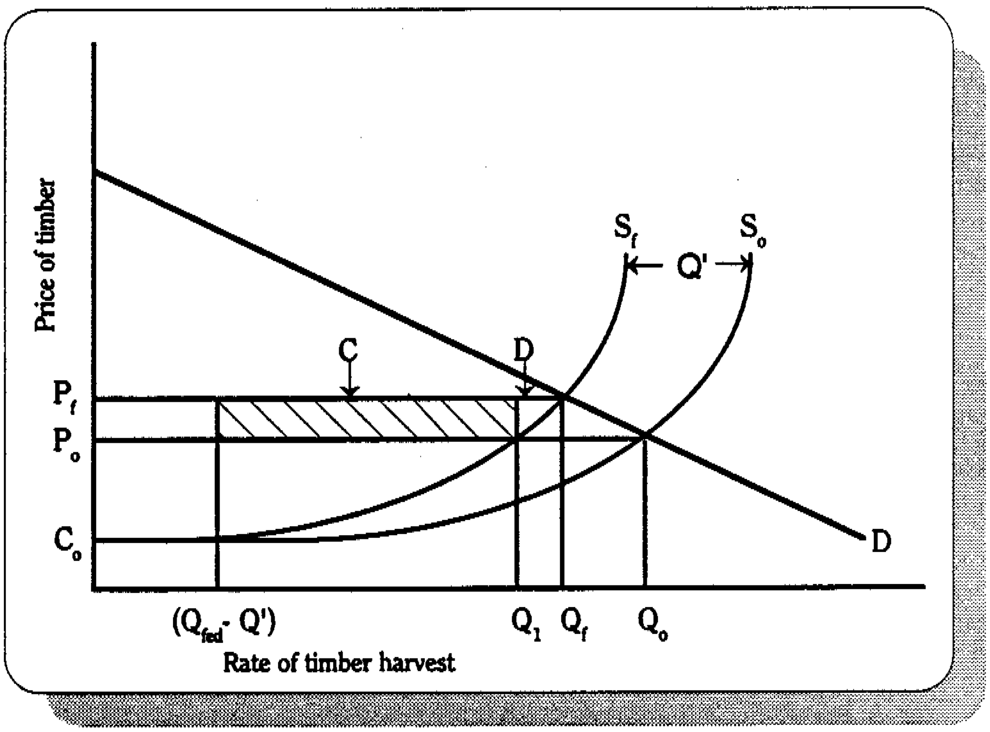


***Figure G.11.** Price-induced gains in economic benefit from private timber harvest.*

environmental costs such as lost recreational opportunities and effects on water quality, were paid by firms harvesting timber and were reflected in the supply curve (S_f), then the losses shown in Figure G.13 would be the total national cost of protecting owl habitat. Because such costs are external to transactions in the timber market, the reduced environmental costs caused by reduced timber harvest must be estimated separately.

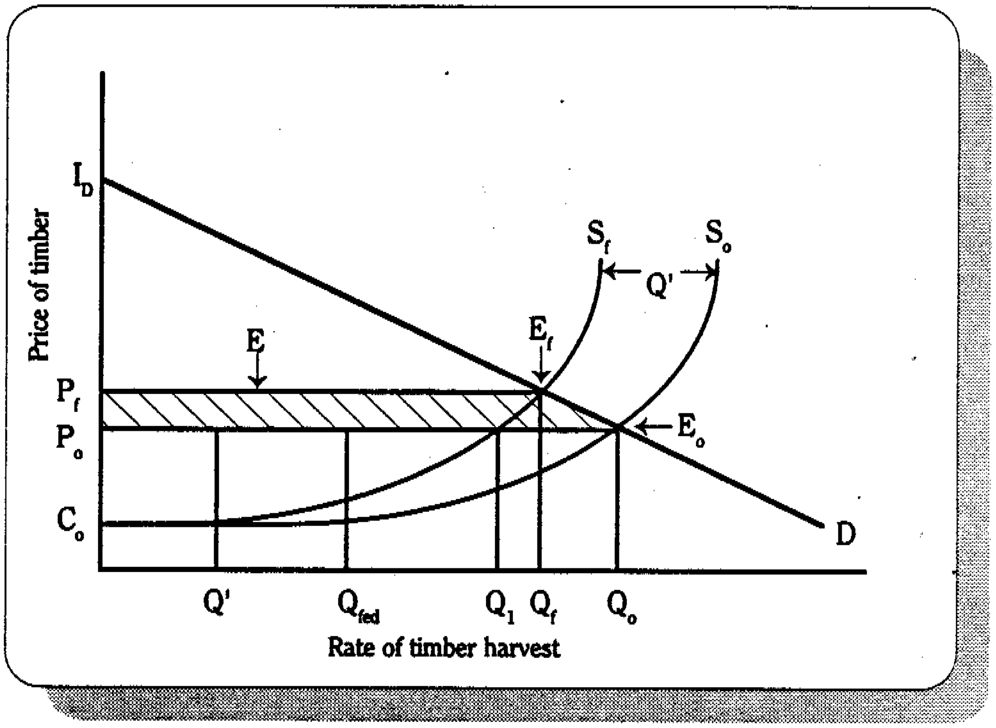


Figure G.12. *Price-induced losses in benefits for timber consumers.*

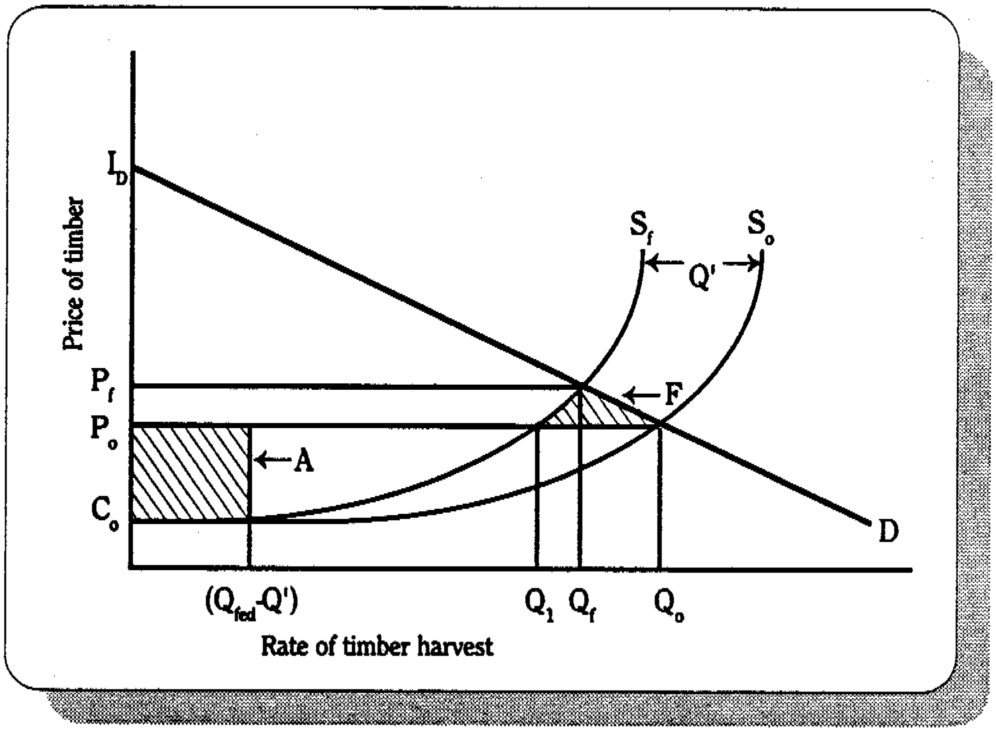


Figure G.13. *Total economic losses from reduction in federal timber harvest.*

The economic effects of protecting owl habitat can be viewed from the regional as well as the national perspective. This requires an accounting of the effects on the regional share of the national economic benefits created by timber harvest as well as for the effects on regional income generated by the purchase of labor, equipment, materials, and services for harvesting and processing timber.

The Pacific Northwest shares in the benefits from timber harvest, shown in Figure G.6, in several ways. First, counties receive 25 percent to 50 percent of federal timber sales receipts. Second, firms that own forestlands in the region earn profits on timber they harvest. State governments also receive revenue from timber harvest on state lands.

The income created by the purchase of labor, equipment, materials, and services used in harvesting and processing timber is also a part of the regional economy. Since the primary component of this income is wages and salaries, analysis of these effects is based upon concepts regarding the demand for labor in the timber industry and the relationship between the level of employment in the timber industry and the level of employment in related industries. The next section presents concepts that are useful for understanding the employment effects of protecting owl habitat.

The analytical concepts discussed earlier are static. They show differences between two future situations, one without protection of owl habitat, one with owl habitat protection. They do not show how the economy would change over time in response to the implementation of a new policy such as the recovery plan. A few observations can be made, however, about the dynamic response of the economy using the same concepts.

The response of the private timber industry to reductions in federal timber harvests in the Pacific Northwest is of particular interest. As shown in Figure G.14, the initial market response to the change in the timber supply is to drive timber prices up to P_i. Private timber owners will respond by increasing their rate of timber harvest to the extent that they can do so at a profit at the higher prices. This increased harvest will partially offset the reduction in the federal timber harvest and will drive the timber price down toward P_r. It appears, however, that the additional harvest from private forestlands will be limited in amount and duration because of the relatively small portion of those lands with trees of harvestable, or nearly harvestable, age.

In general, timber harvest in the present tends to reduce the potential harvest in future years. This effect of timber harvest can be viewed as a tendency for the timber supply curve to shift toward the left over time, because the timber that is harvested tends to be the lower-cost timber in the inventory. The tendency of the supply curve to shift leftward over time due to timber harvest is counteracted by the natural growth of trees in the inventory and by technological developments that reduce the costs of harvest and transportation. The timber market tends to balance the overall rate of harvest with the rates of growth and technological progress.

In recent decades, federal timber harvest policy has provided assurance of future timber supplies, preventing the depletion of timber on private lands from causing expectations of higher future prices which are the market's signal to delay harvest. As a result, private timber harvest has not slowed, creating a dip in the potential for timber harvest during the next decade or two.

The additional harvest from private forestlands also is likely to be limited by two factors that will tend to counteract the tendency for timber prices to remain higher. First, during the period of higher timber prices, some mills will be forced to close. The resulting decrease in mill capacity in the Pacific Northwest would appear in Figure G.14 as a downward shift in the demand curve. Second, the rate of timber harvest in other regions

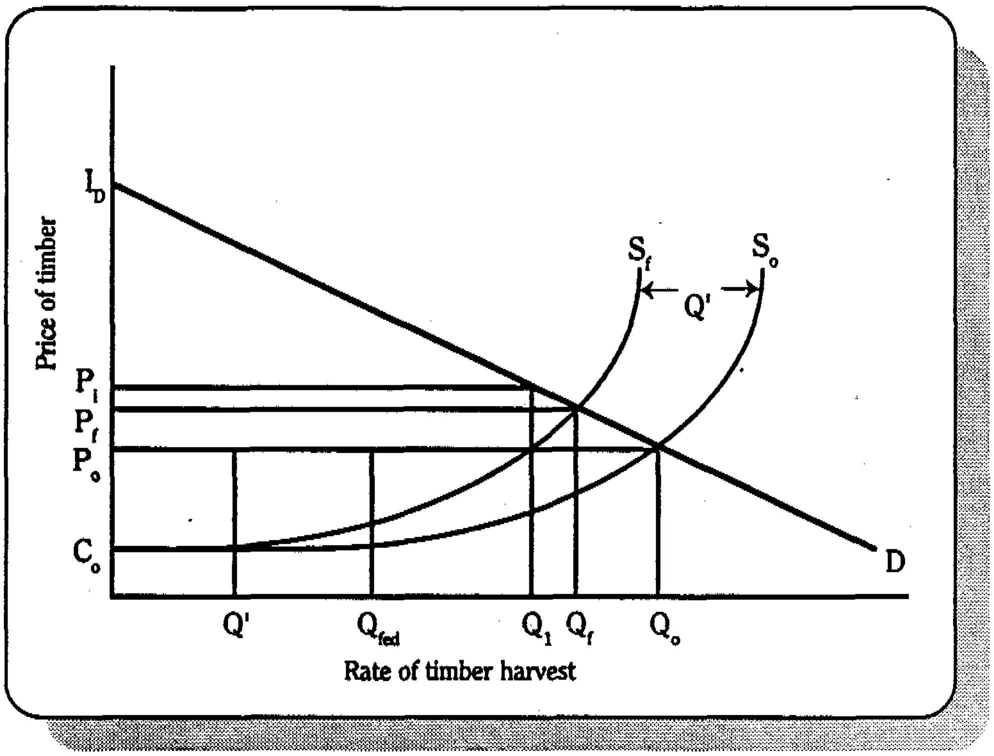


***Figure G.14.** Dynamic effects of removal of timberland on regional timber market.*

also would increase in response to the higher price. More lumber would be produced in other regions, putting further downward pressure on the demand for timber in the Pacific Northwest. The downward movement of the demand curve would tend to put downward pressure on timber prices, undercutting the increased harvest on private forestlands.

b. Benefits

In addition to effects on timber markets, protecting habitat for spotted owls is expected to have beneficial effects on several aspects of environmental quality which will have beneficial economic and social effects. Such environmental benefits occur because the environmental damage caused by timber harvest is lower if the rate of timber harvest is lower. The economic benefits would arise primarily in recreation and fishing. A useful summary of such benefits is provided in USDI 1992a.

In general, implementing the recovery plan would be expected to cause the following benefits:

- Recreational experiences in portions of the federal forestlands that would otherwise be harvested will be higher in value.
- The scenic quality experienced by residents and travelers in the Pacific Northwest will be higher in value.
- The biological diversity of the Pacific Northwest will be greater. (See section III.I. and Appendix D. in the recovery plan for discussions of the benefits to other threatened or endangered species associated with late-successional forests.)

- Conditions in some streams will be more favorable for fishes, other aquatic and riparian organisms, and flora.
- Fishing and other stream-related recreational activities will be higher in value.
- Employment and income in businesses supporting recreation and fishing will be higher.
- Water quality would improve in many areas.

4. The Demand for Labor in the Timber Industry.

Reduced employment is an important effect of owl conservation measures, particularly at the personal and local levels. Because people lose their jobs and income, employment reductions are regarded as undesirable impacts. While such effects are bad at the personal and local level in the short run, paradoxically they are much less damaging over the long run at the regional and national levels. To assess employment effects, it is useful to understand how labor markets operate to put people to work in ways that achieve greater total output and how timber availability affects employment.

Economists usually consider the labor involved in any enterprise like timber harvest or milling to be a cost rather than a benefit. Businesses correctly regard labor costs as an important element of total production costs in their efforts to operate efficiently. The labor used in timber harvest and milling could contribute to producing other goods. Its cost is a measure of the other production given up by using labor in the timber industry. Over the long run, labor-saving measures are usually beneficial to the economy, because they allow the work force to be deployed in a manner that yields greater total output.

However, our economic system does not always shift labor effectively from one activity to another. When people become unemployed, they may not find new employment for an extended period of time. While they are unemployed, they are not contributing their productive services to the economy. In some cases, the new employment opportunities are less productive and less remunerative than previous jobs.

The value of total economic production decreases if people are unemployed or are reemployed in less productive jobs that bring lower wages. At the local level, unemployed people have less money to spend. Lower spending reduces employment in a variety of businesses. At the personal level, unemployment can cause great hardship and stress for unemployed individuals and their families. Extended periods of higher than normal unemployment are bad for the unemployed individuals and the economy as a whole.

Two concepts are useful for understanding the employment effects of owl conservation measures. One is the relationship among the various factors that affect the decisions of businesses with employment directly related to timber harvest, such as sawmills. The key factors of interest are the supplies of timber and labor and the demand for timber. The second is the relationship between direct employment in timber harvest and milling and employment in related industries and in the economy as a whole.

There are a number of factors that affect a sawmill's management decisions. The mill manager determines the rate of lumber production, the rate of timber purchases, and the amount of labor and other inputs the mill needs for that rate of production. These decisions are affected by the price of lumber, the price of timber, and the prices of labor and other inputs. The demand for workers in the timber and wood products industries results from the decisions of many mills and other businesses involved in the harvest, transportation, and processing of timber.

The price of timber provides the connection between the availability of timber as represented by the timber supply curve and the rate of production and levels of employment in timber businesses. As shown in Figure G.6, the price of timber is represented by the intersection between the demand curve for timber and the supply curve.

The demand curve for timber shows the rate of timber consumption at each timber price. The demand for timber is derived from the demand for lumber. If there are many firms producing lumber, none can affect lumber prices. Each sawmill must sell its lumber at the market price. At a given lumber price, each sawmill's profits and production rate depend on the firm's costs. The price of timber is an important factor in the total cost of producing lumber. When timber prices increase, profits and the rate of production decrease.

Some firms are efficient enough to be able to absorb an increase in the price of timber and continue operating, though at lower output. Firms that were marginally profitable before an increase in timber prices will be forced to close. When the price of timber in a region is higher, the total output of lumber will be lower.

To minimize costs, a firm would normally adjust its mix of inputs whenever an input price changed significantly. Often, increased use of some inputs can offset the reduction in use of an input whose price has increased. In sawmill operations, however, there is little flexibility to alter the amount of timber needed to make a board foot of lumber, at least in the short run (the period during which capital equipment cannot be changed). Therefore, to simplify the discussion, it is reasonable to assume that for each rate of lumber production there is a corresponding rate of timber purchases by the mill. Furthermore, for each rate of lumber production, there is a profit-maximizing employment level. Direct employment in the timber and wood products industries is higher when timber prices are lower. If restrictions in the availability of timber for harvest shift the supply curve to the left, as in Figure G.5, timber prices will be higher. As a result, lumber output and direct employment will be lower.

The level of output in a region's timber industry also affects employment outside of that industry. Timber businesses buy goods and services from a variety of firms in other sectors of the economy, from equipment manufacturing to accounting. At lower levels of output, the timber industry uses less of these goods and services. Firms in other sectors must reduce their levels of output to avoid producing goods that cannot be sold. Workers are laid off or new hiring is deferred when such reductions occur. Changes in output in the timber and wood products industries induce changes in employment in other sectors. In addition to the direct employment effects of a change in timber availability, there are indirect employment effects in the related industries.

Further employment effects, called induced effects, occur because of the changes in income levels that are caused by changes in employment. Induced effects result from the reduced consumer spending that is caused when unemployment reduces the income people have to spend. The total employment effects of reducing timber availability include direct, induced, and indirect effects.

5. Effects on the Value of Capital Assets.

The two forms of asset most strongly affected by the reduction of timber harvest are sawmills and homes. Home asset losses result from the decline in income of many residents in a community. Losses in the value of housing cause a transfer of wealth that can seriously affect people's lives, but such losses do not represent a significant loss to the output of the national economy.

Losses in the value of real estate also cause a reduction in the tax base of local governments. When mills close because they cannot make a profit at the higher timber prices that will result from owl conservation, the mill equipment usually is scrapped. Capital equipment of this sort is valued for the profits it can yield. Once the profits disappear, the value of the capital becomes negligible. Although the resulting loss in mill asset values reflects a loss in economic output in the national economy, that loss is already accounted for by the reduction in timber consumers' surplus (that is, profits) discussed earlier. Estimates of housing and mill asset losses are of interest primarily because of their effect on the local or regional economy but they should not be added to the estimates of the underlying losses in the components of income that cause them.

C. Estimating Economic Effects of Implementing the Recovery Plan

As noted earlier, the FWS, with assistance from the Forest Service and BLM, conducted an economic analysis of the critical habitat designation for the northern spotted owl (USDI 1992a). As a part of this analysis the FWS developed methods to estimate the loss of federal timber harvest from various measures to protect owl habitat. The agency developed methods for estimating the employment effects of the resulting harvest reductions in each of the affected counties. It also developed methods to estimate the net effect on the U.S. Treasury and on the timber revenues shared with the county governments. The analysis provided a comparison of the effects of the original forest plans, the implementation of the ISC strategy and the effect of Endangered Species Act protection of the owl, including the designated critical habitat. To provide comparable estimates for the recovery plan, it was decided that the same methods of analysis, with some adjustments appropriate to the recovery plan, would be applied to estimate the economic effects of implementing the recovery plan.

The methods used for making preliminary estimates of the effects of implementing the recovery plan are summarized here.

1. Estimating the Loss of Benefits from Federal Timber Harvest.

The estimation of the loss in the economic benefits from the federal timber harvest that will be foregone to provide owl habitat (Area A in Figure C.13) is straightforward. An estimate of the change in the annual harvest is multiplied by an estimate of the price that would have been bid for the timber. The appropriate price to use in this computation is the price that would occur if the recovery plan is not implemented.

The Forest Service and BLM provided the Recovery Team with estimates of the reduction in federal timber available for sale that would result from implementation of the draft recovery plan which was released in May 1992. The Team used these estimates to derive estimates of timber productivity factors (in board feet per acre) for the DCAs in each national forest and BLM district. These factors were used to estimate the reductions in timber harvest (assuming that annual timber harvests would be, on average, equal to the amount available for sale) that would result from the DCAs proposed in the final recovery plan. In addition to establishing the DCAs, the recovery plan would impose restrictions on timber harvest on federal lands outside of the DCAs, an area called the matrix. The Forest Service and BLM also provided estimates of the reduction in timber harvest that would result from the management guidelines for the matrix.

To assess the economic effects of the recovery plan, it is necessary to specify the baseline to which the conditions resulting from implementation of the recovery plan will be compared. Many people would choose the present or recent past as the baseline. This approach has the advantage of showing the total change people are likely to experience between conditions they have experienced and conditions that will result from implementing the recovery plan. Unfortunately, comparison of current or recent conditions with future conditions under the recovery plan can cause confusion between the effects of the recovery plan and the effects of other economic factors that can affect the timber industry. Such factors include the recent recession, other restrictions in the availability of timber from federal forestlands (such as court orders barring timber harvest on federal lands), and changes in labor productivity in the timber industry. To avoid such confusion, the estimates for the recovery plan were developed by comparing expected economic conditions in the mid-1990s with implementation of the recovery plan to conditions in the mid-1990s without the recovery plan.

Of course, one must then specify what policies would be expected to govern timber harvests on federal lands in the absence of the recovery plan. There are a number of possibilities that could be used for purposes of comparison. One is the conditions that would result if federal forestlands were to be managed according to the plans and policies in effect prior to federal listing of the spotted owl. A second basis for comparison would be the current plans and policies governing the federal forests as presented in the most recent plans or draft plans of the Forest Service and the BLM as well as the current policies of the FWS for enforcement of the provisions of the Endangered Species Act regarding the spotted owl. In this appendix, estimates of economic effects are presented in a manner that allows both comparisons.

It is important to note that the estimated reductions in future timber harvest are based upon the assumptions underlying the baseline estimates of the harvest under Forest Service and BLM plans. In general, factors that would tend to reduce the harvest under these plans also would tend to reduce the harvest under the recovery plan, reducing estimated harvest levels for both the baseline and the recovery plan.

The estimated annual timber harvests for the Forest Service and BLM plans, the current owl management regime (Forest Service and BLM implementation of the ISC strategy), and the recovery plan are in Table G.10.

The estimated loss due to the timber harvest foregone compared to prior agency plans is $830 million per year. This estimate is based on the reduction in timber harvest caused by withdrawal of the lands in the DCAs and on estimates of 1995 timber prices developed by the Forest Service using the Timber Assessment Market Model (TAMM) for conditions expected under the final plans (USDA 1991a).

2. Estimating Employment Effects.

Substantial effort has been made in recent years to develop techniques for estimating the employment effects of reductions in the rate of timber harvest. In its economic analysis of proposed critical habitat, the FWS, with assistance from the Forest Service, developed job response coefficients for use in estimating the employment effects of the designation of critical habitat for the owl. These coefficients were developed by the Forest Service using

Table G.10. Comparison of estimates of federal timber available for harvest, 1995

	(Billons of board feet)			
	Timber Harvest with Timber Harvest with Final Plans***	Timber Harvest Current Owl Management*	Timber Harvest with FS EIS[b] and BLM Draft RMPs[b]	with Recovery Plan (DCAs & Matrix)
Washington				
Forest Service	0.75	0.28	0.33	0.30
Oregon				
Forest Service	1.86	0.98	1.18	1.16
BLM	1.19	0.40	0.49	0.30
Oregon Subtotal	3.05	1.38	1.78	1.46
California				
Forest Service	0.60[a]	0.26	0.28	0.28
BLM	0.00	0.00	0.00	0.00
California Subtotal	0.60	0.26	0.28	0.28
Salvage and Silviculture**	NA	NA	NA	0.13
Three-state Total	4.39	1.92	2.28	2.16
Forest Service	3.20	1.52	1.79	1.84
BLM	1.19	0.40	0.49	0.32

[a]Projections. Final forest plans have not been released.
bCurrent agency plans (Forest Service Final Supplemental EIS and BLM draft Resource Management Plans)
*Estimates based on agency estimates for implementation of Interagency Scientific Committee plan and critical habitat.
**Effects of limited silviculture and salvage in DCAs, allocated in proportion to harvest in agency totals.
***Timber harvest under continuation of policies in Forest Service and BLM plans in effect before the 1990 listing of the northern spotted owl.
DCAs = designated conservation areas.
BLM = U.S. Bureau of Land Management in Oregon and California.
NA = not applicable.
Forest Service = U.S. Forest Service in Oregon, Washington, and California.

IMPLAN, an input-output model that simulates the transactions between various sectors of the economy. Adjustments were made during the development of these job coefficients to reflect the log flows among counties. Adjustments also were made in the coefficients to remove the effects of the large metropolitan areas from the county coefficients. This was done to produce estimates of job losses that would measure the impacts within the rural regions whose economies are most closely related to timber production. A more detailed description of the use of the IMPLAN model and these adjustments are provided in the FWS report (USDI 1992a). The resulting job coefficients generally fall in the middle of the range of other multipliers that have been used for estimating employment effects of changes in timber harvest. They are generally consistent with the results of the review of a number of such studies by Stevens (1991).

The FWS used these job response coefficients to estimate the employment levels that would result from timber harvest under the forest plans, the BLM and Forest Service implementation of the ISC strategy, and the Endangered Species Act, including designation of critical habitat. To provide a consistent analysis of the recovery plan, the same methods of analysis were applied to estimate its employment effects. Table G.4 shows the job coefficients used in this estimation. Table G.11 compares the estimated employment effects of recovery plan implementation with prior final plans . Table G.12 shows the employment effects of the draft recovery plan DCAs by county. It should be noted that those estimates do not reflect all of the employment effects in the three states because large urban areas have been removed in developing the county job coefficients (USDI 1992a).

3. Estimating Wage Losses.

Protection of owl habitat causes wage losses because reductions in the level of employment in the timber industry cause layoffs. People who lose their jobs are unemployed for a period, during which they earn no income, and then at least some are reemployed, often at a lower wage. Some displaced workers gain reemployment in the timber industry, displacing other workers. To estimate the wage losses due to implementation of the recovery plan, it is necessary to estimate the number of workers that would be displaced each year, the period during which those workers would be unemployed, and the wage level at which those workers would be reemployed.

Wage losses were estimated for the recovery plan and for other owl habitat protection plans using the same assumptions used by the FWS in its analysis of the critical habitat designation. These estimates were based on the employment levels estimated for the annual harvest levels for the various plans. To estimate the period of unemployment, the FWS assumed that displaced workers will be reemployed within 2 years, with 92 percent reemployed by the end of the first year after displacement and 8 percent at the end of the second year. For comparison, estimates were made using the assumptions that only 70 percent of displaced workers are reemployed by the end of the first year and 30 percent by the end of the second year. The estimates for wage losses resulting from the recovery plan were based on the following wage data for the three states.

Average Annual Wages
(1990 data adjusted to 1992 dollars)

	Timber and Wood Products Industry	**Trades, Services, Manufacturing**
Washington	31,569	24,497
Oregon	28,644	22,483
California	28,063	28,075

Source: Council of Economic Advisors (pers. comm.)

Using the two reemployment estimates, the wage losses from implementation of the recovery plan were estimated to be $1.6 to $1.8 billion over 20 years (estimated at 10 percent).

4. Estimating the Economic Effects of Silvicultural Practices.

The recovery plan provides for the use of silvicultural techniques in DCAs for the purpose of promoting more rapid development of forest characteristics favorable to the owl in stands that do not currently have the characteristics of suitable habitat. In general, younger stands would be thinned in a manner that promotes more rapid development of larger trees and other structural characteristics of suitable owl habitat. These techniques are described and evaluated in Appendix F. in the recovery plan.

The implementation of silvicultural practices in DCAs is one of the features of the recovery plan with potential to reduce the undesirable economic effects of protecting owl habitat, particularly during the first decade. The direct economic effects of silvicultural practices result from the equipment and labor costs of silvicultural operations, such as thinning, and the removal of timber from younger stands that can be sold commercially.

There are also important indirect effects that could be of significant benefit over the long run. It appears that properly designed silvicultural treatments will be able to significantly shorten the time needed for the development of suitable habitat in regenerated forests. Such practices would mean that stands would provide suitable habitat for owls for a longer period of time. If widely applied for several decades, particularly in concert with longer rotations and selective harvest techniques, it may be possible to evolve a forest landscape to support a viable owl population with much less reduction in timber harvest than otherwise would be needed.

The variable that most strongly affects the economic benefits of silvicultural treatments is the percentage of timber that is removed and sold commercially. The thinning prescriptions specify the density of the stand in trees per acre after thinning. The design of the treatment identifies trees to be cut, leaving sufficient trees to meet the density standard. The design also will specify the percentage of such trees to be removed, left standing, and left on the ground. These design parameters will depend on the characteristics of the stand and the requirements specified for promoting the development of suitable owl habitat.

If no timber is removed during thinning, then the costs of the treatment will not be offset by timber revenues and will need to be borne by agency budgets. Employment will result from the thinning itself, but not from hauling or milling of timber. As the amount of timber removed during thinning is increased, the revenues increase and the employment in hauling and milling logs increases. For each stand, there is a breakeven point which depends on costs of operating on that site, the transportation costs, the diameter of the trees to be removed, and the price of logs. Above the breakeven point, the silvicultural treatment is commercially viable and could be performed under a contract in which the proceeds from sale of the timber removed cover the costs. Any surplus would be bid away to the benefit of the government if such contracts were auctioned like timber sales.

Estimates of the costs and returns of various silvicultural practices in various types of stands were developed by Chadwick Oliver of the University of Washington (Oliver 1991). The costs and returns per acre for various silvicultural systems are in Table F.1 of Appendix F in the recovery plan. A typical regime is the low-density system for west side 30-year-old stands. This treatment calls for thinning to 100 trees per acre at age 30 with subsequent removal of 20 trees per acre at age 50 and again at age 70. The total undiscounted costs with no removal of timber are estimated to be about $340 per acre and the returns (above costs), if all thinned trees are removed, are estimated to be about $7,165 per acre. Although relatively few trees are removed in the second and third thinnings, most of the returns result from sale of that timber since the trees removed are much larger. If the costs

Table G.11. Comparison of estimates of timber employment levels, 1995, related to federal timber harvest (with conservation areas and matrix).

	Employment Level with Final Plans**	Employment Level with Recovery Plan (DCAs & Matrix)
Washington		
Forest Service	10,342	5,058
Oregon		
Forest Service	29,754	19,217
BLM	18,546	6,122
Oregon Subtotal	48,300	25,339
California		
Forest Service	7,728[a]	3,999
BLM	25	0
California Subtotal	7,753	3,999
Salvage and Silviculture*	NA	1,770
Three-state Total	66,395	36,166
Forest Service	47,824	29,729
BLM	18,571	6,437

[a]Projections. Final forest plans have not been released.
*Effects of limited silviculture and salvage in DCAs.
**Continuation of policies in Forest Service and BLM plans in effect before the 1990 listing of the northern spotted owl.
DCAs = designated conservation areas.
BLM = U.S. Bureau of Land Management in Oregon and California.
NA = not applicable.
— = unknown.
Forest Service = U.S. Forest Service in Oregon, Washington, and California.

and returns from thinning at ages 50 and 70 are discounted to present value at the time of the first thinning using an 8 percent discount rate, the costs with no removal become $53 per acre and the returns with full removal become $1,109 per acre. In addition, it was estimated that implementing this prescription uses, on average, about 3.64 person-years per acre and could produce a maximum of about 3,833 board feet per acre.

For purposes of estimating the potential economic effects of silvicultural practices in DCAs, the costs and returns for the low-density system on 30-year-old stands shown in Table F.1 of Appendix F were assumed to be the end points of a linear relationship starting at 0 percent and ending at 100 percent. It was assumed that 50 percent of the thinned trees would be removed on average.

Estimates of the acreage in DCAs that would be an appropriate target for such practices were developed by using estimates of unsuitable habitat acres in DCAs from the Recovery Team's GIS (geographic information system). Unsuitable habitat in the DCAs accounts for nearly 2.5 million acres. Since only stands age 30 to 40 years or stands with trees less than

Table G.12. Estimates of state and county timber industry employment effects of the recovery plan.

State/County	Timber and Wood Products 1989 Employment**	1995 Employment Losses Total Jobs	1995 Employment Losses Direct Jobs	1995 Direct Jobs Lost as Percent of 1989 Timber and Wood Products Employment
Washington				
Chelan	360	414	247	69
Clallam	2,356	864	479	20
Clark	5,171	17	10	*
Cowlitz	7,060	53	34	*
Grays Harbor	4,262	437	242	6
Jefferson	114	0	0	0
King	9,049	55	28	*
Kittitas	194	78	47	24
Klickitat	931	23	14	1
Lewis	2,626	1,522	921	35
Mason	1,456	165	96	7
Okanogan	1,286	160	108	8
Pierce	4,268	322	201	5
Skagit	1,177	52	33	3
Skamania	535	188	114	21
Snohomish	4,959	844	527	11
Whatcom	1,981	90	57	3
Yakima	2,097	0	0	0
Washington Total	**49,882**	**4,281**	**2,559**	**6**
Oregon				
Benton	1,496	42	23	2
Clackamas	3,460	747	502	15
Columbia	0	0	0	0
Coos	2,547	410	236	9
Curry	929	989	554	60
Deschutes	3,428	78	49	1
Douglas	8,228	7,795	5,238	64
Hood River	532	347	235	44
Jackson	6,071	2,357	1,320	22
Jefferson	999	0	0	0
Josephine	2,186	304	161	7
Klamath	3,769	690	430	11
Lane	11,314	5,809	3,164	28
Lincoln	496	64	35	7
Linn	5,557	1,469	800	14
Marion	3,430	1,113	629	18
Multnomah	3,974	108	65	2
Polk	880	5	3	*
Tillamook	423	361	220	52
Wasco	326	271	183	56
Washington	0	0	0	0
Yamhill	1,621	0	0	0
Oregon Total	**61,666**	**22,959**	**13,848**	**22**

Continues –

Continued

State/County	Timber and Wood Products 1989 Employment**	1995 Employment Losses: Total Jobs	1995 Employment Losses: Direct Jobs	1995 Direct Jobs Lost as Percent of 1989 Timber and Wood Products Employment
California				
Colusa	0	0	0	0
Del Norte	478	0	0	0
Glenn	47	0	0	0
Humboldt	4,623	1,602	965	21
Lake	38	0	0	0
Mendocino	3,142	126	79	3
Shasta	2,240	140	45	2
Siskiyou	1,618	1,179	377	23
Tehama	1,774	0	0	0
Trinity	425	701	360	85
California Total	**14,385**	**3,748**	**1,826**	**13**
Three-state Total	**125,933**	**31,991**	**18,834**	**15**

*Less than 1 percent.
**County timber and wood products employment generally has declined since 1989.

11 inches dbh would make good targets, information about the age and size distribution of stands in the national forests and BLM lands was used to determine the percentage of unsuitable habitat likely to be an appropriate age during the 1990s (USDA 1991b, c, d, and Berg pers. comm.). For purposes of estimating the economic effects of silvicultural treatments, it was assumed that 15 percent of unsuitable habitat on Forest Service lands and 30 percent on BLM lands would be appropriate for silvicultural treatment. The resulting target acreage is about 450,000 acres.

Implementation of silvicultural practices to promote development of suitable owl habitat will be the responsibility of the land management agencies, the BLM and Forest Service. The rate of treatment of the target acreage will depend on administrative and budgetary factors that the Recovery Team cannot accurately anticipate. To show the range of potential economic effects from an aggressive program of silvicultural treatment to a go-slow approach, various assumptions were made regarding the percentage of target acreage that would be treated in each year during the first decade of recovery plan implementation.

Estimates for the employment and economic gains from a program of silvicultural treatment in DCAs are in Table G.13. The economic gains are substantial. Even under the assumption that only 50 percent of the thinned trees will be removed, a program treating 50,000 acres per year would yield about 100 million board feet per year. The employment created by such a program also could be significant, about 600 jobs. It is important to note, however, that the wages for thinning are generally much lower than the wages for commercial harvest and that migrant laborers often are used for such work. If the employment created by a silvicultural program is to benefit workers displaced from harvesting timber, employment preferences may need to be made a requirement of the contracts let for such work.

5. Estimating the Economic Effects of Salvage.

As described in section III of the recovery plan, the recovery plan allows limited salvage in the DCAs. Forest Service and BLM timber salvage sales averaged more than 650 million board feet per year during the 1980s. A rough estimate of the economic effects of allowing salvage was made by assuming an annual potential salvage of 600 million board feet total, of which the DCAs would contain approximately one third. The guidelines for salvage in DCAs are in section III.C of the recovery plan. It was assumed that the guidelines would allow 10 to 20 percent of the potential salvage, leaving the rest of the dead trees to contribute to maintenance of habitat conditions. Annual salvage in DCAs could yield 20 to 40 million board feet. The total job coefficients for the timber counties range from 8 to more than 17 jobs per million board feet, averaging 15.7. At the average total job coefficient, salvage in DCAs could support 315 to 630 workers.

6. Estimating the Effects on County Revenues.

In its analysis of the effects of the critical habitat designation, the FWS developed methods to estimate the price effect of restrictions in timber harvest and its effect on the federal receipts from the remaining timber volume. The FWS also worked with the Forest Service and BLM to develop the computational methods needed to allocate the estimated federal timber sale revenues to the counties with which federal receipts are shared. These methods were used to estimate the effects of the DCAs in the recovery plan on the timber revenues that would be received by the counties. These estimates are in Table G.14. These preliminary estimates do not include the effects of asset losses on the tax bases of the counties.

Table G.13. Economic effects of silviculture in designated conservation areas.

Acres Treated Annually	Timber Removed Annually (million Board feet)	Employment (jobs)
10,000	19	120
25,000	48	302
50,000	96	600
100,000	192	1,200

Target Acreage: 450,000 acres currently unsuitable for owl habitat

Table G.14. Estimates of state and county revenue sharing effects of the recovery plan.

State/County	1995 Revenue Share with Final Plans ($thousands)	Loss in 1995 Revenue Share with Recovery Plan ($thousands)	Percent of 1995 Revenue Share Lost	1988-89 County Budget[1] ($thousands)	1995 Revenue Share Loss as Percent of 1988-89 Budget
Washington					
Chelan	4,009	3,320	68	14,523	23
Clallam	2,222	1,700	77	18,543	9
Clark	0	0	0	58,349	0
Cowlitz	624	223	36	28,641	1
Grays Harbor	1,492	1,142	77	19,059	6
Jefferson	1,862	1,425	77	9,098	16
King	1,104	908	82	489,751	**
Kittitas	1,497	1,034	69	8,851	12
Klickitat	208	74	36	8,047	1
Lewis	6,269	2,341	37	25,587	9
Mason	1,417	1,085	77	13,723	8
Okanogan	3,008	-314*	-10*	12,572	-3*
Pierce	395	325	82	159,516	**
Skagit	1,199	986	82	26,515	4
Skamania	13,514	4,807	36	8,549	56
Snohomish	2,012	1,655	82	111,247	1
Whatcom	1,439	1,183	82	38,053	3
Yakima	2,062	1,405	68	38,078	4
Washington Total	**45,242**	**23,299**	**52**		
Oregon					
Benton	8,287	5,800	70	20,125	29
Clackamas	22,255	12, 133	55	98,221	12
Columbia	5,474	3,986	73	9,434	42
Coos	17,121	11,760	69	19,515	60
Curry	18,131	8,186	45	13,323	61
Deschutes	3,512	738	21	22,833	3
Douglas	93,059	53,670	58	67,062	80
Hood River	2,951	546	19	7,166	8
Jackson	45,118	32,110	71	46,736	69
Jefferson	621	152	24	4,285	4
Josephine	37,624	24,313	65	27,870	87
Klamath	16,845	5,047	30	35,896	14
Lane	80,804	44,358	55	115,313	38
Lincoln	8,814	4,186	47	21,343	20
Linn	18,357	9,316	51	31,525	30
Marion	8,091	4,217	52	68,306	6
Multnomah	3,930	2,302	59	211,258	1
Polk	5,807	4,209	72	11,344	37
Tillamook	5,702	2,953	52	10,483	28
Wasco	2,348	435	19	13,260	3
Washington	1,674	1,219	73	119,133	1
Yamhill	3,078	1,910	62	18,313	10
Oregon Total	**409,603**	**233,546**	**57**		

Continues—

Continued–

State/County	1995 Revenue Share with Final Plans ($thousands)	Loss in 1995 Revenue Share with Recovery Plan ($thousands)	Percent of 1995 Revenue Share Lost	1988-89 County Budget[1] ($thousands)	1995 Revenue Share Loss as Percent of 1988-89 Budget
California					
Colusa	459	376	82	17,840	2
Del Norte	5,826	2,519	43	22,026	11
Glenn	1,342	1,101	82	29,586	4
Humboldt	7,834	4,011	51	91,724	4
Lake	1,797	1,474	82	52,155	3
Mendocino	1,776	1,553	87	166,058	1
Shasta	3,901	2,548	65	115,323	2
Siskiyou	9,896	3,293	33	45,310	7
Tehama	1,542	1,158	75	40,697	3
Trinity	12,251	7,374	60	26,697	28
California Total	**46,624**	**25,407**	**54**		
Three-state Total	**501,469**	**282,252**	**57**		

1Data for some counties estimated from 1987-88 data.
*Estimates for Okanogan County show a gain because the effect of a relatively small reduction in timber harvest is offset by the increase in timber prices.
**Less than 1 percent.

Literature Cited

Berg, M., Personal Communication, U.S. Department of the Interior, Bureau of Land Management, Washington, D.C.

Beuter, J.H. 1990. Social and economic impacts of spotted owl conservation strategy. American Forest Resource Alliance, Washington, D.C. Technical Bulletin No. 9003. 37 p.

Booth, D.E. 1991. Estimating prelogging old-growth in the Pacific Northwest. Journal of Forestry. 89:25-29.

Bray, M.; Lee, R.G. 1991. Federal forest revenue sharing with local governments in Washington, Oregon, and California. The Northwest Environmental Journal. 7:35-70.

Council of Economic Advisors (Sherry Glied), Personal Communication, Washington, D.C.

Formann, L.; Kusel, J.; Danks, C.; Moody, L.; Seshan, S. 1990. The human costs of the California forestry crisis. Presentation to The Concern for Sustainable Forests. Department of Forestry and Resource Management. University of California, Berkeley, California.

Greber, B.J.; Johnson, K.N.; Lettman, G. 1990. Conservation plan for the northern spotted owl and other forest management proposals in Oregon: The economics of changing timber availability. Unpublished report. Corvallis, OR: Oregon State University, Forest Research Laboratory. 50 p.

Hamilton, T.; Zimmer, J. and others. 1990. Economic effects of implementing a conservation strategy for the northern spotted owl. Unpublished report. U.S. Department of Agriculture, Forest Service and U.S. Department of the Interior, Bureau of Land Management, Portland, Oregon. 65 p.

Haynes, R.W. 1986. Inventory and value of old-growth in Douglas-fir region. U.S. Department of Agriculture, Forest Sevice, Forest Service Resource Note PNW-438. Portland, Oregon.

Lee, R.G. 1990. Social and cultural implications of implementing a conservation strategy for the northern spotted owl. Unpublished Report. Mason, Bruce, and Girard, Portland, Oregon. 42 p.

Lee, R.G. 1991. Moral exclusion and rural poverty: Myth management and wood products workers. Paper prepared for Rural Sociological Society, Task Force on the Persistence of Rural Poverty.

Lee, R.G.; Carroll, M.S.; Warren, K.K. 1991a. The social impact of timber harvest reductions in Washington state. Chapter 3 in P. Sommers and H. Birss, eds. Revitalizing the Timber Dependent Regions of Washington. Final Report for the Washington Department of Trade and Economic Development. Northwest Policy Center, University of Washington. 30 p.

Lee, R.G.; Sommers, P.; Birss, H.; Nasser, C.; Zientek, J. 1991b. Social impacts of alternative timber harvest reductions on federal lands in O & C counties. Final Report for the Association of O & C Counties. College of Forest Resources and Northwest Policy Center, University of Washington

Lippke, B.; Gilles, P.; Sommers, P.; Lee, R.G. 1990. Three-state impact of spotted owl conservation and other timber harvest reductions: A cooperative evaluation of the economic and social impacts, based on independent studies of University of Washington, University of California, and Oregon State University. Institute of Forest Resources, University of Washington. 43 p.

Mead, W.J.; Muraoka, D.D.; Schniepp, M.; Watson, R.B.; with assistance from Anderson, J. 1990. The economic consequences of preserving old-growth timber for spotted owls in Oregon and Washington. Community and Organization Research Institute, University of California, Santa Barbara, California.

Oliver, C.D. 1991. Thinning and pruning 10- to 30-year-old plantations in western Washington: Investment, social, wood supply, and environmental consequences. Unpublished report. Seattle, Washington. 54 p.

Stevens, B.J. 1991. Final report on the comparative evaluation of two major studies on the employment impacts of the ISC northern spotted owl conservation strategy on Washington, Oregon, and California. Regional Science Research Institute for American Forest Resource Alliance. 24 p.

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, B.R.; Verner, J. 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.

U.S. Department of Agriculture, Forest Service. 1991a. Economics of effects of implementing a proposal designation of critical habitat of the northern spotted owl on national forests. Washington, D.C.

U.S. Department of Agriculture, Forest Service. 1991b. Preliminary timber resource statistics for the Puget Sound area, Washington. Resource Bulletin PNW-RB-179. Portland, Oregon.

U.S. Department of Agriculture, Forest Service. 1991c. Preliminary timber resource statistics for the Olympic Peninsula, Washington. Resource Bulletin PNW-RB-178. Portland, Oregon.

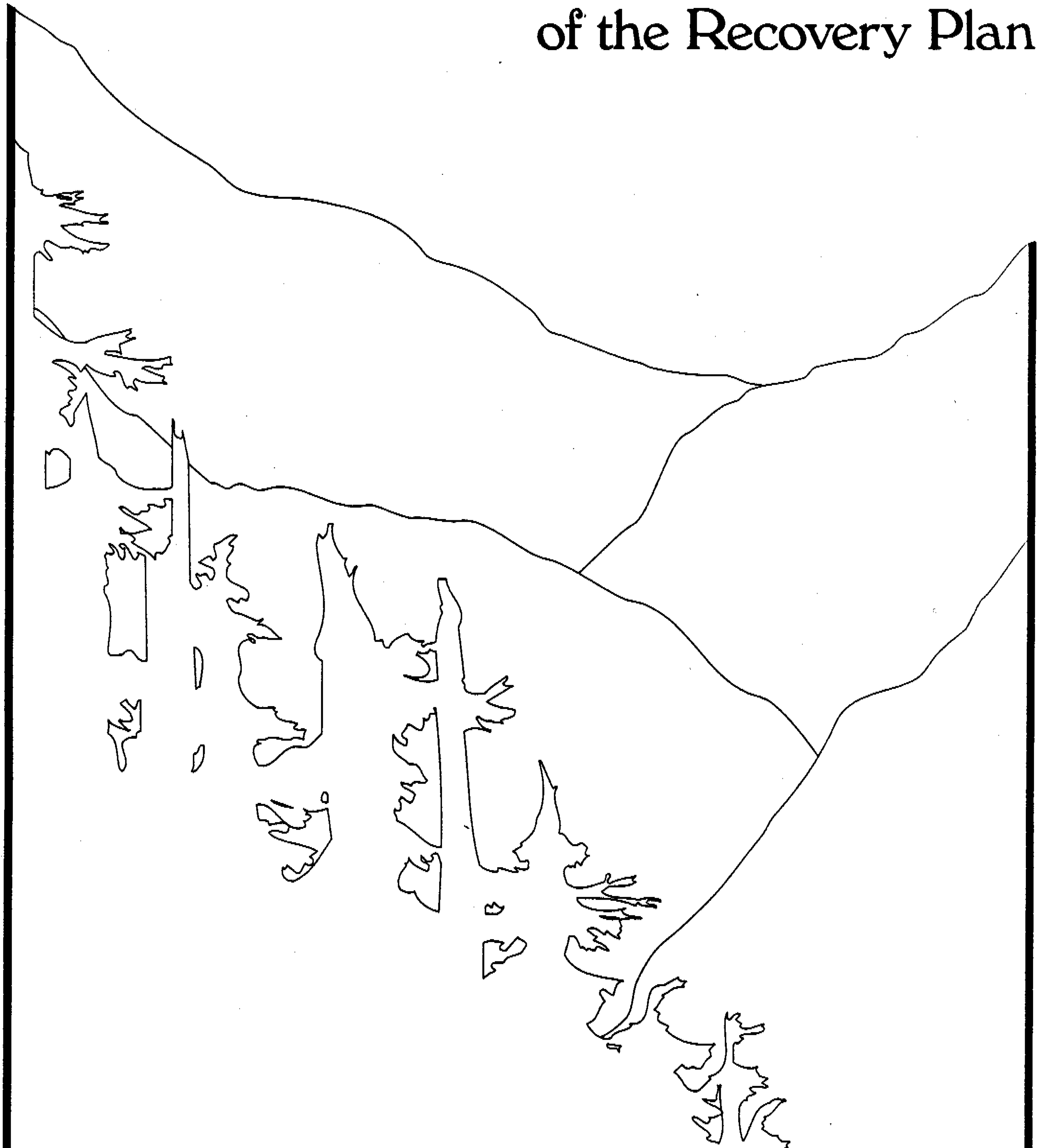
U.S. Department of Agriculture, Forest Service. 1991d. Preliminary timber resource statistics for southwest Washington. Resource Bulletin PNW-RB-177. Portland, Oregon.

U.S. Department of the Interior, Fish and Wildlife Service. 1992. Critical habitat for the northern spotted owl. Portland, Oregon. 73 p.

U.S. Department of the Interior, Fish and Wildlife Service. 1992a. Economic analysis of critical habitat designation effects for the northern spotted owl. Washington, D.C. 94 p.

Appendix H.

Options Considered in Development of the Recovery Plan



Contents

A. Introduction

This appendix discusses the variety of options considered in the development of the Northern Spotted Owl Recovery Plan. It also presents the criteria and procedures used to delineate the designated conservation areas (DCAs) that form one of the main building blocks of the Northern Spotted Owl Recovery Plan.

The recovery plan does not require National Environmental Policy Act (NEPA) documentation because it contains recommendations rather than documenting a proposed action. It is expected that NEPA documentation will be prepared for recovery plan recommendations when they are implemented through federal agency decisions. For that reason, the recovery plan itself does not contain a formal evaluation of alternatives to a proposed action.

Although a formal evaluation of alternatives was not required, the Recovery Team did consider a variety of options during preparation of the recovery plan. The level of consideration ranged from fairly brief reviews to formal analyses. The options, and their consideration by the Recovery Team, are discussed in the following section.

B. Process for Option Development

The Recovery Team began its task by describing, the types of options that might be considered for recovery of northern spotted owls. At the broadest level, the Recovery Team decided that any options that would be seriously considered would have to provide multi-pair areas for owls. This determination was based on information presented in the Interagency Scientific Committee (ISC) report (Thomas et al. 1990). Within that constraint, options were divided into 1) those that allocate the range of the owl into a series of reserves and a connecting forest matrix, and 2) those that manage the entire forest landscape to maintain suitable habitat conditions more broadly distributed throughout that landscape. Options were further subdivided within these two broad categories as follows:

Options with reserves and matrix:

Fixed vs. variable location

- Reserves fixed in location through time.
- Reserves shift through time from one location in the landscape to another.

Managed vs. unmanaged preserves

- Currently suitable habitat managed in the preserves.
- Currently suitable habitat not managed in the preserves.

Broad forest matrix vs. corridors

- Forest matrix managed for a specified forest condition broadly distributed throughout the landscape.
- Forest matrix managed for corridors.

Options without formal reserves:

- Options that attempt to continuously maintain suitable habitat conditions in individual stands through management. These would generally be uneven-aged management options.

- Options where suitable habitat is maintained in the landscape, but not continuously maintained in individual stands.

Recovery Team deliberations about these potential options focused on the availability of evidence indicating that an option was feasible and could be successful. Based on these considerations, it was decided not to do further evaluation of options without formal reserves. No evidence was available that habitat could simply be managed through time in the general forest landscape and successfully provide for recovery of owl populations. The Recovery Team also rejected options where reserves would be shifted from one location to another through time. It was considered that the risk level involved in the relocation of a recovering population from one set of reserves to another set would be too high.

As a result of these deliberations, the Recovery Team ceased consideration of an option that had been presented to it by the U.S. Bureau of Land management (BLM) incorporating a concept called Total Forestry. This fell into the set of options without formal reserves, and so fell outside of the realm that the Recovery Team had decided to further consider.

C. Specific Options for Conservation Areas Considered during Development of the Draft Recovery Plan

During development of the draft recovery plan, the Recovery Team developed data and information about four specific options that met the criterion of having formal reserves. In addition to the draft recovery plan, these included the ISC report (Thomas et al. 1990) and two of the alternatives presented by the Scientific Panel on Late-Successional Forest Ecosystems (Johnson et al. 1991).

1. Interagency Scientific Committee

The ISC proposed a series of reserves for northern spotted owls and management guidelines for intervening forests on federal lands (Thomas et al. 1990). The reserves are called habitat conservation areas (HCAs). The design of the HCAs was based on empirical information about spotted owls and other species and concepts and modeling from the field of conservation biology. Criteria used to map the HCAs are summarized here.

Mapping criteria from the ISC report

1. Map (category 1) HCAs that will support a minimum of 20 currently known or estimated pairs of spotted owls. Size of HCAs should be determined using known owl locations, density, and median home range size; and site-specific geographic and topographic information.

2. Where HCAs cannot be made large enough to support 20 pairs because of natural or human-induced limitations, provide category 2 HCAs supporting 2 to 19 pairs. Again,

determine HCA size using known owl locations, density, and median home range size; and site-specific geographic and topographic information.

3. Provide for single-pair (category 3) HCAs where category 1 HCAs currently cannot achieve objectives. Median home range size should be used to determine target size.

4. Space category 1 HCAs a maximum of 12 miles edge-to-edge and category 2 HCAs a maximum of 7 miles.

5. Consider both currently and potentially suitable habitat in designating the area such that suitable habitat in the future will be as contiguous as possible.

In addition to the HCA network, the ISC report recommended management of intervening forests under the 50-11-40 rule. This rule requires that 50 percent of the federal forested area in each quarter-township be managed to maintain an average dbh of at least 11 inches and canopy closure of at least 40 percent. This same matrix management rule was proposed for all other options discussed here. The effects of the 50-11-40 rule were not included in the data analysis done by the Recovery Team to evaluate biological efficiency since that analysis focused on owl locations and habitat acres contained in HCAs.

2. Most Significant Late Successional/Old-growth Forests

The Scientific Panel on Late-Successional Forest Ecosystems (Johnson et al. 1991) proposed a series of alternatives for managing late successional forests in the Pacific Northwest. One of the alternatives (identified as alternative 5) would protect the most ecologically significant blocks of old-growth forests remaining on federal lands. In developing this alternative, the panel mapped the existing units of old forests with no attempt to provide a specific distribution of those blocks.

3. Most Significant Late Successional/Old-growth Forests with Owl Additions

Once the most significant old-growth acres had been mapped, the panel worked with members of the ISC to make additions that would meet the guidelines used in the HCA network. The resulting network contained all of the most significant old-growth areas with additional acres of spotted owl nesting, roosting, and foraging habitat that met the sizing and spacing criteria used in the ISC report.

4. Recovery Team Map (designated conservation areas)

The Northern Spotted Owl Recovery Team delineated a network of designated conservation areas (DCAs) that were modifications of the HCAs. The overall objective of remapping was to provide a level of protection in DCAs at least as high as that provided by ISC mapping while increasing the biological and economic efficiency of the network and effectively providing for other species. Attempts were made to strengthen the DCA network in areas where deficiencies were identified in the HCA network. The fundamental sizing and spacing criteria from the ISC report were applied during mapping of the DCAs. Additional criteria that were used during this effort follow.

1. Areas were mapped to include as much superior habitat and as many owl locations as possible to achieve a highly effective and efficient network. Where more effective (i.e., more owl locations or better habitat) acres were added to DCAs, opportunities were sought to drop less effective areas so total area did not increase.

2. DCA boundaries were adjusted to accommodate other species' sites where this adjustment could be made without significantly increasing the economic impact of the DCA or significantly decreasing its effectiveness in owl conservation.

3. Areas were mapped to include as high a proportion of reserved lands and other lands unsuited for timber production as possible where consistent with mapping criteria from the ISC report.

4. Where possible, DCA boundaries were modified to place acres capable of full timber yield back into the timber base and replace them in the DCA with acres from which only partial yields were expected because of forest plan allocations.

5. In areas where the existing network was deficient, attempts were made to provide for new owl clusters and populations with the least possible economic impact.

6. Where possible, boundaries were refined to avoid conflict with other economic development proposals.

The process of mapping DCAs was organized by Recovery Team members and involved biologists from the state wildlife management agencies; biologists and timber managers from each of the affected national forests; and biologists and timber managers from each of the affected BLM districts. Maps used in this process included most or all of the following for each national forest and BLM district:

- Spotted owl location maps.
- Spotted owl nesting, roosting, and foraging habitat maps.
- Maps of lands suitable for timber harvest.
- National forest land management plan allocation maps.
- BLM timber production capability maps.
- Sensitive soils maps.
- HCA maps.
- Maps of other old forest-associated species and streams with fish at risk (see Appendix D).
- Base maps at a scale of 1/2-inch to the mile.

Documentation was developed to explain why changes were or were not made to HCA boundaries in the process of developing the DCAs. This documentation included additions and deletions of acres of suitable nesting, roosting, and foraging habitat; lands suitable for timber production; known spotted owl sites; sites of other old forest-associated species; and acres of various land allocations.

The DCAs developed through this process were presented in the draft recovery plan, and there were many public and agency comments on the specific boundaries. These comments were considered by the Recovery Team during a second refinement of the DCA boundaries between the draft and final recovery plans. This refinement followed the same mapping procedure as described for the draft recovery plan.

5. Evaluation of the Options

Information about the options was presented in the draft recovery plan (see Appendix I). That information only addressed effects that could be judged from federal lands. A detailed evaluation of nonfederal lands was not done because there was no overall mapping done for recovery options on nonfederal lands.

Biological effectiveness of the options was evaluated based on their success in meeting the mapping criteria specified earlier and the biological principles discussed in section III.A. of the recovery plan. Specific criteria for reviewing the options in the draft recovery plan were:

1. The number of designated areas that currently contain at least 20 known pairs of owls, and thus have high likelihood of persisting for at least 100 years.

2. The number of designated areas that contain sufficient potential habitat to be able to support 20 pairs of owls in the future.

3. The total number of acres of nesting, roosting, and foraging habitat included in designated areas.

4. The total number of known pairs of owls included in designated areas.

5. The number of sites for other old forest-associated species and miles of streams included in designated areas.

Information from the geographic information system (GIS) data base was used to evaluate options. The data were presented in Appendix I of the draft recovery plan, and reflected information that was in the GIS as of January 1992. Some of the information in the GIS has been updated since that time as the Recovery Team prepared the final recovery plan. However, information for the individual options has not been updated since the draft recovery plan, with the exception of the revised recovery plan map.

The basic conclusion from the evaluation was that the mapping criteria were reasonably satisfied by the ISC, the draft recovery plan, and the most significant late-successional/old-growth forests with owl additions. The draft recovery plan achieved greater efficiency than the ISC report, primarily because two additional years of data were available for its preparation. The late-successional/old-growth areas with owl additions included more acres of nesting, roosting, and foraging habitat and more owl locations than the other three alternatives, but it also would remove significantly more acres from the timber base. The late-successional/old-growth areas without owl additions were less successful in meeting the map criteria since they were not based on those criteria.

D. Options for the Forest Matrix Considered During Development of the Draft Recovery Plan

In addition to these formal options for conservation areas, the Recovery Team made a less formal evaluation of several options for management of the forest matrix. These included 1) linking conservation areas with corridors of high-quality habitat and 2) managing the entire forest matrix for habitat of higher quality than the minimum guideline of 50-11-40.

These options were rejected for the following reasons:

- They would cost more than the 50-11-40 option, but their effectiveness relative to that option is difficult to evaluate.
- The option to provide corridors in place of 50-11-40 may be poorly suited to the owl's natural history since juvenile owls apparently start their dispersal in random directions.
- A review of corridors by Simberloff et al. (1992) suggested that they are an untested concept with little theoretical or empirical support, especially as applied to bird species.

E. Options Considered after Completion of the Draft Recovery Plan

After completing the draft recovery plan, the Recovery Team reviewed three other options at the request of Secretary of the Interior Manuel Lujan Jr. The first of these was the Multi-Resource Strategy for the Conservation of the Northern Spotted Owl (MRS) prepared by the National Forest Products Association and the American Forest Council. The two other options were prepared by the U.S. Department of the Interior's Spotted Owl Management Alternatives Work Group. A summary of Recovery Team findings on these three alternatives is presented here. Complete documentation of the Recovery Team's analysis is in the recovery plan's administrative record.

1. The Multi-Resource Strategy

The MRS defines four zones for owl conservation: reserved and deferred multiple pair areas, research multiple pair areas, connecting habitat, and an owl management zone. Substantial portions of the owl's range (e.g., the northern Oregon Coast Range province, all of the California Coast province) lie entirely outside of these areas and would receive no protection under the MRS. It appears likely (though not certain) that owls would receive a high degree of protection in the reserved and deferred multiple pair areas. These areas, however, include only 12 percent of the known pairs, only two of them are known to contain 20 or more pairs of owls, and they are concentrated in high-elevation areas which have been little studied but are thought to provide sub-optimal habitat for owls. Less than 20 of the areas appear to have the capability of supporting 20 or more pairs of owls in the long-term future. The MRS contains no assurance that the research multiple pair areas will provide suitable habitat for owls.

The management goal for connecting habitat is to provide nesting, roosting, and foraging habitat on 30 to 50 percent of the land. This is an impressive goal, but the Standards and Guidelines of the MRS indicate that stands with as little as 40 percent canopy cover could be counted as suitable habitat when in fact such stands are avoided throughout most of the owl's range, by nesting, roosting, and foraging owls.

The MRS proposes that 40 percent of the owl management zone should be covered by stands with "clearance" beneath the canopy of 20 feet. This rule somewhat resembles the 50-11-40 rule but no rationale is provided for replacing 50-11-40 with the proposed rule.

Based on these findings, it appears that the MRS plan would only provide significant protection for owls in the reserved and deferred multiple pair areas. These areas form a narrow, linear band running north-to-south across the range of the owl. Less than 20 percent of the owl's range is covered by the zone within which the areas are located. The Recovery Team therefore concluded that the MRS would not provide adequate assurance of recovery.

2. The U.S. Department of the Interior Management Alternatives Work Group

The alternatives reviewed by the Recovery Team were prepared by a work group assembled by Secretary Lujan. The objective of the work group was to develop alternatives to the recovery plan that would result in greater employment in the timber industry than would be provided by the recovery plan. The alternatives were not intended to satisfy legal requirements for recovery, but rather to provide for persistence of owls over a fairly brief time, such as 100 years.

The alternatives reviewed were simple reductions of the DCA network proposed in the draft recovery plan. They were developed primarily by either retaining, or completely deleting, recovery plan recommendations for federal lands within entire provinces. The two alternatives, termed V and Z, have a number of features in common. Neither alternative makes provision for northern spotted owl habitat in the California Cascades, California Coast, Oregon Coast Range, western Washington lowlands, or Olympia Peninsula provinces, or the eastern and western Washington Cascades provinces north of the I-90 corridor. Both alternatives eliminate most of the DCA network in the Oregon Klamath province, leave intact the DCA network on federal lands in the western Oregon Cascades province, and leave the DCA network in the California Klamath province substantially intact. The major distinction between the two alternatives is that V retains the DCA network in the eastern Oregon Cascades province and eastern Washington Cascades province south of I-90. Alternative Z eliminates the entire DCA network in the eastern Washington and Oregon Cascades provinces.

The design of the alternatives would result in complete or near-complete isolation of the northern spotted owl populations remaining in Oregon, Washington, and California. In Washington, the owl population would act as two isolates with the Olympic Peninsula population becoming more completely isolated from the Washington Cascades population over time. Habitat and population connections to remaining northern spotted owls in British Columbia would also be eliminated under the alternatives. At the southern end of the northern spotted owl's range, connections to the California spotted owl would be eliminated.

The Recovery Team was asked to respond to two questions for each alternative: 1) what was the likelihood that northern spotted owl populations would stabilize in any part of their range; and 2) what was the likelihood that northern spotted owls would become extinct. These assessments relied on professional judgment because there are no well-developed analytical techniques for them. Based on that professional judgment the Recovery Team's conclusions are that:

- During a period of about 100 years, there would be about a 50-50 likelihood that populations would stabilize in at least one province under alternative Z. The likelihood would be slightly higher than 50-50 under alternative V.

- During the same period, there would be low likelihood of complete extinction of northern spotted owls under alternative V, and a medium-low likelihood of extinction under alternative Z.

- During this same timeframe, it is highly likely that conditions would have been established that would, over a much longer timeframe, eventually result in extinction or near complete extirpation of northern spotted owls.

F. Summary

There has been fairly broad agreement among biologists and policy makers that species conservation plans ought to be analyzed within the framework of risk assessment. The evaluation of alternatives for recovering northern spotted owls was hampered by the lack of analytical tools for such an assessment. As discussed in section III.G., the information and tools necessary to perform a quantitative risk assessment are not currently available. Lacking such tools, the Recovery Team made assessments based on professional judgment. Such judgments form an appropriate basis for conservation planning given our current knowledge. In fact, it is unlikely that analytical tools could ever completely supplant professional judgment. However, the analytical tools will provide valuable input to professional judgments, and their development should be a high priority.

Several models of owl population dynamics have been in development and have seen at least limited use (Doak 1989; Lamberson et al. 1992). A model by McKelvey was used by the BLM to evaluate alternatives for resource management plans (USDI 1992 a,b,c,d,e,f). BLM's use of the model was probably inconclusive since thorough validation of the model had not been completed. Regardless, the BLM's work represented a valuable step in the direction of quantitative analysis. Efforts should be continued to develop models and to gather the data needed to use them in analysis of management alternatives. The following types of efforts should be high priority:

- Compilation of information about vegetation and population dynamics models that have already been developed, including their objectives, primary assumptions, and level of validation.
- Continuation of efforts to validate and refine the most promising of these models.
- Collection of research data about owls and vegetation needed to validate the models and improve their realism and reliability.
- Collection of inventory data about owls and vegetation needed for model inputs.
- Continued efforts to improve the site-specificity of agency plans so that projections of future conditions can be made more realistic.
- Continued efforts to define an appropriate risk analysis framework, and to educate decision-makers on the concept of risk-analysis.

These needs are also outlined in the monitoring and research section (section III.J.) of the recovery plan. Results of the efforts should be used in the implementation and adaptive management of this recovery plan. Section III.K. contains specific recommendations on the use of risk analysis in adaptive management.

Literature Cited

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

Johnson, K.N.; Franklin, J.F.; Thomas J.W.; Gordon, J. 1991. Alternatives for management of late-successional forests of the Pacific Northwest: a report of the Scientific Panel on Late-successional Forest Ecosystems to the U.S. House of Representatives. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

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.

Simberloff, D.; Farr, J.A.; Cox, J.; Mehlman, D.W. 1992. Movement corridors: conservation bargains or poor investments? Conservation Biology. 6:493-504.

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, B.R.; Berner, J. 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.

U.S. Department of the Interior, Bureau of Land Management. 1992a. Coos Bay District: draft resource management plan and environmental impact statement. Oregon State Office. Portland, OR.

U.S. Department of the Interior, Bureau of Land Management. 1992b. Eugene District: draft resource management plan and environmental impact statement. Oregon State Office. Portland, OR.

U.S. Department of the Interior, Bureau of Land Management. 1992c. Klamath Falls District: draft resource management plan and environmental impact statement. Oregon State Office. Portland, OR.

U.S. Department of the Interior, Bureau of Land Management. 1992d. Medford District: draft resource management plan and environmental impact statement. Oregon State Office. Portland, OR.

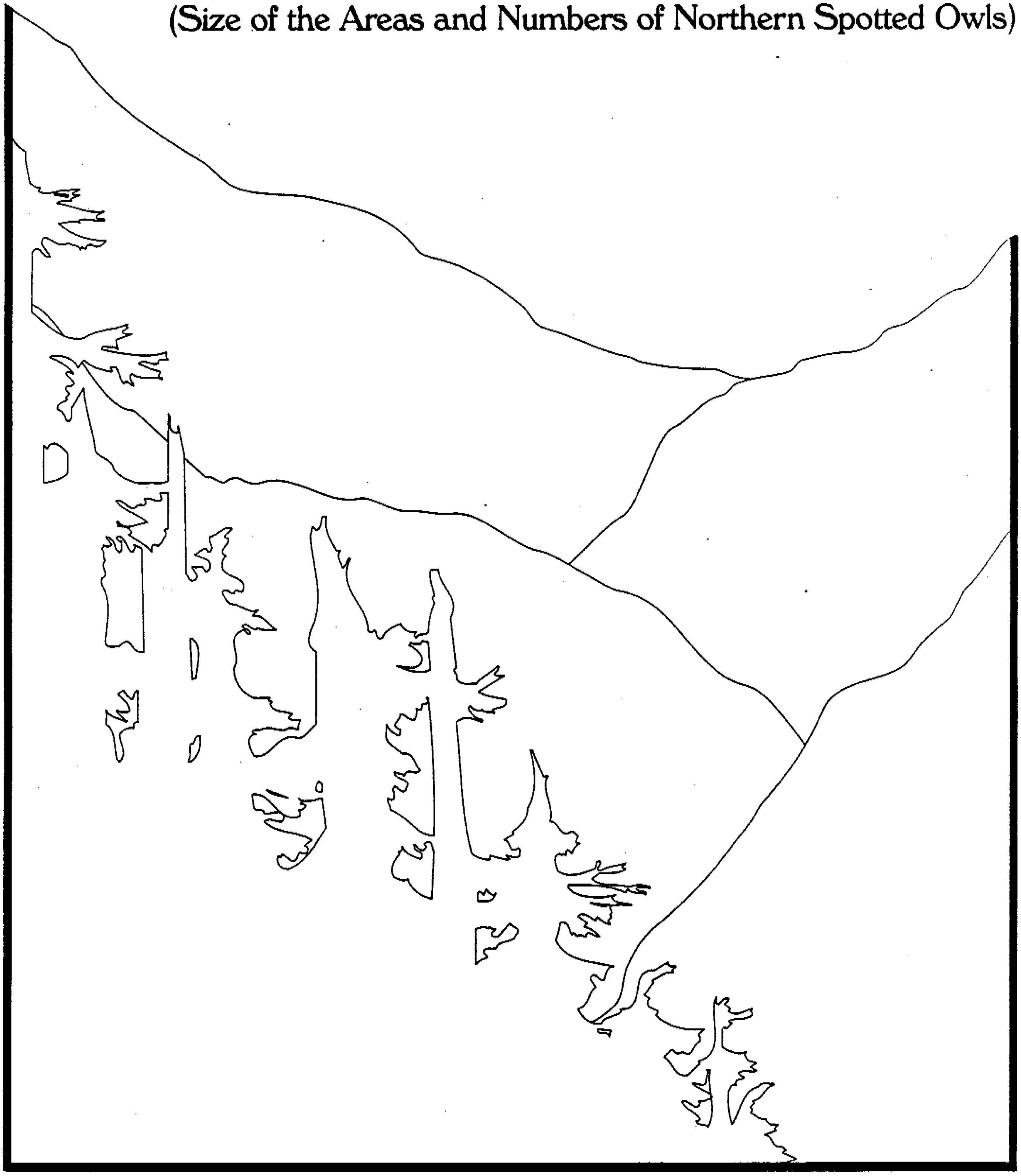
U.S. Department of the Interior, Bureau of Land Management. 1992e. Roseburg District: draft resource management plan and environmental impact statement. Oregon State Office. Portland, OR.

U.S. Department of the Interior, Bureau of Land Management. 1992f. Salem District: draft resource management plan and environmental impact statement. Oregon State Office. Portland, OR.

Appendix I

Designated Conservation Areas

(Size of the Areas and Numbers of Northern Spotted Owls)



Contents

I. Introduction

This appendix presents detailed information about the individual designated conservation areas (DCAs). Tables show the size of the areas, the current condition of habitat within them, the current number of known northern spotted owls, and projections of the near-term and future capability of these areas to support owls. The tables are based on data stored in the geographic information system (GIS) compiled by the Recovery Team.

II. Sources of Information

The map of DCAs used to produce these tables was developed by the Recovery Team as described in Appendix H. The map was digitized for the GIS and then analyzed in conjunction with ownership maps, suitable habitat maps, and maps of owl locations.

Figures are given for acres of nesting, roosting, and foraging (NRF) habitat in the DCAs. The areas identified as NRF habitat include acres that are suitable for some or all of the spotted owl's life needs. Information about habitat was available for all national forests, all U.S. Bureau of Land Management (BLM) districts in Oregon, and national parks in Oregon and Washington. Habitat information was not available for other federal lands or all nonfederal lands.

NRF habitat mapping on national forests was based on regional criteria that were refined by local biologists in the forests. Thus, the criteria varied from location to location (USDA 1988; USDA 1992). Habitat mapping on BLM lands was based on a standard set of criteria that was modified at the local level based on the site-specific knowledge of biologists. NRF habitat for national parks in Oregon and Washington was identified from an analysis of Landsat data completed in 1991 for the U.S. Forest Service. Acres identified as NRF habitat had the following characteristics:

- Canopy closure equal to or greater than 70 percent;
- Tree species includes Douglas-fir, western hemlock, or Pacific silver fir;
- Predominant tree dbh is 21 inches or greater; and
- Development of a second canopy layer.

Known owl locations were identified from data bases supplied by the Washington Department of Wildlife, the California Department of Fish and Game, and the Oregon Department of Fish and Wildlife. For all three states, owl pairs and individuals that had been verified in a 5-year period were tallied (see section II.B., Table 2.3). This period was generally 1987-1991, but information from 1992 was used for some ownerships where earlier surveys were incomplete and new data were available.

III. Projecting Numbers of Owl Pairs

The remaining columns of information, current projected and future projected owl pairs, were based on calculations. The "current projected" number is an estimate of the number of pairs of owls that the DCA would be expected to support if the population stabilized with current habitat conditions. The "future projected" number is an estimate of the number of pairs of owls that the DCA might support at a future time if most of the currently unsuitable area in the DCA developed the characteristics of NRF habitat. For "current projected" and "future projected," estimates were made for federal lands only.

The calculations used to estimate the number of owl pairs that could be supported in a given DCA were refinements of techniques originally used by Thomas et al. (1990). The refinements are described in USDA (1992). Briefly, the calculations are based on:

- The proportion of a landscape that is NRF habitat,
- The relationship between the size of the annual home range of an owl pair and the percentage of that home range in NRF habitat,
- The overlap of home ranges among adjacent pairs of owls,
- A correction for expected long-term occupancy of sites based on the influence of local population size and proportion of suitable habitat in the landscape.

Two mathematical regression formulas were developed to relate the size of annual pair home ranges to the proportion of area in NRF habitat. One was based on data from Washington and the second was based on data from Oregon and California combined.

The Washington formula was:

home range (acres) = 18,364-(17,607 x proportion habitat)

For California and Oregon, the formula was:

home range (acres) = 8,688-(7,054 x proportion habitat)

The proportion habitat term in these equations varies from zero to one.

Calculated home ranges were reduced by 30 percent to account for overlap of adjacent spotted owl pairs.

A. Current Projected Pairs

The following procedure was used to calculate the estimated number of pairs that could be supported in a DCA given current habitat conditions. These calculations were used as a basis for the figures reported as current projected pairs in the tables.

1. GIS information was used to determine the total size of the DCA and the current proportion of NRF habitat.
2. The proportion of NRF habitat was used in the regression equations to calculate home range size.
3. The home range size resulting from the regression was reduced by 30 percent to account for home range overlap.
4. The resulting adjusted home range size was divided into the total DCA size to determine the number of potential pair sites in the DCA.
5. The estimated pair sites were adjusted for the proportion that would likely remain occupied over time using an updated table from Thomas et al. (1990). This table was updated by Voss and Noon (pers. comm.) and predicts the number of sites that would remain occupied over time given an initial number of locally interacting pairs (occupancy correction factor) and the proportion of the area in NRF habitat. In the estimate of

current projected pairs, the occupancy correction factor used was based on the assumption that populations in DCAs were still part of a larger interacting population, i.e., that there is still an owl population in the matrix that interacts with the population in the DCA.

Two additional calculations were used as checks on the current projected pairs. These involved simple calculations using the home range sizes and owl pair densities observed in study areas closest to each DCA. For the calculation involving home range, acres in the DCA were divided by the home range size, and the resulting number was corrected for home range overlap of 30 percent. For the calculation based on density, acres in the DCA were simply multiplied by the owl density expressed on a per acre basis. Only federal acres were used in these calculations.

The final number assigned as the current projected capability presented in Tables I.1. through I.11. was based on inspection of the results of these three calculations plus additional site-specific knowledge of each DCA.

B. Future Projected Pairs

The same basic procedure was used to estimate future projected pairs. For this calculation, it was assumed that 80 percent of the federal nonreserved land in the DCA would develop the characteristics of NRF habitat at some future point in time. The assumption of 80 percent reflects 1) an assumption that not all acreage in a DCA is capable of supporting NRF habitat, and 2) an assumption that natural disturbances always would maintain some portion of the forests in each DCA in younger age classes. The proportion of reserved lands in each DCA that would consist of NRF habitat was assumed to not change over time. These reserved lands have not been subject to human disturbance for a longer period of time, so the proportion of NRF in them is assumed to have reached an equilibrium. Contributions from nonfederal lands were not assumed in these calculations.

Unlike the current projected calculation, the future projections assumed that, in the future, each DCA would operate as a cluster at least partially isolated from other populations since other habitat surrounding the DCA would be managed for dispersal rather than for breeding pairs of owls. Therefore, the occupancy correction factor used for future projections was based only on the number of pair sites calculated for the area (see step 3 in the previous discussion).

Once the calculations were complete, they were used in conjunction with local knowledge of site conditions to assign a final figure for future projected pairs.

Abbreviations and Definitions Used in the Tables:

BLM - lands managed by the U.S. Bureau of Land Management
NFS - lands in the national forests managed by the U.S. Forest Service
NPS - lands in the national parks managed by the National Park Service
OTHER FED - other federal lands; national wildlife refuges; Department of Defens Military Reservations
NRF - nesting, roosting, and foraging habitat for spotted owls

Current projected - an estimate of the number of pairs of owls that the DCA would be expected to support if the population stabilized with current habitat conditions. This number may be either higher or lower than the current known, due to lack of survey information or recent loss of habitat in the vicinity, respectively. Current known numbers of owls may be artificially high due to displacement from surrounding habitat which was harvested recently or because of its proximity to source populations.

Future projected - an estimate of the number of pairs of owls that the DCA might support in the future if nonreserved lands in the DCA were composed of 80 percent NRF habitat and reserved lands maintained their current proportion of habitat.

Note that acreage and known owl numbers in the tables are split only by federal and total land status. The numerical difference between "Total Federal" and "Total" reflects nonfederal acreage and owl numbers.

Literature Cited

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, B.R.; Verner, J. 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.

U.S. Department of Agriculture, Forest Service. 1988. Final supplement to the environmental impact statement for an amendment to the Pacific Northwest regional guide. Portland, OR. 2 Vols.

Voss, C., Personal Communication, U.S. Department of Agriculture, Forest Service, Arcata, CA.

U.S. Department of Agriculture, Forest Service. 1992. Final environmental impact statement on management for the northern spotted owl in the national forests. Portland, OR. 854 p.

Table I.1. Acreage and owl numbers for designated conservation areas in the Olympic Peninsula province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
WD-46	NFS	1,600	2,900	0	0		
	TOTAL FED	1,600	2,900	0	0	0	1
	TOTAL	–	2,900	0	0		
WD-47	NFS	207,600	408,700	79	9		
	NPS	156,400	389,700	38	7		
	TOTAL FED	364,000	798,400	117	16	175	215
	TOTAL		818,200	119	17		
WD-48	NFS	3,200	6,200	1	0		
	TOTAL FED	3,200	6,200	1	0	1	1
	TOTAL		7,800	1	0		
WD-49	NFS	2,800	4,000	1	0		
	TOTAL FED	2,800	4,000	1	0	1	1
	TOTAL		5,900	1	0		
WD-50	NFS	5,600	16,700	1	0		
	TOTAL FED	5,600	16,700	1	0	3	4
	TOTAL		19,900	2	0		
WD-51	NPS	100	34,700	5	2		
	TOTAL FED	100	34,700	5	2	5	8
	TOTAL	100	35,100	5	2		
PROVINCE TOTAL FED		377,300	862,900	125	18	185	230
PROVINCE TOTAL		–	889,800	128	19		

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimter of designated conservation areas. Management of these lands is duscussed in the indivudal province narratives (Section III.E.). Values shows as "–" indicate an unknown number.

Table I.2. Acreage and owl numbers for the designated conservation area in the western Washington lowlands province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
WD-45	OTHER FED	0	65,900				
	TOTAL FED	0	65,900	0	0	0	8
	TOTAL	0	65,900	0	0		
PROVINCE TOTAL FED		0	65,900	0	0	0	8
PROVINCE TOTAL		0	65,900	6	4		

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.E.).

Table I.3. Acreage and owl numbers for designated conservation areas in the western Washington Cascades province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
WD-1	NFS	92,100	148,100	25	0		
	TOTAL FED	92,100	148,100	25	0	25	35
	TOTAL	–	153,700	25	0		
WD-2	NFS	10,300	16,100	3	0		
	TOTAL FED	10,300	16,100	3	0	3	3
	TOTAL	–	16,800	3	0		
WD-3	NFS	84,300	111,700	23	0		
	TOTAL FED	84,300	111,700	23	0	25	32
	TOTAL	–	111,800	23	0		
WD-4	NFS	33,900	48,300	9	1		
	TOTAL FED	33,900	48,300	9	1	10	13
	TOTAL	–	52,200	9	1		
WD-5	NFS	14,900	32,400	12	3		
	TOTAL FED	14,900	32,400	12	3	13	9
	TOTAL	–	54,700	13	4		
WD-6	NFS	74,000	132,400	22	0		
	NPS	29,600	39,000	6	0		
	TOTAL FED	103,600	171,400	28	0	28	39
	TOTAL	–	175,500	28	0		
WD-7	NFS	48,900	100,400	19	5		
	NPS	6,100	10,300	1	0		
	TOTAL FED	55,000	110,700	20	5	16	25
	TOTAL	–	134,700	21	5		
WD-8	NFS	9,900	19,500	3	1		
	TOTAL FED	9,900	19,500	3	1	4	4
	TOTAL	–	35,400	4	1		
WD-9	NFS	18,200	34,100	2	1		
	TOTAL FED	18,200	34,100	2	1	4	6
	TOTAL	–	35,600	2	1		
WD-10	NFS	7,100	12,700	2	0		
	TOTAL FED	7,100	12,700	2	0	4	4
	TOTAL	–	13,600	2	0		

Continues

Continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
WD-11	NFS	19,300	35,200	3	5		
	TOTAL FED	19,300	35,200	3	5	5	7
	TOTAL	–	38,400	3	5		
WD-12	NFS	16,800	30,800	4	0		
	TOTAL FED	16,800	30,800	4	0	5	8
	TOTAL	–	31,300	4	0		
WD-13	NFS	23,800	46,600	5	1		
	TOTAL FED	23,800	46.600	5	1	7	9
	TOTAL	–	46,600	5	1		
WD-14	NFS	6,300	9,300	1	0		
	TOTAL FED	6,300	9,300	1	0	2	2
	TOTAL	–	9,700	1	0		
WD-15	NFS	19,100	26,400	2	0		
	TOTAL FED	19,100	26,400	2	0	5	7
	TOTAL	–	26,400	2	0		
WD-16	NFS	17,200	32,700	4	1		
	TOTAL FED	17,200	32,700	4	1	5	8
	TOTAL	–	33,300	4	1		
WD-17	NFS	51,300	76,700	6	2		
	TOTAL FED	51,300	76,700	6	2	14	18
	TOTAL	–	76,900	6	2		
WD-18	NFS	44,200	84,400	8	1		
	TOTAL FED	44,200	84,400	8	1	11	24
	TOTAL	–	87,900	8	1		
WD-19	NFS	9,600	14,400	4	0		
	TOTAL FED	9,600	14,400	4	0	4	4
	TOTAL	–	14,400	4	0		
WD-20	NFS	19,000	27,000	2	0		
	NPS	100	300	0	0		
	TOTAL FED	19,100	27,300	2	0	5	6
	TOTAL	–	27,300	2	0		
WD-21	NFS	56,200	100,900	12	0		
	NPS	600	1,000	0	0		
	TOTAL FED	56,800	101,900	12	0	14	28
	TOTAL	–	104,100	12	0		
WD-22	NFS	18,900	37,400	4	2		
	NPS	100	300	0	0		
	TOTAL FED	19,000	37,700	4	2	5	9
	TOTAL	–	38,000	4	2		

Continues

Continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
WD-23	NPS	5,400	14,400	0	0		
	TOTAL FED	5,400	14,400	0	0	2	2
	TOTAL	–	14,400	0	0		
WD-24	NFS	5,100	15,700	2	0		
	NPS	26,700	77,400	2	0		
	TOTAL FED	31,800	93,100	4	0	8	10
	TOTAL	–	100,900	4	0		
PROVINCE TOTAL FED		769,000	1,335,900	186	23	224	312
PROVINCE TOTAL			1,433,600	189	24		

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.E.). Values shown as "–" indicate an unknown number.

Table I.4. Acreage and owl numbers for designated conservation areas in the eastern Washington Cascades province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
WD-25	NFS	11,500	26,200	3	0		
	TOTAL FED	11,500	26,200	3	0	3	5
	TOTAL	–	26,200	3	0		
WD-26	NFS	3,300	12,800	1	0		
	TOTAL FED	3,300	12,800	1	0	1	2
	TOTAL	–	12,800	1	0		
WD-27	NFS	5,100	20,100	3	0		
	TOTAL FED	5,100	20,100	3	0	3	3
	TOTAL	–	20,100	3	0		
WD-28	NFS	1,700	11,900	1	0		
	NPS	–	41,100	1	0		
	TOTAL FED	1,700	53,000	2	0	6	10
	TOTAL	–	55,300	2	0		
WD-29	NFS	1,800	11,500	1	0		
	TOTAL FED	1,800	11,500	1	0	1	2
	TOTAL	–	11,500	1	0		
WD-30	NFS	100	10,300	1	0		
	TOTAL FED	100	10,300	1	0	1	1
	TOTAL		10,300	1	0		
WD-31	NFS	2,600	23,400	1	0		
	TOTAL FED	2,600	23,400	1	0	2	4
	TOTAL	–	23,500	1	0		

Continues

Continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Known Singles	Current Projected	Future Projected
WD-32	NFS	5,400	32,300	3	0		
	TOTAL FED	5,400	32,300	3	0	3	5
	TOTAL	–	32,300	3	0		
WD-33	NFS	52,600	94,500	10	0		
	TOTAL FED	52,600	94,500	10	0	15	20
	TOTAL	–	102,600	11	0		
WD-34	NFS	56,700	102,100	5	1		
	TOTAL FED	56,700	102,100	5	1	12	21
	TOTAL	–	104,600	5	1		
WD-35	NFS	1,600	7,600	2	0		
	TOTAL FED	1,600	7,600	2	0	2	2
	TOTAL	–	11,200	2	0		
WD-36	NFS	9,400	24,900	4	0		
	TOTAL FED	9,400	24,900	4	0	4	5
	TOTAL	–	26,700	4	0		
WD-37	NFS	4,800	17,500	7	0		
	TOTAL FED	4,800	17,500	7	0	7	7
	TOTAL	–	24,500	7	0		
WD-38	NFS	54,800	86,300	17	1		
	TOTAL FED	54,800	86,300	17	1	20	24
	TOTAL	–	92,300	17	1		
WD-39	NFS	32,700	57,900	12	0		
	TOTAL FED	33,700	57,900	12	0	12	15
	TOTAL	–	94,800	14	0		
WD-40	NFS	31,700	45,000	11	0		
	TOTAL FED	31,700	45,000	11	0	13	14
	TOTAL	–	60,900	17	0		
WD-41	NFS	33,400	50,700	7	1		
	TOTAL FED	33,400	50,700	7	1	12	13
	TOTAL	–	52,100	7	1		
WD-42	NFS	2,400	9,200	3	0		
	TOTAL FED	2,400	9,200	3	0	3	3
	TOTAL	–	9,200	3	0		
WD-43	NFS	27,500	58,400	10	0		
	TOTAL FED	27,500	58,400	10	0	12	16
	TOTAL	–	58,800	10	0		
WD-44	NFS	25,700	34,200	8	0		
	TOTAL FED	25,700	34,200	8	0	9	10
	TOTAL	–	34,500	9	0		
PROVINCE	TOTAL FED	365,800	777,900	111	3	141	182
PROVINCE	TOTAL	–	864,200	121	3		

*The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.E.). Values shown as "–" indicate an unknown number.

Table I.5. Acreage and owl numbers for designated conservation areas in the Oregon Coast Range province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-33	BLM	28,200	55,800	24	0		
	TOTAL FED	28,200	55,800	24	0	12	17
	TOTAL	–	82,300	24	0		
OD-34	BLM	21,600	48,500	23	2		
	TOTAL FED	21,600	48,500	23	2	10	15
	TOTAL	–	70,700	25	2		
OD-35	BLM	5,700	8,300	8	0		
	TOTAL FED	5,700	8,300	8	0	4	4
	TOTAL		12,500	8	0		
OD-36	NFS	18,500	24,900	4	3		
	BLM	10,400	18,100	6	0		
	TOTAL FED	28,900	43,000	10	3	13	15
	TOTAL	–	53,100	10	3		
OD-37	NFS	14,600	39,000	21	0		
	TOTAL FED	14,600	39,000	21	0	10	16
	TOTAL	–	70,400	21	0		
OD-38	BLM	200	1,800	1	0		
	TOTAL FED	200	1,800	1	0	0	1
	TOTAL	–	3,400	1	0		
OD-39	NFS	22,000	41,400	7	4		
	BLM	8,200	18,600	2	1		
	TOTAL FED	30,200	60,000	9	5	15	20
	TOTAL	–	71,100	9	6		
OD-40	BLM	2,700	4,900	3	0		
	TOTAL FED	2,700	4,900	3	0	1	2
	TOTAL	–	8,500	3	0		
OD-41	NFS	4,500	8,300	5	1		
	BLM	8,400	21,600	5	0		
	TOTAL FED	12,900	29,900	10	1	6	10
	TOTAL	–	39,900	11	1		
OD-42	NFS	38,900	78,900	8	7		
	TOTAL FED	38,900	78,900	8	7	14	25
	TOTAL	–	86,800	8	7		

Continues

Continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-43	NFS	26,800	46,700	2	5		
	TOTAL FED	26,800	46,700	2	5	10	15
	TOTAL	–	53,800	3	5		
OD-44	NFS	6,900	15,800	3	0		
	BLM	4,400	25,600	2	2		
	TOTAL FED	11,300	41,400	5	2	7	13
	TOTAL	–	68,100	5	3		
OD-45	BLM	1,900	7,200	2	0		
	TOTAL FED	1,900	7,200	2	0	1	2
	TOTAL	–	12,800	2	0		
OD-46	BLM	3,000	26,800	2	1		
	TOTAL FED	3,000	26,8800	2	1	3	7
	TOTAL	–	46,300	2	1		
OD-47	NFS	17,200	41,200	2	3		
	BLM	400	2,800	0	0		
	TOTAL FED	17,600	44,000	2	3	4	15
	TOTAL	–	51,800	2	3		
OD-48	NFS	5,200	15,000	0	1		
	BLM	4,700	38,500	1	2		
	TOTAL FED	9,900	53,500	1	3	1	15
	TOTAL	–	70,200	1	3		
OD-49	BLM	200	7,600	2	1		
	TOTAL FED	200	7,600	2	1	0	2
	TOTAL	–	15,000	2	1		
PROVINCE TOTAL FED		254,600	597,300	133	33	111	194
PROVINCE TOTAL		–	816,700	137	35		

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.E.). Values shown as "–" indicate an unknown number.

Table I.6. Acreage and owl numbers for designated conservation areas in the western Oregon Cascades province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-1	NFS	95,800	148,000	11	4		
	TOTAL FED	95,800	148,000	11	4	30	45
	TOTAL	–	148,300	11	4		
OD-2	NFS	61,400	111,500	23	11		
	TOTAL FED	61,400	111,500	23	11	27	35
	TOTAL	–	111,700	23	11		
OD-3	NFS	45,800	70,100	5	8		
	BLM	3,300	19,000	6	0		
	TOTAL FED	49,100	89,100	11	8	20	30
	TOTAL	–	98,200	11	8		
OD-4	NFS	38,100	73,200	23	9		
	TOTAL FED	38,100	73,200	23	9	22	30
	TOTAL	–	77,400	23	9		
OD-5	NFS	33,900	45,300	8	3		
	BLM	15,800	29,200	12	0		
	TOTAL FED	49,700	74,500	20	3	25	30
	TOTAL	–	80,300	21	3		
OD-6	NFS	40,500	63,400	20	4		
	TOTAL FED	40,500	63,400	20	4	20	27
	TOTAL	–	67,700	20	4		
OD-7	NFS	78,300	103,800	20	15		
	TOTAL FED	78,300	103,800	20	15	27	30
	TOTAL	–	103,800	20	15		
OD-8	NFS	40,600	84,000	28	7		
	TOTAL FED	40,600	84,000	28	7	25	35
	TOTAL	–	84,200	28	7		
OD-9	NFS	47,100	82,200	19	11		
	TOTAL FED	47,100	82,200	19	11	25	33
	TOTAL	–	82,200	19	11		
OD-10	NFS	32,800	57,800	23	8		
	BLM	1,800	4,400	1	0		
	TOTAL FED	34,600	62,200	24	8	20	25
	FED	–	66,900	24	8		
OD-11	BLM	600	1,400	2	0		
	TOTAL FED	600	1,400	2	0	0	1
	TOTAL	–	2,600	2	0		

Continues

Continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-12	BLM	400	1,800	0	1		
	TOTAL FED	400	1,800	0	1	0	1
	TOTAL	–	3,000	0	1		
OD-13	BLM	400	2,100	0	1		
	TOTAL FED	400	2,100	0	1	0	1
	TOTAL	–	3,200	0	1		
OD-14	BLM	1,000	7,800	2	0		
	TOTAL FED	1,000	7,800	2	0	1	3
	TOTAL	–	18,300	2	0		
OD-15	BLM	30,500	51,500	33	1		
	TOTAL FED	30,500	51,500	33	1	13	20
	TOTAL	–	89,700	34	2		
OD-16	NFS	49,100	81,800	26	3		
	TOTAL FED	49,100	81,800	26	3	25	35
	TOTAL	–	84,700	26	3		
OD-17	NFS	53,300	80,800	34	5		
	BLM	200	300	0	0		
	TOTAL FED	53,500	81,100	34	5	28	35
	TOTAL	–	84,200	34	5		
OD-18	NFS	32,100	65,400	15	2		
	TOTAL FED	32,100	65,400	15	2	16	22
	TOTAL	–	66,400	15	2		
OD-19	NFS	24,100	45,400	22	7		
	BLM	11,800	18,500	16	1		
	TOTAL FED	35,900	63,900	38	8	22	30
	TOTAL	–	78,000	41	8		
OD-20	NFS	27,700	63,100	25	11		
	NPS	500	900	1	0		
	TOTAL FED	28,200	64,000	26	11	21	28
	TOTAL	–	65,600	26	11		
OD-21	NFS	33,200	69,700	24	2		
	BLM	600	900	0	1		
	TOTAL FED	33,800	70,600	24	3	15	25
	TOTAL	–	76,400	24	3		
OD-22	BLM	12,000	31,100	12	0		
	TOTAL FED	12,000	31,100	12	0	5	10
	TOTAL	–	50,200	12	0		
PROVINCE TOTAL FED		812,700	1,414,400	411	115	387	531
PROVINCE TOTAL			1,543,000	416	116		

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.E.). Values shown as "–" indicate an unknown number.

Table I.7. Acreage and owl numbers for desiganted conservation areas in the eastern Oregon Cascades province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-50	NFS	47,000	68,600	23	1		
	TOTAL FED	47,000	68,600	23	1	21	25
	TOTAL	–	69,000	23	1		
OD-51	NFS	4,500	8,900	1	0		
	TOTAL FED	4,500	8,900	1	0	1	2
	TOTAL	–	9,800	1	0		
OD-52	NFS	8,700	20,000	3	1		
	TOTAL FED	8,700	20,000	3	1	4	5
	TOTAL	–	20,000	3	1		
OD-53	NFS	3,600	12,700	6	0		
	TOTAL FED	3,600	12,700	6	0	2	3
	TOTAL	–	12,700	6	0		
OD-54	NFS	4,100	13,200	6	0		
	TOTAL FED	4,100	13,200	6	0	2	3
	TOTAL	–	13,500	6	0		
OD-55	NFS	4,100	18,000	2	2		
	TOTAL FED	4,100	18,000	2	2	1	4
	TOTAL	–	18,300	2	2		
OD-56	NFS	8,600	16,800	4	0		
	TOTAL FED	8,600	16,800	4	0	4	4
	TOTAL	–	16,800	4	0		
OD-57	NFS	9,300	28,200	6	1		
	TOTAL FED	9,300	28,200	6	1	6	7
	TOTAL	–	28,400	6	1		
OD-58	NFS	22,800	41,700	10	8		
	TOTAL FED	22,800	41,700	10	8	13	17
	TOTAL	–	42,700	10	8		
PROVINCE TOTAL FED		112,700	228,100	61	13	54	70
PROVINCE TOTAL		–	231,200	61	13		

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of deisgnated conservation areas. Management of these lands is discussed in the individual province narratives (section III.E.). Values shown as "-" indicate an unknown number.

Table I.8. Acreage and owl numbers for designated conservation areas in the Oregon Klamath province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
OD-23[b]	NFS	22,200	61,500	24	3		
	TOTAL FED	22,200	61,500	24	3	18	24
	TOTAL	–	72,400	24	3		
OD-24	BLM	5,800	10,300	4	0		
	TOTAL FED	5,800	10,300	4	0	3	4
	TOTAL	–	10,400	4	0		
OD-25	NFS	3,000	7,900	0	0		
	BLM	26,200	48,800	16	1		
	TOTAL FED	29,200	56,700	16	1	13	20
	TOTAL	–	78,100	18	1		
OD-26[c]	NFS	26,200	71,700	16	5		
	TOTAL FED	26,200	71,700	16	5	17	23
	TOTAL	–	74,300	16	5		
OD-27	NFS	53,400	130,300	4	6		
	TOTAL FED	53,400	130,300	4	6	22	30
	TOTAL	–	131,200	4	6		
OD-28	NFS	300	900	0	0		
	BLM	39,800	68,500	9	0		
	TOTAL FED	40,100	69,400	9	0	17	22
	TOTAL	–	74,800	10	0		
OD-29	NFS	33,400	53,700	9	1		
	BLM	4,800	11,600	1	0		
	TOTAL FED	38,200	65,300	10	1	18	23
	TOTAL	–	72,200	10	1		
OD-30	NFS	22,900	40,300	2	0		
	BLM	100	500	0	0		
	TOTAL FED	23,000	40,800	2	0	11	15
	TOTAL	–	43,400	2	0		
OD-31	BLM	15,400	44,800	19	1		
	TOTAL FED	15,400	44,800	19	1	10	15
	TOTAL	–	86,600	23	1		
OD-32	NFS	700	1,600	0	0		
	BLM	23,200	44,200	21	0		
	TOTAL FED	23,900	45,800	21	0	11	15
	TOTAL	–	91,000	26	0		
CD-5	DCA crosses state boundary; data are displayed in California Coast province table (see Table I.10.).						
PROVINCE	TOTAL FED	277,400	596,600	125	17	140	191
PROVINCE	TOTAL		734,400	137	17		

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.
[b]Portions of this DCA lie in the California Klamath province; data illustrated here are for the entire DCA.
[c]Portions of this DCA lie in the California coast province; data illustrated here are for the entire DCA.

Table I.9. Acreage and owl numbers for designated conservation areas in the California Coast province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers: Known Pairs	Owl Numbers: Known Singles	Owl Numbers: Current Projected	Owl Numbers: Future Projected
CD-1	NFS	1,200	7,600	1	1		
	NPS	–	6,100	0	0		
	TOTAL FED	–	13,700	1	1	4	5
	TOTAL	–	34,200	1	1		
CD-2	NPS	–	66,900	1	0		
	TOTAL FED	–	66,900	1	0	18	24
	TOTAL	–	80,300	1	0		
CD-3	BLM	900	3,900	3	1		
	TOTAL FED	900	3,900	3	1	3	3
	TOTAL	–	8,300	3	1		
CD-4	BLM	200	1,000	1	0		
	TOTAL FED	200	1,000	1	0	1	1
	TOTAL	–	1,600	1	0		
CD-5	BLM	900	2,300	4	0		
	TOTAL FED	900	2,300	4	0	3	3
	TOTAL	–	2,300	4	0		
CD-6	BLM	100	40	0	1		
	TOTAL FED	100	40	0	1	1	0
	TOTAL	–	40	0	1		
CD-7	BLM	100	400	0	0		
	TOTAL FED	100	400	0	0	1	1
	TOTAL	–	400	0	0		
CD-8	BLM	4,900	33,900	2	3		
	TOTAL FED	4,900	33,900	2	3	10	12
	TOTAL	–	39,800	2	3		
CD-9	BLM	1,000	2,500	0	0		
	TOTAL FED	1,000	2,500	0	0	1	3
	TOTAL	–	6,500	0	1		
CD-10	BLM	300	1,100	0	1		
	TOTAL FED	300	1,100	0	1	1	2
	TOTAL	–	1,200	0	1		
CD-11	BLM	200	1,700	1	0		
	TOTAL FED	200	1,700	1	0	1	2
	TOTAL	–	2,900	1	0		

Continues

Continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
CD-12	BLM	1,400	2,700	1	0		
	TOTAL FED	1,400	2,700	1	0	1	3
	TOTAL	–	4,500	2	0		
CD-13	BLM	0	1,100	0	0		
	TOTAL FED	0	1,100	0	0	1	2
	TOTAL	–	1,700	0	0		
CD-14	BLM	400	2,700	0	0		
	TOTAL FED	400	2,700	0	0	1	3
	TOTAL	–	3,400	0	0		
CD-15	BLM	100	2,800	3	0		
	TOTAL FED	100	2,800	3	0	3	4
	TOTAL	–	5,400	4	0		
CD-16	BLM	100	9,000	2	0		
	TOTAL FED	100	9,000	2	0	1	3
	TOTAL	–	12,200	2	0		
CD-17	BLM	300	7,100	1	0		
	TOTAL FED	300	7,100	1	0	1	5
	TOTAL	–	12,900	1	0		
CD-18	BLM	100	6,700	0	0		
	TOTAL FED	100	6,700	0	0	0	2
	TOTAL	–	8,100	0	0		
CD-19	BLM	100	2,400	0	1		
	TOTAL FED	100	2,400	0	1	2	3
	TOTAL	–	3,100	0	1		
CD-20	BLM	100	1,800	0	0		
	TOTAL FED	100	1,800	0	0	0	1
	TOTAL	–	2,800	0	0		
CD-21	BLM	300	3,700	0	0		
	TOTAL FED	300	3,700	0	0	1	2
	TOTAL	–	4,700	0	0		
CD-22	BLM	100	4,500	0	0		
	TOTAL FED	100	4,500	0	0	1	2
	TOTAL	–	7,000	0	0		
CD-23	BLM	200	7,000	0	1		
	TOTAL FED	200	7,000	0	1	1	3
	TOTAL	–	8,300	0	1		

Continues

Continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
CD-25	BLM	300	1,600	0	0		
	TOTAL FED	300	1,600	0	0	0	0
	TOTAL	–	1,800	0	0		
CD-24	BLM	200	1,100	0	0		
	TOTAL FED	200	1,100	0	0	1	1
	TOTAL	–	1,100	0	0		
CD-26	BLM	200	900	0	0		
	TOTAL FED	200	900	0	0	1	1
	TOTAL	–	2,600	1	0		
CD-27	BLM	500	3,200	0	0		
	TOTAL FED	500	3,200	0	0	1	2
	TOTAL	–	3,500	0	0		
CD-28	NPS	–	32,600	1	5		
	TOTAL FED	–	32,600	1	5	11	11
	TOTAL	–	74,800	1	12		
OD-26	DCA crosses state boundary; data are displayed in Oregon Klamath province table (see Table I.8).						
PROVINCE TOTAL FED		14,200	218,400	21	14	71	104
PROVINCE TOTAL		–	335,500	24	22		

*The difference between TOTAL FED and TOTAL is nonfederal lands within the perimenter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.E.). Values noted as "-" indicate an unknown number.

Table I.10. Acreage and owl numbers for designated conservation areas in the California Klamath province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
CD-29	NFS	41,500	101,200	7	8		
	TOTAL FED	41,500	101,200	7	8	20	25
	TOTAL	–	102,200	7	8		
CD-30[b]	NFS	24,900	81,400	16	2		
	TOTAL FED	24,900	81,400	16	2	25	29
	TOTAL	–	85,500	16	2		
CD-31	NFS	13,500	51,000	11	6		
	TOTAL FED	13,500	51,000	11	6	18	20
	TOTAL	–	51,100	11	6		
CD-32	NFS	1,600	14,300	9	3		
	TOTAL FED	1,600	14,300	9	3	10	8
	TOTAL	–	23,100	10	4		
CD-33	NFS	71,600	140,400	23	4		
	TOTAL FED	71,600	140,400	23	4	40	42
	TOTAL	–	140,700	23	4		
CD-34	NFS	2,300	6,300	2	1		
	TOTAL FED	2,300	6,300	2	1	3	3
	TOTAL	–	6,300	2	1		
CD-35	NFS	25,300	53,800	19	4		
	TOTAL FED	25,300	53,800	19	4	22	24
	TOTAL	–	54,600	19	4		
CD-36	NFS	18,300	55,100	13	3		
	TOTAL FED	18,300	55,100	13	3	21	23
	TOTAL	–	58,000	13	3		
CD-37	NFS	3,600	8,800	3	1		
	TOTAL FED	3,600	8,800	3	1	4	4
	TOTAL	–	8,900	3	1		
CD-38	NFS	1,400	3,300	1	0		
	TOTAL FED	1,400	3,300	1	0	1	1
	TOTAL	0	3,400	1	0		
CD-39	NFS	1,400	4,200	1	0		
	TOTAL FED	1,400	4,200	1	0	1	1
	TOTAL	–	4,200	1	0		

Continues

Continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
CD-40	NFS	700	1,700	1	0		
	TOTAL FED	700	1,700	1	0	1	1
	TOTAL	–	1,700	1	0		
CD-41	NFS	400	2,200	1	0		
	TOTAL FED	400	2,200	1	0	1	1
	TOTAL	–	2,300	1	0		
CD-42	NFS	200	2,500	1	0		
	TOTAL FED	200	2,500	1	0	1	2
	TOTAL	–	3,800	1	0		
CD-43	NFS	700	4,100	1	0		
	TOTAL FED	700	4,100	1	0	1	2
	TOTAL	–	5,500	1	0		
CD-44	NFS	2,300	7,400	3	0		
	TOTAL FED	2,300	7,400	3	0	3	4
	TOTAL	–	11,200	4	1		
CD-45	NFS	44,500	95,200	11	10		
	TOTAL FED	44,500	95,200	11	10	20	25
	TOTAL	–	95,900	11	10		
CD-46	NFS	27,100	88,200	8	3		
	BLM	3,200	8,100	0	2		
	TOTAL FED	30,300	96,300	8	5	22	24
	TOTAL	–	97,900	8	5		
CD-47	NFS	5,400	22,500	1	3		
	BLM	600	1,100	1	0		
	TOTAL FED	6,000	23,600	2	3	6	8
	TOTAL	–	27,600	2	3		
CD-48	NFS	2,700	11,200	2	1		
	TOTAL FED	2,700	11,200	2	1	3	4
	TOTAL	–	13,200	2	1		
CD-49	NFS	8,700	38,500	4	0		
	TOTAL FED	8,700	38,500	4	0	6	12
	TOTAL	–	53,400	5	1		
CD-50	NFS	14,300	36,000	27	1		
	TOTAL FED	14,300	36,000	27	1	28	25
	TOTAL	–	38,000	27	1		
CD-51	NFS	17,300	51,900	11	3		
	TOTAL FED	17,300	51,900	11	3	21	23
	TOTAL	–	54,900	11	3		

Continues

Continued

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers: Known Pairs	Known Singles	Current Projected	Future Projected
CD-52	NFS	35,200	60,200	15	6		
	TOTAL FED	35,200	60,200	15	6	22	25
	TOTAL	–	63,100	15	6		
CD-53	NFS	24,100	39,800	9	7		
	TOTAL FED	24,100	39,800	9	7	18	20
	TOTAL	–	43,800	9	7		
CD-54	NFS	4,000	27,200	5	0		
	TOTAL FED	4,000	27,200	5	0	5	7
	TOTAL	–	30,000	5	0		
CD-55	NFS	34,700	103,500	9	6		
	BLM	2,500	8,000	0	0		
	TOTAL FED	37,200	111,500	9	6	29	31
	TOTAL	–	117,200	9	6		
CD-56	NFS	13,700	65,000	12	8		
	TOTAL FED	13,700	65,000	12	8	22	24
	TOTAL	–	66,400	12	8		
CD-57	NFS	6,500	35,800	5	5		
	TOTAL FED	6,500	35,800	5	5	10	12
	TOTAL	–	37,400	5	5		
CD-58	NFS	5,400	24,100	5	1		
	BLM	–	200	0	0		
	TOTAL FED	5,400	24,300	5	1	6	8
	TOTAL	–	27,500	6	1		
CD-59	NFS	8,400	43,300	2	2		
	TOTAL FED	8,400	43,300	2	2	6	12
	TOTAL	–	44,400	2	2		
CD-60	NFS	2,300	11,200	3	1		
	TOTAL FED	2,300	11,200	3	1	5	6
	TOTAL	–	12,100	3	1		
CD-61	NFS	5,300	25,300	2	0		
	TOTAL FED	5,300	25,300	2	0	4	7
	TOTAL	–	25,800	2	0		
OD-23	DCA crosses state boundary; data are displayed in Oregon Klamath province table (see Table I.8).						
PROVINCE TOTAL FED		481,000	1,334,000	244	91	405	463
PROVINCE TOTAL		–	1,411,100	248	94		

[a]The difference between TOTAL FED and TOTAL is nonfederal lands within the perimeter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.
[b]Portions of this DCA lie in the Oregon Klamath province; data reflect acreage and owls for entire DCA.

Table I.11. Acreage and owl numbers for designated conservation areas in the California Cascades province.[a]

DCA Ident.	Land Status	Acreage NRF	Acreage Total	Owl Numbers Known Pairs	Owl Numbers Known Singles	Owl Numbers Current Projected	Owl Numbers Future Projected
CD-62	NFS	5,200	36,800	7	0		
	BLM	100	200	0	0		
	TOTAL FED	5,300	37,000	7	0	7	9
	TOTAL	–	44,100	7	0		
CD-63	NFS	–	1,900	1	0		
	TOTAL FED	–	1,900	1	0	1	1
	TOTAL	–	2,500	1	0		
CD-64	NFS	2,000	13,200	0	1		
	BLM	100	200	0	0		
	TOTAL FED	2,100	13,400	0	1	1	2
	TOTAL	–	14,200	0	1		
CD-65	NFS	1,000	2,100	0	0		
	TOTAL FED	1,000	2,100	0	0	0	1
	TOTAL	–	2,100	0	0		
CD-66	NFS	200	5,600	1	0		
	TOTAL FED	200	5,600	1	0	1	2
	TOTAL	–	5,700	1	0		
CD-67	NFS	700	1,900	0	1		
	TOTAL FED	700	1,900	0	1	1	1
	TOTAL	–	1,900	0	1		
CD-68	NFS	900	3,700	0	0		
	TOTAL FED	900	3,700	0	0	0	0
	TOTAL	–	3,700	0	0		
CD-69	NFS	1,300	2,400	0	1		
	TOTAL FED	1,300	2,400	0	1	1	1
	TOTAL	–	2,500	0	1		
CD-70	NFS	400	2,900	0	1		
	TOTAL FED	400	2,900	0	1	1	1
	TOTAL	–	3,000	0	1		
CD-71	NFS	100	2,700	0	0		
	TOTAL FED	100	2,700	0	0	1	1
	TOTAL	–	2,700	0	0		
CD-72	NFS	200	1,100	0	1		
	TOTAL FED	200	1,100	0	1	1	1
	TOTAL	–	1,300	0	1		

Continues

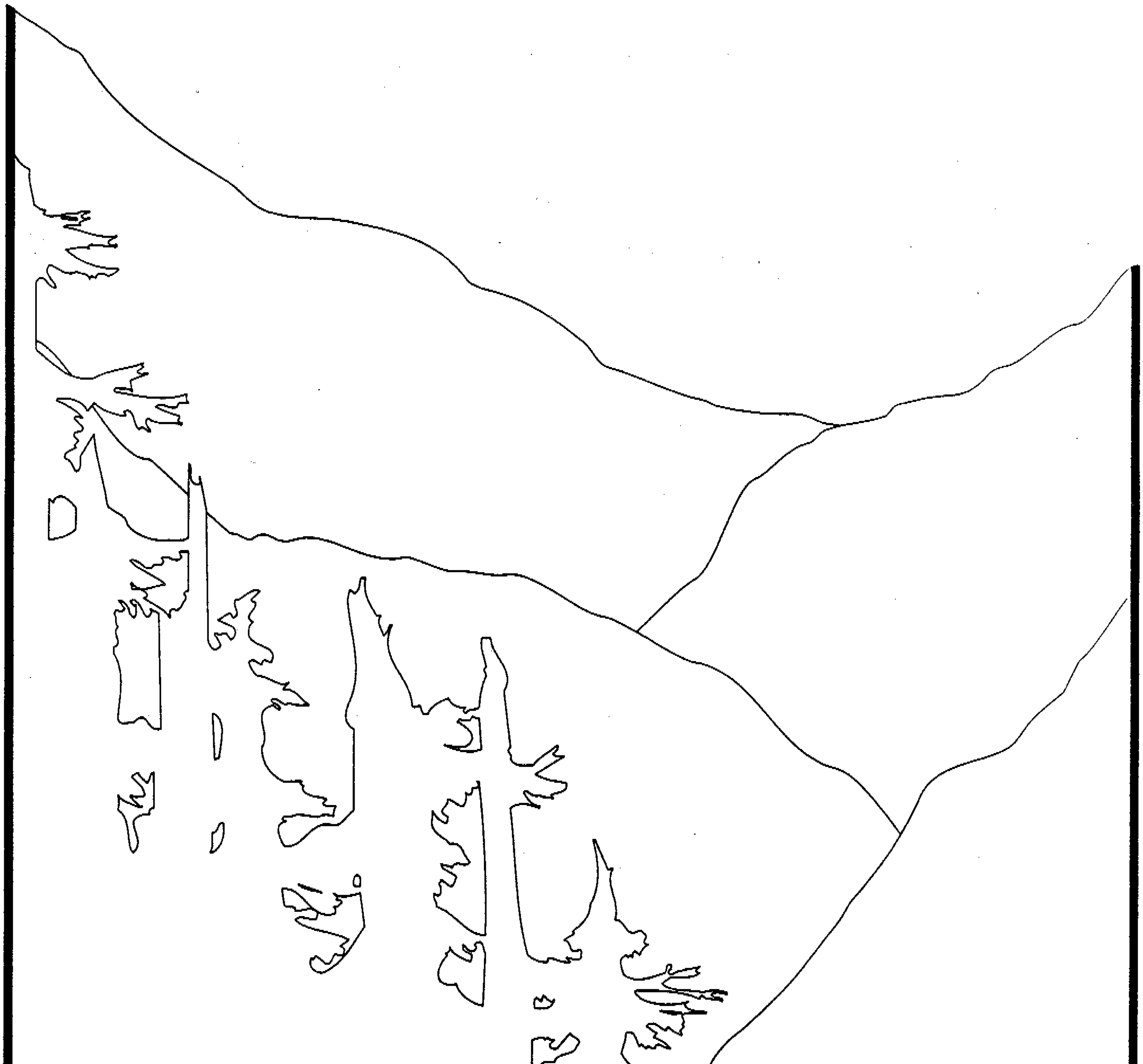
Continued

DCA Ident.	Land Status	Acreage NRF	Total	Owl Numbers Known Pairs	Known Singles	Current Projected	Future Projected
CD-73	NFS	700	1,500	1	0		
	TOTAL FED	700	1,500	1	0	1	1
	TOTAL	–	1,500	1	0		
CD-74	NFS	700	2,200	1	0		
	TOTAL FED	700	2,200	1	0	1	1
	TOTAL	–	2,400	1	0		
CD-75	NFS	1,200	3,100	1	0		
	TOTAL FED	1,200	3,100	1	0	1	1
	TOTAL	–	3,600	1	0		
CD-76	NFS	2,400	2,600	1	0		
	TOTAL FED	2,400	2,600	1	0	1	1
	TOTAL	–	2,700	1	0		
CD-77	NFS	1,100	13,600	2	1		
	TOTAL FED	1,100	13,600	2	1	3	4
	TOTAL	–	14,500	2	1		
CD-78	NFS	200	1,100	1	0		
	TOTAL FED	200	1,100	1	0	1	1
	TOTAL	–	1,100	1	0		
CD-79	NFS	4,100	11,900	2	0		
	TOTAL FED	4,100	11,900	2	0	3	4
	TOTAL	–	13,900	2	0		
CD-80	NFS	2,300	9,600	1	0		
	TOTAL FED	2,300	9,600	1	0	1	3
	TOTAL	–	10,000	1	0		
CD-81	NFS	23,800	67,500	8	4		
	TOTAL FED	23,800	67,500	8	4	12	15
	TOTAL	–	78,900	8	4		
CD-82	NFS	3,900	21,200	1	1		
	TOTAL FED	3,900	21,200	1	1	3	5
	TOTAL	–	33,800	1	1		
CD-83	NFS	300	1,700	0	1		
	TOTAL FED	300	1,700	0	1	1	1
	TOTAL	–	1,700	0	1		
PROVINCE TOTAL FED		52,900	210,600	28	12	43	57
PROVINCE TOTAL		–	247,800	28	12		

*The difference between TOTAL FED and TOTAL is nonfederal lands within the perimiter of designated conservation areas. Management of these lands is discussed in the individual province narratives (section III.). Values shown as "-" indicate an unknown number.

Appendix J

Management Prior to the Recovery Plan



Contents

I. Introduction

Habitat of the northern spotted owl is managed by many individuals, corporations, federal and nonfederal agencies, and Indian tribes. The large number of entities involved and the diversity of statutory and regulatory authorities under which land is managed pose a challenge and provide opportunities for coordinating landscape-level conservation measures for the species. This appendix explains federal, state, and Indian land management authorities throughout the range of the northern spotted owl. The sections are organized to accommodate the specific roles played by the groups that will participate in recovery. In each case, the intention is to show the means available to participants carrying out the recovery plan.

II. Federal Agencies

1. U.S. Forest Service

Management Background

Before the early 1970s, little was known about the northern spotted owl in national forests in Washington, Oregon, and California except that it resided in a variety of forest types. Early research in Oregon and California indicated an association with mature and old-growth forests.

In 1973, an interagency committee was organized, consisting of biologists from the Forest Service, U.S. Bureau of Land Management (BLM), U.S. Fish and Wildlife Service (FWS), Oregon Department of Fish and Wildlife (ODFW), and Oregon State University. The committee, known as the Oregon Endangered Species Task Force, recommended that 300 acres of old-growth forest be retained around every known spotted owl nest site.

During the next 3 years, research provided information about spotted owl habitat needs (Gould 1974, Forsman 1976). In November 1976, the regional forester for the Pacific Northwest Region directed that nest sites of spotted owls be protected in national forests in Oregon, as prescribed by the task force, until biological unit management plans were developed.

In 1976, the Oregon Endangered Species Task Force recommended a long-range goal to maintain 400 pairs of spotted owls on public lands in Oregon. The task force spent 1977 developing objectives and management prescriptions to meet that goal. For that 1-year period, the task force recommended that involved agencies protect locations around northern spotted owl nests and areas where spotted owls had been sighted.

On November 3, 1977, the Oregon Endangered Species Task Force released its Interagency Spotted Owl Management Plan. In the plan, national forests in Oregon were requested to support at least 290 pairs of spotted owls, the BLM was asked to support 90 pairs of spotted owls, and 20 pairs were identified for lands in other ownerships. Each pair of spotted owls was to have a minimum of 1,200 contiguous acres of habitat consisting of a core area of at least 300 acres of old-growth conifer forest (to the extent it was available) and an additional 900 acres, of which at least 50 percent was to be in stands more than 30 years old. Additional criteria were given for the distribution of habitat and proximity among pairs of spotted owls.

On January 11, 1980, there was an appeal of the decision not to prepare an environmental assessment or an environmental impact statement before adoption of the Oregon Endangered Species Task Force's Spotted Owl Management Plan. The Chief, U.S. Forest Service, Washington, D.C., upheld the decision by the regional forester for the Pacific Northwest Region. However, the Chief directed that the Regional Guide for the Pacific Northwest Region, and accompanying environmental impact statement include 1) a biological analysis to determine the number and distribution of spotted owls that would constitute a viable population, 2) regional management and monitoring standards, and 3) an evaluation of needed research. The Forest Service also directed that until the regional plan was approved, 290 pairs of spotted owls should be protected in national forests in Oregon using the guidelines in the Interagency Spotted Owl Management Plan. Where necessary, adjustments were to be made to timber sales offered after October 1, 1980.

In October 1980, national forests in Washington were directed to protect, in accordance with the Interagency Spotted Owl Management Plan, the habitat of all confirmed spotted owl pairs. In April 1981, tentative allocations of spotted owls were assigned for the Gifford Pinchot, Mt. Baker-Snoqualmie, Olympic, and Wenatchee National Forests. These allocations totaled 112 pairs of spotted owls.

Also in 1980, the Spotted Owl Subcommittee, which replaced the task force, revised its Spotted Owl Management Guidelines in light of additional research and information. Results of radio-telemetry studies of spotted owls (Forsman 1980) became available in December 1980. These studies indicated that the amount of suitable habitat that existed within 14 home ranges studied was much larger than 300 acres. The Spotted Owl Subcommittee also worked with other consultants during 1980. One of the consultants (Soulé in Soulé and Wilcox 1980) recommended protection of a population of 500 or more pairs of owls for genetic reasons.

Based on the report from Forsman (1980) and consultation with Soulé, the Oregon-Washington Interagency Wildlife Committee revised the Interagency Spotted Owl Management Plan in February 1981. The revision called for 1,000 acres of old-growth habitat to be maintained for each spotted owl pair, with 300 acres around the nest site, if known, and an additional 700 acres within 1.5 miles of the nest site.

In May 1981, the Forest Service issued the Draft Pacific Northwest Regional Plan. The plan contained direction on the number and distribution of spotted owl pairs to be evaluated in forest planning. It also included in the appendix the February 1981 revision of the Oregon Interagency Spotted Owl Management Plan.

In 1982, the Forest Service, in cooperation with the BLM, initiated an Old-Growth Wildlife Research and Development Program in the Forest Service's Pacific Northwest Research Station.

During 1984, more information about spotted owls was published by Forsman et al. (1984). In May 1984, the Regional Guide for the Pacific Northwest Region and accompanying final environmental impact statement were published. These documents replaced the draft environmental impact statement for the regional plan. The regional guide included standards and guidelines for forest-level planning of spotted owl habitat management, and directed national forests to analyze the effects of protecting at least 375 pairs of spotted owls in Oregon and Washington national forests.

Interim direction in the regional guide specified that until forest plans were approved, national forests were to manage for the tentative regional total of 402 pairs, with each pair being allocated 300 acres of old-growth habitat.

In April 1984, national forests in Oregon and Washington were directed to locate habitat areas to maintain a well-distributed population of spotted owls. Establishment of habitat areas subsequently was considered necessary and sufficient to meet the management requirement for population viability.

On October 22, 1984, the National Wildlife Federation, Oregon Wildlife Federation, Lane County Audubon Society, and Oregon Natural Resources Council filed an administrative appeal to the standards and guidelines for management of northern spotted owl habitat contained in the regional guide. The regional guide was remanded to the Forest Service with direction to prepare a supplemental environmental impact statement.

In California, several national forests had not yet begun by 1984 to implement the regional standards and guidelines because of delays in preparing individual forest management plans. The California Department of Fish and Game and the Forest Service agreed that regional standards and guidelines should be implemented before existing owl management options were lost. As a result, a network of spotted owl habitat areas was established in all western Sierra Nevada and northwestern California national forests.

In January 1987, the Forest Service's Pacific Northwest and Pacific Southwest Regions and Research Stations initiated the Northern Spotted Owl Research, Development, and Application Program. This program was designed to accelerate and coordinate all Forest Service activities concerned with owl habitat and population inventory, monitoring, and research. Results of the program have been used by the Forest Service to amend and revise direction for owl habitat management.

In December 1988, the Chief of the Forest Service approved an amendment to the regional guide for the national forests in Oregon and Washington. This amendment adopted standards and guidelines for management of spotted owl habitat in Washington and Oregon, initiated an accelerated research project on the owl's habitat requirements, and committed the Forest Service to revisit the decision in 5 years or sooner should new information become available.

On February 8, 1989, a complaint was filed in the federal District Court in Seattle by the Seattle Audubon Society and other environmental organizations, alleging that the Forest Service's adoption of the amendment to the Regional Guide for the Pacific Northwest violated the National Forest Management Act (NFMA), the National Environmental Policy Act (NEPA), and the Migratory Bird Treaty Act (MBTA). The plaintiffs requested a preliminary injunction on all timber sales containing 40 or more acres of spotted owl habitat in the 13 national forests with owls in Washington and Oregon. In March 1989, the court enjoined 163 timber sales pending further hearings.

Section 318 of the 1990 Interior and Related Agencies Appropriation Act addressed the issue of the spotted owl; the Seattle Audubon Society lawsuit in particular. The act provided additional protection for old-growth forests and existing designated areas managed for spotted owls.

The 1990 appropriation act directed the Chief of the Forest Service to revise his December 1988 decision. Further, the act directed him to consider the conservation strategy being developed by the Interagency Scientific Committee (ISC) in the revised decision. "A Conservation Strategy for the Northern Spotted Owl, Report of the Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl" was released in April 1990.

On September 28, 1990, the U.S. Department of Agriculture gave notice that the Forest Service was vacating the December 1988 Record of Decision regarding spotted owl management and that it would manage "... not inconsistent with the ISC Report." The Forest Service then completed a spotted owl conservation strategy and has been preparing timber sales in compliance with this strategy since October 1990.

On October 22, 1990, the Seattle Audubon Society filed an amended complaint with the federal District Court in Seattle alleging that the September 3, 1990, notice vacating the 1988 Record of Decision and the spotted owl habitat area system were illegal. Twelve timber sales were challenged under NFMA, NEPA, and MBTA aspects of the case, and were enjoined in December 1990.

The court ruled on March 7, 1991, that listing of a species under the Endangered Species Act did not relieve the Forest Service of its duty to ensure a viable population of the species. The court also held that the October 3, 1990 (55 FR 40412), notice was adopted in violation of NFMA regulations. Eventually, the Forest Service was enjoined from auctioning or awarding any timber sales in suitable owl habitat while the agency prepared an environmental impact statement and otherwise complied with the court's orders.

The Forest Service filed a notice of intent to issue an environmental impact statement on May 8, 1991, and invited public comment for 3 months. The draft environmental impact statement was issued in September 1991. A final environmental impact statement was completed and the record of decision was signed on March 3, 1992. However, timber operations on national forest lands are currently under litigation to respond to new information about owls and to consider the impacts of the plans on other old-growth forest species. As a result, the Forest Service is revising its environmental impact statement on the management of the northern spotted owl for all three states, and a final supplemental environmental impact statement is expected in 1993.

Applicable Law

National Forest Management Act. NFMA requires that national forests develop and maintain land and resource management plans. These plans must be updated every 10 to 15 years. NFMA requires that the management plans include but not be limited to the following:

1. An analysis of present and anticipated uses, demand for, and supply of the renewable resources, with consideration of the international resource situation, and an emphasis on pertinent supply and demand and price relationship trends.

2. An inventory, based on information developed by the Forest Service and other federal agencies, about present and potential renewable resources, and an evaluation of opportunities for improving their yield of tangible and intangible goods and services, together with estimates of investment costs and direct and indirect returns to the federal government.

3. A description of Forest Service programs and responsibilities in research, cooperative programs and management of the national forest system, their interrelationships, and the relationship of these programs and responsibilities to public and private activities.

4. A discussion of important policy considerations, laws, regulations, and other factors expected to influence and affect significantly the use, ownership, and management of forests, rangelands, and other associated lands.

2. U.S. Bureau of Land Management

Within the geographic range of the northern spotted owl, the BLM administers 2.4 million acres in Oregon, Washington, and California. These lands include public as well as railroad grant lands that reverted to federal ownership pursuant to the Oregon and California Sustained Yield Act (O&C Act). The reverted grant lands comprise alternate sections in a checkerboard arrangement in the Medford, Eugene, Coos Bay, Salem, Roseburg, and Lakeview (Klamath Falls Resource Area) districts in western Oregon. The Oregon office manages the largest amount of owl habitat on BLM lands, followed by the California and Washington BLM offices, respectively.

Management Background

The BLM initiated management for the northern spotted owl through land-use plans completed for the five western Oregon districts between 1978 and 1983. These plans provided habitat for 79 owl pairs under management guidelines that called for a central core area of 300 acres of contiguous old-growth or the next older forest, surrounded by an additional 900 acres managed to maintain at least 50 percent of the trees in stands older than 30 years for each pair. The approach to protection and management of the sites varied by district, but generally harvest from commercial forest lands was either prohibited or severely restricted within the 1,200-acre area along with additional prohibition from cutting on other lands within the area designated for other resource management purposes.

In December 1983, the BLM and the ODFW signed an agreement to provide habitat for 90 owl pairs. This agreement added 11 pairs to the existing 79 pairs identified in the land-use plans. The agreement was to remain in effect for 5 years, but was revised in 1987 extending it until the planning process for the 1990s was completed. It was anticipated, at that time, that new land-use plans would be prepared by 1992. Under the revision, an additional 20 pair sites were added bringing the total managed sites to 110. The goal of this agreement was to maintain a well-distributed population of a least 90 pairs of owls on BLM-administered lands in western Oregon. The actual number of sites was later reduced to 109 with the congressional transfer of land, which contained one site, to the Grand Ronde Indian Reservation. This pair was not replaced. Guidelines for providing habitat for the 110 sites were derived from information by Forsman and Meslow (pp.58, 59 in Gutiérrez and Carey 1985). Their radio-telemetry work with six pairs of owls showed an average of 2,200 acres of old-growth habitat within the home ranges of the pairs studied. For purposes of the agreement, the habitat goal for the pair sites was to identify 2,200 acres of forest older than 80 years that was within 3 miles of a site center. Harvest was deferred from these lands unless otherwise agreed to by the ODFW. In practice, the total acreage for the 110 agreement sites was 230,400 acres (later reduced to 228,000 with the change to 109 sites). The acreage per site varied from 734 to 4,188 acres because of home range size data from specific radio-telemetry data or because of the lack of coniferous forests more than 80 years old.

In 1989, an additional 12 sites were established under instructions to the BLM in section 318 of the Fiscal Year 1990 Interior and Related Agencies Appropriations Act (Public Law 101-121). These additional sites were managed under the same guidelines as those under the BLM/ODFW agreement. This brought the total owl management areas to 121 on which the BLM deferred harvest on identified tracts of 80-plus-year-old forests.

Based on data collected between 1985 and 1990, the preceding management provided protection for approximately 20 percent of the known pairs of spotted owls on BLM lands. These interim protection areas were designed to provide for long-term maintenance of one pair in each site; however, it was concluded that additional pairs or singles may live within the boundaries of the designated sites.

In May 1990, the ISC released its report on a conservation strategy for the northern spotted owl. In September 1990, the BLM adopted the Jamison strategy, (named for the BLM's director, Cy Jamison) (Jamison 1990) which incorporated the major elements of the ISC report and established the following guidelines for a 2-year period:

1. All current land-use allocations under existing land-use plans for uses other than timber management will be continued.

2. No regular green timber sales will be offered in proposed habitat conservation areas (HCA) category 1 through 4. All timber sales will be surveyed using BLM timber sale survey protocol, and any new owl pairs in the zone requiring category 3 HCA areas will be protected as per ISC report recommendations.

3. Salvage sales may be offered in HCAs if the action is to have no effect on the spotted owl or its habitat, or if through consultation with the FWS the sale is cleared for harvest.

4. Forest management practices, such as tree planting on previously logged units, seedling maintenance, site preparation, precommercial thinning, and fertilization would also be permitted in the HCAs during the 2-year period.

5. No regular green timber sales will be offered in the 109 spotted owl agreement areas established under the 1987 agreement between the BLM and the ODFW, or in the 12 additional areas established under section 318 of Public Law 101-121. Timber salvage sales may be offered in the ODFW agreement areas only after the concurrence of the ODFW.

6. In planning timber sales outside of category 1 and 2 HCAs consider unit placement, to the extent possible, to reduce or eliminate the impact on the existing habitat conditions for those forestlands which have mean dbh of at least 11 inches and canopy closure of at least 40 percent. The intent of this guideline is to provide dispersal habitat for owls.

7. Prepare a preharvest/postharvest profile of the habitat conditions in the forest matrix (forestlands outside of category 1 and 2 HCAs) using quarter-township assessment areas to describe the percentage of the area in "stands with a mean dbh of at least 11 inches and canopy cover of at least 40 percent" condition. Include the profile narrative, figures, and maps as part of the BLM's biological assessment package on the fiscal year 1991 and 1992 annual timber sale plan that is submitted to the FWS for consultation.

8. Comply with the provisions of the Endangered Species Act relative to the spotted owl by consulting on all actions that constitute a "may affect" situation on the species or its habitat. Implement the mandatory terms and conditions in the FWS biological opinion to minimize incidental "take" of owls and habitat and, as appropriate, implement recommended conservation measures.

The Endangered Species Act generally prohibits the "taking" of listed species. Take is defined in part as harm, harassment, or killing individuals of the species.

The Jamison strategy remained in effect until September 11, 1991, when the U.S. District Court in Eugene, Oregon, enjoined the BLM from implementing the strategy until the BLM complies with section 7 of the Endangered Species Act by submitting the strategy for consultation to the FWS. Management of BLM lands in Oregon will be based on existing timber management plans until completion of new resource management plans in 1993. This court decision did not affect management on BLM lands in California or Washington.

Resource Management Planning

In Oregon, the BLM currently is formulating alternatives for its western Oregon districts. Draft resource management plans were completed in 1992 and an environmental impact statement will be completed in 1993. The BLM is considering five alternatives including one that would emphasize high production of timber and other economically important values on all lands to contribute to community stability; one that would emphasize protection of older forests values such as dispersed nonmotorized recreation opportunities and scenic resources; and one aimed at maintaining biological diversity, such as fish and wildlife habitat, recreation, and scenic resources on all lands. The BLM plans to analyze the effects of each alternative on spotted owls. The BLM, in cooperation with the Forest Service's Pacific Southwest Research Station Redwood Sciences Laboratory, is working to develop a spatially explicit life history simulator (model) for the relative assessment of impacts of management scenarios on the northern spotted owl.

Management of spotted owl habitat in California is confined to the Ukiah District office. Current planning efforts for the Ukiah District, Arcata Resource Area, are focused on completing the record of decision for the resource management plan. The record of decision will defer any further green timber sales or disposal of lands containing old-growth habitat pending the completion of a state-initiated habitat conservation plan (HCP) for the owl. The Redding Resource Area recently released its draft resource management plan and is analyzing comments. Timber stands in the two resource areas are generally less than 300 acres and only rarely adjacent to other agency lands. Six tracts have been designated old-growth research natural areas or areas of critical environmental concern. The BLM Ukiah district manager is a member of the northern spotted owl HCP steering committee and two BLM scientists are members of the HCP scientific committee.

The BLM Spokane (Washington) District office manages approximately 3,000 acres of forestlands within the range of the spotted owl. Owl management has been limited to project clearance, surveys, and protection of suitable habitat in known owl activity areas. No nest sites are currently known.

Present Status of Habitat and Trend

The ISC and the 1990 status review of the northern spotted owl (USDI 1990) referred to the major factors influencing the amount and distribution of owl habitat on BLM lands. The major factors identified include scattered and checkerboard land patterns; past land management activities (primarily timber harvest); and natural occurrences such as forest succession, wildfires, and windstorms. This has created a mosaic patchwork of stands older than 80 years old as habitat for spotted owls. These stand sizes range primarily from 50 to 500 acres, with some exceptions of 2,000 to 5,000 acres. The remainder of the landscape is in recent clear-cuts or forest stands ranging from 5 to 80 years old. Clear-cutting is the predominant harvest practice used by the BLM in western Oregon. Both clear-cutting and selective harvesting have been used in southwestern Oregon and northern California. Only limited use of silvicultural practices has been experimented with to create or maintain spotted owl habitat.

In past years, the BLM has classified forest stands older than 80 years as spotted owl habitat, using forest age classes, size, and crown closure as the main criteria. Because these attributes may not provide an adequate characterization of suitable owl habitat, the BLM refined its habitat figures using forest operations inventory data combined with a quality check by resource area biologists. Spotted owl habitat on BLM lands in western Oregon is identified with two habitat component levels representing levels of habitat quality.

BLM lands in the Ukiah District, Arcata Resource Area, consist of isolated blocks generally 40 to 3,000 acres that are imbedded in a private landscape. The private lands have been subjected to extensive harvest during the last decade and contrast with the older timber stands on the adjacent public lands, where most of the remaining owl territories are found.

Clear-cutting has not been practiced in the Ukiah District since 1981. Starting in 1982, the BLM has practiced the managed old-growth concept of forestland management on all timber sales. These guidelines provide for at least 10 percent of the site's potential basal area to be occupied by trees that have survived at least two 100-year rotation cuttings. These superdominant trees provide a base for future recruitment of snags and down debris. The structural elements of old-growth management include 1) large trees for shade and reproduction, 2) large snags for nesting, 3) large debris for nitrogen fixation and carbon recycling, and 4) coarse woody debris in the headwater areas of drainages for erosion control.

Estimates were made in the 1990 status review of the northern spotted owl (USDI 1990) predicting the rate of decline of habitat during the next 10 to 50 years on BLM-administered lands. Historic data showed a loss of approximately 475,000 acres during the last 20 years. Assuming the harvest rates prior to the listing of the owl, habitat would have been extremely limited within 30 years. However, since the 1990 listing, the actual timber sale level has been reduced to approximately 40 percent of recent historical levels. This change is based on congressional direction and FWS biological opinions on BLM timber sales. Future harvest could be reduced to even lower levels. However, BLM forestlands harvested in the late 1960s and early 1970s could be expected to begin providing limited spotted owl habitat in the next 50 to 60 years.

Inventory and Monitoring

The BLM in Oregon has been surveying its lands for spotted owls since the early 1970s. The proportion of BLM lands that have been inventoried by district ranges from 50 to 90 percent. Early inventories were neither complete nor uniform, although data were accumulated on historic locations of owls throughout the land base. After the completion of land-use plans in 1983, a comprehensive monitoring plan was developed for Oregon and initiated in 1986. This has resulted in more consistent and complete data collection among districts. When surveys found and verified new owl locations, these were added to the list of sites to be monitored. The process is based primarily on locating and tracking owls over time. Oregon data from the period of 1988 through 1990 showed that 518 pairs of owls were verified on BLM lands in western Oregon. Single owls or unconfirmed pairs were found at an additional 110 locations during this same period. More than 60 percent of the owls found were in the Roseburg and Medford Districts.

The BLM also implemented an intensive banding program in 1985 to mark individual owls. Through 1990, more than 1,800 owls were banded, nearly a third of them were juveniles. Results from the banding information will provide insights into longevity, movement, survival, and age at first breeding.

Inventories of northern spotted owl habitat in California since 1977 have been conducted as needed to survey timber harvest plans or other major land-use actions. Complete documented survey data have been maintained only since 1988. With about 25 percent of the habitat surveyed in the Ukiah District, 20 pairs of owls (17 in the Arcata Resource Area and 3 in Redding Resource Area) have been detected on BLM lands in California since 1988. Thirty percent of known spotted owl territories (7 of 17) in the Arcata Resource Area have been monitored continuously since 1987 by researchers from Humboldt State University, but no comprehensive monitoring program has been developed yet for California.

Applicable Law

The principal legislative mandates guiding management of these lands are derived from the O&C Act and the Federal Land Policy and Management Act (FLPMA). The O&C Act applies exclusively to lands in western Oregon, generally configured in an alternate-section checkerboard pattern. The O&C Act directs management of these lands for sustained-yield permanent forest production that contributes to economic stability of local communities and industries. In addition, other management requirements are for permanent timber supply, protection of watersheds, regulating stream flows, and providing recreation facilities. FLPMA provides multiple-use management direction and overall resource-management planning requirements for all lands administered by the BLM.

3. National Park Service

The following areas managed by the National Park Service (NPS) are known to contain northern spotted owls: North Cascades, Mt. Rainier, and Olympic National Parks in Washington; Crater Lake National Park and Oregon Caves National Monument in Oregon; and Redwood National Park, Point Reyes National Seashore, and Muir Woods National Monument in California. Whiskeytown National Recreation Area in California also may be occupied by northern spotted owls. These areas provide up to 540,000 acres of suitable habitat, although none has been surveyed for owls. The NPS currently has no coordinated inventory and monitoring program for spotted owls.

Management Background

Management of areas by the NPS is generally compatible with that required for recovery of the northern spotted owl. In fact, Barry (1990) suggested that few environmental laws are more consistent with NPS objectives than the Endangered Species Act. The primary purpose of the Endangered Species Act is to preserve for future generations endangered and threatened species and the ecosystems upon which they depend, while the goal of the NPS is to "conserve the scenery and the natural and historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations" (NPS Organic Act).

The policy of the NPS is to manage natural resources "with a concern for fundamental ecological processes, as well as for individual species" (NPS Management Policies 1988:4:1) and "identify and promote conservation of all federally listed threatened, endangered, or candidate species within park boundaries and their critical habitats." Active management programs will be conducted as necessary to perpetuate the natural distribution and abundance of threatened or endangered species and the ecosystems on which they depend (NPS Management Policies 1988:4:11).

Management actions will be in accordance with, and follow recovery priorities identified in approved recovery plans (NPS 1991:273). Habitat manipulation, species restoration, or population augmentation are "encouraged if identified as appropriate in the recovery plan and if such activities would result in a more representative distribution of the species within the park" (NPS 1991:274). Such management activities must "consider potential impacts on other native species" and "significant modification of habitat and landform is discouraged unless necessary to prevent extirpation or extinction of the species" (NPS 1991:274). All management actions for endangered or threatened species will be described and assigned priorities in the park's approved resources management plan.

Applicable law

The general authority under which the NPS operates is the NPS Organic Act (16 USC 1), which authorizes the NPS to "regulate the use of the federal areas known as national parks." See the statement of purpose of this act earlier in this section.

Each park also has its own enabling act. Congress has stated in the enabling legislation of most units that they have their own particular purposes and objectives. These may be broad or very specific. For example, Crater Lake National Park was established in 1902 "as a public park or pleasure ground for the benefit of the people of the United States." Redwood National Park, created in 1968, was established "to preserve significant examples of the primeval coastal redwood forests and the streams and seashores with which they are associated for purposes of public inspiration, enjoyment, and scientific study." The Endangered Species Act applies to all national park system areas as it does to other federal lands.

4. U.S. Fish and Wildlife Service

Management Background

The FWS administers several national wildlife refuges within the range of the spotted owl. Two refuges in Oregon and two in Washington contain small parcels of suitable owl habitat. National wildlife refuges are managed in accordance with goals of preserving a natural diversity and abundance of fauna and flora on refuge lands and of preserving, restoring, and enhancing in their natural ecosystems all endangered and threatened species of animals and plants.

The FWS is also responsible for administering the Endangered Species Act. This includes assisting other agencies with implementation of the act, including consultation on actions that may affect listed species. Since the northern spotted owl was proposed for federal listing in 1989, the FWS has conducted hundreds of conferences and consultations under section 7 of the Endangered Species Act concerning the land management activities of federal agencies within the species' range. Since publication of the proposal to designate critical habitat, conference and consultation also have been conducted with regard to effects of federal management on the areas designated as critical habitat. With final designation of critical habitat on January 15, 1992, consultation responsibilities were extended to these areas so designated (USDI 1992).

In 1988 the FWS expanded a 1987 Interagency Agreement with the Forest Service to include the Bureau of Land Management and National Park Service. The Purpose to cooperate on the management and conservation of all 3 subspecies of spotted owls. The FWS signed another interagency agreement in 1990 with three federal agencies (USDA Forest Service, Bureau of Land Management, National Park Service) and three state agencies designated by their respective Governors (Resources Agency of California, Oregon Department of Fish and Wildlife, and Washington Department of Wildlife). The purpose of the interagency agreement is to cooperate and coordinate activities involving the conservation of the northern spotted owl. A formal coordinating group, the Interagency Northern Spotted owl Conservation Group, was established to handle coordination activities for this subspecies.

Applicable Law

The FWS assists other federal agencies in fulfilling their obligations under section 7 of the Endangered Species Act. The act requires agencies to undertake programs for the conservation of endangered and threatened species and to ensure that their actions are not likely to jeopardize the continued existence of a listed species or to destroy or adversely modify its critical habitat. Agencies must consult with the FWS on any action that may affect a listed species or critical habitat.

> *Conservation,* as defined in the Endangered Species Act "means to use and the use of all methods and procedures which are necessary to bring any endangered species or threatened species to the point at which the measures provided pursuant to this Act are no longer necessary."

Consultation. The FWS conducts consultations at the request of an action agency to determine whether actions proposed by federal agencies are likely to "jeopardize the continued existence" of threatened or endangered species, or result in "destruction or adverse modification" of critical habitat designated for listed species. These phrases are defined in regulations (50 CFR 402.02) as follows:

> "*Jeopardize the continued existence* means to engage in an action that reasonably would be expected, directly or indirectly, to reduce appreciably the likelihood of both the survival and recovery of a listed species in the wild by reducing the reproduction, numbers, or distribution of the species."

> "*Destruction or adverse modification* means a direct or indirect alteration that appreciably diminishes the value of critical habitat for both the survival and recovery of a listed species. Such alterations include, but are not limited to, alterations adversely modifying any of those physical or biological features that were the basis for determining the habitat to be critical."

The results of a consultation are summarized by the FWS in a biological opinion. During the consultation, the FWS estimates the amount of take of listed species that will occur incidental to the action. If the proposed action would result in incidental take, then the FWS is required to develop "reasonable and prudent measures" to minimize the level of take. The biological opinion states whether incidental take is authorized (assuming the reasonable and prudent measures are followed), and describes the permissible level of take. The description of allowable take is called an incidental take statement.

If the FWS concludes that the action is likely to jeopardize a species, or lead to the destruction or adverse modification of critical habitat, then the FWS attempts to work with the action agency to develop reasonable and prudent alternatives. Reasonable and prudent alternatives are designed to allow the action to continue without jeopardizing the continued existence of the species or resulting in the destruction or adverse modification of critical habitat.

> "*Reasonable and prudent alternatives* refer to alternative actions identified during formal consultation that can be implemented in a manner consistent with the intended purpose of the action, that can be implemented consistent with the scope of the federal agency's legal authority and jurisdiction, that is economically and technologically feasible, and that the director believes would avoid the likelihood of jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat." (50 CFR 402.02.)

Agencies are required by the Endangered Species Act to follow the provisions of the incidental take statement and to implement the reasonable and prudent measures. The act also requires agencies to avoid jeopardizing any listed species or causing destruction or adverse modification of critical habitat. Agencies may act on their own conclusions, however, about whether a proposed action will have any of these effects; they do not have to accept the judgment of the FWS. Therefore, once consultation is complete, agencies may proceed with the action regardless of the outcome of the consultation as long as they follow the provisions of the incidental take statement and the reasonable and prudent measures (if any).

Further consultation is not required except in the following situations:

> "Federal involvement or control over the action has been retained or is authorized by law and:
>
> a) If the amount or extent of taking specified in the incidental take statement is exceeded;
> b) If new information reveals effects of the action that may affect listed species or critical habitat in a manner or to an extent not previously considered;
> c) If the identified action is subsequently modified in a manner that causes an effect to the listed species that was not considered in the biological opinion; or
> d) If a new species is listed or critical habitat designated that may be affected by the identified action." (50 CFR 402.16)

When a species has been proposed for listing or an area has been proposed for designation as critical habitat, a similar procedure, known as conference, is required. A conference results in an advisory report to the action agency, but does not provide an opinion regarding the likelihood of violation of section 7.

Section 9 prohibition against take. The FWS also enforces the Endangered Species Act's taking prohibitions and participates in conservation planning with nonfederal parties. Development of a conservation plan that satisfies the act's requirements can be the basis for issuance of incidental taking permits to nonfederal land managers or other nonfederal parties involved in a taking situation.

After the northern spotted owl was listed as a threatened species, private timberland owners and congressional sources requested guidance from the FWS on how timber could be harvested without violating the Endangered Species Act. Since the primary requirement of nonfederal entities under the Endangered Species Act is the prohibition against take, the FWS issued guidance on the measures needed to avoid taking owls. The "survey and circle" approach described in that guidance was not intended as a management approach for the owl and would not provide adequate long-term protection for the subspecies. Concern was also raised about the substantial costs being incurred by landowners providing these protective measures. These guidelines were rescinded in 1992. The biological information on which the guidelines were predicated is still recommended as a guide to help landowners predict when their action may biologically impair owls. The FWS is considering development of a regulation to address this issue.

The success of the prohibition against take in contributing to recovery is variable, and is dependent upon the province and existing conditions within owl home ranges. It is also dependent upon the application of the take prohibition guidelines by state regulators and the FWS. Each state has a different ability and capacity to apply the take guidelines based on differences in their regulatory frameworks. There are two mechanisms that may be used to authorize take.

Habitat Conservation Plans. The Endangered Species Act generally prohibits the "taking" of listed species. Take is defined in part as harm, harassment, or killing individuals of the species. Destruction of the species' habitat which ultimately results in harm or harassment to the species may also constitute a taking under the Endangered Species Act. Prior to 1982, the only activities that could be exempted from the prohibition against take were scientific research, captive breeding, and similar conservation actions. In 1982, the Endangered Species Act was amended to permit taking "if such taking is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity." In permitting such "incidental take," Congress hoped to reduce conflicts between listed species and private development and to encourage "creative partnerships" between the private sector and local, state, and federal agencies in the interest of endangered species and habitat conservation.

An applicant for an incidental take permit is responsible for developing an HCP. An HCP can be tailored to an individual landowner's specific situation. The applicant must agree to institute appropriate conservation measures for habitat maintenance, enhancement, and protection, described in a habitat conservation plan (HCP). The FWS reviews the HCP and, before issuing a permit for the incidental take, must find that 1) the taking will be incidental; 2) the applicant will, to the maximum extent practicable, minimize and mitigate the impacts of such taking; 3) the applicant will ensure that adequate funding for the HCP will be provided; 4) the taking will not appreciably reduce the likelihood of survival and recovery of the species in the wild; and 5) other measures that the FWS may require will be met.

Development of HCPs by private companies has begun in California; as of the date of this recovery plan, one HCP has been completed and a "no take" plan has also been accepted. The state of California is also developing a statewide HCP. Development of HCPs is also underway at the state level in Oregon and by some private companies in Washington.

Section 4(d) special rule. For endangered animals, section 9 of the Endangered Species act directly prescribes prohibitions against taking. Take is defined broadly under the act as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture, or collect, or attempt to engage in any such conduct. For threatened animals, section 4(d) of the act directs the Secretary to adopt such regulations as he deems necessary and advisable to provide for the conservation of such species. The regulations applied for a threatened species may adopt any or all of the prohibitions applied by section for endangered species. Since 1975, general regulations (50 CFR 17.31) have applied the full range of taking prohibitions for threatened animal species, but also have provided for the alternative of adopting special rules for particular species as necessary and advisable. The FWS has adopted special rules for more than 30 species.

Critical Habitat. The designation of critical habitat identifies areas that are essential to the conservation of a listed species and which may require special management considerations or protection. This can include areas that are not currently occupied by the listed species if those areas are determined to be essential to the species conservation. The term conservation includes "the use of all methods and procedures which are necessary to bring" any list species "to the point at which the measures are no longer necessary". Protection of critical habitat is applicable to actions planned, authorized, or conducted by federal agencies under section 7 of the Endangered Species Act (see previous discussion on consultation).

Designation and revision of critical habitat are regulatory processes that require a proposal and final determination. In addition, the Endangered Species Act requires that an economic analysis be conducted on the effects of the designation and areas excluded from critical habitat if the benefits of the exclusion outweigh the benefits of designation so long as the exclusion would not result in the extinction of the species. The regulatory process takes about 1-2 years to complete and is subject to public review in the rule-making process.

III. States

1. State of California

Regulatory Programs

Forest Practices Act. The Forest Practices Act established a comprehensive system for the regulation and management of timberlands to assure that productivity is restored, enhanced, and maintained, and that the goal of maximum sustained production of high-quality timber products is achieved while giving consideration to watershed, wildlife, recreational, and other important values related to forest ecosystems. The program applies to more than 7 million acres of state and private timberlands.

Rules adopted by the California Board of Forestry implement the provisions of the Forest Practices Act and the requirements of other statutes, such as the California Environmental Quality Act.

The forest practices regulatory programs and review process for timber harvest plans (THP) have been certified by the Secretary of Resources as functionally equivalent to environmental impact report and analysis under the California Environmental Quality Act. Before timber harvest may begin, the Department of Forestry and Fire Protection must review and approve a THP which discloses information on the proposed timber harvest operation and its effects on the environment. A THP may not be approved as proposed if there are feasible alternatives or mitigation measures available that would substantially lessen any significant adverse environmental impacts from implementation of the proposal.

1. Silvicultural Requirements

A THP must indicate which selected silvicultural methods are appropriate to the site conditions to protect environmental values. The THP is subjected to a review process that includes consultation with other departments, such as the Department of Fish and Game and California Water Quality Control Boards, and public review and comment.

2. Sensitive Species Listing Process

The California Board of Forestry identifies by regulation plant and animal species or subspecies that require special consideration in the review of THPs to avoid damage to their habitat areas. The process is similar to the listing process specified under the California Endangered Species Act.

The state forestry board regulations include specific requirements for protecting these species. The northern spotted owl is among the species for which these requirements apply.

3. Watercourse and Lake Protection Zones

The watercourse and lake protection rules ensure protection of the water quality, beneficial uses, and biological characteristics of watercourses and lakes in timberlands. Within fixed protection zones timber operators are restricted or constrained (e.g., by prohibition of clear-cutting and limits on road building) to prevent discharge of materials and erosion in and around watercourses and lakes.

4. Cumulative Effects Assessment

The preparation of a THP must include an assessment of potentially significant cumulative impacts from the proposed timber harvest operation for a number of environmental variables. The assessment process must indicate whether the proposal, when considered with the impacts of past projects and reasonably foreseeable future projects, would result in significant adverse environmental impacts.

Evaluation of cumulative effects on biological resources includes identifying resources of concern, such as threatened and endangered species, sensitive species, important wildlife resources such as game animals, and specific components of wildlife habitat.

Mitigation measures and other protection are included in THPs as needed to avoid, reduce, or offset significant adverse cumulative effects. Direct and indirect effects resulting from the proposed action must be addressed. While the rule does not contain specific mitigation requirements, it does provide an analytical basis for requiring site-by-site protection if needed.

Evaluating potential timber harvest impacts to northern spotted owls in the analysis of cumulative effects provides several benefits for owl conservation: 1) the impacts of a proposed timber operation are assessed in the context of past, present, and future projects in the same area; 2) impacts are assessed on broader temporal and spatial scales than those addressed by individual THPs and an assessment limited to direct impacts; and 3) the assessment process tailors the analysis to fit unique conditions of owl populations and habitat, information availability, and perceived threshold of impacts.

5. Specific Northern Spotted Owl Rules

The state forestry board has adopted specific rules for the protection and conservation of the northern spotted owl (emergency rules in August 1990; permanent rules in February 1991), which are designed to prevent take of northern spotted owls. Approval of any harvest plan that would cause significant long-term damage to the owl must be withheld. Other rules require a THP to provide specific information about owl habitat and owls in the proposed harvest area and adjacent areas. The California Department of Forestry and Fire Protection and the California Department of Fish and Game have developed a procedure whereby plans are reviewed and a determination is made whether the plan will result in a take. This process has the concurrence of the FWS.

6. Nonindustrial Timber Management Plan

As an alternative to THP review, the state forestry board has adopted rules to permit nonindustrial timberland owners holding less than 2,500 acres to submit long-term management and harvest plans. The plans are required to prescribe uneven-age management of the forestlands. The landowner must submit management information regarding silvicultural methods, harvest scheduling, existing and future stand conditions, and other pertinent information. Using this option, spotted owl conservation needs can be integrated with timber harvest and management of nonindustrial timberlands.

California Environmental Quality Act (CEQA). The CEQA is similar to the National Environmental Policy Act; before state or local agencies may approve or undertake any project that may result in significant environmental impacts, they must review and disclose the potential impacts, adopt feasible mitigation measures, and adopt findings regarding the impacts of the proposed project.

California Endangered Species Act. The California Endangered Species Act of 1984 established a process whereby the public or the Department of Fish and Game may submit a petition to the Fish and Game Commission with a recommendation to list (or delist) as threatened or endangered, any native species or subspecies of plant or animal.

If a species is considered a candidate for listing, restrictions on import, export, take, possession, purchase, or sale go into effect. If the species is listed, additional restrictions regarding jeopardy, consultation with California lead agencies, required mitigation measures and commitment to conservation, protection, and enhancement go into effect. The northern spotted owl is not currently listed as a threatened or endangered species under this act.

Land Management

State Parks. Lands in state parks are administered by the California Department of Parks and Recreation to protect and perpetuate natural resource systems and values. Commercial resource development, including timber harvest, is not permitted in state park units. There are 27 state park system units in the northern coastal portions of the owl's range. Eighteen of the units are known to support at least one owl activity center. The Department of Parks and Recreation is participating in the California habitat conservation plan efforts for the northern spotted owl.

State Forests. The California Department of Forestry and Fire Protection administers the state forest system in accordance with a management plan approved by the state forestry board. The Jackson Demonstration State Forest is within the range of the northern spotted owl. It encompasses 50,000 acres that are used for demonstration and research experiments addressing fish and wildlife conservation needs, watershed protection measures, recreational uses, and commercial timber harvest. The state forest is completing a spotted owl and small mammal survey. Timber harvest operations fall under the Forest Practices Act and must comply with all forest practices rules, including those prescribing protection for northern spotted owls under that act.

Protection from Fire. The California Department of Forestry and Fire Protection has primary responsibility for fire prevention and protection for the 32 million acres of state-responsibility lands. The department is responding aggressively to the increasing fire risks associated with prolonged drought and the movement of a significantly larger number of people to rural California. The department is particularly aware of the need to reduce the risk of large, catastrophic fires, such as those likely to affect conservation measures for the northern spotted owl.

Forestry Assistance. Several forestry assistance programs for private landowners are coordinated through the Department of Forestry and Fire Protection, including the California Forest Improvement Program and the Federal Forest Improvement Program. These programs share costs of tree planting and forest management on nonindustrial forestland ownerships. These programs benefit the northern spotted owl by providing another means of establishing habitat over time on lands that might otherwise not be restored or might be converted to nonforest uses.

Assessment, Planning, and Monitoring

Timberland Task Force. The Timberland Task Force was established in January 1990, pursuant to legislative direction (Assembly Bill 1580) to develop a long-term, more comprehensive, process for addressing wildlife issues in the context of forestlands management. The Timberland Task Force is charged with developing a coordinated base of scientific information for analyzing cumulative impacts on the biological diversity of forestlands ecosystems, evaluating timberland habitat for its contribution to the overall maintenance of specific wildlife species, contracting for studies to validate wildlife models and develop mitigation, and identifying critical habitat areas and species of special status. The task force includes representatives from state and federal agencies.

The task force will submit its recommendations in a report to the governor and California legislature. The coordinated data base will be a tool useful in reviewing the cumulative impacts of timber harvest on wildlife over time. The data base includes geographic information system (GIS) analysis of vegetation and habitat on forestlands (a pilot vegetation/habitat mapping project covering approximately 6 million acres within the range of the northern spotted owl has been completed) and linkage with the state's Wildlife Habitat Relationships data base (WHR) to relate vegetation growth and yield models to possible land management options.

Developing from the initial work of the Timberland Task Force, and in recognition of the need for increased coordination among state, federal, and local agencies, a memorandum of understanding establishing an executive council to set guiding principles and policies for efforts to conserve biological diversity was signed on September 19, 1991. This memorandum provides the long-term framework for developing a statewide strategy to conserve biological diversity and for coordinating implementation through regional and local institutions.

The Statewide Executive Council, chaired by the Resources Agency Secretary and consisting of state and federal agencies, will set statewide goals for the protection of biological diversity, and will encourage and assist the establishment of bioregional councils to achieve protection of biological diversity. Under this umbrella, a Klamath bioregion project addressing the range of the northern spotted owl in California is developing, and will build on HCPs.

Habitat Conservation Plans. The California Board of Forestry and Fire Protection initiated the state's habitat conservation planning (HCP) for the northern spotted owl in November 1990, anticipating a future application for an incidental take permit under the federal Endangered Species Act. This effort is in addition to the adoption of rules to ensure that timber harvest on state and private lands in California would not result in a take of northern spotted owls.

The HCP and the associated environmental impact report/environmental impact statement are being developed under the guidance of a broadly based steering committee appointed by the state forestry board.

The steering committee operates under a set of objectives intended to promote development of a plan that fully meets the requirements of the federal Endangered Species Act while also limiting effects on private landowners and economic impacts.

The steering committee and a scientific committee currently are evaluating eight options, which resulted from extensive public scoping efforts and represent a range of levels of protection for the owl. The alternatives have been developed with the assumption that a comprehensive owl conservation strategy, such as the ISC proposal, would be implemented on federal lands. A draft HCP was available for public review in late 1992.

Forest and Rangeland Resources Assessment Program. The Forest and Rangeland Resources Assessment Program (FRRAP) was established in 1978. The charge of the program is to describe and analyze the current conditions of California's forest and range resources base and to anticipate emerging management problems that require public or private action. The FRRAP is involved in a number of efforts related to spotted owl conservation including long-term monitoring of forestlands condition through periodic mapping; development of a statewide GIS for assessing impacts, uses, and trends; development and use of long-term timber harvest simulators that also track impacts on wildlife habitat; and economic impact estimation. The FRRAP provides primary staff to the Timberland Task Force and HCP efforts.

California Natural Diversity Data Base. The Department of Fish and Game maintains the California Natural Diversity Data Base, a computerized inventory of the locations and conditions of endangered, threatened, and rare animal and plant taxa, as well as significant terrestrial and aquatic plant communities which was developed in cooperation with The Nature Conservancy. Project proponents and agencies consult the data base during project development and during the environmental review of various land management activities under the provisions of CEQA. Detailed northern spotted owl sighting information is maintained in an associated data base that is accessed on a "need to know" basis.

Natural Community Conservation Planning. Recent California legislation has established the natural community conservation planning (NCCP) process to meet the needs of threatened and endangered species and to provide protection for significant areas that support natural ecosystems and biological diversity. A memorandum of understanding signed on December 4, 1991, between the FWS and the State of California (Resources Agency and Department of Fish and Game), provides for sharing data and cooperatively developing an NCCP pilot program in southern California.

2. State of Oregon

Oregon has regulatory programs, technical assistance programs, land management objectives, and research that are aimed at conservation efforts for the northern spotted owl.

Regulatory Programs

Forest Practices. The Forest Practices Act (FPA) was enacted to assure the continuous growing and harvesting of forest tree species while protecting soil, air, wildlife, and water resources on 10.1 million acres of private, state, and county forestlands. It regulates commercial forest operations to ensure forest practices that maintain and enhance the benefits of all forest resources.

Under the FPA, threatened and endangered fish and wildlife species are inventoried. This resource inventory will be used to inform forest landowners of their obligation to protect the owl; furthermore, it may help local governments protect some natural resource sites in compliance with Oregon's land-use laws.

Spotted owl nesting sites and activity centers are protected under the FPA rules. Proposed and ongoing forest operations within 1 mile of a spotted owl nest site or activity center must obtain approval of a written plan from the Oregon Department of Forestry before proceeding. Harvest operations must leave a core area comprising 70 acres of the best available habitat in the vicinity of a nest site. The Oregon Department of Fish and Wildlife (ODFW) provides site-specific assessment and advice to landowners when owl sites are identified on nonfederal lands. Overall, forest practices that would significantly reduce suitable habitat in the core area are not allowed. Forest practices that would disturb owl nesting behavior and possibly result in nest failure must not be carried out during the breeding season. In addition to complying with the provisions of the FPA, landowners must comply with the federal Endangered Species Act.

Oregon Endangered Species Act. The northern spotted owl is listed as a threatened species under Oregon's Endangered Species Act. This act authorizes the Oregon Fish and Wildlife Commission to conduct research, census, law enforcement, propagation, transplantation, and habitat acquisition and maintenance for listed species. Agencies must consult with the ODFW before taking any action that may harm owls on state-owned lands.

Statewide Land-Use Planning Program. The State of Oregon has an extensive program for land-use planning. While it is not the first or only statewide planning effort, it is one of the most comprehensive. The program has many aims and objectives, but the most important ones relating to protection of threatened and endangered species are in Goal 4 (Forest Lands) and Goal 5 (Open Spaces, Scenic and Historic Areas, and Natural Resources) of the program.

Department of Forest Land Management. The Oregon Department of Forestry is responsible for managing nearly 786,000 acres of forestlands to secure the greatest permanent value to the state. Production of timber on a sustained-yield basis is established as the primary goal, but due consideration must be given to all other appropriate uses of the land.

Of the 786,000 acres managed, 654,000 acres are Oregon Board of Forestry lands (county trust lands) and 132,000 are Common School lands. Aside from timber harvest, the state forester is authorized to permit other forest uses such as recreation, watersheds, and fish and wildlife conservation. Those lands which, in the opinion of the state forester, have exceptional scenic and/or fish or wildlife habitat values, and on which commercial forest management would significantly degrade those values, are classified as "conservancy." Twenty-six thousand acres of Oregon forestlands are classified as conservancy and reserved from timber harvest. Another 24,000 acres of state forestland are classified as noncommercial (not capable of sustaining timber harvest) and also are withdrawn from timber harvest.

Land Acquisition, Sale, and Exchange. The Oregon Board of Forestry acquired title to lands during the 1930s and 1940s from counties that had foreclosed on the lands for nonpayment of taxes. There is an implicit trust arrangement with the counties requiring payment to the counties of a share of the revenues generated by the land-management activities conducted on these lands. More than two-thirds of these lands are in the Tillamook State Forest, located primarily in Clatsop and Tillamook Counties. The county court or board of county commissioners of any county in which such land is situated also must approve exchanges; only after this approval may the exchange be consummated.

Under Oregon law, the primary objectives for managing Oregon Board of Forestry lands are to 1) generate revenue for county governments and local taxing districts, 2) make raw materials available on a sustained-yield basis to help meet demands for forest products, 3) obtain the greatest permanent value for Oregon, 4) provide community stability, 5) encourage efficiency in harvesting and processing, 6) encourage full economic utilization of the forest resource, and 7) provide employment.

The State Land Board holds title to the Common School lands. About two-thirds of the acreage is in the Elliott State Forest in Coos and Douglas Counties, with the balance scattered in 30 other counties. The state forester manages the Common School lands under a contract with the State Land Board. The primary objective for the management of these lands is to generate income for the Common School Fund consistent with sound land and timber management practices. The State Land Board and the Oregon Board of Forestry each are required separately to approve exchanges by resolution.

Forestry Assistance. This program helps Oregon's private forest landowners meet their resource management objectives. This includes increasing forest growth and harvest potential to help ensure future supplies of timber and other forest products; promoting forest health; and enhancing and protecting fish, wildlife, soil, air, water, recreation, and aesthetics. Technical advice on applying the principles of integrated pest management, minimizing disease mortality and growth loss, forest management, and wildlife enhancement is provided upon request to private forest landowners.

Other Public Forestlands. Oregon's state parks include 74,000 acres of forestlands withdrawn from timber production. Some of Oregon's parks, including Silver Falls and

Saddle Mountain State Parks, provide suitable habitat for northern spotted owls. Several of the coastal state parks adjacent to federal lands may provide additional habitat.

The ODFW owns 30,000 acres of forestlands devoted to producing wildlife habitat. County and municipal governments also have withdrawn 36,000 acres of their 146,000-acre timberland base.

Wild and Scenic Rivers. The federal Wild and Scenic Rivers Act designated 40 rivers in Oregon for inclusion in this system. Additional segments of these and other rivers are protected by the Oregon Scenic Waterways Act, administered by the Oregon Parks and Recreation Department. The Oregon Scenic Waterways Act protects the character of the rivers for fish, wildlife, and recreation.

Governor's Watershed Enhancement Board. This board provides technical assistance and grants for projects that focus on improvements to streams and upland areas of watersheds. These improvements, such as the enhancement of riparian areas, also may provide some owl habitat.

Research

ODFW is engaged in a project to assess the viability of northern spotted owl pairs on state-owned lands. Researchers are banding owls to track them over time. The focus of the study is spotted owl turnover and reproductive rates.

Coastal Oregon Productivity Enhancement (COPE) Program is a cooperative research effort among several groups, including the Forest Service's Pacific Northwest Experiment Station and the College of Forestry at Oregon State University. Among the goals of the COPE program are conducting large-scale operational testing of forest management strategies; developing methods to assess the effect of various riparian and reforestation management systems on water, timber, and wildlife; and making scientific information more accessible to forest managers in the region. The COPE program currently has proposals to study several nontraditional silvicultural methods for simultaneously producing timber and wildlife values.

Oregon State University's College of Forestry's research forest is being used by a group of researchers to conduct a study entitled *New Perspectives for Management of Timber and Mature-Forest Wildlife in Douglas-fir Forests.* Researchers are examining different silvicultural systems that might enable foresters to manipulate stands to produce the kind of habitat needed by interior-forest species like the spotted owl.

3. State of Washington

Existing programs in Washington contributing to or having the potential to contribute to owl conservation include forest practices and land-use regulations, management of state-owned lands, land acquisition, research, and various landowner assistance or incentive programs. In the past 2 years, considerable efforts have been made that have benefitted spotted owls through administration of forest practices regulations and cooperative planning for certain state-owned lands.

Regulatory Programs

State Forest Practices Act and Regulations. The Forest Practices Act and its implementing regulations are intended to afford protection to forest soils, fisheries, wildlife, water quantity and quality, air quality, recreation, and scenic beauty coincident with maintenance of a viable forest products industry. The regulations, administered by the regulatory branch of the Department of Natural Resources, apply to 12 million acres of state and private lands.

Timber harvest, road construction, and chemical spray on "lands known to contain a breeding pair or the nest or breeding grounds" of a federally listed species, or within the federally designated critical habitat of such species are subject to review under the State Environmental Policy Act (SEPA). "Lands known to contain" currently is interpreted to include all occupied suitable habitat subject to federal prohibitions on taking. State permit decisions currently restrict harvest practices within a 500-acre circle around a known pair of spotted owls. State lands are subject to the same regulatory requirements as those on other lands.

SEPA review entails information gathering, including owl surveys, and findings as to significant adverse environmental impacts. Surveying protocols and interpretation of results are provided by the Washington Department of Wildlife, which also maintains a data base documenting locations of all known owl sites in Washington.

Substantive forest practice permit decisions under SEPA require a balance between avoiding or mitigating identified adverse impacts and maintaining a viable forest products industry. Therefore, while state permit decisions currently reflect the biological thinking that was embodied in take guidelines adopted by the FWS, decisions may diverge from those guidelines in some respects. Nevertheless, state permittees are not relieved of any responsibilities they may have under federal law. Several hundred permit applications were affected in some way during 1990 by Washington regulatory requirements related to the northern spotted owl. The regulations also provide protection to nontimber resources, including wildlife habitat, within designated riparian areas.

Washington Environmental Policy Act. This law is similar to the National Environmental Policy Act. Implementing regulations require environmental analysis and public review, and set substantive environmental goals for all agencies.

Local Zoning and Land-use Control. Local government permits are required for land-use conversion, clearing and grading, and building construction. Permits generally are subject to SEPA analysis.

Wildlife Laws. Pursuant to Washington's wildlife laws, the state Wildlife Commission may by rule designate a species of wildlife as endangered. Hunting of or trafficking in endangered wildlife species is prohibited. The northern spotted owl is listed as endangered under Washington law.

Land Management

State Lands–Federally Granted Trusts. These lands were granted to Washington by the federal government to be managed in trust for the financial benefit of schools and other legally designated beneficiaries. About 1.3 million acres of forestlands are currently in this ownership. Common law requires the state, acting through the Department of Natural Resources, to exercise the same prudence a private person would exercise in managing his or her own land. Case law requires undivided loyalty to the trust beneficiaries. Forested trust lands are managed on a sustained-yield basis. Trust lands are subject to the same regulatory requirements as other lands. Beyond regulatory requirements, wildlife habitat objectives are incorporated into management, consistent with trust requirements.

State Lands–Forest Board. State statute created this state ownership of approximately 620,000 acres. These lands, mostly second-growth, are dedicated to perpetuate the forest resource. Revenues from management benefit county junior taxing districts and the state general fund. Case law indicates that the state has a trust relationship to county beneficiaries.

Commission on Old-Growth Alternatives. In June 1989, this broad-based citizens' commission made consensus recommendations to the Department of Natural Resources on management of old-growth forests on state lands on the western Olympic Peninsula. Recommendations included a 15-year harvest deferral on 15,000 acres of the most critical owl habitat, acquisition from the trusts of 3,000 acres of land with high ecological value, creation of a 260,000-acre experimental forest and a forest research center, and calculation of a sustained-yield level for these lands distinct from other state lands. These proposals are in various stages of consideration and implementation.

Industrial Lands. This is the largest nonfederal forestlands ownership category in Washington, responsible for more than half of the total state timber supply in recent years. Although managed to provide economic returns, industrial lands are subject to the state forest practices regulations described earlier. In some cases, relatively large contiguous ownership blocks are conducive to effective voluntary management for some nontimber values, including wildlife. In other cases, scattered or checkerboard ownership with federal lands complicates management.

Nonindustrial Private Lands. Nonindustrial lands comprise almost a quarter of the forestlands ownership in Washington. These lands may or may not be managed primarily for timber. Because they are located close to human populations, management of these lands has important effects on supply of nontimber values. However, due to their small size and generally young timber, opportunities for management of these lands to promote owl conservation are limited.

Land Acquisition

Washington Wildlife and Recreation Coalition. Created in 1988 as a coalition of citizen groups, this organization lobbies the state legislature for funds to bring high-priority habitat and park lands into public ownership. To date, $113 million have been appropriated for these purposes.

Trust Land Purchase Program. In 1989-90, the Washington legislature appropriated approximately $150 million in state general funds to purchase environmentally sensitive state trust lands. When completed, these purchases will bring about 60,000 acres into conservancy management. The value of the timber (usually about 90 percent) goes to the same trust accounts as does timber sale revenue. The land value goes to purchase replacement trust lands.

Other Preserved Lands. Several hundred thousand acres of state lands are managed in a preserve status as natural area preserves, state parks, wildlife areas, and under related designations. Periodically, additional lands are added to these categories. Some of these lands may contribute to owl habitat, but for the most part, they are of small individual size.

Assistance Programs

Washington provides a number of programs of technical and financial assistance to small-acreage forest landowners to encourage improved management of lands for a variety of objectives, including timber supply, watershed protection, and wildlife habitat. In the future, additional funds are expected to be available to address a broader range of resource objectives.

Incentive Programs

Several programs of state and local governments currently provide a variety of tax and other incentives for land management that promote open space, farmland preservation, and other resource objectives. These programs may contribute incidentally to owl conservation, but would need expansion and direction to make more substantive and intentional contributions.

Research

The Department of Natural Resources and the Department of Wildlife conduct and participate in research programs concerned with the spotted owl. For the most part, these research programs are funded and led by federal resource agencies.

IV. Indian Lands

Indian reservation lands have been set aside for the exclusive use and benefit of Indian people pursuant to treaties, statutes, and executive orders. In addition, Indians retain treaty-secured cultural, economic, and hunting and fishing rights within lands ceded to the United States. Indian reservation lands are held in trust by the United States, with the Secretary of the Interior having the principal responsibility for maintaining that trust. Each reservation is governed by a sovereign tribal government. Tribal governments have among their many sovereign powers the right to regulate the uses of land and resources within their reservation boundaries, including the use and management of fisheries and wildlife resources and habitat.

Indian people revere all lands, forests, and wildlife. They have managed their lands prudently for centuries. They recognize the environmental, cultural, and spiritual values of those lands, as well as the economic values and the importance of appropriate forestlands management to wildlife. They have taken and will continue to take measures to protect reservation wildlife populations, including the spotted owl. Given this historical perspective, the Tribes are voluntarily managing portions of their reservation trust lands in a manner consistent with the northern spotted owl recovery effort. These ongoing voluntary contributions are made because the protection of all species–including spotted owls–is ingrained in Indian culture.

Within the range of the northern spotted owl, there are six Indian reservations that contain northern spotted owl activity centers: the Yakima Indian Reservation in the eastern Washington Cascades province; the Quinault Indian Reservation in Washington's Olympic Peninsula province; the Warm Springs Indian Reservation in the eastern Oregon Cascades province; the Grand Ronde Indian Reservation in the Oregon Coast Range province; the Hoopa Valley Indian Reservation in the California Klamath province; and the Round Valley Indian Reservation in the California Coast province. The following accounts of contributions to owl recovery were provided by the respective Tribes.

1. Yakima Indian Reservation, Washington

Timber harvests on the Yakima Indian Reservation are done almost exclusively under uneven-aged management prescriptions. This reduces impacts to suitable owl habitat while allowing harvesting to proceed. The reservation contains approximately 500,000 acres of forested habitat, of which about 50 percent (250,000 acres) currently is classified as suitable owl habitat. Typically, the northern spotted owl habitat on the Yakima Indian Reservation lies within a band approximately 30 miles (north to south) by 25 miles wide. This band starts near the Cascade crest at elevations below 5,000 feet and extends east until it reaches pure ponderosa pine timber stands. Within that habitat there is an existing block of 60,000 acres of prime suitable habitat that is in Tribally designated reserve status. To date only about 45 percent of the total suitable habitat and less than 5 percent of the reserved area habitat have been surveyed for owls. Forty-one activity centers were located during 1989-1992 owl surveys. At a minimum, the Tribal biologists estimate a total of at least 50 nesting sites will be found when surveys of all owl habitat have been completed.

The Yakima Indian Nation has a large, effective, fisheries and wildlife staff that reviews all on-reservation activities that may have environmental impacts. Currently, the Yakima Indian Nation employs 14 full-time biologists and wildlife technicians on northern spotted owl inventory, monitoring, and habitat utilization studies. Data from these studies will yield valuable insights into the compatibility of uneven-aged forest management techniques in maintaining spotted owl habitat suitability.

2. Quinault Indian Reservation, Washington

Under the Indian Allotment Act the 208,000-acre reservation was allotted to individual Indians in 40- and 80-acre parcels. In order to obtain quick cash many of the allottees either obtained fee patents and sold the land to non-Indian timber interests or demanded that their timber be harvested at an accelerated rate. By 1987 the Quinault Indian Nation owned less than 15,000 acres of its 208,000-acre reservation. By 1992 this ownership had increased to nearly 54,000 acres. The Nation's aggressive reacquisition of its reservation was enhanced by the passage of Public Law 100-638. This law returned a portion of the northern boundary of the reservation to the Nation because of a previous survey error (12,000 acres of actual ownership and 5,400 acres along the eastern boundary of the reservation in which 45 percent of the revenues are pledged to the Nation). A prime stipulation in P.L. 100-638 was that revenues generated from the harvest of timber from the north boundary area must be used by the Nation for consolidating land ownership within the Quinault Reservation. This act is proving to be very successful and will enable the Nation, in the long term, to better manage wildlife and fisheries throughout the reservation.

Spotted owl surveys have been completed on 90 percent of all suitable habitat within the reservation. Three activity centers have been located. These centers are in the north boundary area. Harvest within this area will be adjusted to protect these activity center cores as long as they remain occupied. These activity centers are adjacent to the Olympic National Park, which provides the majority of suitable habitat in the area.

It should be noted that the Quinault River valley (approximately 50 square miles on the reservation) and the river's many tributaries form the most important reservation resource to the Quinault people. Preservation and conservation of five species of salmon, two species of trout, and other wildlife always will be a main Quinault objective. All other wildlife in this area also are considered in the management scheme. Because the Quinault Reservation originally was allotted to individual Indians in 40- and 80-acre parcels, management of the area as a single unit historically has been difficult. To protect this resource, the Quinault Nation has placed a high priority on consolidation of the river valley into Tribal ownership through land purchase. With consolidated ownership, the Tribe will affect a more consistent and improved riparian zone management. The valley will continue to offer wildlife and fish protection as the primary management objective.

3. Warm Springs Indian Reservation, Oregon

Currently, 80 percent of the habitat suitable for northern spotted owls has been surveyed on the Warm Springs Indian Reservation. Thirty-six activity centers have been located, primarily in the northwestern portion of the reservation.

The Confederated Tribes of Warm Springs voluntarily have acknowledged the designation of 18,722 acres to be managed for owls as a "Warm Springs Special Habitat Preservation Area" in the southern end of the reservation. This area is a portion of one of several larger Tribal conditional use areas, which are limited-entry set-asides. The primary function of this area is to serve as a connecting corridor and habitat expansion between two designated conservation areas (DCAs) in the Deschutes National Forest.

On a short-term basis, other suitable owl habitat will be managed to maintain some owl activity centers primarily centered on and around the 60,549 acres of Tribal conditional use areas, including the area discussed earlier. Additional restricted land use occurs on riparian zone "A" lands, which consist of 21,086 acres where timber harvest is not allowed and two extensive management zones; one zone contains 7,224 acres where timber harvest is not allowed, and a second zone contains 7,418 acres of 200+-year extended age harvest rotation under uneven-aged management prescriptions. All these set-aside or special management areas contain suitable owl habitat. All these special management areas consist of 96,277 acres of forested land or 25 percent of the Confederated Tribes' total forest resource.

On a long-term basis, the Tribes will mesh owl protection into their overall wildlife management plan in such a manner as to contain all the necessities of owl survival.

4. Grand Ronde Indian Reservation, Oregon

The entire reservation has been surveyed and only small amounts of suitable northern spotted owl habitat exists. All of this suitable habitat is in second-growth stands with the majority of the area located on the eastern part of the reservation in the Coast Creek drainage. The Coast Creek drainage has been occupied by a successfully breeding owl pair since 1974. An additional resident owl resides on the western part of the reservation. Much of the surrounding Forest Service and BLM timber stands in the Coast Creek area are now or are approaching suitable habitat conditions for northern spotted owls.

The enabling legislation establishing the Grand Ronde Indian Reservation has as its principal purpose to provide economic and cultural stability for the restored Grand Ronde Tribe. One of the terms of the Grand Ronde Reservation Act provides that, beginning September 1988 and for the following 20 years, 30 percent of all timber revenue is to be set aside for economic development primarily in Yamhill, Polk, and Tillamook Counties. Given those situations, the Tribe and U.S. Bureau of Indian Affairs have conducted on-the-ground surveys with the FWS to explore alternatives that will provide protection for northern spotted owls and allow a metered harvest of timber from the Coast Creek area. This agreed upon action was begun in 1991, and will continue as long as necessary.

5. Hoopa (Hupa) Valley Indian Reservation, California

Owl surveys have located 44 activity centers within the reservation. Voluntary consultation (meeting section 7 requirements) with the FWS has been and will continue to be completed prior to timber harvests.

Approximately 6,000 acres of the total 88,000 acres of the reservation are inherently unsuitable for northern spotted owls (natural prairies, urban areas, water bodies, etc.). Of the remaining 82,000 acres, approximately 39 percent is designated as reserves, cultural sites, stream zones or as the Hoopa Valley Wild and Scenic River view shed (Valley View Shed) along the Trinity River, where timber harvest is limited to partial cutting. The Valley View Shed is approximately 2 miles wide (17,000 acres) and serves specifically as a view shed to the Trinity River but also effectively serves to connect DCAs on Forest Service lands north and south of the reservation.

The principal protection provided to wildlife and fish species on the reservation is the maintenance of stream protection zones which are up to 400 feet wide. Stream protection zones include 4,700 acres. The Tribe is concerned with the protection of threatened and endangered species of fish; wildlife and plants; and also culturally important species such as, chinook and coho stocks, lampreys, fishers, pileated woodpeckers, acorn woodpeckers, bald eagles, ospreys, Port Orford cedars, and others.

6. Round Valley Indian Reservation (Covelo Indian Community), California

A wildlife management survey has been initiated to survey all wildlife species on the Round Valley Indian Reservation. Spotted owl surveys were conducted in the 1991 and 1992 field seasons, resulting in the location of two activity centers. Within the 30,000-acre reservation a survey was conducted on land recently purchased: 11,304 acres purchased with a timber cutting right easement where conifers more than 11 inches in diameter remain the property of the prior landowner. This resource area had one spotted owl activity center. If harvest is not undertaken under the easement and after a complete survey of the reservation has been done, the Tribe will reevaluate its management to provide protection for this activity center.

The Tribe has a new Fish and Wildlife Program that works in conjunction with the Natural Resource Program to manage and protect its wildlife resources within the reservation. For now, the Tribe will manage for the northern spotted owl and continue to inventory this species' habitat and will develop its own management plan.

Literature Cited

Barry, D. 1990. The Endangered Species Act. Pages 85-97 in: Mantell, M.A., ed. Managing national park system resources: a handbook on legal duties, opportunities, and tools. The Conservation Foundation, Washington, D.C.

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

Forsman, E.D. 1980. Habitat utilization by spotted owl in the west-central Cascades of Oregon. Corvallis, OR: Oregon State University. 93 p. Ph.D. dissertation.

Forsman, E.D.; Meslow, E.C. 1985. Old-growth forest retention for spotted owls—how much do they need? Pages 58-59 in: Gutiérrez, R.J.; Carey, A.B., eds. Ecology and management of the spotted owl in the Pacific Northwest. General Technical Report PNW-185. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station.

Gould, G.I., Jr. 1974. The southern range limits of the northern spotted owl. Sacramento, CA: California Department of Fish and Game, Nongame Section. Unpublished paper. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Ave., Portland, OR 97232-4181.

Gutiérrez, R.J.; Carey, A.B. eds. 1985. Ecology and management of the spotted owl in the Pacific Northwest. Ecology and management of the spotted owl in the Pacific Northwest. General Technical Report PNW-185. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station. 119 p.

Hedges, N., Personal Communication, U.S. Department of the Interior, Bureau of Land Management, Wenatchee, WA.

Jamison, C. 1990. The Jamison Plan. Unpublished report of the U.S. Department of the Interior, Bureau of Land Management. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911 N.E. 11th Aven., Portland, OR 97232-4181.

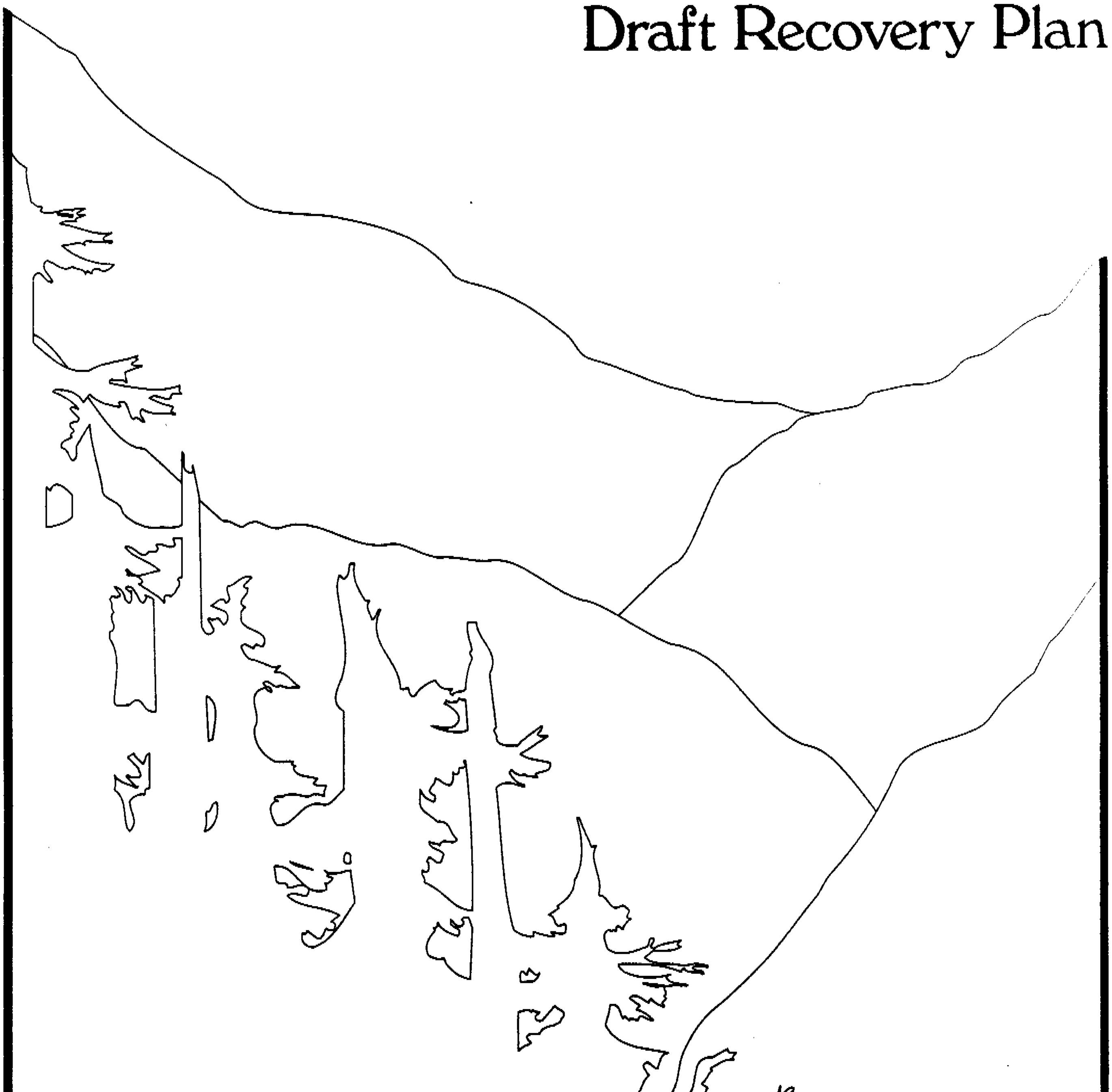
Soulé, M.E.; Wilcox, B.A. eds. 1980. Conservation biology, an evolutionary - ecological perspective. Chapter by I.R. Franklin and chapter by M.E. Soulé. Sunderland, MA: Sinauer Associates.

U.S. Department of the Interior, Fish and Wildlife Service. 1990. Endangered and threatened wildlife and plants; determination of threatened status for the northern spotted owl. Washington, D.C.: Federal Register 55:26114-26194.

U.S. Department of the Interior, Fish and Wildlife Service. 1992. Endangered and threatened wildlife and plants determination of critical habitat for the norther spotted owl. Washington, D.C.: Federl Register 57:1796-1838.

Appendix K.

Response to Public Comment on the Draft Recovery Plan



Contents

K.
Introduction

The public comment period on the draft recovery plan for the northern spotted owl, initiated with the plan's release on May 14, 1992, closed on August 13, 1992. During that period, more than 1,600 written comments were received. In addition, the Recovery Team held three public meetings in June 1992, to receive comments. One meeting was held in each of the three affected states (Arcata, California; Roseburg, Oregon; and Seattle, Washington). In addition to issues raised in written comments and public meetings, the Department of the Interior's review of the draft recovery plan also led to suggestions that other topics be addressed as the Recovery Team refined the recovery plan for review and approval by the Secretary of the Interior.

This appendix addresses the most significant issues raised during the public comment and review processes. It is not intended as a depiction of all comments included in the recovery plan's administrative record. The appendix is divided into two sections. Part I discusses the major changes made for the final recovery plan that specifically address certain significant issues. Part II discusses other significant issues that the Recovery Team considered but which did not result in substantive revisions to the draft recovery plan, although the recovery plan's recommendations have been clarified in several instances. It should be noted that several issues discussed in Part II will be addressed as the final recovery plan is implemented, particularly in monitoring, research, and adaptive management activities.

I. Major Changes from Draft to Final

A. Management for Dispersal Habitat on Federal Lands

1. Background

The recovery of the spotted owl depends on the maintenance of a reproductive population of owls in designated conservation areas (DCAs) and the successful movement of owls among DCAs. The movement, or dispersal, of owls is expected to require habitat that will support roosting and foraging. The provision of nesting habitat would probably improve the likelihood of successful owl dispersal throughout larger areas.

The Interagency Scientific Committee (ISC) (Thomas et al. 1990) first developed the 50-11-40 rule in an effort to describe the types of forest conditions which would help provide for successful owl dispersal. The "11-40" portion of the rule was based on studies of habitat use by individual owls within home ranges. This work indicated that owls consistently avoided forest stands with trees that were smaller than 11 inches average dbh and had less than 40 percent canopy closure. The standard requiring that 50 percent of the federal landbase meet these conditions was based on the professional judgment that such a landscape would adequately provide for dispersal and allow an acceptable level of timber harvest. Section III.K. contains a full discussion of the basis for the 50-11-40 rule.

During preparation of the draft recovery plan, the Recovery Team considered several possible alternatives to provide for dispersal habitat. These included 1) corridors of high-quality habitat among DCAs and 2) provision of higher-quality habitat than the 11-40 condition distributed throughout less than 50 percent of the landscape. However, there was inadequate information available to accept either of these alternatives or to reject the 50-11-40 rule. Therefore, the Recovery Team adopted the 50-11-40 rule as a recommendation for dispersal habitat on federal lands.

During the public comment period, the Recovery Team received many comments about the 50-11-40 rule. Most comments questioned the scientific basis of the rule and noted that the rule was difficult to meet in some landscapes because of natural and human-caused conditions. Secretary Lujan asked the Recovery Team to review the 50-11-40 rule and determine if there were credible alternatives that could be applied in some parts of the spotted owl's range.

The Recovery Team pursued two courses of action to investigate the 50-11-40 rule. First, the Recovery Team queried owl research biologists to learn if they had any new information about habitat use by dispersing owls, and whether this new information could lead to changes in the 50-11-40 rule. This effort did not uncover any new information.

The second effort to review the 50-11-40 rule was circulation of a questionnaire to the U.S. Bureau of Land Management (BLM) and U.S. Forest Service offices within the owl's range. The questionnaire was designed to identify geographic areas where the 50-11-40 rule was difficult to meet, and the specific reasons for failure to meet the rule.

A summary of the 84 returned questionnaires indicated that the 50-11-40 rule was being implemented throughout much of the owl's range without great difficulty. In the 2 years since the ISC report was issued, most federal lands have been analyzed for compliance with the 50-11-40 rule, and federal land managers have become familiar and comfortable with the techniques used to do the analysis. The 11-40 habitat standard seems to cause few problems in most of the west side forest types.

Three major problems have been identified in the implementation of the 50-11-40 rule. First, in checkerboard ownerships, federal agency compliance with the rule may actually result in a forest landscape that only meets a 25-11-40 condition if the interspersed nonfederal lands are managed without provision for dispersal habitat.

Second, the rule may result in undesirable forest conditions in some areas. Attempts to provide for 50-11-40 in some east side forest types could result in canopy conditions that favor damaging insects such as spruce budworms. Radio-telemetry and habitat-use research have not been completed in these forest types to allow investigation of alternative standards.

Third, national forests and BLM districts have discovered that lands under their management cannot meet the 50-11-40 rule in some areas. More than half of the questionnaire respondents said that past timber harvest has made it impossible to meet 50-11-40 in at least one quarter-township. This would mean that timber harvest in these areas would not be allowed until the forest conditions improved. In some areas this has led to a significant reduction in timber harvest.

2. Final Recovery Plan

While there was inadequate information to allow an informed modification of the 50-11-40 rule, efforts have been initiated to investigate the issue further. The Recovery Team has identified dispersal habitat as an issue that should be immediately addressed through adaptive management. Section III.K. begins this process and describes how the coordinating group, recommended to help implement the recovery plan, should determine if some adjustment of the dispersal habitat guideline is appropriate.

The final recovery plan recognizes that deviations from the 50-11-40 rule are likely to occur in some situations, and that this may be less significant in some places than in others. Some of these situations have already been addressed during section 7 consultation under the Endangered Species Act, and the final recovery plan discusses a variety of factors that should be considered during consultations.

B. Management Guidelines for Designated Conservation Areas (DCAs)

1. Background

Establishment of the DCAs is one of the primary mechanisms for achieving recovery of northern spotted owls. The objective for managing DCAs is to improve habitat conditions for owls through time. While the DCAs were patterned after the habitat conservation areas (HCAs) of Thomas et al. (1990), the draft recovery plan provided broader latitude for management of DCAs than had been prescribed for HCAs. Management recommendations in the draft recovery plan were focused on 1) silvicultural activities designed to improve habitat conditions in younger stands, 2) opportunities for salvage, and 3) activities directed at reducing the risks of large-scale catastrophic disturbance. Provisions were also made for the management of facilities, such as campgrounds and trails, inside the DCAs.

Comments on the draft recovery plan addressed nearly every provision of DCA management. Some commenters responded that the draft recovery plan was too liberal in allowing activities in DCAs. Others expressed the opinion that the management provisions were too conservative and that substantially more management of forest stands should be allowed. BLM and Forest Service representatives were concerned that the management guidelines were too prescriptive. They suggested that the recovery plan should simply state management objectives and not contain detailed management guidelines.

Between draft and final versions of the recovery plan, the Recovery Team reviewed all the comments on DCA management and reviewed the basis for the original recommendations. As part of these reviews, the Recovery Team took part in several case studies of Forest Service and BLM efforts to implement the guidelines. These included salvage plans in DCAs in the Willamette and Olympic National Forests, and a DCA management plan in the BLM's Salem and Eugene Districts.

2. Final Recovery Plan

As a result of the reviews, many changes were made to the DCA management guidelines for the final recovery plan. These changes responded to specific agency concerns and suggestions. The most significant changes are summarized here.

Guidelines for silviculture were changed in three significant ways. First, the language describing stands that could be treated was revised to clarify the primary criterion for identifying such stands. This criterion is that there be a high degree of confidence that management would actually accelerate the development of habitat conditions suitable for owls. Specific guidelines for stand size and structure identify stands where this is most likely to be the case, but other types of stands may also be treated and treatment of all stands has to be supported by specific justification.

The second change clarified that all silviculture in DCAs was to be conducted according to prescriptions prepared to the highest professional standards. It was also clarified that all activities in DCAs would be subject to technical review by the coordinating group established to help implement the recovery plan.

The final change provided for the possibility of exceptions to the guideline specifying that only 5 percent of the total area in any DCA could be managed within the first 5 years of recovery plan implementation. The need for this change was recognized when the Recovery Team reviewed a BLM plan for managing a DCA in which only about 10 percent of the acreage is currently suitable for owl nesting, roosting, and foraging.

Guidelines for salvage were changed in three significant ways. First, the guideline restricting salvage to areas of disturbance larger than 10 acres was modified. The intent of this guideline was to ensure that natural processes would continue to operate in small gaps in the forest. Such gaps are an important part of the structure of old-growth forests. However, several commenters noted that most gaps are much smaller than 10 acres, and are generally smaller than 1 acre. Therefore, the final guideline was substantially modified to allow salvage to areas of disturbance as small as 1 acre.

Second, a provision was added to allow some deviation from the basic guidelines "to provide reasonable access to salvage sites and feasible logging operations." The need for this change became apparent when reviewing a Forest Service salvage plan for the Warner Creek area in the Willamette National Forest. Virtually no salvage could have taken place under the guidelines in the draft recovery plan due to worker safety concerns and lack of access to the site. The modified guideline would allow activities in some small areas that would not comply with basic guidelines. These in turn would provide access to larger areas which could then be harvested safely and in accordance with the guidelines. For example, some small areas in a large salvage operation might be clear-cut to allow access for helicopter logging.

The final change was a clarification of the intent to have the recovery plan act only as umbrella guidance for salvage. The final recovery plan reinforces the recommendation that agencies develop province-specific guidelines before writing salvage plans for specific areas. The use of interagency groups to establish province-specific guidelines is encouraged, and the guidelines should be subject to review by the coordinating group.

Guidelines to reduce risks of large-scale disturbances were modified in one significant way. A provision was added permitting some risk reduction activities in currently suitable habitat inside the DCAs. Such activities might reduce the suitability of those stands, but would only be permitted in areas with very high risks of catastrophic loss. This change responded to a concern about the forest health conditions in DCAs in the eastern Oregon Cascades province.

Guidelines for other multiple-use activities were slightly modified in many places. The overall intent was to clarify that activities should be allowed wherever they do not interfere with the primary goal of owl recovery.

C. Adaptive Management

1. Background

Because they have been at the center of a public policy issue, northern spotted owls are extremely well-researched. However, even the extensive knowledge available about this species leaves significant questions unanswered. Additional information about owls and their interaction with their ecosystem is expected to result from the monitoring and research program. This information is likely to suggest useful changes in the strategy that has been proposed for northern spotted owl recovery.

Even if complete knowledge were available about owls, a static series of recommendations would be an inappropriate strategy for their recovery. The forest ecosystem that the owls inhabit, and the social and economic climate in which they find themselves, are dynamic. In addition, basic understanding of biological processes is far from complete. For example, scientists have only a partial understanding of the processes that lead to extinction of species, so even with full knowledge of a species they could not precisely predict the conditions under which it might become extinct.

For these reasons, it would be inappropriate to consider that the strategy for spotted owl recovery was complete and would not change. The strategy should continue to be dynamic as long as new information is gathered about owls or about the biological and social systems that they inhabit. It would also be inappropriate to simply halt all activities in the owl's range while waiting for perfect information. Controversy about management for owls and their habitat has continued for nearly 10 years, and much has been learned during that period. At some point, a judgment must be made that a strategy is adequate for a starting point, and that further changes will be made as part of the process of implementing the strategy.

The Recovery Team judges that the strategy proposed here is a legitimate starting point for spotted owl recovery. At the same time, the Recovery Team encourages changes in the strategy over time that would improve it. The process of incorporating changes in an ongoing management strategy is termed adaptive management.

There is widespread agreement that adaptive management is appropriate for a policy issue as large and complex as the one addressed here. However, it is frequently treated as an afterthought, with few details provided about how it will operate. The final recovery plan contains substantial recommendations for the adaptive management questions that should be pursued and the process that should be used to pursue them.

While adaptive management was not raised as a major issue in public comment on the draft recovery plan, it will actually serve as the most likely response to many issues that were raised. There is not adequate information to deal fully with those issues at this time, but adaptive management will allow new information to be focused on the issues as it becomes available. Recommendations in the recovery plan that are most likely to be modified through adaptive management in the near future include the guidelines for dispersal habitat and guidelines for specific management activities in DCAs.

2. Final Recovery Plan

Recommendations for adaptive management are in section III.K. of the final recovery plan. This section includes a list of the key adaptive management questions, a specific process that can be used to direct the investigation of each of these questions, an example of this process applied to the standards and guidelines for management of dispersal habitat, a discussion of the roles of various entities in adaptive management, a recommendation on the role that case studies could play in the adaptive management process, and a recommendation that the initial steps in this process be completed for all the key questions immediately upon release of the recovery plan. Completion of these steps would result in a full description of the monitoring and research needed for each key question. It would also result in identification of trigger points which, when reached, would require reconsideration of each of the major recommendations in the recovery plan. The questions raised in this adaptive management section were also used to help shape the monitoring and research recommendations in section III.J.

D. Specific DCA Mapping and Boundary Changes

1. Background

One of the major features of the recovery plan is the set of maps displaying federal lands that are recommended to be managed as DCAs. These areas, and the owl populations that they support, are essential to the success of the recovery plan. During the comment period, there was a substantial number of comments on the location and specific boundaries of these areas. Between the draft and final recovery plans, the Recovery Team reviewed all of these boundaries and modified some of them based on 1) public comments, 2) comments from the land management agencies, and 3) an internal review of compliance of the areas with size and spacing guidelines established for them. Actual establishment and management of these areas will be done by the management agencies (i.e., Forest Service, BLM, National Park Service) through their own planning processes.

2. Final Recovery Plan

The final DCA boundaries are shown on maps enclosed with the final recovery plan. Table K.1 shows a comparison of federal acres included in DCAs from the draft and final recovery plans.

Table K.1. Comparison of federal acres in DCAs from the draft and final recovery plans. Figures shown are in millions of acres.

	Draft Plan			Final Plan		
State	Reserved Land	Non-reserved Land	Total	Reserved Land	Non-reserved Land	Total
California	.500	1.254	1.754	.492	1.271	1.763
Oregon	.533	2.433	2.966	.507	2.329	2.836
Washington	1.058	1.908	2.966	1.119	1.924	3.043
Total	**2.091**	**5.595**	**7.686**	**2.118**	**5.524**	**7.642**

E. Lack of Risk Analysis and Basis for Believing the Recovery Plan Will Work

1. Background

Several recent efforts to develop management guidelines for northern spotted owls have been criticized because they lacked formal, quantitative risk assessments. These included the report of Thomas et al. (1990); the adoption of that report by the Forest Service (USDA 1992); and the draft of this recovery plan. These challenges assert that, without a formal risk analysis, there is no demonstration that the management plans will provide for conservation or recovery of the species. These challenges deserve attention. A formal, quantitative risk assessment would help to determine whether the strategy presented here would ultimately be successful.

Despite the potential value of a risk assessment, it is unlikely that a truly compelling assessment could be produced any time in the near future, if ever. As noted previously, a valid, quantitative assessment would require complete knowledge about owl responses to a full spectrum of habitat and landscape conditions. Some of these conditions are not currently observable within the owl's range, so their study is not possible. A risk assessment would also require full knowledge of owl population responses to dynamic landscapes. Complete knowledge in this area is years or decades away. Full understanding of habitat trends, including responses to management and projections of catastrophic events, would also be required.

Even with all this information, there would still be substantial challenges in the development of a reliable risk assessment. All of this information would have to be synthesized, most likely by bringing it together in a modeling framework. Assumptions in the model, and the overall model structure, would require validation. These requirements make the development of a robust model, and a truly quantitative risk analysis, problematic. However, models can still be useful. They can contribute to the understanding of implications of a variety of assumptions, and they can help generate new research hypotheses. They also can help us simulate the possible responses of owls to the dynamics of future landscapes. The results of modeling efforts make a substantial contribution to risk assessments, even if the final assessment is ultimately dependent on professional judgment.

2. Final Recovery Plan

The final recovery plan contains a discussion of the possible risks to the population of northern spotted owls and the features of the recovery plan designed to mitigate those risks (see section III.G.). This section describes the Recovery Team's basis for believing the recovery plan will be successful. It also contains recommendations that a variety of modeling efforts continue, and that their results, in conjunction with other research and monitoring efforts, be considered in ongoing assessments of risk. Modeling and risk assessment must play a key role in adaptive management of the recovery plan (see section III.K.). Modeling efforts that should continue include further assessments of the demographic data and its analysis; further work on models that simulate owl population dynamics in response to landscape dynamics; and efforts to improve the ability to project future habitat conditions in managed and unmanaged situations.

While risk assessments will continue to rely on professional judgments into the foreseeable future, results of these efforts and other efforts outlined in section III.J. will help to improve those professional judgments.

II. Other Major Issues Raised in Public Comments

A. Demographics of Northern Spotted Owls

Much concern has been expressed about the results of demographic analysis reported in the draft recovery plan (see Appendix C). These results indicated that 1) territorial populations were declining in all demographic study areas for which at least 5 years of data were available, 2) there was a statistically significant decline indicated by the data pooled for the five northern spotted owl demographic study areas, and 3) adult female survivorship was declining over time.

It has been asserted that the ISC strategy was predicated on the assumption of a low rate of population decline, and that the rates reported in the recent analysis violated the working hypotheses of the ISC plan. The strategy presented in the draft recovery plan was similar to the ISC strategy, and the Recovery Team was challenged to explain how it responded to the new demographic information.

In responding to this challenge, the Recovery Team reviewed several lines of evidence of population decline, including the original demographic results (see Appendix C). The additional information included:

- New data about juvenile owl survival and emigration in the Roseburg, Olympic Peninsula, and Wenatchee study areas (Thomas et al. In Prep.)
- Updated survival and fecundity data from the H.J. Andrews, Roseburg, and Olympic Peninsula study areas (Thomas et al. In Prep.)

- Density data collected during varying periods of years for 12 northern spotted owl demographic study areas (Thomas et al. In Prep.) and a regression analysis of that data (Franklin and Ward 1992)
- A sensitivity analysis of models used to analyze demographic data (Bart In Prep.).

In general, the data suggest that there is some latitude in the interpretation of demographic data and population trends. Based on this information and broad professional experience, the Recovery Team reached the following tentative conclusions concerning the demographic information:

1. The population of northern spotted owls is currently declining throughout its range. Declines are indicated by data and inference from a variety of sources including the demographic information, trend analysis of density data, and trends in habitat. While each of these sources has limitations, the combined evidence indicates that populations are declining.

2. It is likely that the rate of decline is less steep than the rate shown by the demographic analysis in Appendix C. A variety of biases is possible in the data used for the demographic analysis (Bart In Prep.), and recent data from radio-marked juvenile owls suggest that assumptions about survivorship of emigrating juveniles may be significantly biased. The true rate of decline probably falls between the figure from the demographic analysis and a figure that could be determined from density data that have been collected in the demographic study areas. The rate of decline predicted from that data could be stable or as low as 2 or 3 percent annually.

3. None of the data that has become available invalidates the basic working hypothesis of the ISC. It is important to note that development of the original ISC strategy was not predicated on an assumption of a specific rate of decline in owls. Sizing and spacing of HCAs were based on 1) inferences from other species and 2) modeling that assumed a lambda (λ) of 1 within HCAs at a future time when disturbance of habitat had ceased. Thus, the demographic data neither confirm nor refute any assumptions underlying the basic strategy of the ISC, and the experts who developed the ISC strategy still believe that it adequately provides long-term conservation of northern spotted owls.

4. Despite their overall confidence in the ISC strategy, the experts agree that the period of greatest risk under the ISC and recovery plan strategies is when habitat and populations outside of the conservation areas are declining while habitat and populations inside of the conservation areas have not been fully restored. The declines outside of the conservation areas are likely to be more rapid than the improvements inside. The degree of risk created by this situation can only be characterized qualitatively at this time. Despite improved data and improved analysis, the determination of this risk level will always ultimately depend on professional judgment. The strategy for the recovery plan shares a similar level of risk with the ISC, although the recovery plan does make additional provisions for owls outside of the DCAs on federal and nonfederal lands.

As previously noted, determining the risk level of the transition period is not simply a matter of better data and analysis. However, better information can improve professional judgments, and the Recovery Team will continue to push forward efforts to better understand this risk. Those efforts, which should continue after the recovery plan is finalized, are described in section III.G.

B. Comparison of Alternatives

Several reviewers proposed that the final recovery plan should contain a more complete set of alternatives for achieving recovery, and that the cost, feasibility, and effects of each alternative should be investigated. The recovery plan, however, is not a National Environmental Policy Act document, and does not require a detailed discussion of alternatives beyond the final proposal. The Recovery Team did, however, consider a variety of options for recovery of owls during development of the recovery plan. These options, and the general level of consideration given to them, are discussed in Appendix H. Compared to the final recovery plan, some of these options would have provided greater security to owls, while others would have allowed for larger timber harvest.

C. Means versus Ends

Some commenters stated that the recovery plan overemphasized means as opposed to ends. One reviewer even stated that the recovery plan should simply describe the recovery objectives and delisting criteria and let the agencies decide how to achieve the objectives. Recovery plans, however, must provide much more detail than that. They must provide "site specific management actions" necessary to achieve recovery. The recovery plan stresses, however, that the specific management actions it recommends are probably not the only way to achieve recovery, and that the process of adaptive management should be used to refine the recovery plan and make it more efficient. All actions are recommended for consideration and evaluation through agency management planning processes.

D. Why Rangewide Recovery was Sought.

The northern spotted owl was listed as threatened throughout its range. During the public review period, many commenters asked why recovery was sought throughout the owl's range rather than just in a portion of the range. The Recovery Team reached its decision for two basic reasons.

The first reason is biological. The security of the northern spotted owl population will be greater if recovery is achieved throughout the range as explained in section III.A. Four biological reasons for this increased security are that: 1) recovery throughout the range will provide for a larger number of local populations which will make the overall population (i.e., metapopulation) more secure; 2) any reduction in range would decrease the overall range of environments occupied by the species, making it more vulnerable to random environmental change; 3) habitats in different geographic areas and environmental settings may act as refugia for the species in the face of chronic or rapid environmental change; and 4) range reduction at the fringes of the range could reduce the ability of the species to adapt to change since these areas are often the site of the most rapid adaptation in a species.

The second reason is legal: if rangewide recovery were not achieved, and the U.S. Fish and Wildlife Service (FWS) attempted to delist the species, it is likely that a new listing would be sought for that part of the range where the owls were not recovered. This would not be helpful in achieving resolution of the status of the owl.

E. How Many Owls are There and How Many are Needed?

Estimates of the number of northern spotted owls have been the subject of intense interest. When the draft recovery plan was released, a number of commenters noted that the number of known pairs of spotted owls had increased steadily through time. This led them to ask three basic questions. First, had the population actually increased? Second, do increasing numbers of known pairs indicate that the owl is less threatened than previously thought? And, third, is there a specific population level which would indicate that the species is recovered?

The number of known spotted owls has increased over time as the intensity of surveys has increased. In 1986, the National Audubon Advisory Panel on the Northern Spotted Owl estimated that there were 4,000 to 6,000 individuals in the owl's population. In 1988, the Forest Service (USDA 1988) summarized a variety of literature sources that reflected known and estimated pairs of owls. Based on those sources, it reported 500 pairs of owls in Washington, 1,200 pairs in Oregon, and 560 pairs in California. The numbers were not offered as population estimates.

In 1990, the ISC (Thomas et al. 1990) reported on the number of pairs of owls that had been confirmed in surveys from 1985 to 1989. This 5-year window was used because it reflected the period of most intensive surveys for owls, was consistent with an owl generation time of 8 years, allowed the elimination of duplicate reporting of sites, and did not count some historic sites that might have already been eliminated by timber harvest. For this time period in Washington, Oregon, and northern California, the ISC reported 2,022 owl pairs. The ISC emphasized that this was simply the number of pairs that had been located during that time period and was not a population estimate. The FWS reported a nearly identical number (2,030 known pairs) for the same time period in the status review of the owl (USDI 1990b).

The most recent reports on owl numbers were published in the Forest Service's environmental impact statement on owl management (USDA 1992) and in the draft recovery plan. Both reports were based on a 5-year window of owl locations; either 1986-1990 or 1987-1991, depending on ownership. The Forest Service reported 3,461 pairs throughout the range of the owl and the Recovery Team reported 3,500 pairs. Both documents emphasized that this was simply the number of owl pairs located during the period, not a population estimate. The final recovery plan reports 3,602 pairs of owls located between 1987 and 1991 for most ownerships and between 1988 and 1992 for a few ownerships (Table 2.3).

True population estimates cannot be derived from these tallies of known pairs. However, some additional information can help put the numbers in perspective. More than 78 percent of the currently known pairs occur on federal lands, and survey efforts on those lands are not complete (Table K.2). It should be expected that more pairs of owls will be located as more of the federal lands are surveyed. Additional surveys of nonfederal lands will also result in more known owl locations in some areas.

It is likely that some of the owls located during a 5-year window have already been eliminated due to timber harvest or other loss of habitat. For example, in 1990 and 1991 the FWS issued more than 1,200 permits for incidental take of spotted owl pairs or territorial singles in Oregon and Washington (FWS comments to draft recovery plan). While it is not expected that all of these sites would immediately become unoccupied, this

Table K.2. Percentage of spotted owl habitat surveyed for owls on Forest Service, BLM, and National Park Service lands between 1987 and 1991. For purposes of this table, habitat is defined as any forested area with trees of 11 inches dbh and 40 percent canopy closure.

	Washington	Oregon	California
Forest Service			
Reserved	22	46	17
Nonreserved	45	77	54
Total	**40**	**73**	**44**
BLM			
Total	**NA**	**61**	[1]
National Park Service	Significant survey has only been conducted in Olympic National Park where approximately 10 percent of potential habitat was surveyed.		

[1]Information was not available for BLM lands in California.
NA = not applicable.

large number of take permits suggests that some known sites have been eliminated. Because the surveys for owls are incomplete, and are likely to remain incomplete, other types of information must be examined to determine how the owl population is changing over time. As indicated in Appendix C, there are several direct lines of evidence indicating that populations are declining over time. Analysis of demographic and density data demonstrates that owl populations have been declining in recent years. These different sources suggest different rates of decline, but each indicates that decline is occurring.

It has also been suggested that the increasing number of known owl sites indicates that the owls are less threatened than previously thought. However, there is not a direct link between the number of owls located in a 5-year period and the degree of threat to that population. The northern spotted owl was not originally classified as threatened (USDI 1990a) due to low numbers, but because of trends in habitat and the resulting trend in population. Therefore, it is the trend in the owl's population, and not its absolute size, that is of most importance. The population trend must stabilize before the threat to the owl can be considered significantly diminished.

If the observed population size were large enough to violate some of the basic assumptions of the recovery plan, then population size might be considered a basis for review of the plan. This might be the case, for example, if the known numbers were so great that they caused the Recovery Team to question whether owls need large areas to live and reproduce. Other supporting data, such as home range size, density, and demographic performance, also would have to support such a review.

Finally, it has been suggested that there ought to be a target number of owls which, if reached, would provide for delisting. Again, it is the trend in the owl population and not the absolute number of owls that must be considered. The Recovery Team has made recommendations concerning the population trends necessary for delisting. However, the population must also be well-distributed and large enough to avoid the long-term risks that would be associated with small populations. The DCA network was proposed to stabilize populations and satisfy these criteria. One could calculate the number of owls that could be supported by the DCA network, but that number is not a goal.

F. The Role of Nonfederal Lands

The recovery plan states that, in many areas, federal lands are not adequate for recovery. This raised the question, during the public comment period, of whether recovery can be achieved without a contribution from nonfederal lands. Stated differently, will the absence of contributions from nonfederal lands make recovery unattainable?

Achieving recovery of the owl throughout its range will require contributions from nonfederal lands. The level of contribution needed to achieve recovery depends on the relative amount of federal and nonfederal lands in each physiographic province. Nonfederal contributions will be especially important in those areas where there is little federal land ownership: the western Washington lowlands, the California Coast, and the northern part of the Oregon Coast Range provinces.

This issue is related to the issue of allowing for delisting of the owl by province. Delisting criteria will probably be attainable with relatively minor nonfederal contributions in provinces with minimal nonfederal lands. Conversely, provinces with large proportions of nonfederal lands are likely to require proportionately higher nonfederal contributions.

The recovery plan clarifies this issue in two areas. First, it explicitly states that delisting is allowed by province, thereby acknowledging the differences in both biology and land ownership among the 11 provinces in the owl's range, and allowing each region to move forward at its own pace. Second, the recovery plan gives clear guidance and recommendations for goals to be met from nonfederal lands, separate from the suggested options for means to attain those goals. The goals for nonfederal lands represent the Recovery Team's assessment of the nonfederal contribution needed to achieve recovery. These recommendations for each province are in section III.E. For example, the goals for nonfederal contributions in the California Coast province are "to provide demographic stability and maintain northern spotted owl distribution throughout the province." Specific contributions are recommended to achieve these conditions and thereby allow delisting. If the recommended contributions from nonfederal lands should change, based on monitoring and research programs, they will still focus on achieving the conditions that would allow delisting.

G. Sales under Contract

The Secretary of the Interior asked the Recovery Team to prepare a recommendation for management of sold timber sales within DCAs. To prepare the recommendation, the Recovery Team gathered information about the magnitude of the issue. Federal land management agencies were asked to identify the acreage and volume of sold timber sales inside draft recovery plan DCAs. (Note that this information was estimated from the draft DCA boundaries; changes made in the final mapping were not reflected, but were not expected to have a significant effect.)

Initial review indicated that 39 percent of DCAs contained sold timber sales. Some sales may have significant effects on the ability of an individual DCA to fully function in the DCA network, especially in the short term. This is true of smaller DCAs, or those with relatively little suitable owl habitat. The Recovery Team did not have access to detailed information about timber sale impacts to individual owl home ranges. The local land management agencies have this information. Without the detailed information, the Recovery Team is not able to provide recommendations for specific DCAs.

However, the Recovery Team makes the following general recommendation. Implementing agencies should review all sold timber sales in the final recovery plan DCAs to assess sold timber sale impacts on the short-term risk to the owl population and recovery. This review should be coordinated with the FWS through informal consultation. The review should consider: 1) acreage of suitable habitat in the DCA, 2) proposed harvest prescription and impacts to suitable habitat, 3) number of owl activity centers known and expected to be supported in the DCA, and 4) impacts of the harvest to individual owl activity centers. This coordinated review should conclude with decisions on specific timber sales which are deemed to have significant adverse effects to short-term stability of local owl populations, and which the agencies should consider dropping or modifying.

Rather than reviewing all of these timber sales, the Recovery Team suggests the following criteria for deciding which sales to review:

1. Sales that would result in incidental take of one or more owl activity center,
2. Sales that would remove more than 1 percent of the suitable habitat in a DCA that currently has less than 50 percent suitable habitat.

The objective of the review should be to determine which sales have such significant effects that the agencies should consider either buying back the volume or mitigating impacts by modifying the sale location or locating substitute timber volume.

For a majority of the timber sales, section 7 consultation has already been conducted and the information has been partially gathered. Regardless of the past assessments and consultation, this reassessment should be conducted and documented before sales are allowed to proceed. Reinitiation of consultation may be necessary in some cases and should be discussed with the FWS.

H. Implementation of the Recovery Plan

Implementation of the recovery plan will require a level of effort that is without precedent, covering a period of several decades, and will include long-term commitments of funding and personnel from a variety of governmental entities and the private sector. Activities will encompass a large and varied geographic area, and involve intensive monitoring, evaluation, research, and management tasks. Efficient and effective implementation will require a mechanism to coordinate the wide variety of activities by the participating entities.

The recovery plan recommends establishment of a strong interagency coordinating group that would play the major role in overseeing and assisting in implementation, but structured in a way to avoid potential conflicts with the statutory mandates of the agencies involved. The recovery plan recommends that the coordinating group be based regionally and explicitly constituted to facilitate interdisciplinary and managerial communication among agencies, states, and the private sector in addressing the biological, forestry, economic, and policy issues associated with recovery. A permanent full-time staff, consisting of personnel representing participating agencies, would provide a strong basis for success. The Recovery Team recommends that the coordinating group be chartered to address the areas that encompass broad policy and programmatic concerns that are critical to progress in the recovery effort and ultimately to achieve delisting. This group would play a key role in managing the monitoring and research programs and interagency data bases (particularly the geographic information system data base) that are key to the success of this effort, provide technical advice to help agencies avoid conflicts, facilitate changes in land management as new data arise, and provide a forum to promote effective communication and coordination among the various federal and nonfederal entities involved in recovery.

The state and federal agencies involved in the recovery effort established an Interagency Northern Spotted Owl Conservation Group under a 1990 interagency agreement to facilitate and coordinate interagency activities relative to the conservation of the northern spotted owl. This group recently expanded its efforts and established a number of subgroups whose responsibilities include many of the tasks noted in the recovery plan. Since that group includes the major state and federal agencies responsible for this issue, it will form the basis for an interagency coordinating group. The group has already begun to assume tasks identified through the recovery planning process.

I. Other Species

Review comments on the sections of the draft recovery plan concerning other species were not extensive. However, several significant changes were made as a result of 1) refining DCA boundaries, 2) improving the data about some of the species, and 3) a concurrent review by Forest Service scientists to assess population viability of a variety of species under each of the alternatives from the Forest Service's final environmental impact statement on northern spotted owl management (USDA 1992).

First, the remapping of DCAs changed their boundaries. In addition, the Recovery Team included the 1992 survey data for the marbled murrelet because of its recent listing as a threatened species in Oregon, Washington, and California (USDI 1992). The remapping and the 1992 data on marbled murrelets changed the number of sites/locations of priority species in DCAs. Also, some errors were corrected in the number of miles of streams in DCAs with fish stocks that are considered at risk. All of these changes are reflected in Table 3.36 in section III.I.

Secondly, the Forest Service organized a scientific analysis team to address Judge Dwyer's decision (Federal District Court, Seattle, Washington) on the northern spotted owl pertaining to the effects on other species and their population viability. This effort (Thomas et al. In Prep.) was coordinated with members of the Recovery Team and provided a review of the Recovery Teams's list of other species and an assessment of species' population viability under each of the Forest Service's alternatives. As a result of this effort, numerous species that are associated with late-successional forests, or components thereof, were added to the Recovery Team's list. Additions of vascular and nonvascular plants were particularly numerous. A review of the draft recovery plan section on arthropods and the report by Lattin and Moldenke (1992) was conducted by Dr. David Olson of the University of California, Davis. This resulted in additions of arthropods to the Recovery Team's list. Olson's review can be found in the Recovery Team's administrative record. These additions are reflected in the tables in Appendix D and the table in section III.I.

Lastly, the Forest Service organized several panels of experts to qualitatively assess the population viability of species associated with late-successional forests under each of the agency's alternatives for management of the owl (Thomas et al. In Prep.). This assessment was conducted only for Forest Service lands and for the ISC strategy (Thomas et al. 1990), not the recovery plan, so the results are not directly comparable to the recovery plan. However, the recovery plan is based on the ISC strategy so each plan would probably have similar effects. A summary of the assessment results is in Appendix D, and this information provides a partial response to the questions the Recovery Team received on the population viability of other species under the recovery plan. The additions to the list of other species and the assessment of their population viability were the major changes in the other species sections between the draft and final versions of the recovery plan.

Literature Cited

Bart, J. [In Preparation]. Evaluation of population trend estimates for northern spotted owls calculated using capture-recapture and population projection methods. Columbus, OH: Ohio State University, Ohio Cooperative Fish and Wildlife Research Unit. 33 p.

Franklin, A.B.; Ward, J.P. 1992. Density of northern spotted owls: a meta-analysis. Presentation at the annual meeting of the Raptor Research Foundation. November 11-15, 1992. Bellevue, WA. On file with: USDI Fish and Wildlife Service, Northern Spotted Owl Recovery Team, 911, N.E. 11th Ave., Portland, OR 97232-4181.

Lattin, J.; Moldenke, A.R. 1992. Ecologically sensitive invertebrate taxa of Pacific Northwest old-growth conifer forests. Portland, OR: U.S. Department of the Interior, Fish and Wildlife Service, Northern Spotted Owl Recovery Team; report. 42 p.

Thomas, J.W.; Forsman, E.D.; Lint, J.B.; Meslow, E.C.; Noon, R.R.; Verner, J. 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., Forsman, E.D.; Gunderson, A.G.; Holthausen, R.S.; Marcot, B.G.; Raphael, M.G.; Reeves, G.H.; Sedell, J.R.; Solis, D.M. [In Preparation]. Report of the Scientific Analysis Team. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region, Portland, OR.

U.S. Department of Agriculture, Forest Service. 1988. Final supplement to the environmental impact statement for an amendment to the Pacific Northwest regional guide. Portland, OR. 2 Vols.

U.S. Department of Agriculture, Forest Service. 1992. Final environmental impact statement on management for the northern spotted owl in the national forests. Portland, OR. 854 p.

U.S. Department of the Interior, Fish and Wildlife Service. 1990a. Endangered and threatened wildlife and plants; determination of threatened status for the northern spotted owl. Washington, D.C.: *Federal Register* 55:26114-26194.

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

U.S.Department of the Interior, Fish and Wildlife Service. 1992. Endangered and threatened wildlife and plants; determination of threatened status for the marbled murrelet. Washington, D.C.: *Federal Register* 57:45328-34.

Appendix L

Recovery Team Members and Activities

Contents

The Recovery Team

The Recovery Team was comprised of 18 members appointed by Secretary of the Interior Manuel Lujan Jr. The members included biologists, ecologists, foresters, economists, federal policy and land managers, and representatives of the governors of the States of California, Oregon, and Washington.

Secretary Lujan directed the Recovery Team to develop a recovery plan for the northern spotted owl, giving appropriate consideration to the needs of other species and economic effects.

The Recovery Team began its work in March 1991. It held numerous meetings, as a team and in smaller committees working on specific matters such as owl biology, consideration of other species, economic and social effects, implementation, and silviculture. Members visited a variety of owl habitats and forests in the three states, including lands in the Mt. Hood, Willamette, and Six Rivers National Forests, Olympic National Park, the U.S. Bureau of Land Management Eugene District, the Yakima Indian Reservation, Oregon's Tillamook State Forest, and Washington state forestlands. Privately owned commercial forests toured included those of Fruit Growers Timber Company, Port Blakely, Sierra Pacific, Weyerhauser, Willamette Industries, and the National Council for Air and Stream Improvement (NCASI) study area.

Beginning with information compiled by the Interagency Scientific Committee (ISC), the Recovery Team then sought new information about owls from a variety of sources and commissioned special reviews about topics such as silvicultural practices, and management of forest threats from fire, insects, and diseases. An automated geographical information system (GIS) was developed to manage the great array of data about owl sites, habitat areas, timber resources, and other species, such as the marbled murrelet. This system includes information about federal and nonfederal lands which was helpful in formulating the recovery plan.

Early in the recovery planning process, most of each week-long Recovery Team meeting was held in open session, attended by interest group representatives, elected officials, news media representatives, and the general public. During the planning process, the Recovery Team sent agenda summaries of meetings to a mailing list of nearly 400 persons, including interest groups, news media, and local, state, and federal elected officials. Also, two letters requesting specific new information about owls were sent to the same mailing list. A number of people, representing various interests, presented information or points of view to the Recovery Team or its committees. Periodic briefings were held for elected officials and agency staff. In addition, the draft recovery plan was peer-reviewed.

On May 14, 1992, Secretary Lujan released the draft recovery plan for public review. A 60-day public comment period was announced and three public meetings were held, one meeting in each of the three states. The public comment period and public meetings were announced in the news media. In addition, three letters were sent to the Recovery Team's mailing list requesting new information. Attendance at the public meetings ranged from less than 100 in Arcata, California, and Seattle, Washington, to about 1,000 in Roseburg, Oregon. Numerous oral comments were delivered at those meetings.

On July 13, 1992, a 30-day extension of the public comment period was announced in the news media. During the full 90-day public review period nearly 1,600 comments were received. After the public comment period, the Recovery Team reviewed and considered all written and oral public comments. Presentations were solicited from federal agencies at two additional meetings in August and September to give the Recovery Team an opportunity to discuss their comments. The Recovery Team continued to solicit information to help in determining the steps to take to revise and complete the draft recovery plan.

After review and consideration of public comments, the Recovery Team began its final deliberative process in October 1992. Final Recovery Team meetings were announced, but were not open to the public to allow the Recovery Team the opportunity to come to closure on major issues. The final draft recovery plan was completed and presented to Secretary Lujan on December 16, 1992.

On January 14, 1993, Secretary Lujan congratulated the Recovery Team for its 2-year effort, but expressed continuing concern about the social and economic impacts of owl conservation. He decided not to approve the final recovery plan, but instead directed the Recovery Team to complete its work on the final draft and make the document available for public review and consideration at the proposed forest summit.

The public will have further opportunities to consider and comment on measures in the recovery plan before these measures are implemented by individual land management agencies. The National Environmental Policy Act requires federal agencies to follow a process of evaluating alternatives, environmental effects, and public comments before adopting any changes in land use practices, such as the requirements of this recovery plan.

Team Members

Members of the Recovery Team were appointed by Secretary Lujan because of their affiliation and expertise. However, during the 2-year planning process, some members changed affiliation or positions; changes are noted where appropriate.

Donald R. Knowles - *Secretary's representative and team coordinator.*
Affiliation: Associate Deputy Secretary, U.S. Department of the Interior, Washington, D.C.
Experience includes: Professional staff member, U.S. Senate Committee on Appropriations, including subcommittee assignments on funding for the Forest Service, Bureau of Land Management, Fish and Wildlife Service, National Park Service, Coast Guard, and the Federal Highway Administration; various management, program and budget analyst positions with the U.S. Department of Commerce and U.S. Department of Agriculture.
Education: B.A. in economics from North Carolina State University; M.P.A. with major in water resources from North Carolina State University.

Marvin Plenert - *Team leader.*
Affiliation: Regional Director, U.S. Fish and Wildlife Service Pacific Region (Washington, Oregon, California, Idaho, Nevada, Hawaii, and the Pacific Trust Territories), Portland, Oregon.
Experience Includes: Assistant Director, Refuges and Wildlife, Fish and Wildlife Service (FWS) national headquarters; Deputy Assistant Regional Director, Refuges and Wildlife, FWS Rocky Mountain region; refuge supervisor for operations, FWS Alaska region.
Education: B.S. and M.S. in wildlife management from Kansas State University.

Jonathan Bart - *Team chair.*
Affiliation: Assistant Leader of the Ohio Cooperative Fish and Wildlife Research Unit; Associate professor in the Department of Zoology at Ohio State University, Columbus, Ohio.
Experience includes: teaching graduate seminars and courses in wildlife biology, biometry and behavioral ecology; publications in the areas of survey design and evaluation, survival analysis, quantitative analysis, and behavioral ecology.
Education: B.S. in biology from Syracuse University, M.S. in ecology from Cornell University, Ph.D. in wildlife biology from Cornell University.

Robert G. Anthony
Affiliation: Assistant Unit Leader and Professor of Wildlife Ecology, Oregon Cooperative Wildlife Research Unit, Oregon State University, Corvallis, Oregon.
Experience includes: Teaching mammalogy, wildlife natural history, and wildlife biometrics; researching, and directing graduate students in research in the areas of wildlife ecology, dynamics of wildlife populations, and application of quantitative procedures to ecological concepts; Assistant and Associate Professor of Wildlife Ecology, Pennsylvania State University; 15 publications within the last 5 years.
Education: B.S. in biology from Fort Hays Kansas State College; M.S. in Wildlife Biology from Washington State University; Ph.D. in zoology from University of Arizona.

Melvin Berg
Affiliation: Chief, Division of Forestry, U.S. Bureau of Land Management, Washington, D.C.
Experience includes: Bureau of Land Management (BLM) district manager, Roseburg, Oregon; BLM associate district manager; BLM area manager, natural resource specialist, realty specialist, access specialist, and forester.
Education: B.S. in forest management from Iowa State University.

John H. Beuter
Affiliation: Deputy Assistant Secretary of Agriculture for Natural Resources and Environment, Washington, D.C.
Experience includes: Consulting Forester with Mason, Bruce and Girard, Inc., Portland, Oregon; professor and department head of Forest Management at Oregon State University; director of Oregon State University research forests.
Education: B.S. in forestry, M.S. in forest economics from Michigan State University, Ph.D. in forestry and economics from Iowa State University.

Wayne Elmore
Affiliation: U.S. Bureau of Land Management State Riparian Specialist for Oregon and Washington, Prineville, Oregon.
Experience includes: Bureau of Land Management resource area forester, and BLM district wildlife biologist in Spokane, Washington; BLM district wildlife and fisheries biologist in Prineville, Oregon; approximately 20 publications on riparian ecosystem function and management.
Education: B.S. in forest management from Oklahoma State University, post-graduate studies in fisheries and wildlife management.

John Fay
Affiliation: Listing Branch Chief, Division of Endangered Species, U.S. Fish and Wildlife Service, Washington D.C.
Experience includes: Botanist, Division of Endangered Species, Fish and Wildlife Service (FWS); Assistant Chief, Branch of Biological Support, Office of Endangered Species, FWS; Associate Editor, Flora North America; Botanist, Pacific Tropical Botanical Garden; former FWS representative on Species Survival Commission, International Union for the

Conservation of Nature and Natural Resources; numerous scientific and Federal Register publications.
Education: B.S. in biology from Fordham College; Ph.D. in biology from City University of New York.

R. J. Gutiérrez
Affiliation: Professor, Department of Wildlife, Humboldt State University, Arcata, California. Current major studies ongoing in habitat, dispersal, genetics, and population dynamics of the spotted owl.
Experience includes: Chairman of Wildlife, Humboldt State University; assistant professor in the Department of Natural Resources at Cornell University; more than 70 wildlife consulting projects for universities, associations, and corporations; more than 30 peer-reviewed publications on avian ecology.
Education: B.S. in wildlife biology from Colorado State University; M.S. in biology from University of New Mexico; Ph.D. in zoology from University of California, Berkeley.

H. Theodore Heintz, Jr.
Affiliation: Assistant Director for Economic Analysis, Office of Policy Analysis, U.S. Department of the Interior, Washington, D.C.
Experience includes: Staff Director of the President's Task Force on Outer Continental Shelf Leasing and Development; Research Director, Commission of Fair Market Value Policy for Federal Coal Leasing; Director of Economics and Systems Analysis, Earth Satellite Corporation, Washington, D.C.
Education: B.E.E. in electrical engineering from Cornell University; M.P.A. in public affairs from the Woodrow Wilson School of Public and International Affairs at Princeton University.

Richard S. Holthausen
Affiliation: National Wildlife Ecologist, U.S. Forest Service, Corvallis, Oregon.
Experience includes: Regional Wildlife Ecologist, U.S. Forest Service Pacific Northwest Region; Assistant Wildlife Ecologist, National Fish and Wildlife Ecology Unit, Forest Service; forest planner, Bighorn National Forest; forest planning biologist and range conservationist, Bighorn National Forest; range scientist, Peter Kiewit Sons Mining, Sheridan, Wyoming; various teaching and course design work in forest management, wildlife and fish ecology.
Education: B.S. in ecology and mathematics from Cornell University; M.S. in ecology from Utah State University.

Kenneth Lathrop
Affiliation: Supervisory Forester, Forest Products and Sale Administration, U.S. Bureau of Indian Affairs, Portland, Oregon.
Experience includes: Assistant Forester - Timber Sales, Portland Area Bureau of Indian Affairs; District Ranger and Timber Sale Officer, White Swan Ranger Station, Yakima Indian Reservation.
Education: B.S. in forestry from Michigan Technological University; post graduate work in forestry, wildlife, Indian culture, and public administration at Oregon State University, Washington State University, University of Washington, Central Washington College, and Lewis and Clark College.

Kent Mays
Affiliation: Program Manager for Spotted Owl Research, Development and Application program involving 24 national forests and two forest and range experiment stations, U.S. Forest Service, Portland, Oregon.
Experience includes: 34 years with the U.S. Forest Service in various line and staff

positions, including District Ranger and Forest Supervisor, on seven national forests in four states; worked in various positions in the U.S. Forest Service National Headquarters in Washington D.C. in recreation, planning, and legislative affairs; and the President's Commission on American Outdoors.
Education: B.S. in forestry from Oregon State University, studies in Public Administration at American University, awarded an American Political Science Association Congressional Fellowship.

Richard Nafziger - *Representing the Governor of the State of Washington.*
Affiliation: Special Assistant to the Governor for Timber Policy and Rural Development; Coordinator of Interagency Task Force on Timber Community Development, Olympia, Washington.
Experience includes: Member of Governor's Economic Recovery Coordination Board; senior policy analyst for Economic Development and Labor, Office of Financial Management.
Education: B.A. in religion from Macalester College, St. Paul, Minnesota; M.S. in economics, New School for Social Research, New York, New York.

Martha Pagel - *Representing the Governor of the State of Oregon.*
Affiliation: Oregon Governor's Senior Policy Advisor on Natural Resources, Salem, Oregon (because of a change of position within the State, Bob Warren was substituted for Martha Pagel).
Experience includes: Director, and Deputy Director, Oregon Division of State Lands; Assistant Attorney General, General Counsel Division, Oregon Department of Justice, providing general legal advice to various natural resource agencies.
Education: B.A. in journalism from San Diego State University; J.D., Willamette University College of Law.

Christine Sproul - *Representing the Governor of the State of California.*
Affiliation: Assistant Secretary, Legal Affairs, The Resources Agency of California, Sacramento, California.
Experience includes: Staff Counsel, Office of the General Counsel, California Air Resources Board; Staff Counsel, Office of the Chief Counsel, State Water Resources Control Board.
Education: B.A. in international relations from University of California, Davis; J.D. from Martin Luther King Jr. Law School, University of California, Davis.

Edward E. Starkey
Affiliation: Research Biologist and Terrestrial Ecology Program Leader, National Park Service Cooperative Park Studies Unit, Oregon State University; Professor of terrestrial ecology, Departments of Forest Resources, and Fisheries and Wildlife, Oregon State University, Corvallis, Oregon.
Experience includes: Chief scientist and wildlife ecologist for the National Park Service Denver Service Center; research and teaching assistant in zoology and biology at Washington State University; more than 30 publications (and six theses supervised) since 1980, mostly concerning deer and elk in old-growth forests, fire ecology, and nutritional ecology.
Education: B.S. in biology from Bemidji State University; M.A. in biology from St. Cloud State University; Ph.D. in zoology from Washington State University.

John C. Tappeiner
Affiliation: Professor of Forestry at Oregon State University, Corvallis, Oregon, teaching silviculture and forest ecology, research in shrub and hardwood ecology and vegetation management and forest stand growth (currently with the U.S. Bureau of Land Management Cooperative Research Unit, Corvallis, Oregon).

Experience includes: Lecturer in forestry, University of California, Berkeley; Regional Silviculturist for U.S. Forest Service Region 5 (17 national forests in California); international forestry consulting; associate professor University of Minnesota Cloquet Forest Research Center; numerous peer-reviewed papers.
Education: B.S., M.S., and Ph.D. in forestry (specializing in forest ecology and silviculture) all from University of California, Berkeley.

Robert D. Warren *Representing the Governor of the State of Oregon (appointed to the Recovery Team to replace Martha Pagel on October 22, 1992).*
Affiliation: Special Assistant for Forest Policy and Director of the Governor's Forest Planning Team.
Experience includes: 5 years as congressional aide for U.S. Representative Peter DeFazio, specializing in forest policy and natural resource issues.
Education: B.S. in business administration and marketing from California State University, Long Beach; currently studying public affairs at University of Oregon.

Table L.1. Committee membership

Committee	Leader	Members	(Support)
Spotted Owl	Holthausen Gutiérrez	Starkey Berg Mays Lathrop Anthony	(Bruce) (Hayys) (Gould) (Ogden)
Forest Ecology	Tappenier	Beuter Berg Mays Lathrop	(Hanus) (Raettig) (Tuazon)
Economic	Heintz	Fay Nafziger	(Raettig) (Tuazon)
Other Species	Anthony	Starkey Elmore Fay	(Bruce)
Planning	Elmore Nafziger	Berg Mays Lathrop Beuter Pagel Sproul	(Hanus) (Tuazon) (Finfer) (Partridge) (Elliott) (Ogden) (Mulder)
Executive	Bart	Holthausen Fay Anthony Nafziger Elmore Gutiérrez Tappeiner Henitz	(Finfer)

Team Support

Charles Bruce, Oregon Department of Fish and Wildlife
Philip Carroll, U.S. Fish and Wildlife Service
Catherine Elliott, Washington Governor's Timber Team
Lawrence Finfer, U.S. Department of the Interior
Gordon Gould, California Department of Fish and Game
Ann Hanus, Oregon Department of Forestry
David Hays, Washington Department of Wildlife
David Johnson, Oregon Department of Fish and Wildlife
Linda Kucera, U.S. Fish and Wildlife Service
Barry Mulder, U.S. Fish and Wildlife Service
Cay Ogden, U.S. Fish and Wildlife Service
Craig Partridge, Washington Department of Natural Resources
Fred Seavey, U.S. Fish and Wildlife Service
Raul Tuazon, California Department of Forestry and Fire Protection

Technical Reports Prepared for the Recovery Team[a]

Benson, G. 1991. Summary of northern spotted owl nest site information in eastern Washington. Unpublished manuscript. Spotted owl RD&A (research, development, and applications) Program, Pacific Northwest Experiment Station, U.S. Forest Service, Portland, Oregon. 2 p.

Benson, G. 1991. Characterization of spotted owl habitat: east slope of the Washington and Oregon Cascades (Draft). Unpublished manuscript. Spotted owl RD&A (research, development, and applications) Program, Pacific Northwest Experiment Station, U.S. Forest Service, Portland, Oregon. 9 p.

Birch, K. 1991. Silviculture systems for Douglas-fir. Unpublished report submitted to the Northern Spotted Owl Recovery Team. 6 p.

Frest, T.J.; Johannes, E.J. 1991. Present and potential candidate molluscs occurring within the range of the northern spotted owl. Unpublished manuscript. Deixis Consultants. Seattle, Washington. 30 p.

Grenier, J. 1991. Review of information on structure of old-growth stands and old-growth stands used by spotted owls in western Oregon and Washington. Unpublished manuscript submitted to the Northern Spotted Owl Recovery Team. 51 p.

Lamberson, R.H.; Brooks, S. 1991. An examination of the high density of northern spotted owls in northwestern California. Unpublished manuscript. Department of Mathematics and Program in Environmental Systems, Humboldt State University, Arcata, California. 31 p.

McComb, W.C. 1991. The role of dead wood in habitat of spotted owl prey and other old forest vertebrates. Unpublished manuscript. Department of Forest Science, Oregon State University, Corvallis, Oregon. 57 p.

Morrell, J.J. 1991. Role of fungi in coarse woody debris. Unpublished manuscript. Department of Forest Products, Oregon State University, Corvallis, Oregon. 19 p.

Oliver, C. 1991. Northern spotted owl habitat in previously managed forests in western and eastern Washington with and without further management. Unpublished manuscript. College of Forestry, University of Washington, Seattle, Washington. 82 p.

Perry, D. 1991. The ecology of coarse woody debris in Pacific Northwest forests: overview, and the role of down logs in ecosystem processes. Department of Forest Science, Oregon State University, Corvallis, Oregon. 39 p.

Stere, D.H. 1991. A discussion of forest stand simulators. Unpublished manuscript. Oregon Department of Forestry, Salem, Oregon. 13 p.

Weatherspoon, P.; Ritchie, M. 1991. Silvicultural prescriptions for mixed-conifer stands in northern California. Unpublished report submitted to the Northern Spotted Owl Recovery Team. 13 p.

Reports Prepared by the Northern Spotted Owl Recovery Team[a]

Northern Spotted Owl Recovery Team. April 1992. A review of the multi-resource strategy for the conservation of the northern spotted owl. Portland, Oregon. 33 p.

Northern Spotted Owl Recovery Team. May 1992. A review of management plans developed by the spotted owl management alternatives work group. Portland, Oregon. 14 p.

[a]All reports are on file with the Northern Spotted Owl Recovery Team.

Table L.2. Chronology of Recovery Team Activities.

Date	Event	Subject
3-05-91	Recovery Team meeting Portland, Oregon	Discussion of Recovery Team structure, schedule and reporting dates, and logistics.
3-27 thru 3-29-91	Recovery Team meeting Portland, Oregon	Overview of Endangered Species Act and other applicable laws, introduction to recovery planning, briefings on owl biology, silviculture, and forest ecology.
4-05-91	Other Species Subgroup meeting Portland, Oregon	Discussions of species and communities likely to benefit from the recovery plan, strategy for incorporating these into development of the plan, and benefits of reserves versus corridors between reserves.
4-15 and 4-16-91	Spotted Owl Subgroup meeting Portland, Oregon	Discussions of peer review, data bases available to Recovery Team, criteria for owl range map, need for updating information on defining suitable habitat.
4-22 and 4-23-91	Recovery Team meeting Portland, Oregon	Committee reports. Discussion of ISC Appendices F, G, H, O, and P. Discussion of owl range. Executive session: budgetary issues, travel vouchers, staff needs.
4-24-91	Recovery Team field trip	Mt. Hood National Forest with Estacada Ranger District Forest Service personnel.
4-25-91	Economic Subgroup meeting Salem, Oregon	Met with experts from State of Oregon agencies and universities.
5-03-91	Other Species Subgroup meeting Portland, Oregon	Discussion of old-growth ecosystem concerns, GIS mapping strategies, importance of corridors.
5-9-91	Economic Subgroup meeting University of California, Berkeley, California	Met with experts from State of California agencies, universities, and consulting groups.
5-13-91	Other Species Subgroup meeting Corvallis, Oregon	Final assignments made and deadlines agreed to.
5-14 thru 5-16-91	Recovery Team meeting Lake Crescent, Washington (Olympic Peninsula)	Committee reports. Discussion of ISC Appendices L, R, S, and T; economic impacts of recovery; critical habitat; proposed other recovery goals; recovery options previously identified.

Continues

Continued

Date	Event	Subject
5-17-91	Recovery Team field trip	Lake Crescent, Washington (Olympic Peninsula).
5-20-91	Economic Subgroup meeting University of Washington, Seattle, Washington.	Met with experts from State of Washington agencies and universities.
5-24-91	Other Species Subgroup meeting Olympia, Washington	Meeting at Forest Service Pacific Northwest Research Station to discuss species that may be influenced by the recovery plan.
5-29-91	Other Species Subgroup meeting Portland, Oregon	Meeting with J. Sedell and G. Reeves (Forest Service) to discuss native fish that might be benefitted by the recovery plan.
5-29 thru 5-30-91	Spotted Owl Subgroup meeting Portland, Oregon	Update on range mapping, status and threats section, descriptions of suitable habitat and mapping of suitable spotted owl habitat, summary of vegetation data bases, discussion of roles of silvicultural prescriptions, report on goals and objectives.
6-06 and 6-07-91	Other Species Subgroup meeting Portland, Oregon	Meeting with California Departments of Fish and Game, Forestry to discuss lists of sensitive species.
6-12-91	Economic Subgroup meeting Portland, Oregon	Evaluation of economic outline.
6-12 thru 6-14-91	Spotted Owl Subgroup meeting Portland, Oregon	Discussion of final review of goals, review of status and criteria for range mapping; review of status and threats section; review of suitable habitat definitions.
6-17 and 6-18-91	Recovery Team field trip to California	Visit to Sierra Pacific Industries forestland, Sacramento Canyon and Deadwood, Fruitgrowers Supply Company forestland, Willow Creek study area, and Simpson timberland.
6-19 thru 6-21-91	Recovery Team meeting Arcata, California	Committee reports, discussion of revised recovery goals, plan organization, process for identifying options and establishment of milestones, presentation of options being considered by BLM.

Continues

Continued

Date	Event	Subject
6-26 thru 6-28-91	Spotted Owl Subgroup meeting Portland, Oregon	Discussion of suitable habitat definition, GIS, range mapping, delisting criteria, process for evaluating option. Presentation by J. Agee on fire and windthrow.
7-02-91	Other Species Subgroup meeting Oregon State University Corvallis, Oregon	Review of other species to be considered, principles and objectives, and outline for appendices.
7-03-91	Planning Committee meeting Portland, Oregon	Discussion of implementation on federal and nonfederal lands, incentives for private land wildlife protection.
7-10 thru 7-13-91	Spotted Owl Subgroup meeting Portland, Oregon	Revision of significant threats document, options for recovery, delisting criteria, range mapping.
7-10-91	Planning Committee meeting Portland, Oregon	Review of documents on recovery plan implementation, problems, and issues federal and nonfederal lands.
7-16 thru 7-19-91	Recovery Team meeting Springfield, Oregon	Committee reports. Discussion of recovery goals and delisting criteria, options for achieving recovery.
7-17-91	Planning Committee meeting Portland, Oregon	Definition of goals. Division of assignments.
7-18-91	Recovery Team field trip	BLM Coast Range Resource Area Springfield, Oregon.
7-29 thru 7-31-91	Spotted Owl Subgroup meeting Portland, Oregon	Review of states' progress on significant threats document, range maps, report on McKelvey model, options for recovery, and delisting criteria. Presentation by J. Thomas on old-growth preserve options presented to Congress.
8-08 and 8-09-91	Recovery Team workshop Portland, Oregon	Other species and ecosystem issues. Presentations on marbled murrelets, riparian ecosystems, sensitive streams and stocks of native fish, amphibians, spotted owl prey, goshawks, bald eagles, martens, and fishers, plants associated with older forest ecosystems, and ecological corridors.
8-14 thru 8-16-91	Spotted Owl Subgroup meeting Portland, Oregon	Review of range map, map of physiographic provinces, delisting criteria, evaluation process and data needed.

Continues

Continued

Date	Event	Subject
8-19 thru 8-22-91	Recovery Team meeting and field trip Portland, Oregon	Committee reports. Presentation on stand simulators and Douglas County project. Discussion of evaluation procedures, old-growth preserves, and critical habitat.
8-21-91	Recovery Team field trip	Yakima Indian Reservation Forest, Yakima, Washington.
8-22-91	Planning Committee meeting Portland, Oregon	Discussion of items needed in recovery plan from planning group and division of assignments.
9-04 thru 9-05-91	Spotted Owl Subgroup meeting Portland, Oregon	Completion of map work. Review status and threats by province, contributions from private lands.
9-06-91	Other Species Subgroup meeting Oregon State University Corvallis, Oregon	Discussion of priorities for marbled murrelets, native fish and wolves, grizzly bears, and goshawks. Role of ecological corridors and coarse woody debris.
9-09 thru 9-13-91	Spotted Owl Subgroup meeting Portland, Oregon	Completion of options for federal lands. Discussion of working groups for each state to finalize options.
9-11-91	Planning Committee meeting Portland, Oregon	Briefing on state and private lands recovery options, recovery plan implementation, HCPs, private land incentives, and analysis of harvest impacts.
9-16 thru 9-20-91	Spotted Owl Subgroup meeting Portland, Oregon	Review salvage report, data layers in GIS and salvage and silvicultural activities. Discuss options for nonfederal lands. Presentation of industry proposal for recovery plan.
9-19-91	Planning Committee meeting Portland, Oregon	Discussion of institutional mechanisms for nonfederal lands, principles of implementation, individual management plans for DCAs (designated conservation areas), and critical habitat. Presentation on Bull Run watershed.
9-23 thru 9-27-91	Recovery Team meeting Portland, Oregon	Committee reports. Presentation on Bull Run watershed. Discussion of ecological significance of coarse woody debris; effects of fire, wind, insects, and diseases; silvicultural methods for improving and retaining owl habitat inside and outside of DCAs.

Continues

Continued

Date	Event	Subject
9-26-91	Spotted Owl Subgroup meeting Portland, Oregon	Meeting with Forest Ecology Committee to discuss management of catastrophic risk in DCAs.
9-27-91	Planning Committee meeting Portland, Oregon	Discussion of process for evaluating proposals, writing tasks, four-step process for integration, development of landscape alternative, oversight mechanism, and critical habitat.
10-04-91	Planning Committee meeting Portland, Oregon	State and private participation, critical habitat, implementation issues.
10-11-91	Planning Committee meeting Portland, Oregon	Conference call to discuss take, habitat conservation plans (HCP), section 4(d) rule.
10-15 and 10-16-91	Planning Committee meeting Oregon	Discussion of critical habitat, take, HCP, section 4(d) rule. Report on "silviculture, salvage and catastrophic risk management in DCAs." Review of draft material on implementation on state and private lands, coordination and oversight mechanisms, current management.
10-17 and 10-18-91	Recovery Team meeting Portland, Oregon	Committee reports. Progress report on chapters. Discussion of recommendations for critical habitat, DCA network matrix management, management on east side forests, development of research and monitoring program, and demographic analysis.
10-29 thru 11-01-91	Recovery Team meeting Portland, Oregon	Mapping designated conservation areas with participation of representatives from the national forests and BLM districts.
11-04 thru 11-08-91	Recovery Team meeting Portland, Oregon	Committee reports. Discussion of management guidelines for DCAs and matrix.
11-05-91	Planning Committee meeting Portland, Oregon	Discussion of state proposals and current management.
12-03 thru 12-06-91	Recovery Team meeting Portland, Oregon	Committee reports. Discussion of critical habitat, Washington D.C. review, Chapters I, II, and III.
1-14 and 1-15-92	Recovery Team meeting Portland, Oregon	Report on Washington D.C. review of draft recovery plan, results from peer review, Appendices A, B, H, and I, proposed revisions to plan, and Secretary's directive to the Recovery Team.

Continues

Continued

Date	Event	Subject
2-18 and 2-19-92	Recovery Team meeting Portland, Oregon	Status of draft recovery plan and Secretarial decision to delay release; committee reports on changes to draft; preparation for review of industry plan; discussion on salvage, monitoring, and models.
4-2-92	Recovery Team meeting Portland, Oregon	Discuss plans for release of draft recovery plan and schedule for public comment process; discuss Recovery Team review of industry plan; alternatives.
5-14-92	Press conference with Recovery Team, Washington, D.C. and Portland, Oregon	Announce release of draft recovery plan and initiation of 60-day public comment period.
5-28-92	Recovery Team meeting Portland, Oregon	Committee reports; discussion on salvage, public review process; review of alternative plan.
6-19-92	Public meeting Arcata, California	Public meeting; presentations and discussions with members of the public.
6-22-92	Public meeting Roseburg, Oregon	Public meeting; presentations and discussions with members of the public.
6-26-92	Public meeting Seattle, Washington	Public meeting; presentations and discussion with members of the public.
8-4 thru 8-6-92	Recovery Team meeting Portland, Oregon	Presentation of Recovery Team awards; discussion on public comments with presentations by the Forest Service, Bureau of Land Management, U.S. Fish and Wildlife Service, Bureau of Indian Affairs, National Park Service, U.S. Department of Defense; strategy for completing recovery plan.
8-30 and 8-31-92	Spotted Owl Subgroup meeting Portland, Oregon	Update on data bases; discussion on salvage, DCA delineation and documentation; review public comments; review example DCA plans.
9-8-92	Recovery Team field trip southwestern Washington	Field trip to view industry lands in southwestern Washington; meeting with Port Blakely (and Weyerhauser, Washington Department of Natural Resources, private landowners, and Board of Forestry officials) to discuss HCP process and habitat conditions.
9-9-92	Spotted Owl Subgroup meeting Portland, Oregon	Discussions on salvage, reserved pair area acreage calculations and recommendations, demographic analysis, and McKelvey model.
9-9-92	Implementation Subgroup meeting Portland, Oregon	Review and discussion of public comments; updates on assignments.

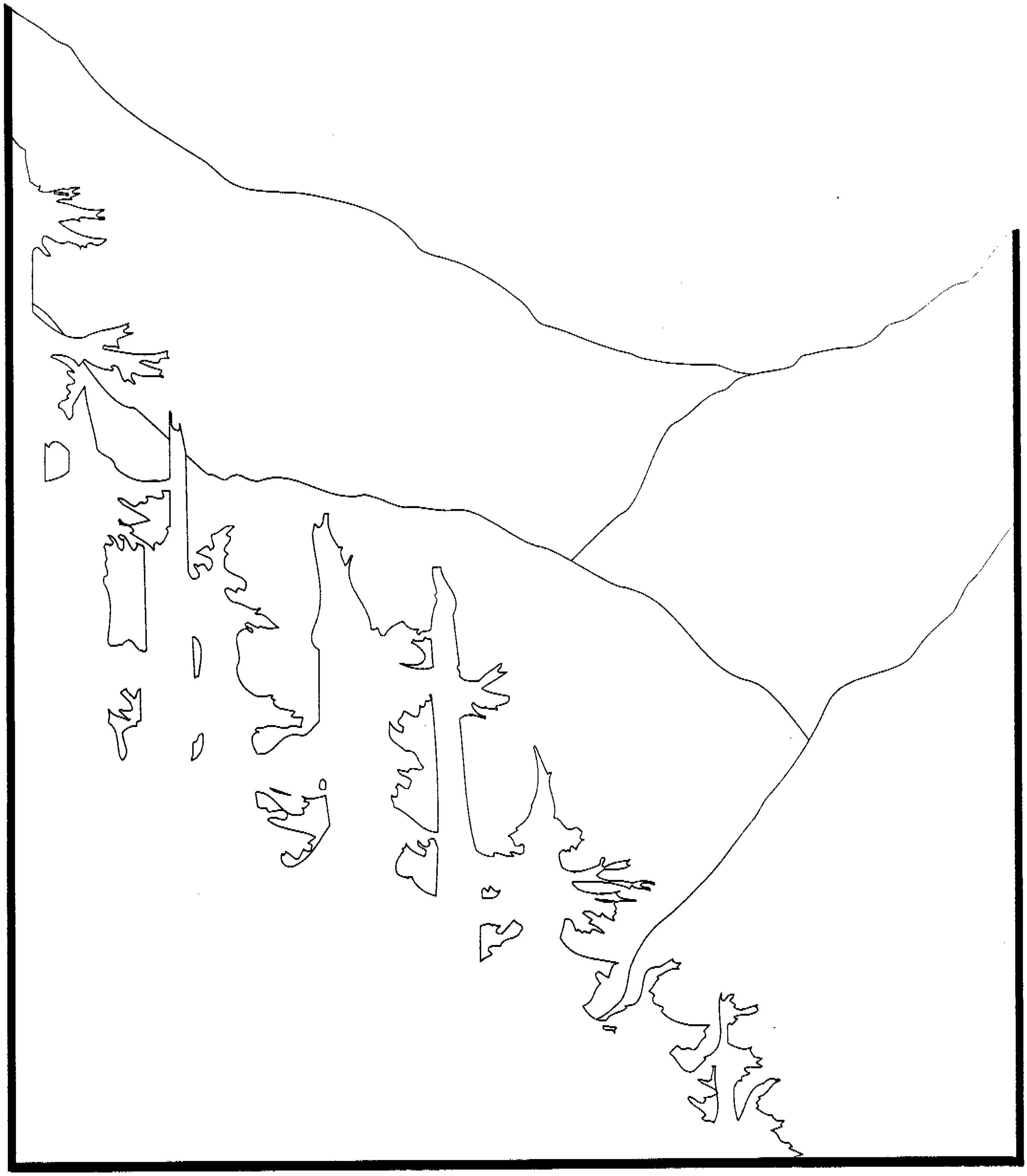
Continues

Continued

Date	Event	Subject
9-10 and 9-1192	Recovery Team meeting Portland, Oregon	Committee reports on public comments: discussion on nonfederal lands and salvage; Forest Service presentation on environmental impact statement status; Bureau of Land Management presentation on Resource Management Plans status; schedule for recovery plan completion.
9-16-92	Recovery Team briefing Portland, Oregon	Briefing on status and content to Interagency Northern Spotted Owl Conservation Group (INSOCG).
9-29 thru 10-20-92	Spotted Owl Subgroup remapping meetings	Members of the Spotted Owl Subgroup met with Forest Service and Bureau of Land Management biologists to review, remap the DCAs in Washington, Oregon, and northern California.
10-13 thru 10-16-92	Recovery Team meeting Portland, Oregon	Committee reports; discussion and summary of public comments; schedule on recovery plan completion.
11-4 thru 11-6-92	Recovery Team meeting Portland, Oregon	Committee reports; schedule on recovery plan completion.
11-24-92	Spotted Owl Subgroup demographic workshop Portland, Oregon	Presentations and discussions on new demographic information and analyses, population declines, and assumptions about the rate of decline.
12-1-92	Recovery Team meeting Portland, Oregon	Committee reports; review of final draft recovery plan.
12-16-92	Recovery Team briefing Washington D.C.	Presentation to Department of the Interior and agency officials on final draft recovery plan.
1-11 and 1-12-93	Spotted Owl Subgroup Portland, Oregon	Discussion on research priorities and monitoring program.
1-14-93	Secretarial Decision	Letter from Secretary Lujan instructing the team to complete and release the plan for use in forest summit.

Appendix M

Glossary



Glossary

50-11-40 rule - a guideline developed to provide habitat conditions adequate for movement of juvenile and adult owls throughout the landscape. It requires that 50 percent of the forest in a quarter-township be maintained with an average tree dbh of at least 11 inches and 40 percent canopy closure.

Activity center - an area of concentrated activity of either a pair of spotted owls or a territorial single owl.

Adaptive management - the process of implementing policy decisions as scientifically driven management experiments that test predictions and assumptions in management plans, and using the resulting information to improve the plans.

Allelic difference - the distinguishing characteristics among all forms of a gene.

Allometric - of or pertaining to allometry: the increase in size of one part of an organism related to the growth of the whole.

Allometric analysis - an assessment of the relationship of a body trait (e.g., body mass) and home range size.

Allometric equations - a mathematical expression of the relationship between body mass and home range size among owls.

NOTE: The following acronyms are used to indicate the sources of many of the definitions in this glossary.

CFR - "Code of Federal Regulations," 36 CFR and 40 CFR
DST - "A Dictionary of Statistical Terms," Third Edition, M.G. Kendall and W.R. Buckland
EFG - "Ecology Field Glossary - A Naturalist's Vocabulary," Walter H. Lewis
FSM - "Forest Service Manual 2410"
GET - "Glossary of Engineering Terms," Pacific Northwest Forest and Range Experiment Station, USDA-Forest Service, 1979
MWFH - "Management of Wildlife and Fish Habitats in Forests of Western Oregon and Washington," USDA-Forest Service, Pacific Northwest Region, 1985
NAD - "New American Dictionary"
OLR - "Oregon Law Review, Land and Resource Planning in the National Forests," C.F. Wilkinson and H.M. Anderson, University of Oregon Law School, 1985
RG - "Glossary from the Regional Guide for the Pacific Northwest Region," May 1984
RH - "Random House Dictionary of the English Language," College Edition, 1969
SAF - "Society of American Foresters Dictionary of Forestry Terms"
WEB - "Webster's New Collegiate Dictionary"
WPG - "Wildland Planning Glossary," Pacific Southwest Forest and Range Experiment Station, USDA-Forest Service, General Technical Report PSW 13/1976

Allopreening - reciprocal or ritual cleaning of feathers by members of an owl pair.

Allozyme electrophoresis - Allozymes are different forms of the same enzyme. Electrophoresis is a technique to distinguish among allozymes by comparing their relative mobility in an electrical field.

Anadromous fish - those species of fish that mature in the sea and migrate into streams to spawn. Salmon, steelhead, and shad are examples. *RG*

Aspect - the direction a slope faces with respect to the cardinal compass points. *GET*

Autocorrelation - a measure of the similarity of consecutive numbers in a temporal, or other one-dimensional, series of observations.

Basal area - the area of the cross-section of a tree stem near its base, generally at breast height and including bark. *SAF*

Biological diversity - the variety of life and its processes, including complexity of species, communities, gene pools, and ecological functions.

Biological growth potential - the average net growth attainable in a fully stocked natural forest stand. *RG*

Biological unit management - Forest Service usage. Any unit for management of a particular species or any unit of intensive or special management. The term includes any big-game management unit as recognized by a cooperating state, even though it may not be strictly a herd unit. In the case of fisheries management, the term may include a drainage system. *WPG*

Biomass - the total quantity (at any given time) of living organisms of one or more species per unit of space (species biomass), or of all the species in a biotic community (community biomass). *RG*

Birth-pulse population - a population assumed to produce all of its offspring at an identical, and instantaneous, point during the annual cycle.

BLM - Bureau of Land Management, U.S. Department of the Interior.

Blowdown - trees felled by high winds.

Board foot - lumber or timber measurement term. The amount of wood contained in an unfinished board 1 inch thick, 12 inches long, and 12 inches wide. *WPG*

Breast height - a standard height from average ground level for recording diameter, girth, or basal area, generally 4.5 feet (1.37 meters). *GET*

Broadcast burn - allowing a prescribed fire to burn over a designated area within well-defined boundaries for reduction of fuel hazard or as a silvicultural treatment, or both. *RG*

Brooms (as in mistletoe) - a cluster of branches, radiating from a single point, that results from damage in a tree from agents such as mistletoe.

BT - *Bacillus thuringiensis*, a bacterium used for biological control of spruce budworm.

Cambium - the layer of tissue between the bark and wood in a tree or shrub. New bark and wood originate from this layer.

Canopy - a layer of foliage in a forest stand. This most often refers to the uppermost layer of foliage, but it can be used to describe lower layers in a multistoried stand.

Canopy closure - the degree to which the crowns of trees are nearing general contact with one another. Generally measured as the percent of the ground surface that would be covered by a vertical projection of foliage in the crowns of trees.

Capability - the potential of an area of land to produce resources, supply goods and services, and allow resource uses. Capability depends upon current vegetation conditions and site conditions such as climate, slope, landform, soils, and geology. *RG*

Center of activity - the nest site of a breeding pair of owls or primary roost area of a territorial individual owl.

CFR - Code of Federal Regulation.

Checkerboard ownership - a land ownership pattern in which every other section (square mile) is in federal ownership as a result of federal land grants to early western railroad companies.

Class E (fire) - a fire that extends over an area ranging from 300 to 1,000 acres.

Clear-cut - an area where the entire stand of trees has been removed in one cutting. *SAF*

Climax - the culminating stage in plant succession for a given site where the vegetation has reached a highly stable condition. *RG*

Closed sapling pole - sapling and pole stands which are characterized by a closed tree canopy and minimal little ground cover. Tree crown closure will exceed 60 percent and often reaches 100 percent.

Cluster - see nonfederal cluster.

Clutch - the number of eggs laid by a female bird at one time. *EFG*

Cohort - individuals all resulting from the same birth-pulse, and thus all of the same age.

Colonization - the establishment of a species in an area not currently occupied by that species. Colonization often involves dispersal across an area of unsuitable habitat.

Conferencing - informal consultation that takes place between the U.S. Fish and Wildlife Service and another federal agency when it is determined that a proposed federal action may jeopardize the continued existence of a species proposed as threatened or endangered or result in adverse modification of proposed critical habitat.

Confidence interval - an interval that is calculated from a series of samples intended to estimate the value of a parameter. The confidence level is the probability that the true value of the parameter falls within the confidence interval.

Confidence level - the probability that the true value for a parameter is included within the confidence interval calculated for a sample of that parameter.

Congressionally classified and designated areas - areas that require congressional enactment for their establishment, such as national wilderness areas, national wild and scenic rivers, and national recreation areas. *RG*

Conifer - a tree belonging to the order Gymnospermae, comprising a wide range of trees that are mostly evergreens. Conifers bear cones (hence coniferous) and needle-shaped or scale-like leaves. *SAF*

Connectivity - a measure of the extent to which intervening habitat truly connects DCAs for juvenile spotted owls dispersing among them.

Conservation - the process or means of achieving recovery.

Conspecifics - belonging to or pertaining to the same species.

Consultation - a formal interaction between the U.S. Fish and Wildlife Service and another federal agency when it is determined that the agency's action may affect a species that has been listed as threatened or endangered or its critical habitat.

Contiguous habitat - habitat suitable to support the life needs of owls that is distributed continuously or nearly continuously throughout the landscape.

Corridor - a defined tract of land, usually linear, through which a species must travel to reach habitat suitable for reproduction and other life-sustaining needs.

Cost efficiency - the usefulness of specified inputs (costs) to produce specified outputs (benefits). In measuring cost efficiency some outputs, including environmental, economic, or social impacts, are not assigned monetary values, but are achieved at specified levels in the least costly manner. Cost efficiency usually is measured using present net value, although use of benefit-cost ratios and rates-of-return may be appropriate. *RG*

Critical habitat - specific areas in the geographical area occupied by a species on which are found those physical or biological features essential to conservation of the species.

Crown - the upper part of a tree or other woody plant which carries the main system of branches and the foliage. *SAF*

Crown closure - see canopy closure.

CWD (coarse woody debris) - portion of a tree that has fallen or been cut and left in the woods. Usually refers to pieces at least 20 inches in diameter.

DBH - diameter at breast height. The diameter of a tree measured 4 feet 6 inches from the ground. *RG*

DCA - designated conservation area.

Defoliators - insects that feed on foliage and act to remove some or all of the foliage from a tree, shrub, or herb.

Demographic model - a model that predicts the future state of an animal population based on its birth and death rates.

Demography - the quantitative analysis of population structure and trends; population dynamics. *EFG*

Density, biological population - the number or size of a population in relation to some unit of space. It is usually expressed as the number of individuals or the population biomass per unit area or volume. *RG*

Depauperate - poorly developed. In biology, it usually refers to an area that has relatively few plant and animal species.

Designated conservation area (DCA) - a contiguous area of habitat to be managed and conserved for spotted owls. This general description can be applied to two categories:
DCA 1 - category of DCA intended to support at least 20 pairs of spotted owls.
DCA 2 - category of DCA intended to support one to 19 pairs of spotted owls.

Dispersal - the movement, usually one way and on any time scale, of plants or animals from their point of origin to another location where they subsequently produce offspring.

Dispersal capability - ability of members of a species to move from their area of birth to another suitable location and subsequently breed.

Dispersal habitat - habitat that supports the life needs of an individual animal during dispersal. Generally satisfies needs for foraging, roosting, and protection from predators.

Distribution (of a species) - the spatial arrangement of a species within its range.

Disturbance - a significant change in structure and/or composition caused by natural events such as fire and wind or human-caused events such as cutting.

Diversity - see biological diversity.

Down log - portion of a tree that has fallen or been cut and left in the woods.

Early seral stage forests - stage in forest development that includes seedling, sapling, and pole-sized trees.

East side forests - the 12 national forests in Washington, Oregon, and California that lie partly or wholly east of the Cascade crest: Colville, Deschutes, Fremont, Klamath, Malheur, Ochoco, Okanogan, Shasta-Trinity, Umatilla, Wallowa-Whitman, Wenatchee, and Winema National Forests. *RG*

Ecosystem - an interacting system of organisms considered together with their environment; for example, marsh, watershed, and lake ecosystems. *RG*

Edge - where plant communities meet or where successional stages or vegetative conditions within plant communities come together. *RG* See also edge contrast and horizontal diversity.

Edge contrast - a qualitative measure of the difference in structure of two adjacent vegetated areas; for example, "low," "medium," or "high" edge contrast. *RG*

Electrophoresis - a technique used to distinguish among allozymes by comparing their relative mobility in an electrical field.

Empirical - derived from direct observation or experimentation.

Endangered species - any species of animal or plant that is in danger of extinction throughout all or a significant portion of its range; plant or animal species identified by the Secretary of the Interior as endangered in accordance with the 1973 Endangered Species Act. *RG*

Endemic - a species that is unique to a specific locality.

Environmental analysis - an analysis of alternative actions and their predictable short- and long-term environmental effects, incorporating physical, biological, economic, and social considerations. *RG*

Environmental assessment - a concise public document required by the regulations implementing the National Environmental Policy Act. *RG*

Environmental stochasticity - random variation in environmental attributes such as temperature, precipitation, and fire frequency.

Epiphyte - a plant that grows upon another plant and that is nonparasitic. Most of the plant's necessary moisture and nutrients are derived from the atmosphere. *RG*

Even-aged forest - a forest stand composed of trees with less than a 20-year difference in age.

Even-aged management - the application of a combination of actions that result in the creation of stands in which trees of essentially the same age grow together. Managed even-aged forests are characterized by a distribution of stands of varying ages (and, therefore, tree sizes) throughout the forest area. The difference in age among trees forming the main canopy level of a stand usually does not exceed 20 percent of the age of the stand at harvest rotation age. Regeneration in a particular stand is obtained during a short period at or near the time that a stand has reached the desired age or size for harvesting. Clear-cut, shelterwood, or seed tree cutting methods produce even-aged stands. *RG*

Extended rotation - a period of years that is longer than the time necessary to grow timber crops to a specified condition of maturity. *SAF* See rotation.

Extended rotation age - a point in time when trees are harvested or planned to be harvested that is beyond the age when harvest ordinarily would occur. *SAF* See rotation age.

Extinct - A species is extinct when it no longer exists. *EFC*

Extirpation - the elimination of a species from a particular area.

Fecundity - number of female young produced per adult female.

Fire regime - the characteristic frequency, extent, intensity, severity, and seasonality of fires in an ecosystem.

Fire severity - the degree to which a site has been altered or disrupted by fire. Severity reflects fire intensity and residence time.

Fledge - to rear until ready for flight or independent activity. *WEB*

Floaters - nonbreeding adults and subadults that move and live within a breeding population, often replacing breeding adults that die; nonterritorial individuals.

Food chain - organisms that are interrelated in their feeding habits, each feeding upon organisms that are lower in the chain and in turn being fed on by organisms higher in the chain.

Forest fragmentation - the change in the forest landscape, from extensive and continuous forests of old-growth to a mosaic of younger stand conditions.

Fragmentation - see forest fragmentation.

Fuel loading - the amount of combustible material present per unit of area, usually expressed in tons per acre.

FWS - Fish and Wildlife Service, U.S. Department of the Interior.

GIS - geographical information system. This is a computer system capable of storing and manipulating spatial (i.e., mapped) data.

Group selection cutting - removal of groups of trees ranging in size from a fraction of an acre up to about 2 acres. Area cut is smaller than the minimum feasible under even-aged management for a single stand. *RG*

Guideline - a policy statement that is not a mandatory requirement (as opposed to a standard, which is mandatory). *RG*

HA (hectare) - a measure of area in the metric system equal to approximately 2.5 acres.

Habitat - the place where a plant or animal naturally or normally lives and grows. *RG*

Habitat capability - the estimated number of pairs of spotted owls that can be supported by the kind, amount, and distribution of suitable habitat in the area. As used in the recovery plan, this means the same as capability to support spotted owl pairs.

Harvest cutting method - methods used to harvest trees. Harvest cutting methods are classified as even-aged and uneven-aged. *RG*

HCA (habitat conservation area) - as proposed by the Interagency Scientific Committee, a contiguous block of habitat to be managed and conserved for breeding pairs, connectivity, and distribution of owls; application may vary throughout the range according to local conditions.

HCP (habitat conservation plan) - an agreement between the Secretary of the Interior and either a private entity or a state that specifies conservation measures that will be implemented in exchange for a permit that would allow taking of a threatened or endangered species.

High-grading - timber removal that focuses on the largest, most commercially valuable trees. This practice often leaves a stand composed of trees in poor condition, and may result in a change in tree species composi tion.

Home range - the area within which an animal conducts its activities during a defined period of time.

Home range of a pair - the sum of the home ranges of each member of a pair minus th area of home range overlap.

Horizontal diversity - the distribution and abundance of plant and animal communities and successional stages across an area of land; the greater the number of communities, the higher the degree of horizontal diversity. *RG*

Hummocky - a landscape characterized by small, well-drained areas rising above the general level of poorly-drained land.

Hybrid - an offspring that results from the mating of individuals of different races or species.

Hybridization - the crossing or mating of two different varieties of plants or animals.

Incidental take - "take" of a threatened or endangered species that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. See take.

Inholding - land belonging to one landowner that occurs within a block of land belonging to another. For example, small parcels of private land that occur inside national forests.

INSOCG (Interagency Northern Spotted Owl Conservtion Group) - a committee formed under a 1990 Interagency Agreement to cooperate on the management and conservation of the northern spotted owl; including the U.S. Forest Service, U.S. FWS, Bureau of Land Management, National Park Service, and States of California, Oregon and Washington.

Integrated pest management - a process for selecting strategies to regulate forest pests in which all aspects of a pest-host system are studied and weighed. Regulatory strategies are based on sound silvicultural practices and ecology of the pest-host system and consist of a combination of tactics such as timber stand improvement plus selective use of pesticides. *RG*

Interagency Spotted Owl Subcommittee - a subcommittee of the Oregon-Washington Interagency Wildlife Committee that was formed to recommend guidelines to federal land management agencies for the protection of the northern spotted owl.

Interspecific - occurring among members of different species.

Interspecific competition - the condition of rivalry that exists when a number of organisms of different species use common resources that are in short supply; or, if the resources are not in short supply, the condition that occurs when the organisms seeking that resource nevertheless harm one or another in the process. Competition usually is confined to closely related species that eat the same sort of food or live in the same sort of place. Competition typically results in ultimate elimination of the less effective organism from that ecological niche. *WPG*

Intraspecific --occurring among members of a single species.

ISC (Interagency Scientific Committee) - a committee of scientists that was established by the U.S. Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and National Park Service, to develop a conservation strategy for northern spotted owls.

Isolate - a population that is isolated. See isolation.

Isolation - absence of genetic crossing among populations because of distance or geographic barriers. *SAF*

Jamison strategy - a spotted owl conservation strategy adopted by the U.S. Bureau of Land Management that included some but not all of the major provisions of the ISC strategy.

Jeopardy - a finding made through consultation under the Endangered Species Act that the action of a federal agency is likely to jeopardize the continued existence of a threatened or endangered species.

Kuchler vegetative types - potential natural vegetation of the coterminous United States, classified by Kuchler. *RG*

Lambda (λ) - the rate of population change (population size in year 2 divided by the population size in year 1).

Landsat - a satellite that produces imagery used in remote sensing of forests. Analysis of this imagery produces maps of vegetation condition.

Late seral stage forest - stage in forest development that includes mature and old-growth forest.

M - thousand. *RG*

Managed forest - refers to any forestland, including owl habitat, that is treated with silvicultural practices and/or harvested. Generally applied to land that is harvested on a scheduled basis and contributes to an allowable sale quantity.

Managed pair areas - In some portions of the northern spotted owl's range it is necessary to provide additional protection in the matrix for pairs of owls and territorial singles. This consists of delineating a core habitat area, plus additional acreage of suitable habitat around the core. The acreage to be delineated around the core varies throughout the range, based on data for pairs in that area. The suitable acreage must be delineated in an area equal to the mean home range for that physiographic province. Appropriate silvicultural treatment is encouraged in suitable and unsuitable habitat in the acreage around the core.

Management prescription - the management practices and intensity selected and scheduled for application on a specific area to attain multiple-use and other goals and objectives. *RG*

Matrix - land within the range of the northern spotted owl that lies outside of category 1 and 2 designated conservation areas.

Mature stand - A mappable stand of trees for which the annual net rate of growth has culminated. Stand age, diameter of dominant trees, and stand structure at maturity vary by forest cover types and local site conditions. Mature stands generally contain trees with a smaller average diameter, less age class variation, and less structural complexity than old-growth stands of the same forest type. Mature stages of some forest types are suitable habitat for spotted owls; however, mature forests are not always spotted owl habitat, and spotted owl habitat is not always mature forest.

MBF - thousand board feet. Lumber or timber measurement term. *RG*

Mean - a central value of a series or set of observations obtained by dividing the sum of all observations by the number of observations. *SAF*

Mesic - pertaining to or adapted to an area that has a balanced supply of water. Neither wet nor dry.

Metapopulation - a population comprised of a set of local populations that are linked by migrants, allowing for recolonization of unoccupied habitat patches after local extinction events.

Minimum viable population - the low end of the viable population range. *RG*

Mixed conifer - as used in this document, refers to stands of trees, made up of pine, Douglas-fir, and true firs, that are generally found east of the Cascade Range.

Mixed-conifer forest - a forest community that is dominated by two or more coniferous species.

Mixed-evergreen forest - a forest community that is dominated by two or more species of broad-leaved hardwoods whose foliage persists for several years: important western species include madrone, tanoak, chinquapin, canyon live oak, and California-laurel.

MM - million. *RG*

MMBF - million board feet. Lumber or timber measurement term.

Modal - of or relating to a statistical mode that is the highest-frequency value for a variable in a data set. *WEB*

Model - an idealized representation of reality developed to describe, analyze, or understand the behavior of some aspect of it; a mathematical representation of the relationships under study. The term model is applicable to a broad class of representations, ranging from a relatively simple qualitative description of a system or organization to a highly abstract set of mathematical equations.

Monitoring - a process of collecting information to evaluate whether objectives of a management plan are being realized.

Multiple use - the management of renewable resources so that they are utilized in the combination that will best meet the needs of people. *RG*

Multistoried - term applied to forest stands that contain trees of various heights and diameter classes and therefore support foliage at various heights in the vertical profile of the stand.

Multivariate analysis - a field of statistics in which multiple variables are used to compare sample groups. Multivariate analysis contrasts with univariate analysis, in which single variables are used to compare sample groups.

NAAQS - National Ambient Air Quality Standards. *RG*

Natal area - the location where an animal was born.

NEPA - National Environmental Policy Act of 1969. *RG*

Nesting, roosting, and foraging (NRF) habitat - forest vegetation with appropriate structure and composition to meet some or all of the life needs of northern spotted owls.

Nexus - a means of connection. Often used in a legal context to refer to the legal connection between one action and another.

NF - national forest. *RG*

NFMA - National Forest Management Act of 1976. *RG*

Nocturnal - referring to organisms that are active or functional at night. *EFG*

Nonfederal cluster - a cluster of three or more spotted owl activity centers on nonfederal lands. An area that contains habitat capable of supporting three or more breeding pairs of spotted owls with overlapping or nearly overlapping home ranges.

Nonmarket --products derived from resources that do not have a well-established market value; for example, recreation, wilderness, wildlife. *RG*

Occupancy rate - in reference to northern spotted owls, the proportion of inventoried spotted owl habitat that is estimated to be occupied by breeding pairs of spotted owls.

Off-road vehicles (ORVs) - vehicles such as motorcycles, all-terrain vehicles, four-wheel drive vehicles, and snowmobiles. *RG*

Old-growth - a forest stand with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; a high incidence of large trees with large, broken tops, and other indications of decadence; numerous large snags; and heavy accumulations of logs and other woody debris on the ground.

Old-growth species - plant and animal species that exhibit a strong association with old-growth forests.

Old-growth stand - a mappable area of old-growth forest.

Oregon-Washington Interagency Wildlife Committee - a committee composed of administrators from federal and state agencies; including the U.S. Forest Service, U.S. Fish and Wildlife Service, U.S. Bureau of Land Management, Oregon Department of Fish and Wildlife, and Washington Department of Game.

Overstory --trees that provide the uppermost layer of foliage in a forest with more than one roughly horizontal layer of foliage.

Owl site - any site where there has been a recent or historic observation of a single spotted owl or a pair of owls.

Pair site - an amount of habitat that is considered capable of supporting one pair of spotted owls.

Phenology - the annual recurrence of plant and animal phenomena that is influenced by seasonal and other environmental changes, e.g., flowering of plants, ripening of fruit.

Physiographic province - a geographic region in which climate and geology have given rise to a distinct array of landforms. Biology and habitat relationships of spotted owls vary by physiographic province due to differences in climate, vegetation, and productivity of habitats.

Platform nest - a relatively flat nest constructed on a supporting structure such as a broad branch.

Population density - number of individuals of a species per unit area.

Population dynamics - the aggregate of changes that occur during the life of a population. Included are all phases of recruitment and growth, senility, mortality, seasonal fluctuation in biomass, and persistence of each year class and its relative dominance, as well as the effects that any or all of these factors exert on the population. *SAF*

Population viability - probability that a population will persist for a specified period of time throughout its range despite normal fluctuations in population and environmental conditions.

Potential habitat - a stand of trees of a vegetation type used by spotted owls that is not currently suitable, but is capable of growing or developing into suitable habitat in the future. In general, potential habitats are stands in the earlier successional stages of forest types used by spotted owls.

Power - the probability of rejecting the null hypotheses in a statistical test.

Precommercial thinning - the practice of removing some of the trees less than merchantable size from a stand so that remaining trees will grow faster. *RG*

Predator - any animal that preys externally on others, i.e., that hunts, kills, and generally feeds on a succession of hosts, i.e., the prey. *SAF*

Prescribed fire - a fire burning under specified conditions that will accomplish certain planned objectives. The fire may result from planned or unplanned ignitions. *RG*

Presuppression - activities organized in advance of fire occurrence to ensure effective suppression action. *RG*

Protective management - measures taken by nonfederal entities to conserve spotted owls and/or their habitat; measures may include participation in conservation planning (as defined in Endangered Species Act section 10) or other actions that benefit owls; entities may be states, private landowners, Indian tribes, or others.

Province - see physiographic province.

Quarter-township - an area approximately 3 miles square containing nine sections of land.

Radio-telemetry - automatic measurement and transmission of data from remote sources via radio to a receiving station for recording and analysis. In this recovery plan, it refers to the tracking of spotted owls by means of small radio transmitters attached to them. *NAD*

Random - being or relating to a set or to an element of a set each of whose elements has equal probability of occurrence; also characterized by procedures to obtain such sets or elements. *WEB*

Range (of a species) - the area or region throughout which an organism occurs. *EFG*

Recovery - action that is necessary to reduce or resolve the threats that caused a species to be listed as threatened or endangered.

Recruitment - the addition to a population from all causes, i.e., reproduction, immigration, and stocking. Recruitment may refer literally to numbers born or hatched or to numbers at a specified stage of life such as breeding age or weaning age. *SAF*

Reforestation - the natural or artificial restocking of an area with forest trees; most commonly used in reference to artificial restocking. *RG*

Refugia - havens of safety where populations have high probability of surviving periods of adversity.

Regeneration - the actual seedlings and saplings existing in a stand; or the act of establishing young trees naturally or artificially. *RG*

Regulated forest - a theoretical managed forest from which the same acreage of stands can be harvested annually in perpetuity.

Regulations - generally refers to the Code of Federal Regulations.

Rescue effect - immigration of new individuals sufficient to maintain a population that might otherwise decline toward extinction.

Reserved lands - lands that have been removed from the acreage base used to calculate timber yields. These lands often have a preservation or protection status. Wilderness areas, research natural areas, and national recreation areas are examples of reserved lands.

Reserved pair areas - in those portions of the species' range where habitat and owl populations were inadequate to apply the criteria creating DCAs 1 and 2, individual pair areas were also reserved. These are areas of suitable habitat identified for pairs and territorial single owls. The acreage of these areas varies throughout the range, based on data for pairs in each physiographic province. All suitable habitat is reserved in an area equal to the mean home range for that province.

Residual habitat area - a 100-acre area of nesting, roosting, and foraging habitat encompassing the activity center for a pair of owls or a territorial single owl in the matrix.

Residual stand - the trees that remain standing after some event such as selection cutting. *RG*

Riparian area - a geographically delineated area with distinctive resource values and characteristics that comprises aquatic and riparian ecosystems. This includes floodplains, wetlands, and all areas within a horizontal distance of approximately 100 feet from the normal line of high water of a stream channel or from the shoreline of a standing body of water. *RG*

Roost - the resting behavior of an animal.

Roost sites - sites where an animal roosts. Can refer to daytime and nighttime roosting. Sites often provide protection from environmental conditions and from predators.

Rotation - the planned number of years between the regeneration of an even-aged stand and its final cutting at a specified stage.

Rotation age - the age of a stand when harvested at the end of a rotation. *RG*

Sanitation salvage - removal of dead, damaged, or susceptible trees primarily to prevent the spread of pests or pathogens and to promote forest hygiene. *RG*

Sapling - a loose term for a young tree no longer a seedling but not yet a pole. It is generally a few feet high and 2 to 4 inches dbh, typically growing vigorously and without dead bark or more than an occasional dead branch. *SAF*

Second-growth - relatively young forests that have developed following a disturbance (for example, wholesale cutting, serious fire, or insect attack) of the previous old-growth forest.

Section 7 - the section of the Endangered Species Act that specifies the roles of interagency coordination in accomplishing the objective of species recovery.

Section 9 - see Take.

Sensitive species - those species that 1) have appeared in the Federal Register as proposed for classification and are under consideration for official listing as endangered or threatened species; or 2) are on an official state list; or 3) are recognized by the U.S. Forest Service or other management agency as needing special management to prevent their being placed on federal or state lists. *RG*

Seral - a biotic community that is a developmental, transitory stage in an ecological succession. *RG*

Seral species - species associated with an early stage in the development of a biotic community.

Sexual dimorphism - the differences in size, weight, color, or other morphological characteristics that are related to the sex of the animal.

Shelterwood - an even-aged silvicultural system in which the old forest is removed in two or more successive cuttings. *SAF*

Silviculture - the science and practice of controlling the establishment, composition and growth of the vegetation of forest stands. It includes the control or production of stand structures such as snags and down logs, in additions to live vegetation.

Sink - population whose average reproductive rate is less than its average rate of mortality: such areas attract immigrants not expected to contribute significantly to future populations. See source.

Slash - the residue left on the ground after timber cutting. It includes unused logs, uprooted stumps, broken or uprooted stems, branches, twigs, leaves, bark, and chips. *RG*

Snag - a standing dead tree. *GET*

Socioeconomic - pertaining to, or signifying the combination or interaction of, social and economic factors. *RG*

SOHA (spotted owl habitat area) - a habitat area designated to support one pair of owls. Such areas were prescribed in some previous plans for northern spotted owl conservation.

SOMA (spotted owl management area) - an area designated to support three pairs of owls with home ranges separated by no more than 1.5 miles. Such areas were prescribed in some previous plans for northern spotted owl conservation.

Source - an actively breeding population that has an average birth rate that exceeds its average death rate; produces an excess number of juveniles that may disperse to other areas.

Species - 1) a group of individuals that have their major characteristics in common and are potentially interfertile. *EFG* 2) the Endangered Species Act defines species as including any species or subspecies of plant or animal. Distinct populations of vertebrates also are considered to be species under the act.

Stand (tree stand) - an aggregation of trees occupying a specific area and sufficiently uniform in composition, age, arrangement, and condition as to be distinguishable from the forest in adjoining areas. *RG*

Stand condition - a description of the physical properties of a stand such as crown closure or diameters. *SAF*

Stand-replacing event - a disturbance that is severe enough over a large enough area (for example, 10 acres) to virtually eliminate an existing stand of trees and initiate a new stand.

Standards and guidelines - the primary statement of direction for land managers. In the recovery plan, standards and guidelines are recommended as actions necessary to accomplish recovery.

Stochastic - random, uncertain; involving a random variable.

Stochastic model - a model that includes representation of random events.

Stocking - the degree of occupancy of an area of land by trees as measured by basal area or number of trees and as compared to a stocking standard; that is, the basal area or number of trees required to fully use the growth potential of the land. *RG*

Stumpage - the value of standing timber.

Subadult - a young spotted owl that has dispersed but has not yet reached breeding age. Subadults are in their second, or in some cases, third year of life.

Subpopulation - a well-defined set of interacting individuals that comprise a proportion of a larger, interbreeding population.

Subspecies - a population of a species occupying a particular geographic area, or less commonly, a distinct habitat, capable of interbreeding with other populations of the same species. *EFG*

Successional stage - a stage or recognizable condition of a plant community that occurs during its development from bare ground to climax; for example, coniferous forests in the Blue Mountains progress through six recognized stages: grass-forb; shrub-seedling; pole-sapling; young; mature; old-growth. *RG* See also seral.

Suitable habitat - in the recovery plan, an area of forest vegetation with the age-class, species of trees, structure, sufficient area, and adequate food source to meet some or all of the life needs of the northern spotted owl. See also nesting, roosting, and foraging habitat.

Suitable spotted owl habitat - *see suitable habitat.*

Superior habitat - in the recovery plan, habitat selected in excess of availability by the majority of individual northern spotted owls.

Supplemental pair areas - habitat delineated and maintained on nonfederal lands to support spotted owl pairs or territorial singles. Habitat may be managed or reserved from timber harvest; size of the areas varies by province.

Suppression - the action of extinguishing or confining a fire. *RG*

Survivorship - the proportion of newborn individuals that are alive at a given age. *EFG*

Sustained yield or production - the amount of timber that a forest can produce continuously from a given intensity of management; implies continuous production; a primary goal is to achieve a balance between incremental growth and cutting.

Take (Section 9) - Under the Endangered Species Act, take means to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect an animal, or to attempt to engage in any such conduct.

Taking - implementing an action that results in take.

Taxon - a category in a scientific classification system, such as class, family, or phylum.

Territorial single - an unpaired owl that is defending a territory.

Territory - the area that an animal defends, usually during breeding season, against intruders of its own species.

Thermoregulation - the physiological and biological process whereby an animal regulates its body temperature.

Threatened species - those plant or animal species likely to become endangered species throughout all or a significant portion of their range within the foreseeable future. A plant or animal species identified by the Secretary of the Interior as threatened, in accordance with the 1973 Endangered Species Act. *RG*

Timber classification - the following are definitions of timber classifications:

1. *Nonforest* - land that has never supported forests and land formerly forested where use for timber production is precluded by development or other uses.
2. *Forest* - land at least 10 percent stocked (based on crown cover) by forest trees of any size, or formerly having had such tree cover and not currently developed for nonforest use.
3. *Suitable* - commercial forestland identified as appropriate for timber production.
4. *Unsuitable* - forestland withdrawn from timber utilization by statue or administrative regulation (for example, wilderness), or locally identified as not appropriate for timber production.

Timber harvest schedule - the quantity of timber planned for sale and harvest, by time period, from the area of land administered by a federal agency. The first period, usually a decade, of the selected harvest schedule provides the allowable sale quantity. *RG*

Timber production - the purposeful growing, tending, harvesting, and regeneration of regulated crops of trees to be cut into logs, bolts, or other round sections for industrial or consumer use other than for fuelwood. *RG*

Timber stand - see stand.

Timber stand improvement - measures such as thinning, pruning, release cutting, prescribed fire, girdling, weeding, or poisoning of unwanted trees aimed at improving growing conditions for the remaining trees. *RG*

Trophic level - the level in the food chain at which an organism sustains itself.

Understory - the trees and other woody species growing under a more or less continuous cover of branches and foliage formed collectively by the upper portions of adjacent trees and other woody growth. *WPG*

Uneven-aged management - the application of a combination of actions needed to simultaneously maintain continuous tall forest cover, recurring regeneration of desirable species, and the orderly growth and development of trees through a range of diameter or age classes. Cutting methods that develop and maintain uneven-aged stands are single-tree selection and group selection. *RG*

Unsuitable habitat - forested lands that currently do not meet the habitat needs of spotted owls for nesting, roosting, or foraging, but are ecologically capable of doing so. This habitat is deficient in tree size, canopy closure, and/or stand decadence. It results from timber harvest or natural disturbance. Also referred to as "potential habitat."

USDA - U.S. Department of Agriculture.

USDI - U.S. Department of the Interior.

Verified pair - a pair of spotted owls of specified breeding status identified according to a standard field survey procedure.

Vertical diversity - the diversity in a stand that results from the complexity of the above ground structure of the vegetation; the more tiers of vegetation or the more diverse the species makeup (or both), the higher the degree of vertical diversity. *RG* See also horizontal diversity.

Viability - the ability of a population to maintain sufficient size so that it persists over time in spite of normal fluctuations in numbers; usually expressed as a probability of maintaining a specific population for a specified period.

Viable population - a population that contains an adequate number of individuals appropriately distributed to ensure the long-term existence of the species. *RG*

Vital rates - rates of key demographic functions within a population, such as the birth rate and survival rate.

Vole - any rodent of the genus Microtus and related genera, that resembles rats or mice, but has a relatively short tail. *NAD*

Well distributed - a geographic distribution of habitats that maintains a population throughout a planning area and allows for interaction of individuals through periodic interbreeding and colonization of unoccupied habitats.

West side forests - the 11 national forests within the range of the northern spotted owl in Washington, Oregon, and California that lie west of the Cascade crest. They are the Gifford Pinchot, Mendocino, Mt. Baker-Snoqualmie, Mt. Hood, Olympic, Rogue River, Siskiyou, Siuslaw, Six Rivers, Umpqua, and Willamette National Forests. *RG*

Wetlands - areas that are inundated by surface water or groundwater with a frequency sufficient to support, and under normal circumstances do or would support, a prevalence of vegetative or aquatic life that require saturated or seasonally saturated soil conditions for growth and reproduction (Executive Order 11990). *RG*

Wild and scenic rivers - those rivers or sections of rivers designated as such by congressional action under the 1968 Wild and Scenic Rivers Act, as supplemented and amended, or those sections of rivers designated as wild, scenic, or recreational by an act of the legislature of the state or states through which they flow. Wild and scenic rivers may be classified and administered under one or more of the following categories:

1. *Wild River Areas* - those rivers or sections of rivers that are free of impoundments and generally inaccessible except by trail, with watersheds or shorelines essentially primitive and waters unpolluted. These represent vestiges of primitive America.
2. *Scenic River Areas* - those rivers or sections of rivers that are free of impoundments, with watersheds still largely primitive and shorelines largely undeveloped, but accessible in places by roads.
3. *Recreational River Areas* - those rivers or sections of rivers that are readily accessible by road or railroad, that may have some development along their shorelines, and that may have undergone some impoundment or diversion in the past. *RG*

Wilderness - areas designated by congressional action under the 1964 Wilderness Act. Wilderness is defined as undeveloped federal land retaining its primeval character and influence without permanent improvements or human habitation. Wilderness areas are protected and managed to preserve their natural conditions, which generally appear to have been affected primarily by the forces of nature, with the imprint of human activity substantially unnoticeable; have outstanding opportunities for solitude or for a primitive and confined type of recreation; include at least 5,000 acres or are of sufficient size to make practical their preservation, enjoyment, and use in an unimpaired condition; and may contain features of scientific, educational, scenic, or historical value as well as ecologic and geologic interest. *RG*

Wildfire - any wildland fire that is not a prescribed fire. *RG*

Windfall - trees or parts of trees felled by high winds. See also blowdown and windthrow.

Windthrow - a tree or group of trees uprooted by the wind.

Yarding - the moving of logs from the stump to a central concentration area or landing. *RG*

YUM (yarding of unmerchantable material) - moving unmerchantable portions of trees from the stump to a central concentration area.