U.S. Fish & Wildlife Service

Recovery Plan for the Northern Spotted Owl

(Strix occidentalis caurina)

Final Recovery Plan for the Northern Spotted Owl (*Strix occidentalis caurina*)

May 2008

Region 1
U.S. Fish and Wildlife Service
Portland, Oregon

Approved: ______________________________
Regional Director, U.S. Fish and Wildlife Service

Date: MAY 13, 2008

Disclaimer

Recovery plans describe reasonable actions and criteria that are considered necessary to recover listed species. Plans are approved and published by the U.S. Fish and Wildlife Service (Service) and are sometimes prepared with the assistance of recovery teams, contractors, State agencies, and others.

This Northern Spotted Owl Recovery Plan (Recovery Plan or Plan) was prepared with the assistance of a Recovery Team representing Federal agencies, State governments, and other affected and interested parties, as well as the assistance of a contractor (Sustainable Ecosystems Institute or SEI). The Recovery Team members served as independent advisors to the Service for the development of the Draft Recovery Plan. This Plan does not necessarily represent the view or official position of any individual or organization—other than that of the Service—involved in its development. Additional valuable support was provided by three work groups of Federal and State agency scientists and academic researchers.

Approved Recovery Plans are subject to modification as dictated by new findings, changes in species status, and the completion of Recovery Actions. The objectives in the plan will be achieved subject to availability of funding and the capability of the involved parties to participate while addressing other priorities.

Notice of copyrighted material

Citation

U.S. Fish and Wildlife Service. 2008. Final Recovery Plan for the Northern Spotted Owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. xii + 142 pp.

Electronic copy

A copy of the Recovery Plan and other related materials can be found at http://www.fws.gov/pacific/ecoservices/endangered/recovery/NSORecoveryPlanning.htm.

Acknowledgments

The Service gratefully acknowledges the effort and commitment of the many individuals involved in the conservation and recovery of the northern spotted owl (spotted owl) who participated in the preparation of this Plan. Without their individual expertise and support, this Plan would not have been possible. To advise the Service in the development of this Plan, the Service initially appointed a Recovery Team. The Recovery Team was supported by an Interagency Support Team (IST) led by a Recovery Plan Project Manager. During the development of the Draft Recovery Plan, the Recovery Team convened several panels of experts to advise them and provide information on scientific and land management issues (noted as Implementer Panelists below). The Recovery Team was only involved in writing the Draft Recovery Plan, published in April, 2007. The Service organized and conducted four public meetings in May, 2007. Some Recovery Team members participated in the public meetings and the Recovery Team remained in place until the close of the comment period in October, 2007. With the publication of the Draft Recovery Plan and the close of the public comment period, the responsibilities of the Recovery Team were completed and no further action on its part was required. The Service is indebted to all of these individuals for the guidance provided during the preparation of the Draft Plan. Their names, affiliations, and roles are listed below.

Recovery Team Members

Tim Cullinan, National Audubon Society, Washington State Office
Dominick DellaSala, National Center for Conservation Science and Policy
Lowell Diller, Green Diamond Resource Company
Scott Gremel, National Park Service
Mike Haske, Bureau of Land Management
Cal Joyner, U.S. Forest Service
John Mankowski, Washington Office of the Governor/Lenny Young, Washington Department of Natural Resources
Ed Murphy, Sierra Pacific Industries
Jim Paul, Oregon Department of Forestry (April 2006 to November 2006)/ Mike Cafferata, Oregon Department of Forestry (November 2006 to November 2007)
John Siperek, California Department of Fish and Game
David Wooten, Bureau of Indian Affairs
David Wesley, Fish and Wildlife Service, Team Leader

Alternate Recovery Team Members

Sarah Madsen, U.S. Forest Service
Rosemary Mannix, Oregon Department of Forestry

Scientist Panelists

Robert Anthony, U.S. Geological Survey
Bill Baker, University of Wyoming
Joe Buchanan, Washington Department of Fish and Wildlife
Louisa Evers, Bureau of Land Management/U.S. Forest Service

Alan Franklin, U.S.D.A. Animal and Plant Health Inspection Service
Eric Forsman, Pacific Northwest Research Station
Rocky Gutiérrez, University of Minnesota
Tom Hamer, Hamer Environmental
Richy Harrod, U.S. Forest Service
Dale Herter, Raedeke Associates
Larry Irwin, National Council for Air and Stream Improvement
Bill Laudenslayer, U.S. Forest Service
John Lehmkuhl, Pacific Northwest Research Station
Trent McDonald, Western Ecosystems Technology
Ron Neilson, US Forest Service
Robert Pearson, Private Consultant
John Pierce, Washington Department of Fish and Wildlife
Marty Raphael, U.S. Forest Service
Peter Singleton, Pacific Northwest Research Station
Carl Skinner, U.S. Forest Service
Jim Thrailkill, U.S. Fish and Wildlife Service
Brian Woodbridge, U.S. Fish and Wildlife Service

Implementer Panelists

Klaus Barber, U.S. Forest Service
Richard Bigley, Washington Department of Natural Resources
William Gaines, U.S. Forest Service
Eric Greenquist, U.S. Bureau of Land Management
Jim Harper, U.S. Bureau of Land Management
Scott Horton, Washington Department of Natural Resources
Margaret Kain, U.S. Forest Service
Patricia Krueger, U.S. Forest Service
Trent McDonald, Western Ecosystems Technology (WEST)
Steve Mealey, U.S. Forest Service, retired; Private Consultant
Tony Melchiors, Weyerhaeuser Company
Mark Nuetzmann, Yakama Nation
Ken Risenhoover, Port Blakely Tree Farms
Duane Shintaku, California Department of Forestry and Fire Protection

Peer Reviewers of the Background Section

Robert Anthony, U.S. Geological Survey
Eric Forsman, Pacific Northwest Research Station
Alan Franklin, U.S.D.A. Animal and Plant Health Inspection Service
Larry Irwin, National Council for Air and Stream Improvement

Interagency Support Team Leader and Recovery Plan Project Manager

Paul Phifer, U.S. Fish and Wildlife Service

Interagency Support Team Members

Kath Collier, Bureau of Land Management
Joe Lint, Bureau of Land Management
Kent Livezey, U.S. Fish and Wildlife Service
Elaine Rybak, U.S. Forest Service

Brendan White, U.S. Fish and Wildlife Service

Additional Participants in the Interagency Support Team

Bruce Marcot, Pacific Northwest Research Station
Steve Morey, U.S. Fish and Wildlife Service
Kristi Young, U.S. Fish and Wildlife Service
Rich Young, U.S. Fish and Wildlife Service
Michele Zwartjes, U.S. Fish and Wildlife Service

Contributors

Scott Center, U.S. Fish and Wildlife Service
Ray Davis, U.S. Forest Service
Karl Halupka, U.S. Fish and Wildlife Service
Jim Hines, U.S. Geological Survey
Matt How, U.S. Fish and Wildlife Service
Jim Nichols, U.S. Geological Survey

The Draft Recovery Plan generated more than 75,800 public comments. The IST provided continued staff support to the FWS Regional Director. They reviewed and responded to comments, compiled a list of concerns to be resolved for the final plan and edited the Draft Recovery Plan to reflect the decisions of the Regional Director in the Final Recovery Plan. To evaluate scientific and management issues raised during the comment period, the Service contracted with an independent consultant (SEI) to provide assistance. In addition, the Service appointed three scientific work groups to evaluate comments and provide guidance on the best science concerning the three major areas of concern raised during the comment period: spotted owl habitat, fire, and barred owls. We thank all of these individuals; they are listed below.

Contractor (Sustainable Ecosystems Institute)

Steven Courtney
Kate Engel
Katie Fehring
Lisa Sztukowski

Panel Members for Contractor

Andrew Bohonak, San Diego State University
Andy Carey, Pacific Northwest Research Station (retired)
Martin Cody, University of California, Los Angeles
Keith Crandall, Bringham Young University
Jerry Franklin, University of Washington
Mark Fuller, U.S. Geological Survey
Rocky Gutiérrez, University of Minnesota
Miles Hemstrom, Pacific Northwest Research Station
Paul Hessburg, Pacific Northwest Research Station
John Lehmkuhl, Pacific Northwest Research Station
Jim Nichols, Patuxent Wildlife Research Center
Ken Pollock, North Carolina State University
Scott Stephens, University of California, Berkeley

Robert Zink, University of Minnesota

Liaison between Work Groups and the Service

Lenny Young, Washington Department of Natural Resources

Habitat Work Group Members

Robert Anthony, U.S. Geological Survey
Joe Buchanan, Washington Department of Fish and Wildlife
Katie Dugger, Oregon State University
Jeff Dunk, Humboldt State University
Eric Forsman, U.S. Forest Service
Chuck Meslow, U.S. Fish and Wildlife Service (retired)

Fire Work Group Members

Bill Gaines, U.S. Forest Service
Richy Harrod, U.S. Forest Service
Tom Spies, Pacific Northwest Research Station
Tom Sensenig, Pacific Northwest Research Station
Carl Skinner, Pacific Southwest Research Station

Barred Owl Work Group Members

Joe Buchanan, Washington Department of Fish and Wildlife
Lowell Diller, Green Diamond Resource Company
Scott Gremel, National Park Service
Peter Singleton, Pacific Northwest Research Station

Executive Summary

Current Status

The northern spotted owl (*Strix occidentalis caurina*) (spotted owl) inhabits structurally complex forests from southwest British Columbia through the Cascade Mountains and coastal ranges in Washington, Oregon, and California, as far south as Marin County (Appendix A). After a status review (USFWS 1990a), the spotted owl was listed under the Endangered Species Act (ESA) as threatened on June 26, 1990 (USFWS 1990b) because of widespread loss of suitable habitat across the spotted owl's range and the inadequacy of existing regulatory mechanisms to conserve the spotted owl. Many populations of spotted owls continue to decline, especially in the northern parts of the subspecies' range, even with extensive maintenance and restoration of suitable habitat in recent years. Managing sufficient habitat for the spotted owl now and into the future is essential for its recovery. However, it is becoming more evident that securing habitat alone will not recover the spotted owl. Based on the best available scientific information, competition from the barred owl (*S. varia*) poses a significant and complex threat to the spotted owl. Past habitat loss and current habitat loss are also threats to the spotted owl, even though loss of habitat due to timber harvest has been greatly reduced on Federal lands for the past 2 decades.

Based on the best available scientific information, competition from the barred owl (*S. varia*) poses a significant threat to the spotted owl.

Habitat Requirements

Scientific research and monitoring indicate that spotted owls generally rely on mature and old-growth forests because these habitats contain the structures and characteristics required for nesting, roosting, and foraging. Although spotted owls can disperse through highly fragmented forested areas, the stand-level and landscape-level attributes of forests needed to facilitate successful dispersal have not been thoroughly evaluated or described.

Delisting

In order to consider a species recovered, analysis of five listing factors must be conducted and the threats from those factors reduced or eliminated. The five listing factors are:

A. The present or threatened destruction, modification, or curtailment of the species' habitat or range
B. Overutilization for commercial, scientific, or educational purposes
C. Disease or predation
D. Inadequacy of existing regulatory mechanisms
E. Other natural or manmade factors affecting its continued existence

Recovery Strategy

The Service recognizes the barred owl constitutes a significantly greater threat to spotted owl recovery than was envisioned when the spotted owl was listed in 1990. As a result, the Service recommends specific actions to address the barred owl threat begin immediately and in a coordinated manner.

In addition to describing specific actions to address the barred owl threat, the Recovery Plan continues to recognize the importance of maintaining habitat for the recovery and long-term survival of the spotted owl.

In addition to describing specific actions to address the barred owl threat, the Recovery Plan continues to recognize the importance of habitat for the recovery and long-term survival of the spotted owl.

This Recovery Plan relies on Federal lands to provide the major contribution for spotted owl recovery. In the western Physiographic Provinces (Figure A1), Managed Owl Conservation Areas (MOCAs) are recommended to provide habitat for the recovery of the spotted owl. Outside of MOCAs, substantially all older and more structurally complex multi-layered confer forests on Federal lands are to be maintained in the western Provinces. In the fire-prone Provinces (East Cascades Provinces of Washington and Oregon, California Cascades), a landscape-management approach is recommended to allow spotted owl recovery in an area strongly influenced by natural disturbances. In the Oregon and California Klamath Provinces, this Plan calls for an adaptive management approach to fire management and spotted owl recovery. Conservation Support Areas (CSAs) are also described and are intended to support the MOCA network and the landscape-management approach.

Recovery Plan Lifespan

The estimated time to delist the species is 30 years if all actions are implemented and effective. A longer time to delisting would be required if these assumptions are not met. Total cost for delisting over these 30 years is $489.2 million.

Due to the uncertainties associated with the effects of barred owl interactions with the spotted owl and habitat changes that may occur as a result of climate change, the Service intends to revisit this Recovery Plan within 10 years to determine if the Plan is leading the species to recovery. Even during this relatively short period, the actions needed to address the decline of the spotted owl should be revisited on a frequent basis to ensure the highest priority actions are being conducted. The Service and other implementers of this plan will have to employ an active adaptive management strategy to achieve results and focus on the most important actions for recovery. For these reasons, the useful life of this plan is approximately 10 years before a revision is anticipated.

Recovery Goal

The goal of this Recovery Plan is to begin improving the status of the species so it can be removed eventually from protection under the Endangered Species Act. However, because of immediate threats to the spotted owl, this plan is developed for a 10-year time frame with the goal of reducing the population declines and answering some fundamental questions necessary for full recovery.

Recovery Objectives

The long-term objectives of this Recovery Plan are:

- Spotted owl populations are sufficiently large and distributed such that the species no longer requires listing under the ESA.
- Adequate habitat is available for spotted owls and will continue to exist to allow the species to persist without the protection of the ESA.
- The effects of threats have been reduced or eliminated such that spotted owl populations are stable or increasing and spotted owls are unlikely to become threatened again in the foreseeable future.

The interim expectations for the next 10 years are:

- The Barred Owl Work Group has quantified the threats from the barred owl on the spotted owl, control techniques and appropriate implementation plans have been developed, and a decision on managing barred owls has been made.
- The MOCA network has been established in the western Provinces with appropriate management of habitat-capable lands inside the MOCAs to support spotted owls.
- The Dry-Forest Landscape Work Group has developed, and Federal land management agencies have initiated and are implementing, a comprehensive program to restore ecological processes and functions, thus reducing the potential for significant habitat loss by stand-replacement fires, insects, and disease.

Recovery Criteria

There are four long-term Recovery Criteria in this Recovery Plan.

Recovery Criterion 1: The population trend of spotted owls is stable or increasing over 10 years of monitoring, as measured by a statistically reliable method, in each Province (excluding Western Washington Lowlands and Willamette Valley), with a low probability of concluding the population is stable or increasing when it actually is declining.

Recovery Criterion 2: Within each State the distribution of spotted owls is such that at least 80 percent of Category 1 MOCAs contain at least 15 occupied spotted owl sites when surveyed over a 5-year period.

Recovery Criterion 3: In each of the East Cascades Provinces in Washington and Oregon and the California Cascades Province, at least 30 percent of the Province contains high-quality habitat and 75 percent of that habitat is within at least one home-range radius of an activity center of a territorial pair of spotted owls, as measured over a 5-year period**.**

Recovery Criterion 4: To monitor the continued stability of the recovered spotted owl, a post-delisting monitoring plan has been developed and is ready for implementation with the States of Washington, Oregon, and California (ESA 4(g)(1)).

Recovery Actions

Recovery actions are recommendations to guide the activities needed to accomplish the recovery objectives and criteria. This Recovery Plan presents 34 actions that address overall recovery through maintenance and restoration of suitable habitat for spotted owls, monitoring of avian diseases, development and implementation of a delisting monitoring plan, and management of the barred owl. The Recovery Plan calls for the establishment of an inter-organizational Northern Spotted Owl Work Group to coordinate implementation of the Plan.

Table of Contents

Acronyms and Abbreviations

AMA	Adaptive Management Area
BLM	U.S. Bureau of Land Management
BOWG	Barred Owl Work Group
CDF	California Department of Forestry and Fire Protection
CDFG	California Department of Fish and Game
CDP&R	California Department of Parks and Recreation
CHU	Critical Habitat Unit
CI	confidence interval
CSA	Conservation Support Area
dbh	diameter at breast height
DCA	Designated Conservation Area
DFLWG	Dry-Forest Landscape Work Group
ESA	Endangered Species Act
FEMAT	Forest Ecosystem Management Assessment Team
FS	U.S. Forest Service
HCA	Habitat Conservation Area
HCP	Habitat Conservation Plan
ISC	Interagency Scientific Committee
LRMP	Land and Resource Management Plan (for BLM and FS)
LSR	Late-Successional Reserve
LUA	Land-Use Allocation
MOCA	Managed Owl Conservation Area
NPS	National Park Service
NSOWG	Northern Spotted Owl Work Group
NWFP	Northwest Forest Plan
ODF	Oregon Department of Forestry
PVA	Population Viability Analysis
SE	standard error
SEI	Sustainable Ecosystems Institute
SHA	Safe Harbor Agreement
SOSEA	Spotted Owl Special Emphasis Areas
TBD	to be determined
USFWS	U.S. Fish and Wildlife Service (Service)
USGS	U.S. Geological Survey
WDNR	Washington Department of Natural Resources
WFPB	Washington Forest Practices Board
WNV	West Nile virus

I. Introduction

Recovery Planning, Risk, and Timeframes

The Endangered Species Act (ESA) of 1973, as amended (16 USC 1531 *et seq*.) establishes policies and procedures for identifying and conserving species of plants and wildlife that are endangered or threatened with extinction. To help identify and guide species recovery efforts, Section 4(f) of the ESA directs the Secretary of the Interior to develop and implement Recovery Plans for listed species. These plans are to include:

- a description of site-specific management actions necessary for conservation and survival of the species,
- objective, measurable criteria that, when met, will allow the species to be delisted, and
- estimates of the time and funding required to achieve the plan's goals and intermediate steps.

Recovery plans are not regulatory documents; rather, they provide guidance to bring about recovery and establish criteria to be used in evaluating when recovery has been achieved. There may be many paths to recover a species. The U.S. Fish and Wildlife Service (Service) developed this Plan in consultation with a recovery team, Federal and State management agencies, and multiple other parties, and believes this Plan represents effective guidance for recovering the spotted owl. Recovering a wide-ranging species takes time and significant effort from a multitude of entities. Recovering a species is a dynamic process, and judging when a species is recovered requires an adaptive management approach that is sensitive to the best available information and risk tolerances. Given the adaptive nature of this iterative process, recovery may be achieved without fully following the guidance provided in this Recovery Plan.

Risk and Uncertainty

When writing a Recovery Plan, the Service must use the best scientific information available. A central issue here is the use of "best available science." "Although most scientists are appropriately cautious about the limits of their data and conclusions, and the profession enforces a high standard for publication etc., the Service must use whatever is available" (SEI 2008:7). However, the information available rarely fully addresses the questions at hand, meaning there will usually be some degree of uncertainty. Hence, Recovery Plans include an element of risk management (especially for wide-ranging species which face a multitude of threats) because the Service must make recommendations in the face of incomplete information which, in turn, creates risk and uncertainty.

Given the scientific uncertainty involved with issues this complex, a plan requires assumptions about current information (*e.g.,* that we really have an understanding of what's affecting the species) and of future conditions (*e.g.,* that the future magnitude of threats is predictable). Because these are assumptions, there is a measure of uncertainty associated with them. It is the Service's task to weigh the risk (the possibility of causing harm) to the species of making a poor recommendation based on the uncertainty associated with the assumptions. A poor recommendation may entail not acting, over-reacting, or acting in a manner that does not actually benefit the species. SEI (2008:8-9) states:

> "Evaluating risk involves determining or assessing the consequences of making an incorrect conclusion. For instance, it is quite possible to have a high degree of uncertainty on an issue, but for there to be few consequences of such uncertainty – the converse is equally true. Hence it is important to distinguish uncertainty over a conclusion, from the risk that follows if a conclusion is incorrect. Both uncertainty and risk can be assessed by scientists—formally (*e.g.,* in a PVA and sensitivity analysis) or informally (*e.g.,* by 'scientific opinion')—however the acceptability of a particular risk is a policy decision, not a scientific one."

For example, while many strands of evidence indicate a significant negative competitive effect of barred owls on spotted owls, such an effect is still not conclusively supported in the scientific literature. Although the specific causative mechanisms or effects of barred owl competition may be unresolved, the Service (as described in this Plan) must address, with utmost expediency, the assumed consequences of this competition. The Service now concludes that the risk of assuming there is little or no threat from barred owls when the threat may be real is too high not to act. By delaying these actions, future recovery options are likely to be precluded; thus, the Service is choosing to limit the risk of making a poor recommendation in the face of uncertainty.

In another instance, scientists consulted in the development of this Plan recommended that high-quality habitat and occupied spotted owl habitat on Federal and non-Federal ownerships outside of MOCAs on the western side of the Cascade Mountains be maintained. The purpose was to provide additional support to spotted owls while habitat was being restored in the MOCAs and the threat from barred owls was further investigated. The Service agrees with this recommendation and suggests a Recovery Action to maintain substantially all older, multi-layered forests (its interpretation of high-quality habitat) on Federal lands outside of MOCAs on the west side of the Cascades crest (the east side of the crest is all managed under a dynamic landscape approach and does not contain MOCAs). The Service is also encouraging non-Federal landowners to maintain such habitat. This Plan, however, does not recommend focusing on occupied habitat as doing so would require costly and time-consuming pre-project surveys and would include risks involved in not detecting spotted owls when actually present due to depressed calling response caused by presence of barred owls. Further, the Service believes, based on internal assessments, that maintenance of older, multi-layered forests will include much of the occupied habitat.

In the recovery planning process, assessing the risk of making a poor recommendation is valuable, yet formally doing so is not always possible with accuracy given the timeframe or currently available information. In addition, formal qualitative risk assessments on issues this complex would involve multiple assumptions and provide only general guidelines, not specific management direction. Rather than conduct such a risk assessment, the Service chose to give this Plan a short lifespan and describe the need for an adaptive management approach with the goal of frequently determining the Plan's effectiveness.

Where there is risk, there is also uncertainty. When evaluating any element of the Recovery Plan, whether it is a scientific conclusion or a management recommendation, it is helpful to also evaluate the uncertainty associated with that element. Uncertainty is normal, and is usually resolved or at least clarified, by further research, analysis, or management experience. However, as with risk, the Service does not always have the time or resources to reduce uncertainty to a desired level, but the agency still has a responsibility to produce a strategy for recovery.

To be successful, Recovery Plans must describe goals the Service concludes are achievable and biologically sustainable. For example, it may be argued the best action to protect spotted owl is to remove thousands of barred owls currently occupying its habitat. Whether this action is feasible is another important part of the discussion. Feasibility varies as new information arises, the species' population status changes, and society's risk tolerance evolves.

A mix of risk, uncertainty, and feasibility are involved in all recovery planning processes. When discussing the ISC strategy, Thomas *et al.* (1990:8–9) state:

> "Conservation problems cannot be solved through biological information alone, nor from applying "scientific truth." Rather, solution comes from a combination of considerations that satisfy society's interests. A strategy that has any chance of adoption in the short term and any chance of success in the long term must include consideration of human needs and desires. To ignore the human condition in conservation strategies is to fail."

In this Recovery Plan, the Service describes a precautionary approach to recovery. That is, in the face of significant scientific uncertainty, we propose three key measures:

- a 10-year lifespan for this Recovery Plan
- frequent review of this Plan's effectiveness within this 10-year timeframe and an adaptive management framework, and
- maintenance of substantially all older, multi-layered forests as a habitat buffer as we attempt to address the threat from barred owls.

It is understood that this Plan's expression of risk, as embodied by the recovery strategy and actions, may not match the risk tolerance of every interested party. However, it is the conclusion of the Service that the actions in this plan will put the species on a trajectory toward recovery. Yet, given the risk and uncertainty, this conclusion must be revisited frequently as part of an adaptive management process.

Recovery Plan Goal and Objectives

The ultimate goal of this Recovery Plan is to delist the spotted owl. Its objectives describe a situation in which the spotted owl's population is stable or increasing, well distributed, and affected by manageable threats. To meet this goal and these objectives, interim expectations are defined to guide us as we learn more about the multiple uncertainties surrounding this species.

Adaptive Management

In order to deal with uncertainty and risk the Service will employ an active program of adaptive management to be more fully described and implemented by the Northern Spotted Owl Working Group. Adaptive management includes identifying areas of uncertainty and risk and implementing a research and monitoring approach to clarify these areas, and making decisions to change management direction that is not working while still maintaining management flexibility (see Thomas *et al.* 1990; USFWS 1992b). Through adaptive management, a learning cycle is institutionalized so that new information can be quickly incorporated into management decisions. Where possible, such an approach is recommended in this Plan.

Delisting Process

When sufficient progress toward recovery has been made, a separate team will assess the spotted owl's status in relation to the five listing factors found in Section 4(a)(1) of the ESA to determine whether delisting is appropriate (see Executive Summary). This subsequent review may be initiated without all of the Recovery Criteria in this Plan having been fully met. For example, one or more criteria may have been exceeded, while other criteria may not have been fully accomplished. In this instance, the Service may judge that, overall, the threats have been minimized sufficiently and the species is robust enough to be considered for delisting. If sufficient progress toward recovery has not been made, the spotted owl may retain its current status. If the spotted owl's condition deteriorates, it may be necessary to change its status to endangered.

New recovery opportunities or scientific information may arise that were unknown at the time this Recovery Plan was finalized. Under the adaptive management framework, these new opportunities may encompass more effective means of achieving recovery or measuring recovery. In addition, new information may alter the extent to which criteria need to be met for recognizing recovery of the species. Conversely, new information may result in new challenges, and achieving recovery may be less efficient than we now believe.

Development of This Recovery Plan

This Plan builds extensively on the 1992 Draft Recovery Plan for the Northern Spotted Owl (USFWS 1992b) and the 1994 Northwest Forest Plan (NWFP; USDA and USDI 1994a, b). In 1994, the NWFP was considered to be the Federal contribution to the recovery of the spotted owl. However, given that the NWFP also addresses many other forest-dependent species, this Plan considered the 1992 Final Draft Recovery Plan the most recent spotted-owl-specific Recovery Plan available.

The NWFP amended the land and resource management plans (LRMPs[1]) that guide the management of each of the 19 National Forests and seven Bureau of Land Management (BLM) Districts across the range of the spotted owl. The LRMPs adopted a set of reserves and standards and guidelines described in the Record of Decision for the NWFP. This Plan recognizes the required management the existing LRMPs provide for the conservation of the spotted owl.

The following is a chronology of the process involved in writing this Plan.

- April 2006: Formation of 12-member multi-agency, multi-disciplinary Recovery Team
- April 26, 2007: Draft Recovery Plan published and 60-day public comment period opened
- May 2007: Public meetings in Redding, California, Roseburg and Portland, Oregon, and Lacey, Washington to present Draft Recovery Plan
- June, 2007: Additional 60-day comment period opened
- September 5, 2007: Additional 30-day comment period opened; approximately 75,800 comments were received during comment periods
- October 2007: Initiation of revisions to Draft Recovery Plan
- December 2007: SEI contracted to review science and peer review comments on the draft plan
- January–February 2008: Expert panel workgroups on barred owl, habitat and fire convened to assist with public and peer review technical responses and to evaluate SEI recommendations
- April 2008: SEI contracted report completed
- May 2008: Completion of Final Recovery Plan

The Recovery Criteria and actions are at the front of the Plan. Information concerning the spotted owl's biology is in Appendix A, and a description of the threats to the spotted owl is presented in Appendix B.

This Plan was developed using the best scientific information available and a "step-down" approach of objectives, criteria, and actions. Recovery Objectives are broad statements that describe the conditions under which the Service would consider the spotted owl to be recovered. Recovery Criteria are objective, measurable metrics that indicate when recovery objectives have been met.

---

[1] Throughout this Plan, the term "LRMPs" references the 26 LRMPs that were amended by the NWFP.

Recovery Actions are the Service's recommendations to guide the activities needed to accomplish the Recovery Criteria. Recovery Actions are recommended throughout the U.S. range of the spotted owl and are designed to address the specific threats identified in this Plan. Implementation of the full suite of Recovery Actions will involve participation from the States, Federal agencies, non-Federal landowners, and the public.

Implementation of the full suite of Recovery Actions will involve participation from the States, Federal agencies, non-Federal landowners, and the public.

Biological Constraints and Needs

Like any species, the spotted owl has biological requirements that, if not met, will reduce its ability to persist. Loss of late-successional forests and competition with barred owls were identified by a panel of spotted owl and fire experts as factors limiting the ability of spotted owls to recover.

Listing History and Recovery Priority

The spotted owl was listed as threatened on June 26, 1990. The Service recovery priority number for the spotted owl is 6C, on a scale of 1C (highest) to 18 (lowest) (USFWS 1983a, 1983b, 2004b). This number reflects a high degree of threat, a low potential for recovery, and the spotted owl's taxonomic status as a subspecies. The "C" reflects conflict with development, construction, or other economic activity. The spotted owl was originally listed with a recovery priority number of 3C, but that number was changed to 6C in 2004 during the 5-year review of the species.

The spotted owl was listed in 1990 as a result of widespread loss and adverse modification of suitable habitat across the spotted owl's entire range and the inadequacy of existing regulatory mechanisms to conserve the spotted owl.

Reasons for Listing and Assessment of Threats

The spotted owl was listed as threatened throughout its range "due to loss and adverse modification of suitable habitat as a result of timber harvesting and exacerbated by catastrophic events such as fire, volcanic eruption, and wind storms" (USFWS 1990b:26114). More specifically, threats to the spotted owl included low populations, declining populations, limited habitat, declining habitat, inadequate distribution of habitat or populations, isolation of populations within Physiographic Provinces (Figure A1), predation and competition, lack of coordinated conservation measures, inadequacy of regulatory mechanisms, and vulnerability to natural disturbance (USFWS 1992b). These threats were characterized for each Province as severe, moderate, low or unknown (USFWS 1992b). The range of the spotted owl is divided into 12 physiographic Provinces from Canada to northern California and from the

Pacific Coast to the eastern Cascades (Appendix A). Declining suitable habitat was recognized as a severe or moderate threat to the spotted owl throughout its range, isolation of populations was identified as a severe or moderate threat in 11 Provinces, and a decline in population was a severe or moderate threat in 10 Provinces. Together, these three factors represented the greatest concerns about range-wide conservation of the spotted owl. Limited suitable habitat was considered a severe or moderate threat in nine Provinces, and low populations were a severe or moderate concern in eight Provinces, suggesting that these factors were also a concern throughout the majority of the spotted owl's range. Vulnerability to natural disturbances was rated as low in five Provinces.

The Service conducted a 5-year review of the spotted owl in 2004 (USFWS 2004b), based in part on the content of an independent scientific evaluation of the status of the spotted owl (Courtney *et al.* 2004) performed under contract with the Service. For that evaluation, an assessment was conducted of how the threats described in 1990 might have changed by 2004. Some of the key ideas relative to threats identified in 2004 were: (1) "Although we are certain that current harvest effects are reduced, and that past harvest is also probably having a reduced effect now as compared to 1990, we are still unable to fully evaluate the current levels of threat posed by harvest because of the potential for lag effects" (Courtney and Gutiérrez 2004:11-7); (2) "Currently the primary source of habitat loss is catastrophic wildfire, although the total amount of habitat affected by wildfires has been small" (Courtney and Gutiérrez 2004:11-8); and (3) "We are convinced that Barred Owls are having a negative impact on Spotted Owls at least in some areas" (Courtney *et al.* 2004:7-43) and "there are no grounds for optimistic views suggesting that Barred Owl impacts on Northern Spotted Owls have been already fully realized" (Courtney *et al.* 2004:7-38).

On June 1, 2006, a panel of seven experts was assembled to help the spotted owl Recovery Team identify the most current threats facing the species. Six of the seven panelists were experts on the biology of the spotted owl, and a seventh panelist was an expert on fire ecology. The workshop was conducted as a modified Delphi expert panel in which seven experts scored the severity of threat categories. The baseline assumption of this meeting was that existing habitat-conservation strategies (*e.g.,* the NWFP) would be in place. With that assumption, the panelists identified and ranked threats to the spotted owl. The Recovery Team then had an opportunity to interact with them to discuss their rankings and thoughts on spotted owl threats. Then panelists re-ranked the threats.

This workshop panel unanimously identified past habitat loss, current habitat loss, and competition from barred owls as the most-pressing threats to the spotted owl, even though timber harvest recently has been greatly reduced on Federal lands. The panel noted that evidence of these three threats is presented in the scientific literature. The range of threat scores made by the individual panelists was narrowest for barred owl competition and slightly greater for habitat threats, indicating that there was more agreement about the threat from barred owls. The panel identified disease and the effect of climate change on vegetation as potential and more uncertain future threats.

The panelists ranked the threats by importance in each Province. Among the 12 physiographic Provinces, the more fire-prone Provinces (Eastern Washington Cascades and Eastern Oregon Cascades, California Cascades, Oregon and California Klamath) scored high on threats from ongoing habitat loss as a result of wildfire and the effects of fire exclusion on vegetation change. Westside Provinces (Western Washington Cascades and Western Oregon Cascades, Western Washington Lowlands, Olympic Peninsula, and Oregon Coast Range) generally scored high on threats from the adverse effects of habitat fragmentation and ongoing habitat loss as a result of timber harvest. The Province with the fewest number of threats was Western Oregon Cascades, and the Provinces with the greatest number of threats were the Oregon Klamath and the Willamette Valley. For a more complete description of the threats, see Appendix B.

Barred Owls

SEI (2008:ii) states the 2007 Draft Recovery Plan "does not over-state the threat from Barred Owls." It is the Service's belief that the threat from barred owls is extremely pressing and complex, requiring immediate consideration. Barred owls have been found in all areas where surveys have been conducted for spotted owls. In addition, barred owls inhabit all forested areas throughout Washington and Oregon where nesting opportunities exist, even outside of the specific range of the spotted owl (Kelly and Forsman 2003, Buchanan *et al.* 2005). Consequently, the Service assumes barred owls are in all areas occupied by resident, dispersing, and displaced spotted owls.

The workshop panel unanimously identified past habitat loss, current habitat loss, and competition from barred owls as the most-pressing threats to the spotted owl, even though timber harvest recently has been greatly reduced on Federal lands.

Addressing the threats associated with past and current habitat loss must be conducted simultaneously with addressing the threats from barred owls. Addressing the threat from habitat loss is relatively straightforward with predictable results. However, addressing a large-scale threat of one raptor on another, closely related raptor has many unknowns and has never been attempted.

Given the threat from barred owls, the Service hopes spotted owls can persist in portions of their range due to factors including elevation/gradient preferences by barred owls in some areas (see Appendix B), but this may be overly optimistic. At this time, it appears long-term lethal control of significant numbers of barred owls should be assessed to recover the spotted owl. Before considering whether to fund and fully implement such an action, however, the Service needs to be confident this control would benefit spotted owls. This confidence could come from control experiments proposed in this Plan.

Further, to not increase competitive pressure while the threat from barred owls is being addressed, this Plan recommends maintaining older, multi-layered forests outside of the MOCAs on Federal lands in the Provinces west of the Cascades crest.

Habitat Management

On the west side of the Cascade Mountains in Washington and Oregon, and in the California Klamath and California Coast Range Provinces, this Plan identifies a network of MOCAs on Federal lands (Appendices C and D). On the fire-dominated east side of the Cascade Mountains in Washington and Oregon and the California Cascades, this Plan describes a Province-wide habitat-management approach in response to the area's dynamic natural disturbance regime.

The MOCA network is based on previous designs of conservation areas for the spotted owl (Thomas *et al.* 1990; USFWS 1992b), and is intended to support a stable number of breeding pairs of spotted owls over time and allow for movement of spotted owls across the network. Conservation Support Areas (CSAs) outside of Federal lands were added to support the MOCA network and assist in achieving the Recovery Criteria.

Any Recovery Plan relying on specific conservation areas for its success must address questions of change. While this Plan has been prepared with clearly delineated MOCAs, it is recognized that, as new information arises, changes are inevitable. The need for flexibility has been recognized throughout previous recovery efforts and is well documented.

Habitat Terms

This Plan uses habitat terms as defined in Table 1.

Table 1. Definitions of habitat terms used in this Recovery Plan.

Habitat term	Definition	Reference
Suitable habitat	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 spotted owl.	(USFWS 1992b)
Nesting/roosting and foraging habitat	Suitable habitat that provides nesting, roosting and foraging opportunities for spotted owls. Important stand elements are high canopy closure, a multilayered, multispecies canopy with larger overstory trees and a presence of broken-topped trees or other nesting platforms (*e.g.*, mistletoe clumps). Some suitable habitat may have limited nesting opportunities, but still provide foraging opportunities.	

Habitat term	Definition	Reference
High-quality habitat	Older, multi-layered structurally complex forests that are characterized as having large diameter trees, high amounts of canopy cover, and decadence components such as broken-topped live trees, mistletoe, cavities, large snags, and fallen trees. This is a subset of suitable habitat.	
Dispersal habitat	Optimally, forest stands with average tree diameters ≥11 inches and conifer overstory trees with closed canopies (>40 percent canopy closure) and with open space beneath the canopy to allow spotted owls to fly. However, spotted owls will disperse across a range of forest conditions, including younger stands and open patches.	Thomas *et al.* (1990:310)
Habitat-capable area	Forests below the elevation limits of occupancy by territorial spotted owls, excluding serpentine soil areas, that are capable of growing and sustaining structural conditions of spotted owl habitat.	Davis and Lint (2005:30)
Mid-seral forest	The period in the life of a forest from crown closure to first merchantability, usually ages 15–40. Due to stand density, brush, grass, or herbs rapidly decrease in the stand.	USDA (1993:IX-31)
Late-seral forest	Stage in forest development that includes mature and old-growth forest.	USDA (1993:IX-18)
Mature forest	A mappable stand of trees for which the annual net rate of growth has peaked. Stands are generally greater than 80–200 years old and less than 180–200 years old. Stand age, diameter of dominant trees, and stand structure at maturity vary by forest 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 are suitable habitat for spotted owls. However, mature forests are not always spotted owl habitat, and spotted owl habitat is not always mature forest.	USDA (1993:IX-20)
Old-growth forest	A forest stand usually at least 180–220 years old with moderate to high canopy closure; a multilayered, multispecies canopy dominated by large overstory trees; high incidence of large trees, some with broken tops and other indications of old and decaying wood (decadence); many large snags; and heavy accumulations of wood, including large logs on the ground.	Moeur *et al.* (2005:107)

Changes in Management Approaches

This recovery strategy is based on Federal land-use allocations and management approaches that are subject to review and change. Under the principle of adaptive management, approaches other than those described in current Federal land use plans may be shown to be effective in accomplishing recovery goals and objectives. The potential for these changes to affect the recovery of the spotted owl were not considered because the changes are unknown.

Substantive changes to existing, underlying Federal land use allocations and management plans that the MOCAs and some CSAs are based upon will follow the process of public involvement required under the National Environmental Policy Act (NEPA) of 1969, as amended (42 USC 4321 *et seq*.) and consultation under Section 7 of the ESA. The determination of the consistency of these approaches to meet the goals and objectives of this Recovery Plan would be done concurrently with NEPA and ESA reviews. The Service, in its review of any proposed changes to land use plans, will consider whether any such proposal would either significantly increase the length of time necessary to achieve recovery or render recovery unlikely.

Need for Cooperative Effort

Because many jurisdictions and agencies are involved in, or affected by, management for spotted owls, cooperation is essential for success. The Service encourages all involved to work closely and cooperatively. To that end, this Plan has three Recovery Actions concerned with establishing interagency work groups. This cooperation is especially important among the States and regulatory agencies. Coordination and, if possible, regulatory reviews will help to ensure that high-priority Recovery Actions will be implemented in a timely manner.

All agencies and individuals involved are challenged to create more effective ways of working together for the benefit of the spotted owl. While the Service encourages all parties to immediately implement the priority actions presented in this Recovery Plan, we also want to learn if actions are not working as planned so that we can work with the involved parties to find actions that will work better.

Ongoing Actions

This Plan is intended to complement and provide guidance for ongoing activities. Such ongoing activities include prioritizing the research needed to understand and address the threat posed by the barred owl and interagency research and mapping efforts to develop strategies for addressing fire risk and forest health issues in dry forest Provinces.

II. Recovery Goal, Objectives, and Strategy

Recovery Goal

The goal of every Recovery Plan is to improve the status of the species so it can be removed from protection under the Endangered Species Act. The long-term goal for this species is the same. However, because of the uncertainties associated with the threats to the spotted owl, this plan is developed for a 10-year time frame with a goal of reducing the population declines and answering some fundamental questions necessary for a long-term recovery strategy.

Recovery Objectives

The long-term objectives of this Recovery Plan are:

- Spotted owl populations are sufficiently large and distributed such that the species no longer requires listing under the ESA.
- Adequate suitable habitat is available for spotted owls and will continue to exist to allow the species to survive without the protection of the ESA.
- The effects of threats have been reduced or eliminated such that spotted owl populations are stable or increasing and spotted owls are unlikely to become threatened again in the foreseeable future.

The interim expectations for the next 10 years are:

- The Barred Owl Work Group has quantified the threats from the barred owl on the spotted owl, control techniques and appropriate implementation plans have been developed, and decisions on managing barred owls have been made.
- The MOCA network has been established in the western Provinces with appropriate management of habitat-capable lands inside the MOCAs to support spotted owls.
- The Dry-Forest Landscape Work Group has developed, and Federal land management agencies have implemented, a comprehensive program of forest management on dry forest lands that reduces the fire threat and encourages the development of forest habitat suitable for spotted owls.

Recovery Strategy

Currently, the most important range-wide threats to the spotted owl are competition with barred owls, ongoing loss of suitable habitat as a result of timber harvest and catastrophic fire, and loss of amount and distribution of suitable habitat as a result of past activities and disturbances. To address these threats, the present recovery strategy has the following three essential elements: barred owl control, dry-forest landscape management strategy, and MOCAs.

Habitat

This recovery strategy builds on concepts and information presented by the Interagency Scientific Committee (ISC) in "A Conservation Strategy for the Northern Spotted Owl" (Thomas *et al.* 1990) and the 1992 Final Draft Recovery Plan for the Northern Spotted Owl (USFWS 1992) which focused on managing large blocks of suitable habitat in designated conservation areas throughout the range of the spotted owl that could support self-sustaining populations of 15 to 20 pairs of spotted owls, and spacing the blocks and managing the areas between them to permit movement of spotted owls between blocks. To this end, the ISC delineated and mapped a network of 193 Habitat Conservation Areas (HCAs). The 192 Designated Conservation Areas (DCAs) in the 1992 Final Draft Recovery Plan were modifications of the HCAs from the ISC. In 1994, the NWFP amended 26 LRMPs to provide a network of land-use allocations identified as Late-Successional Reserves (LSRs) to provide habitat for late-successional forest species, including the spotted owl (Davis and Lint 2005). The 2004 Scientific Evaluation of the Status of the Northern Spotted Owl (Courtney *et al.* 2004) acknowledged this conservation strategy of reserves was based on sound scientific principles which have not substantially changed since the species was listed.

The MOCA network in this Plan used the 1992 DCAs, as well as information from the 1992 Draft Recovery Plan, as a starting point to identify habitat-capable lands in Oregon, Washington, and northern California that could support clusters of reproducing spotted owls. As a baseline, it assumed all other existing management plans throughout the range of the spotted owl are being implemented.

MOCAs in non-fire-dominated Provinces. The foundation of this Plan for the non-fire-prone western Provinces of Washington and Oregon is the MOCA network on Federal lands. An interim MOCA network is also identified on Federal lands in the Klamath Provinces of Oregon and California until a landscape-management strategy is developed and adopted in these fire-prone provinces (Appendices C and D). MOCAs are intended to support stable and well-distributed populations of spotted owls over time and allow for movement of spotted owls across the network.

This Recovery Plan recommends specific management actions both inside and outside of MOCAs that are influenced by existing Federal land use allocations, regulatory frameworks, and standards and guidelines from the LRMPs. MOCAs represent areas that contain or will develop suitable habitat considered essential for spotted owl recovery. In the western Provinces, MOCAs are the geographic areas where monitoring will be carried out to determine whether, at some future time, delisting may be warranted.

Two types of MOCAs are identified: MOCA 1s that have enough "habitat-capable" area to support 20 or more pairs of breeding spotted owls now or in the future, and MOCA 2s that are capable of supporting 1–19 pairs of breeding spotted owls. "Habitat-capable areas" were defined by Davis and Lint (2005) as forest-capable land below the elevation limits of occupancy by territorial spotted owls, excluding serpentine soil areas. MOCA 1s are considered the population strongholds, meaning these areas are expected to eventually support stable source populations. MOCA 2s were identified within 7 miles of MOCA 1s when insufficient Federal habitat-capable lands were available to allow placement of a MOCA 1.

Dry-forest landscape-management approach. On the fire-dominated east side of the Cascade Mountains in Washington and Oregon, and the California Cascades, the habitat management strategy described here is intended to maintain spotted owl habitat in an environment of frequent natural disturbances. No MOCAs are identified in these Provinces, given the assumption that the severe natural disturbance regime precludes long-term persistence of any static habitat management areas. Rather, a landscape approach is described—one that promotes spotted owl recovery within the broader goal of ecological sustainability.

Conservation Support Areas. The Recovery Plan also identifies CSAs in Washington, the west side of the Cascades in Oregon, and in California. CSAs are areas between or adjacent to MOCAs where habitat contributions by private, State, and Federal lands are expected to support the MOCA network and the dry-forest landscape management approach. In most instances, CSAs recognize existing management compatible with spotted owl conservation such as Habitat Conservation Plans under the ESA, State parks and other Federal lands.

Modifications to boundaries of MOCAs and CSAs. Although effort was made to carefully delineate the boundaries of the MOCAs and CSAs, each MOCA and CSA was not intensively analyzed. Therefore, some minor adjustments may be necessary to align these boundaries to coincide with recognizable physiographic features (*e.g.,* major ridge lines, perennial streams, and permanent roads).

In addition, this Plan recognizes the need for Federal land managers to have the flexibility to make minor adjustments to the identified MOCA boundaries. It is incumbent on the Federal land managers to justify how any divergence from the MOCA network remains consistent with the objectives of this Plan's MOCA network. Similarly, CSA adjustments may be necessary. These adjustments will be governed by applicable regulations and policies for the management of those areas, as informed by the Recovery Plan.

Boundary adjustments should be forwarded to the Service, which will share the information with the Northern Spotted Owl Work Group (see Recovery Action 1). Modifications to boundaries of MOCAs and CSAs should be neutral or beneficial to spotted owl recovery and would not change the Recovery Criteria for MOCAs as described in this Plan.

The Willamette Valley and Western Washington Lowland Provinces are excluded from the MOCA network; given their low population numbers and isolation from other robust populations, especially the Western Washington Lowland Province, it is assumed they can not play an essential role in recovering the species. Further, because of the recommended landscape approach in the fire-prone Provinces, these Provinces are not included in the MOCA network.

Barred Owl

The threat posed by barred owls to spotted owl recovery is better understood now than when the spotted owl was listed. Barred owls reportedly have reduced spotted owl site occupancy, reproduction, and survival (see Listing Factor E and Appendix B). Because the abundance of barred owls continues to increase, effectively addressing this threat depends on initiating action as soon as possible. The Recovery Actions address research of the competition between spotted and barred owls, experimental control of barred owls, and, if recommended by research, management of barred owls.

Monitoring and Research

This Plan recommends a research and monitoring program be implemented to track progress toward recovery, inform changes in recovery strategy by a process of adaptive management, and ultimately determine when delisting is appropriate. The following three primary elements of this strategy will provide information required to evaluate progress toward the Recovery Criteria.

Monitoring of spotted owl population trend. Currently, this monitoring is done within a network of demographic study areas, but it may be possible to monitor trends using other reliable methods. Recognizing that the demographic monitoring efforts are costly, it is recommended that, in the absence of another method that would provide reliable trend data at an improved cost-effectiveness, these existing studies should be continued, while other methods are piloted and tested. The current demographic studies provide region-specific demographic data that provide the basis for many of the current and proposed studies of spotted owl ecology. Also, because monitoring in the demographic study areas has been ongoing for approximately two decades, the data from these efforts allow trend estimates in the near term that would not be available for a considerable length of time if new methods were implemented. Given the immediacy of the barred owl threat, the continuation of monitoring in the demographic study areas provides a timely opportunity to integrate barred owl removal experiments to assess any demographic response to removal of barred owls.

Inventory of spotted owl distribution. When trend data indicate that populations are stable or increasing in the Provinces specified in Recovery Criterion 1, sampling would then be required to determine the distribution of spotted owls.

A comprehensive program of barred owl research and monitoring. This is needed to experimentally determine the effects of barred owls on spotted owls and to incorporate this information into management to reduce negative effects to a level that would promote spotted owl recovery.

III. Recovery Criteria and Recovery Actions

Recovery criteria serve as objective, measurable guidelines to assist in determining when an endangered species has recovered to the point that it may be downlisted to threatened, or that the protections afforded by the ESA are no longer necessary and the species may be delisted. However, meeting all or most of the recovery criteria does not automatically result in delisting, nor does not meeting all criteria preclude delisting. A change in status (downlisting or delisting) requires a separate rule-making process based on an analysis of the same five factors (referred to as the listing factors) considered in the listing of a species, as described in Section 4(a)(1) of the ESA:

A. the present or threatened destruction, modification, or curtailment of its habitat or range
B. overutilization for commercial, recreational, scientific, or educational purposes
C. disease or predation
D. the inadequacy of existing regulatory mechanisms, and
E. other natural or manmade factors affecting its continued existence.

Recovery Criteria in this Plan represent our best assessment of the conditions that may result in a determination in a 5-year review that delisting the spotted owl is warranted, followed by a formal regulatory rule-making process to delist the species. Each Recovery Criterion includes a parameter to be measured and, when known, a threshold to be reached. Recovery Actions are those activities deemed necessary to achieve the Recovery Criteria or to determine whether the Recovery Criteria have been met.

The first three Recovery Criteria assess the spotted owl's population status and distribution. The Service believes these three criteria are the best way to assess whether the five listing factors—that is, the threats facing the spotted owl—are addressed. Ultimately, the spotted owl population's positive response to the Recovery Actions will mean recovery is occurring. Such a positive response will be measured in accordance with the three population-related Recovery Criteria.

Generally, this section follows the order of the listing factors. However, the first three Recovery Criteria, their associated Recovery Actions, and Recovery Action 1 do not fit into any of the listing factors and so are presented first. For a more complete description of the threats to the spotted owl addressed by these Recovery Actions, see Appendix B.

Lifespan of Recovery Actions

All the Recovery Actions have a 10-year lifespan, matching the expected duration of this Recovery Plan before it will require revision.

NSO Work Group

The first Recovery Action pertains to all listing factors and Recovery Criteria.

- ***Recovery Action 1. Establish an inter-organizational spotted owl working group ("NSO Work Group") to oversee the implementation of the Recovery Plan.*** Implementation of a Recovery Plan with the breadth and scope of this Plan would benefit greatly from a working group to oversee implementation of the numerous Recovery Actions necessary to carry out the Plan and recover the spotted owl. The NSO Work Group will be comprised of State, Federal, and other members as needed and managed by a coordinator, and it will have the authority to designate other work groups and invite other members as it deems appropriate. It will also serve as the clearinghouse for information needed to implement the Recovery Plan.

  The NSO Work Group's responsibilities include:

  1. Oversee implementation of the Northern Spotted Owl Recovery Plan and all management and research activities necessary to provide for recovery of the northern spotted owl
  2. Review and comment on actions proposed by the Dry Forest Landscape and Barred Owl Work Groups
  3. Review and comment on research activities proposed by the Work Groups
  4. Make provisions for implementation of approved Recovery Actions.

  The group will be responsible also for designing and overseeing the appropriate adaptive management frameworks for this Plan. SEI (2008: 76) states, "A formal framework for adaptive management would include, but not be limited to the following: clear objectives (these would be realistic and relevant to the owl and other natural resources), expected results, an appropriate quasi-experimental or true experimental design (*i.e.,* the design would be capable of providing the information necessary to answer the objectives), proper execution of the design, monitoring of treatments, a rigorous mechanism for oversight, clear assignment of responsibility at each level of the framework, and a clear feedback and adaptive response mechanism that is quickly capable of recognizing and mitigating errors or deficiencies of the framework or individual management treatments."

Recovery Criteria Concerning Population Trend and Distribution

The spotted owl listing identified population decline, small population size, and related demographic conditions as threats. In the current assessment, these conditions were viewed as results of other threats and not threats *per se*. However, Recovery Actions are identified here that are intended to address and ameliorate such demographic conditions. To ensure the long-term recovery of the spotted owl, populations in most of the physiographic Provinces must be stable or increasing, and the species must be well distributed throughout 10 of the 12 physiographic Provinces. This will be accomplished when Recovery Criteria 1, 2, and 3 are met.

Recovery Criterion 1: The population trend of spotted owls is stable or increasing over 10 years of monitoring, as measured by a statistically reliable method, in each Province excluding Western Washington Lowlands and the Willamette Valley, with a low probability of concluding the population is stable or increasing when it actually is declining.

Recovery Criterion 2: Within each State the distribution of spotted owls is such that at least 80 percent of Category 1 MOCAs contain at least 15 occupied spotted owl sites when surveyed over a 5-year period.

Recovery Criterion 3: In each of the East Cascades Provinces in Washington and Oregon and the California Cascades Province, at least 30 percent of the Province contains high-quality habitat and 75 percent of that habitat is within at least one home-range radius of an activity center of a territorial pair of spotted owls, as measured over a 5-year period.

Monitoring and Inventory

- ***Recovery Action 2: Continue monitoring the population trend of spotted owls to determine if the population is decreasing, stationary, or increasing.*** Monitoring in demographic study areas is currently the primary action to assess the status of populations of spotted owls. Other statistically valid monitoring methods (*i.e.,* analytically robust and representative of the entire Province) may be possible and should be tested.

- ***Recovery Action 3: Conduct occupancy inventory or predictive modeling needed to determine if Recovery Criteria 1, 2, and 3 have been met.*** It is expected this inventory will be initiated at a date when it appears the spotted owl is close to meeting Recovery Criteria 2 and 3. Periodic assessment of the distribution of spotted owls is important because the demographic study areas may not be representative of range- wide conditions. As part of this Recovery Action, a sampling design to estimate occupancy needs to be developed (with, for example, frequency of sampling, number of samples, location of samples). Modeling techniques have improved over the years, so it is not unreasonable to believe predictive modeling will be a plausible technique for estimating spotted owl occupancy across the range.

Listing Factor A: The present or threatened destruction, modification, or curtailment of the species' habitat or range.

The key threats identified that relate to this listing factor are (1) loss of habitat and changes in distribution of habitat as a result of past activities and disturbances due especially to timber harvest and permanent conversion of habitat, and (2) ongoing habitat loss from natural disturbance (especially fire) timber harvest, and permanent conversion of habitat (see Appendix B). The basis for these habitat strategies is presented in Appendices C and E. Implementation of the following Recovery Actions should ensure spotted owls have sufficient suitable habitat for recovery.

Spotted owl suitable habitat varies across the species' range, from the drier, more disturbance-adapted southern and eastern portions of the range to the more mesic western and northern portions. Specific Provincial definitions of how suitable habitat varies have not been defined and were not done for this Plan. The Plan includes a Recovery Action to standardize Province-specific habitat definition across the range.

Habitat Management in Western Forests (MOCAs)

For wet forest types, this Plan identifies a network of habitat blocks managed for spotted owls as a fundamental element required to recover the species. The identification of these MOCAs is based on principles of conservation biology (*e.g.*, larger blocks spaced closer together are generally better than smaller blocks spaced farther apart) and are meant to provide the spotted owl with the habitat required to develop and maintain a stable or increasing, well-distributed population. The MOCAs are designed to provide a high likelihood of interconnectivity among MOCAs based on research concerning dispersal distances of spotted owls. While there is uncertainty regarding the forest conditions required for spotted owl dispersal, it is assumed dispersal success is better when the habitat between the blocks more closely resembles suitable habitat. Land use allocations such as visual corridors, riparian management zones, unstable soil areas, and special management areas for other species that support higher-quality spotted owl habitat embedded in a landscape of forest lands managed for timber production should facilitate dispersal of spotted owls.

The MOCAs are derived from multiple analyses including the Interagency Scientific Committee (1990), the 1992 Northern Spotted Owl Draft Recovery Plan, the Northwest Forest Plan (1994), and spotted owl population modeling in the 1990s and revised in 2008.

- ***Recovery Action 4: Establish a network of MOCAs (as presented in Appendices C and D) that are of sufficient size and spacing to achieve long-term recovery of spotted owls.***
- ***Recovery Action 5: Manage habitat-capable lands within MOCAs to produce the highest amount and highest quality spotted owl habitat the lands are capable of producing.*** Given natural events such as fire, wind storms, and insect damage, not all habitat-capable lands in a MOCA are likely to be high-quality habitat at any one time. Activities with demonstrated long-term benefits for spotted owls (*e.g.,* thinning of younger forests and fire-risk reduction) are encouraged even if they cause short-term negative effects.

Habitat Management in Dry Forests (slightly revised from SEI 2008)

Monitoring indicates only partial success conserving dense older forests used by spotted owls in the dry, fire-prone Provinces (Mouer *et al.* 2005; Spies *et al.* 2006). In these Provinces, the rate of loss of older forests to stand-replacement wildfire has been relatively high. If recent trends persist, the area of older dense forests available to the spotted owl could decline dramatically over the next several decades. Further, there is evidence that wildfire activity will continue or increase in coming years as the climate changes (Westerling *et al.* 2006). Thus, it is unlikely that designating spotted owl habitat reserves within fire-prone landscapes will be effective (Agee 2003; Spies *et al.* 2006).

This Plan recognizes management of the entire landscape is needed to meet spotted owl conservation objectives and active management is needed to create more fire-resilient and fire-resistant forests. Under such a strategy, spotted owl habitat areas are considered to be spatially dynamic as a result of stand-replacement wildfires and replacement habitat will be needed to maintain sufficient levels and patterns of habitat for the species.

Treatments to reduce risks of fires and insect outbreaks in spotted owl habitat should be done in the larger context of restoring broader ecological functions and processes. In the dry-forest environments, there are three components of an integrated landscape strategy that need to be implemented at the Provincial scale: identification of existing high-quality spotted owl habitat, strategic placement of fuel-reduction treatments, and management for sustainable ecosystem processes and functions.

This strategy could have short-term local impacts on spotted owl habitat in order to achieve the long-term landscape strategy goal of creating a more sustainable, resilient landscape. The goal of the fire strategy is to reduce the risk of large scale habitat loss to uncharacteristic high-severity wildfire while restoring ecosystem processes and functions.

The following approach was adapted from SEI (2008). More complete information on this strategy is presented in Appendix E.

Habitat Management in Eastern Washington Cascades, Eastern Oregon Cascades, and California Cascades Provinces (explanatory text revised from SEI 2008)

Recovery Action 6: Identify, maintain, and restore approximately 30–35 percent of the total dry forest (ponderosa pine, Douglas-fir, and dry grand fir plant association group) habitat-capable area as spatially dynamic high-quality spotted owl habitat patches, and approximately 50–75 percent of the total moist forests (moist grand fir, western hemlock, and Pacific silver fir plant association groups) habitat-capable area as high-quality spotted owl habitat patches. Habitat-patch sizes are not defined here because identification of patches of high-quality spotted owl habitat will vary and be informed by local conditions as will the appropriate patch size (*i.e.,* it could be lower in amount in areas dominated by the driest-forest types and somewhat higher in areas dominated by the moistest-forest habitats). The pattern and distribution of this habitat should be informed by local interdisciplinary teams and based on a number of ecological criteria including: existing spotted owl locations, desired patch sizes, topography, barred owl locations, prey base, risk of loss from fires, future fire behavior, insects, and diseases although habitat patches are expected to move around the landscape over time as disturbances will inevitably remove existing habitat. The size and spacing of these habitat patches should be determined by interdisciplinary teams of appropriate experts. Habitat percentages for dry and moist forests should be measured for each fourth-field watershed[2] to assure habitat is well distributed.

Target levels of dense old forest in the dry (30–35 percent) and moist forest types (50–75 percent) in this Plan are at the high end of the range of variation in order to provide short-term habitat benefits for spotted owls. Historical abundance of late-successional forests plus old forests in fire-prone areas ranged from about 5–40 percent (Hessburg *et al.* 1999, 2000). This means that landscape-management objectives may target levels of dense old forest that are on average difficult to retain in dry-forest environments in the long term (*e.g.,* longer than 100 years). Active management to reduce wildfire and insect outbreak risks will be required to offset risks of habitat loss. Ultimately, initial approaches for managing dry forests to sustain substantial amounts of dense conditions may not be fully successful. Monitoring and adaptive management are necessary to allow adjustment.

Historical abundance of late-successional habitats within moist forests ranged from 20–75 percent (Agee 2003; Hessburg *et al.* 2000; Wimberly *et al.* 2000). These forests have longer fire-return intervals allowing a larger portion of the landscape to develop late-successional forest characteristics (Agee 2003).

---

[2] Fourth-field watersheds or sub-basins represent the geographic area of part or all of a surface drainage basin, a combination of drainage basins, or a distinct hydrologic feature.

Recovery Action 7**: **Manage lands in these Provinces outside of the high-quality habitat patches to restore ecological processes and functions, and to reduce the potential for significant losses by stand-replacement fires, insects, and disease. This Recovery Action includes three elements: (1) active management of dry forests, (2) development of large tree structure, and (3) long-term management of dry forests to reduce the potential for future high-severity fires and hasten the recovery of structurally diverse forests. These elements are described further below. Once treatments are done, follow-up treatments will be needed at regular intervals. Lack of follow-up treatments likely would increase fire risks quite dramatically and lead to recreation of current high-hazard conditions (Ager *et al.* 2007; Huff *et al.* 1995).

1. Active management in dry forests primarily concerns restoring sustainable ecological conditions, with significant populations of intermediate-sized and large trees throughout. Mature and old trees will provide the framework for replacement spotted owl habitat when suitable habitat patches are lost to fire. Habitat can be developed in a relatively short time by allowing in-growth of additional canopy layers when a large-tree overstory is already present.

A large portion of the dry-forest landscape (the complementary 65–70 percent of the Province outside of areas identified in Recovery Action 6) may be treated to reduce risks to suitable spotted owl habitat and achieve other management objectives (Finney *et al* 2007; Lehmkuhl *et al* 2007; Kennedy *et al* 2008). Treatments in dry-forest landscapes should emphasize a combination of spotted owl habitat concerns and other ecological and management objectives including fuel reduction and modifying fire behavior. The proportions of the landscape in this developing spotted owl habitat will vary with characteristics such as topography, productivity, land management (*e.g.*, Wilderness Areas), and ownership patterns. Dry-forest treatments should be done in a way that manages surface fuels, fuel ladders, and density, but maintains structural conditions supporting prey occurrence and abundance in current or potential nesting roosting and foraging habitat, maintains structural conditions conducive to spotted owl foraging, and allows for rapid development of replacement nesting, roosting and foraging habitat.

Of the 65–70 percent of each Province that may be treated (*i.e.,* the area outside of the habitat patches), this Plan recommends that at least 20–25 percent *(i.e.,* 12–18 percent of each total Province) should be strategically managed to reduce the risk of habitat loss due to high severity fire, diseases, and insects and to increase the resiliency and sustainability of spotted owl habitat. These treatments would be the most intensive fuel treatments at the stand scale. Some of these treatments could include suitable owl habitat if it is deemed necessary. Fuel treatment principles developed by Agee and Skinner (2005), Agee (2002), Hessburg and Agee (2003), Hessburg *et al.* (2005), Peterson *et al.* (2005), Stephens and Moghaddas (2005), and Finney (2004) should be used. At least 20–25 percent of the landscape needs to be treated if treatments are spatially optimized to constrain severe fire behavior (Finney 2004; Ager *et al.* 2006; Lehmkuhl *et al.* 2007; Kennedy *et al.* 2008). Particular attention should be given to effective fuel treatments around existing suitable spotted owl habitat. Treatment percentages should be measured at both the fourth-field watershed level and at the Province level.

2. In addition to treating fuels, restoration of fire tolerance should restore large, fire-tolerant tree species to their former role in dry-forest landscapes. Large, old ponderosa pine, western larch, Douglas-fir, sugar pine, incense cedar, Jeffrey pine and a few other species (depending on location) have thick, fire-resistant bark and other attributes that allow them to withstand most low- and mixed-severity wildfires. Large, old trees of these species provide the habitat "anchors" for spotted owls and other species habitat in dry forests, often surviving for centuries while smaller trees in the lower- and mid-canopy come and go with disturbance. Even sapling and pole-sized ponderosa pine are more tolerant of low- and mixed-severity fires than Douglas-fir, grand fir, and white fir in equivalent sizes. Smaller size classes of fire-tolerant tree species provide the recruitment resource for future large and very large fire-tolerant trees. In moist forests within spotted owl habitat capable areas, management should focus on thinning stands created by past harvest or fire in order to accelerate the development of large tree structures.

3. Relative to long-term management of dry forests, active management outside of the high-quality habitat patches is a high priority. Treatments in dry-forest landscapes should continue to be motivated by a combination of spotted owl habitat concerns and other ecological and management objectives.

Habitat Management in the Oregon and California Klamath Provinces

SEI (2008:69-70) provides clarification concerning the uniqueness of the Oregon and California Klamath Provinces:

> "The forest landscapes of the Klamath Mountains are unique…because of complex interactions among topography, land surface forms, surface lithologies, forest types, and regional climate. Taylor and Skinner (1998, 2003) and Skinner *et al.* (2006) show that historical fire regimes of the dry and mesic forest types were influenced by the regional climate and the broader landscape context rather than by the vegetation type. This is fundamentally different than the eastern Cascades of Oregon and Washington. …The loss of Northern Spotted Owl habitat to high-severity wildfire in the Klamath and Cascade Provinces has been relatively high over the last decade and if this trend continued, could significantly impact the owl in these drier forests. …An important difference between the Klamath Mountains and the dry forests of the eastern Cascades is the greater amount of annual precipitation occurring in the Klamath Mountains…it is uncertain the extent to which understanding gained

> from wildfire studies of the eastern Cascades may be applied to these forests. …At the time of this report, the review panel could not agree on a clear direction for managing the dry forests of the Klamath Mountains because of limited information about the natural variability and changes in the landscape ecology of these forests, and due to the highly constrained timeline for the review. Scientists also expressed concerns about a shortage of Province-relevant science, relative to fire ecology and owl biology. For these reasons, the panel made only two specific recommendations: 1) that there be substantial new research focus, in the near term, on remedying scientific uncertainties, and 2) that knowledge gained from studies of the eastern Cascades dry forests or wet coastal forests not be applied directly to the Klamath Mountains forests."

Given the current scientific uncertainty, this Plan calls for an adaptive management approach to fire management and spotted owl recovery in the Oregon and California Klamath Provinces. While a reserve network may ultimately not be the best strategy to achieve recovery in a fire-dominated landscape, it is unclear how, or if, a landscape-management approach similar to that described for the other dry-forest Provinces is feasible in the Klamath Provinces.

This Plan recommends implementation of a MOCA network for the Klamath Provinces, but it will be considered an interim strategy until such time another strategy is adopted. A change to a non-MOCA landscape approach, at least on the Forest Service lands, is expected following the work of the Dry-Forest Landscape Work Group (discussed below).

The MOCAs in the Klamath Provinces in Oregon and California coincide with the proposed Late Successional Management Areas (LSMAs) in the BLM's preferred alternative for its Western Oregon Plan Revision and with U.S. Forest Service LSRs. There is a significant difference in land ownership patterns between the BLM and U.S. Forest Service in this area (*i.e.,* much of the BLM-owned land is in a checkerboard pattern, while the Forest Service administers large contiguous blocks of land). BLM's checkerboard land ownership means the agency generally does not manage more than 50 percent of the land in a given area, so its approach to fire management and spotted owl recovery may differ from that of the U.S. Forest Service. The best approach for spotted owl recovery now appears to be to maintain the MOCAs on BLM land and to implement a landscape-management approach on U.S. Forest Service land, but this discussion requires further analysis.

- ***Recovery Action 8: Manage the Klamath Provinces in Oregon and California to meet spotted owl recovery objectives while creating more fire-resilient and fire-resistant forests.*** An interagency work group will be needed to develop a strategy to achieve an ecologically sustainable landscape that supports spotted owl recovery (see Recovery Action 9 and Appendix E for further information).

Dry-Forest Landscape Work Group

- ***Recovery Action 9: Create an interagency Dry-Forest Landscape Work Group to coordinate a range-wide, integrated, and comprehensive program for fire-prone Provinces which includes a monitoring and an adaptive management program.*** The Dry-Forest Landscape Work Group (DFLWG) will report to and coordinate with the NSO Work Group (see Recovery Action 1). The first task of the Work Group will be to review the interim strategy for the Klamath Provinces and make recommendations for a final strategy there. The review should entail:
    1. inclusion of appropriate scientists, Federal agencies, and interested parties as appropriate,
    2. description of the best approach to recovering the spotted owl given existing Federal land ownership patterns,
    3. description of research and actions needed to implement such research, and
    4. consideration of other fire-prone areas that may benefit from a landscape-management approach, such as the southern West Cascades of Oregon.

  The Dry-Forest Landscape Work Group will also be asked to coordinate a range-wide, integrated, and comprehensive program for all of the fire-prone Provinces. These duties may entail (but are not limited to):
    1. coordination of relevant research
    2. standardization, to the extent possible, of new prescriptions and treatments for fuel reduction and other dry forest management to facilitate regional comparisons by meta-analysis and to maximize the scientific and management value of studies
    3. standardization, to the extent possible, of experimental designs to ensure comparability across the region and to ensure statistically valid results
    4. development of plans that include landscape-specific habitat objectives, treatment strategies, and projected outcomes, and
    5. development of monitoring techniques and coordination of effort. Given the uncertainties concerning sustaining spotted owl habitat in dry-forest landscapes, monitoring is imperative. Characteristics that may be important to monitor in any dry-forest landscape managed for spotted owl habitat include:
        - Total spotted owl habitat area and condition
        - Dispersal habitat and condition
        - Effectiveness of spatial isolation on spotted owl habitat clusters
        - Pattern, amount, and timing of management activities and natural disturbances
        - Preferred timing of follow-up treatments by area
        - Patch recruitment potential and timing as replacement spotted owl habitat relative to fledging success; interactions with barred owls; and stand-level prey response to treatments,

including habitat elements that support prey (mistletoe, snags, downed wood, forage lichens, truffles abundance)
- Spotted owl response to habitat and dispersal areas and dispersion
- Occupancy by breeding pairs or single spotted owls

6. Help local land managers with the design and development of new prescriptions and treatments for fuel reduction and other dry-forest management strategies through training, workshops or other information transfer methods.

Additional Habitat Actions for All Areas (Unless Specified Otherwise)

- ***Recovery Action 10: In MOCAs and in all areas of the Dry-Forest Landscape Strategy, post-fire habitat modifications should focus mainly on habitat restoration, conserving habitat elements that take the most time to develop or recover (e.g., large trees, snags, downed wood), or actions that are part of a fuels reduction, fire protection, or reforestation strategy.*** The retention of large-tree, snag, and downed-wood legacy structures is important for the future development of suitable spotted owl habitat.

  SEI (2008) cites 10 attributes of restored ecosystems from the Society for Ecological Restoration Primer on Ecological Restoration (SERPER 2002). From these attributes, SEI (2008; 75–76) concludes:

  > "[T]he panel holds that in a Final Recovery Plan for the Northern Spotted Owl, the salient issue regarding 'salvage' (and other activities such as planting) is whether it will enhance Spotted Owl conservation (by restoration of habitat, or reduction in risks). Any such benefit would then have to be weighed against any presumed detrimental effect."

  It is understood that short-term negative effects to spotted owls or spotted owl habitat may occur in the implementation of this Recovery Action.

- ***Recovery Action 11: Design and conduct experiments on forest stand structure to better understand relationships between spotted owl habitat, spotted owl prey, and spotted owl demographic response.*** Such forest management experiments should be given high-priority in non-reserved Federal lands ("matrix" in NWFP), Adaptive Management Areas, and non-Federal lands in areas not having important conservation functions for spotted owls. Such experiments should include assessing the effects of various thinning prescriptions on spotted owls.

- ***Recovery Action 12: Standardize Province-specific habitat definitions across the range of the spotted owl using a collaborative process.*** Identification of existing spotted owl habitat and the management of lands to provide new habitat in the future would benefit greatly from a set of Province-specific definitions of spotted owl habitat (*e.g.,* high-quality, nesting, dispersal, foraging). Variation in habitat structure and use across the spotted owl's range drives the need for Province-specific definitions. The definitions should use forest composition and structure vernacular so that spotted owl habitat can be described in forest-management terms.

- ***Recovery Action 13: Encourage applicants to develop Habitat Conservation Plans/Safe Harbor Agreements that are consistent with the recovery objectives.*** Habitat Conservation Plans (HCPs) and Safe Harbor Agreements (SHAs) are important tools that non-Federal landowners can voluntarily use to assist in the recovery of the spotted owl. Although HCPs do not require recovery standards, voluntary Recovery Actions included in an HCP can promote recovery.

- ***Recovery Action 14: Establish a comprehensive incentives program to develop creative opportunities for non-Federal landowners to engage in management strategies consistent with the recovery objectives.*** Many non-Federal landowners and land managers in the region have adjusted their management strategies to emphasize short harvest rotations (*e.g.*, 40–50 years) and the processing of comparatively small diameter trees. Some lumber mills have been modified such that they are no longer capable of processing larger trees. This emphasis on smaller and younger trees means forests grown on longer rotations (*i.e.*, those that might function for some period as spotted owl habitat), even if eventually harvested, result in loss of return on investment and potentially significant costs to modify mills for larger wood. Incentives should be identified and developed as a means to reward landowners and land managers for implementing “new forestry” procedures designed to recruit and maintain spotted owl habitat. Some incentives may be economic. Implementation of the incentives program could be coupled with the Safe Harbor Agreement process to provide regulatory protection for landowners who create or enhance spotted owl habitat.

- ***Recovery Action 15: Streamline the process of a landowner gaining approval of an HCP and SHA.*** The Service and the National Marine Fisheries Service should reduce processing time and make the HCP and SHA processes more easily implemented.

- ***Recovery Action 16: Create and adopt measurable habitat objectives for use in landscape planning within CSAs using a collaborative process.*** Having measurable objectives will help establish common understanding of goals in these important landscapes, reduce uncertainty, and improve coordinated work to achieve spotted owl recovery.

- ***Recovery Action 17: In Washington, areas currently managed for spotted owls should be designated as CSAs.*** These CSAs are based on existing Spotted Owl Special Emphasis Areas (SOSEAs) designated by the Washington Forest Practices Board. The management provisions for these areas will provide valuable habitat for territorial pairs and connectivity between Federal habitat blocks.

- ***Recovery Action 18: In Oregon, encourage development of dispersal habitat and habitat for spotted owl demographic support in CSAs.*** The three mapped and two unmapped CSAs provide a mix of demographic or dispersal support.
- ***Recovery Action 19: In California CSAs, encourage the continued provision of habitat to support reproducing pairs of spotted owls.*** There are five different types of CSAs in California: State and county parks, private land HCPs, Department of Defense, State demonstration forest, and a potential private land HCP.

Listing Factor B: Overutilization for commercial, scientific, or educational purposes

There is no known threat to the spotted owl relative to this listing factor, so no Recovery Criteria or Recovery Actions are identified specific to this listing factor.

Listing Factor C: Disease or predation

There is no known imminent threat to the spotted owl from disease or predation, so no Recovery Criteria are identified specific to this listing factor.

Diseases

Sudden oak death. Sudden oak death is a potential threat to spotted owl habitat (Courtney *et al.* 2004). This disease is caused by a non-native, recently introduced, fungus-like pathogen, *Phytopthora ramorum*. This pathogen has killed hundreds of thousands of oak and tanoak trees along the California coast (from southern Humboldt County to Monterrey County) and hundreds of tanoak trees on the southern Oregon coast (southwestern Curry County) (Goheen *et al.* 2006).

According to Goheen *et al.* (2006:1):

> "The pathogen has a wide host range including Douglas-fir, grand fir, coast redwood, and many other tree and shrub species common in Oregon and Washington forests. Tree mortality, branch and shoot dieback, and leaf spots result from infection depending on host species and location. *Phytopthora ramorum* spreads aerially by wind and wind-driven rain and moves within forest canopies and tree tops to stems and shrubs and from understory shrubs to overstory trees. The pathogen survives in infected plant material, litter, soil, and water. It is moved long distances in nursery stock. …State and federal personnel regularly survey forests and nurseries in the Pacific Northwest to detect the disease."

Due to its potential impact on forest dynamics and alteration of key prey and spotted owl habitat components (*e.g.*, hardwood trees, canopy closure, and nest tree mortality), sudden oak death poses a potential threat to spotted owls, especially in the southern portion of the owl's range (Courtney *et al.* 2004).

Avian disease. At this time, no avian diseases are significantly affecting spotted owls. It is unknown whether avian diseases such as West Nile virus (WNV) or avian flu will significantly affect spotted owls. Carrying out the following monitoring action would alert us if any disease becomes a threat.

- ***Recovery Action 20: Monitor for sudden oak death and avian diseases (e.g., WNV, avian flu) and address as necessary.*** Monitoring is necessary to assess the degree to which sudden oak death affects spotted owl habitat and whether any avian disease becomes a threat. If one or more pathogens or diseases pose a threat to spotted owls or their habitat, specific responses would need to be developed and implemented.

Predation

Known predators of spotted owls are limited to great horned owls (Forsman *et al.* 1984), and, possibly, barred owls (Leskiw and Gutiérrez 1998). Other suspected predators include northern goshawks, red-tailed hawks, and other raptors (Courtney *et al.* 2004). Occasional predation of spotted owls by these raptors is not considered to be a threat to spotted owl populations, so no criteria or actions are identified. Recovery Criteria and Actions relative to the threat from barred owls are presented in Listing Factor E.

Listing Factor D: Inadequacy of existing regulatory mechanisms

One of the original reasons for listing the spotted owl was the inadequacy of the applicable regulatory mechanisms as they existed in 1990. Subsequent to the listing of the spotted owl, extensive Federal and State regulations have been promulgated. The Service believes existing regulatory mechanisms do not preclude, and may support, the Recovery Actions identified in this Plan. The actions identified in this Plan are believed needed to achieve recovery. The current existing regulatory framework will not hinder recovery. This conclusion will need to be reassessed if the existing regulatory framework changes.

Listing Factor E: Other natural or manmade factors affecting its continued existence

Barred Owl

The three main threats to the spotted owl are competition from barred owls, past habitat loss, and current habitat loss. Barred owls reportedly have reduced spotted owl site occupancy, reproduction, and survival (see Appendix B). Limited experimental evidence, correlational studies, and copious anecdotal information all strongly suggest barred owls compete with

Because the abundance of barred owls continues to increase, the effectiveness in addressing this threat depends on action as soon as possible.

spotted owls for nesting sites, roosting sites, and food, and possibly predate spotted owls. The threat posed by barred owls to spotted owl recovery is better understood now than when the spotted owl was listed. Because the abundance of barred owls continues to increase, the effectiveness in addressing this threat depends on action as soon as possible.

There are substantial information gaps regarding ecological interactions between spotted owls and barred owls, and how those interactions may be managed to meet Recovery Criteria 1, 2, and 3. Recovery Actions should provide the information needed to identify effective management approaches and guide the implementation of appropriate management strategies. Many of the following actions should be done concurrently. Figure 1 shows how these Actions may inform one another, and Figure 2 shows an approximate timeline for implementation of these Actions. The Service is the primary agent to oversee implementation of any strategy for the management of barred owls.

- ***Recovery Action 21: Establish a work group of entities involved with barred owl research and management (Federal and State agencies, Tribes, timber industry, universities, and non-governmental organizations) to coordinate actions relative to barred owl research, management, monitoring, and public outreach.*** Coordination among all agencies and non-governmental organizations that can contribute to research on ecological interactions between spotted owls and barred owls is needed to prioritize research topics, maximize funding opportunities, minimize redundancies, increase efficiency, identify potential management strategies, and communicate with decision-makers. This Barred Owl Work Group could be facilitated by the NSO Work Group. The Barred Owl Work Group would be involved in guiding or helping conduct the activities shown in the flowchart and timeline.

- ***Recovery Action 22: Analyze existing data sets from the demographic study areas relative to the effects of barred owls on spotted owl site occupancy, reproduction, and survival.*** Data mining of decades of data on barred owls obtained incidentally during spotted owl studies in demographic study areas and density study areas should be done to investigate, to the extent practicable, the effects of barred owls on spotted owl site occupancy, reproduction, and survival.

- ***Recovery Action 23: Establish protocols to detect barred owls and document barred owl site status and reproduction.*** Protocols to detect barred owls and document important population information, including pair status and reproduction, are needed to standardize data collection regarding barred owl presence and population status. Protocols should be developed for areas with and without spotted owls. In areas with spotted owls, it may be cost-effective to modify ongoing spotted owl monitoring procedures to adequately detect barred owls. Surveys should be conducted so they do not increase the likelihood of aggressive encounters between barred owls and spotted owls.

- ***Recovery Action 24: Ensure that protocols adequately detect spotted owls in areas with barred owls.*** The presence of barred owls has been shown to decrease the detectability of spotted owls. Consequently, survey protocols for spotted owls should be evaluated and modified as needed to account for the presence of barred owls.

- ***Recovery Action 25: Analyze resource partitioning of sympatric barred owls and spotted owls.*** Radio-telemetry studies of sympatric spotted and barred owls need to be conducted to: determine how the two species use their habitat and resources, including prey, in various areas; identify characteristics of habitats used by spotted owls in areas with substantial barred owl populations; and determine how habitat use by barred owls and spotted owls changes as barred owl numbers increase.

- ***Recovery Action 26: Create and implement an outreach strategy to educate the public about the threat of barred owls to spotted owls.*** It is crucial that the public be kept informed concerning this difficult aspect of the recovery of the spotted owl. The public needs to be informed of the potential consequences of not addressing this threat. Public outreach could include production and distribution of brochures, kiosk displays, press releases, and public meetings relative to research and management options.

- ***Recovery Action 27: Expedite permitting of experimental removal of barred owls.*** The concern regarding the current and future negative effects of barred owls on the recovery of spotted owls is considerable, and immediate research is needed. State and Federal permitting of scientifically sound research on removal experiments will be necessary to answer the question of the impacts of barred owls on spotted owls.

- ***Recovery Action 28: Identify key spotted owl areas.*** Key spotted owl areas are those areas judged most likely to retain spotted owls for the future, given the current declines. Identification of these areas should be done through an interagency process involving members from the Barred Owl Work Group, NSO Work Group, and Dry-Forest Landscape Work Group. Barred owl control experiments and other efforts (described in other Recovery Actions) should focus on these areas, recognizing additional control/experiment areas will be needed for research purposes.

- ***Recovery Action 29: Design and implement large-scale control experiments in key spotted owl areas to assess the effects of barred owl removal on spotted owl site occupancy, reproduction, and survival.*** Experimental control of barred owls (Buchanan *et al.* 2007) "should provide an unambiguous result regarding the effect of barred owls on spotted owl population declines" (Gutiérrez *et al.* 2007:191), and it is believed control of barred owls would provide local benefits to spotted owls. Given the rapidity and severity of the increasing threat from barred owls, barred owl control in key spotted owl areas should be done as soon as possible. These control efforts should be conducted as well-designed removal experiments that will have the potential to substantially expand our knowledge of the ecological interactions between spotted owls and barred owls. Such studies may identify important cause-and-effect relationships between barred owls and the population declines of spotted owls, as well as the densities at which negative effects from barred owls occur. These densities may vary throughout the spotted owl range. The key areas in which to initiate these experiments and control efforts will be identified per a different Recovery Action. In addition to these key areas, removal experiments should be conducted in various parts of the spotted owl's range, including a wide range of barred owl/spotted owl densities in both managed and unmanaged lands, to provide the most useful scientific information.

- ***Recovery Action 30: Manage the negative effects of barred owls on spotted owls so that Recovery Criteria 1, 2, and 3 can be met.*** Implement the results of research to adaptively manage the effects of barred owls in those areas required to meet Recovery Criteria 1 and 2. Management could include silvicultural treatments for stand structure and composition (*e.g.,* habitat management for spotted owl prey), local or large-scale control of barred owl populations, and/or other activities at present unforeseen but informed by research results.

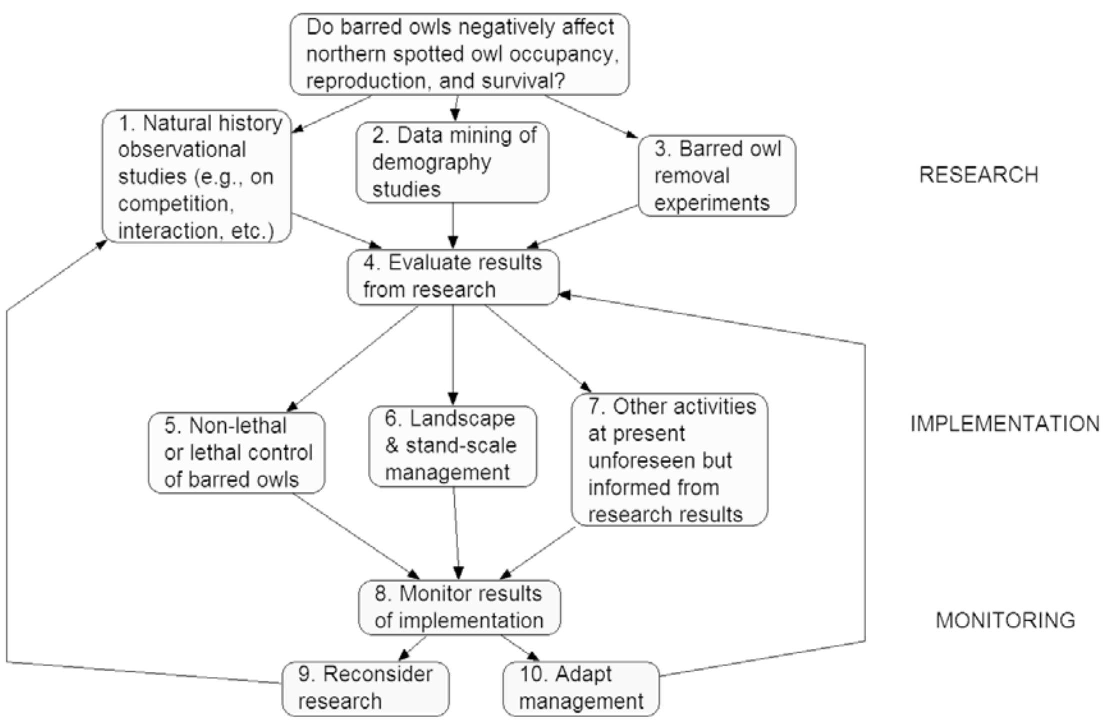


Figure 1. Flowchart of barred owl Recovery Actions.

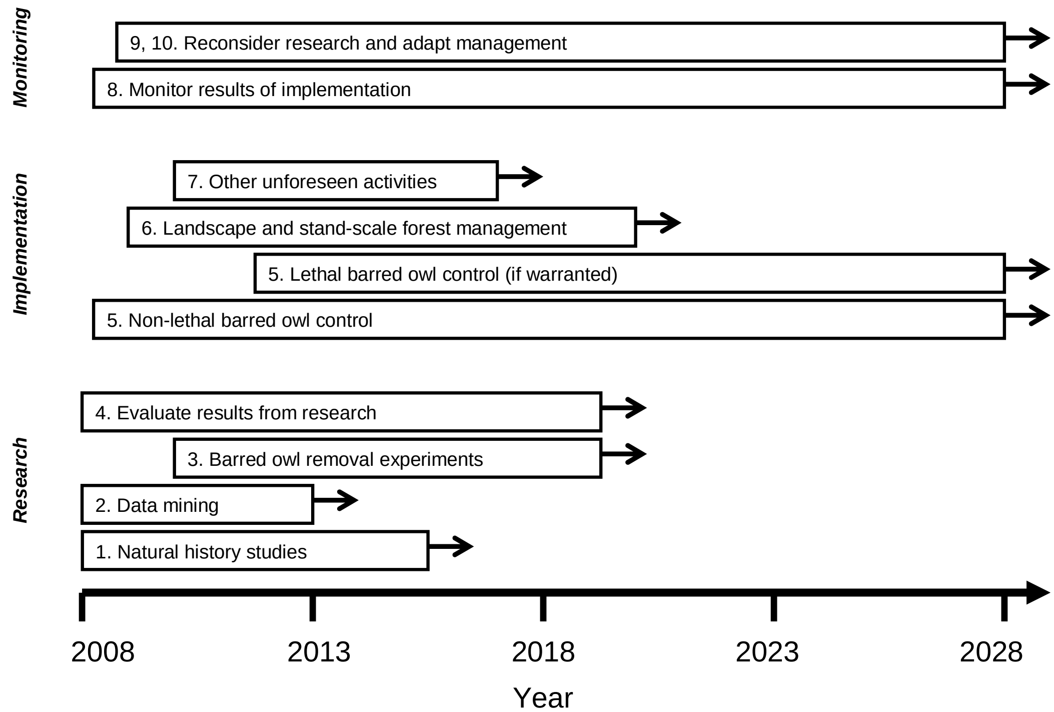


Figure 2. Approximate timeline of barred owl Recovery Actions. Arrows indicate when actions could continue. Numbers in the timeline refer to steps in Figure 1.

Conducting natural history studies (step 1 in Figures 1 and 2) is ongoing. Data mining (step 2) involves evaluating past data sets from demography study areas by adding barred owl covariates to test whether presence of barred owls affected detection rates, occupancy, reproduction, and survival of spotted owls. Many Actions (*e.g.,* data mining, improving detection protocols for both species, outreach, identification of key spotted owl areas) can begin immediately. Preliminary findings from barred owl removal experiments (step 3) could be realized in 1–3 years, whereas estimates of spotted owl vital rates may require more time. Evaluation of results from research (step 4) is ongoing, and includes research already completed. Identification of management strategies should be based on research results, considerations for different geographic areas, costs, and changes in risk-levels to spotted owls over time. This may lead to control of barred owls (step 5) through non-lethal or lethal methods. Non-lethal control could begin soon. If research indicates local or large-scale maintenance control of barred owl populations is needed, then public outreach, coordination among agencies, Migratory Bird Treaty Act permitting, and NEPA compliance would be required. Evaluation of results from research (step 4) also may result in landscape and stand-scale management of spotted owl habitat (step 6) and/or other activities unforeseen at present (step 7).

- ***Recovery Action 31: Develop mechanisms for land-owners and land-managers to support barred owl management using a collaborative process.*** Creating incentives, such as easily implemented Safe Harbor Agreements or Habitat Conservation Plans, can decrease a private landowner's concern or opposition regarding barred owl management that may increase the presence of spotted owls, and the associated issues that come with a listed species under the ESA.

- ***Recovery Action 32: Maintain substantially all of the older and more structurally complex multi-layered conifer forests on Federal lands outside of MOCAs in the Olympic Peninsula, Western Washington Cascades, Western Oregon Cascades, Oregon Coast Range, Oregon and California Klamath, and California Coast Provinces, allowing for other threats, such as fire and insects, to be addressed by restoration management actions. These forests are characterized as having large diameter trees, high amounts of canopy cover, and decadence components such as broken-topped live trees, mistletoe, cavities, large snags, and fallen trees. Encourage maintenance of forests with these conditions on non-Federal lands.*** Maintaining forests with these conditions on Federal lands west of the Cascade crest will provide additional support for reducing key threats faced by spotted owls. Protecting these forests will not further exacerbate competitive interactions between spotted owls and barred owls as would occur if the amount of shared resources were decreased. Maintaining these forests will also support increased spotted owl populations in areas adjacent to MOCAs, and allow time to determine the competitive effects of barred owls on spotted owls and the effectiveness of barred owl control measures.

  Identification of forest stands meeting this Recovery Action will be conducted by the agencies that administer lands with these forest conditions along with technical assistance from the Service. Forest stands meeting the described conditions are a subset of suitable habitat and actual stand conditions vary across the range.

  It is recognized that in order to maintain older, multi-layered forests, especially in the Klamath Provinces of Oregon and California, a broader, non-MOCA management approach will likely be necessary due to the inherent role of fire in these ecosystems. This Recovery Action is expected to change in these provinces when land managers implement a province-scale habitat management strategy (non-MOCA) based upon work to be completed by the Dry-Forest Landscape Workgroup. Federal land managers are encouraged to use their authorities within current land management plans to take actions necessary to sustain owl habitat within MOCAs as well as other high quality spotted owl habitat. Full implementation of the Workgroup's strategy would occur during normally-scheduled land use plan revisions.

An alternative method considered for this action was to protect all occupied spotted owl sites on Federal lands in these Provinces. The recommendation above to protect forests meeting certain conditions is chosen because: (1) these stands include occupied sites, (2) costly pre-project surveys can be avoided, and (3) chances are reduced of modifying sites either temporarily not occupied by spotted owls or actually occupied by spotted owls but not detected (due to presence of barred owls).

Land managers have made significant investments of time and resources in planning projects that may have been developed prior to the approval of this Recovery Plan, thus some forests meeting the described conditions might be harvested (*e.g.,* for timber, fire risk reduction, or restoration). Within that context, for the life of this plan, managers are encouraged to meet the intent to maintain substantially all of the described forests through new project planning and harvest scheduling starting with the finalization of this Plan.

Climate Change

The abundance and distribution of species, including those of the spotted owl, are dynamic relative to a variety of factors including climate. As climate changes, the abundance and distribution of species are expected to change. Many of the current future climate projections for the Pacific Northwest suggest the spotted owl and its habitat probably will be affected by climate change through several pathways, including but not limited to changes in fire regime; patterns of rain and snowfall; wildlife diseases; and abundance and distribution of native and nonnative species of fish, wildlife, and plants. We have begun compiling and reviewing the best-available information on this subject, and we anticipate modifications to our recovery strategy will likely be needed in the next decade.

- ***Recovery Action 33: Assess how climate change may affect spotted owls and their habitat over time, and adjust protection and management of spotted owl habitat relative to these projected changes.***

Recovery Criterion Concerning Post-delisting Monitoring

Recovery Criterion 4: To monitor the continued stability of the recovered spotted owl, a post-delisting monitoring plan has been developed and is ready for implementation with the States of Washington, Oregon, and California (ESA 4(g)(1)).

- ***Recovery Action 34: Develop a post-listing monitoring plan ready for implementation with the States of Washington, Oregon, and California (ESA 4(g)(1)).*** Such a plan is necessary to meet the requirements of the ESA.

IV. Implementation Schedule and Cost Estimates

Recovery plans are intended to assist the Service and other stakeholders in planning and implementing actions to recover or protect threatened or endangered species. The following implementation schedule identifies priority number, duration, potential stakeholders, responsible agencies, and estimated costs for the Recovery Actions described in this Recovery Plan. It is a guide for planning and meeting the objectives discussed in this Plan.

Due to the uncertainties associated with the effects of barred owl interactions with the spotted owl, results from ongoing and new research, and habitat changes that may occur as a result of climate change, the actions needed to stabilize and begin to recover the spotted owl can be forecast, with any degree of reliability, only for the next decade. Even during this relatively short period, the actions needed to address the decline of the spotted owl should be revisited on an annual basis to ensure the highest priority actions remain the highest priority and are being conducted. The Service and other implementers of this plan will have to employ an active adaptive management strategy to achieve results and focus on the most important actions for recovery.

The implementation schedule and cost estimate (Table 2) outlines Recovery Actions and their estimated costs for the first 5 years of this recovery program; total costs are estimated for the entire 30-year period. The costs are broad estimates and identify foreseeable expenditures that could be made to implement the specific Recovery Actions. Actual expenditures by identified agencies and other partners will be contingent upon appropriations and other budgetary constraints.

Total estimated cost for delisting over these 30 years is $489.2 million. Approximately 70 percent of these costs are associated with Recovery Actions to manage the threat of fire on suitable spotted owl habitat. Approximately 8 percent of these costs are associated with assessing the barred owl threat.

The actions identified in the implementation schedule are those that, in our opinion, should bring about the recovery of this species. However, the actions are subject to modification as dictated by new findings, changes in the species' status, and the completion of other Recovery Actions. The priority for each action is assigned as follows:

Priority 1: An action that must be taken to prevent extinction or prevent the species from declining irreversibly in the foreseeable future

Priority 2: An action that must be taken to prevent a significant decline in the species' population/habitat quality or some other significant negative impact short of extinction

Priority 3: All other actions deemed necessary to meet the recovery objectives.

The column "Action Duration" indicates whether the action is one of five types. (1) Discrete actions are shown by the number of years estimated to complete the action. (2) Continuous actions are to be implemented every year once begun. (3) Ongoing actions are currently being implemented and will continue until the action is no longer necessary. (4) Intermittent actions are to be implemented as needed. (5) "TBD" (to be determined) actions are those for which the duration was impossible to estimate.

While the ESA assigns a strong leadership role to the Service for the recovery of listed species, it also recognizes the importance of other Federal agencies, States, and other stakeholders in the recovery process. The "responsible parties" identified in the implementation schedule are those partners who can make significant contributions to specific recovery tasks and who may voluntarily participate in any aspect of Recovery Actions listed. In some cases, the most logical lead agency has been identified with an asterisk. The identification of agencies and other stakeholders in the implementation schedule does not constitute any additional legal responsibilities beyond existing authorities. However, parties willing to participate may benefit by being able to show in their own budgets that their funding request is for a Recovery Action identified in an approved Recovery Plan and is therefore considered a necessary action for the overall coordinated effort to recover the spotted owl. Also, Section 7(a)(1) of the ESA directs all Federal agencies to use their authorities in furtherance of the purposes of the ESA by carrying out programs for the conservation of threatened and endangered species.

We listed the agencies and other parties that we believe are the primary stakeholders in the recovery process, and have the authority, responsibility, or expressed interest to implement a specific Recovery Action. However, the list of possible stakeholders is not limited to the parties below; other stakeholders are invited to participate.

There are five assumptions associated with these cost estimates:

1. Estimates include Federal government reimbursement of travel and per-diem costs of non-governmental employees to participate in Recovery Actions.
2. Responsible parties include both organizations that carry out the activity and organizations that fund the activity.
3. The cost of each Action is estimated independently, unless otherwise noted.
4. The opportunity cost of managing these lands for spotted owls instead of other uses is not included in this analysis.
5. Actions to reduce the risk of high-severity fire or to manage habitat are implemented for multiple reasons, one of which is to support habitat for the spotted owl. It would be inaccurate to attribute the entire cost of fire risk reduction or habitat management to spotted owl recovery. We

estimate 10 percent of the costs associated with fire risk reduction and habitat management can be attributed directly to spotted owl recovery.

For most of the actions identified in this Plan, there is no way of deriving a precise cost estimate. A variety of assumptions were used to produce these estimates. For actions that called for meetings or formation of workgroups, we assumed the cost of meetings based on the current cost of a single Recovery Team meeting. For research and monitoring related actions, current similar research or monitoring projects were used as surrogates to estimate these costs. In some cases, researchers were asked to estimate the cost of a particular study or monitoring program.

Several actions call for habitat alteration to benefit the spotted owl. These comprise two categories: actions calling for modification of existing practices to benefit the spotted owl, and actions calling for specific types of management. For modifications, the cost of adjusting the action during planning was estimated, rather than the actual cost of implementing the project. In these instances, the cost of conducting the ESA Section 7 consultation was used as a surrogate for the cost of modifying an action; this was represented by the estimated cost of a single Level 1 interagency consultation team meeting, under the Streamlined Consultation Procedures. For the actions that call for specific management, actual estimates for conducting a given type of management were used, but the cost attributable to spotted owl recovery was set at 10 percent of this total cost. To complete the estimates for some habitat-related actions, base numbers were obtained using the costs and accomplishments of the FS and BLM within the range of the spotted owl.

Two examples of such estimates follow. Assumptions used to estimate costs for Recovery Action 6 were adapted from estimates made for the East Cascades Province by the Wenatchee National Forest. This Forest estimated treatments were needed on 60,000 acres/year to have the desired effect on fire-risk reduction. Approximately one-third of the work would be done commercially, so the costs associated with that portion of the work would be for planning only. The remaining two-thirds of the cost would be for non-commercial work and would be either by contract or by Forest Service employees. Costs would be approximately:

- 20,000 acres commercial harvest at $150/acre (planning) = $3 million
- 40,000 acres non-commercial harvest at $500/acre = $20 million
- Total for one Province = $23 million/year
- Total for three Provinces = $69 million/year
- 10% percent of total cost attributed to spotted owl recovery = $6.9 million/year.

For Recovery Action 8, we used the same rationale as for Recovery Action 6 except Recovery Action 8 includes only two Provinces and no costs were anticipated the first year because the Dry-Forest Landscape Work Group would need to formulate treatments during 2008.

The costs are broad estimates and identify foreseeable expenditures that could be made to implement the specific Recovery Actions. Actual expenditures by identified agencies and other partners will be contingent upon appropriations and other budgetary constraints. There are no Recovery Actions for Listing Factors B or D.

In Table 2, "Land managers" means non-Federal land managers, "Landowners" means non-Federal landowners, and "States" means State governments of Washington, Oregon, and California.

Table 2. Implementation schedule and cost estimates (following pages).

Action No.	Priority No.	Action Description	Action Duration	Resp. Parties (* = lead)	FY Cost Estimate (in $1,000s)					
					30-yr Total	2008	2009	2010	2011	2012
1	1	Establish Northern Spotted Owl Work Group (NSOWG)	Continuous	FWS	180	6	6	6	6	6
2	3	Monitor population trend	Ongoing	FWS, FS, BLM*, NPS, NSOWG	69,000	2,300	2,300	2,300	2,300	2,300
3	3	Monitor occupancy	Start TBD, intermittent thereafter	NSOWG	5,000	0	0	0	0	0
Listing Factor A: The present or threatened destruction, modification, or curtailment of the species' habitat or range										
4	1	Establish MOCAs	Continuous	FWS, BLM, FS	0	0	0	0	0	0
5	1	West side: Manage MOCAs for highest amount and quality habitat	Continuous	FS, BLM, FWS	0	0	0	0	0	0
6	1	East-side: Maintain areas in high-quality habitat	Continuous	DFLWG, FS	207,000	6,900	6,900	6,900	6,900	6,900
7	1	East-side: Manage to reduce habitat losses by fire (costs included in Recovery Action 6)	Continuous	DFLWG	in RA 6	in RA 6	in RA 6	in RA 6	in RA 6	in RA 6
8	1	Klamath: Manage for more fire-resilient and fire-resistant forests	Continuous	DFLWG,FS,BLM	133,400	0	4,600	4,600	4,600	4,600
9	1	Establish Dry Forest Landscape Work Group (DFLWG)	Continuous	FWS	186	12	6	6	6	6
10	2	Post-fire habitat modifications focused on restoration	Continuous	DFLWG,FS,BLM	NA	NA	NA	NA	NA	NA
11	3	Design and conduct experiments concerning habitat and spotted owl fitness	Continuous	FS, BLM, FWS, NPS, WDNR, ODF, CDF, CDFG, landowners	17,750	1,750	1,250	1,250	500	500
12	3	Standardize habitat definitions	2 years	NSOWG	120	60	60	0	0	0

Action No.	Priority No.	Action Description	Action Duration	Resp. Parties (* = lead)	FY Cost Estimate (in $1,000s)					
					30-yr Total	2008	2009	2010	2011	2012
13	3	Develop HCPs and SHAs that are consistent with spotted owl recovery	Continuous	FWS	8,000	400	400	400	400	400
14	3	Establish incentives program	Continuous	FWS	6,000	200	200	200	200	200
15	3	Streamline HCP and SHA process	3 years	FWS	90	30	30	30	0	0
16	3	Recognize designated CSAs in Washington	1 year	WFPB*, landowners, land managers	6	6	0	0	0	0
17	3	Washington: Create measurable habitat objectives for CSAs	2 years	WFPB, WDNR, land managers, landowners	20	10	10	0	0	0
18	3	Oregon: Encourage development of dispersal habitat in CSAs to allow movement among MOCAs	Continuous	ODF*, FS, BLM, landowner	300	10	10	10	10	10
19	3	California: Encourage provision of habitat to support reproducing spotted owls	Continuous	CDF*, CDP&R, Army Corps of Engin., CDFG, Marin Water Dist, landowners	300	10	10	10	10	10
Listing Factor C: Disease or predation										
20	3	Monitor and address diseases	Continuous	NSOWG	300	10	10	10	10	10
Listing Factor E: Other natural or manmade factors affecting its continued existence										
21	1	Establish Barred Owl Work Group (BOWG)	Continuous	FWS	186	12	6	6	6	6
22	2	Analyze existing data sets for effects of barred owls	5 years	BOWG*, FWS, FS, BLM, NPS	250	50	50	50	50	50
23	2	Establish protocols to detect barred owls	Continuous	BOWG*, FWS, FS, BLM, NPS	225	75	75	75	0	0

Action No.	Priority No.	Action Description	Action Duration	Resp. Parties (* = lead)	FY Cost Estimate (in $1,000s)					
					30-yr Total	2008	2009	2010	2011	2012
24	3	Ensure protocols adequately detect spotted owls	2 years	BOWG*, FWS, BLM, FS, NPS, States, landowners	200	100	100	0	0	0
25	2	Analyze resource partitioning	5 years	BOWG*, USGS, FS, FWS, NPS, BLM	1,820	190	510	440	440	120
26	2	Implement public outreach strategy	Continuous	BOWG*, FWS	48	15	5	1	1	1
27	1	Expedite permitting of experimental removals	1 year	FWS, States	6	6	0	0	0	0
28	1	Define key NSO areas	1 year	BOWG,* NSOWG, DFLWG	50	50	0	0	0	0
29	1	Conduct experimental removal studies	10 years	BOWG*, TBD	3,000	600	600	600	600	600
30	1	Manage negative effects of barred owls	Start time TBD, continuous once started	BOWG*, FS, BLM, NPS, States, FWS, landowners	35,400	1,180	1,180	1,180	1,180	1,180
31	2	Develop mechanisms so there is not an incentive to oppose barred owl management	2 years to create; implementation continuous once created	BOWG*, FWS, FS, BLM, NPS, States, landowners	12	6	6	0	0	0
32	2	Maintain high-quality habitat outside of MOCAs	Continuous	FWS, BLM, FS	0	0	0	0	0	0
33	3	Assess effects from climate change	Continuous	FWS	300	10	10	10	10	10
34	3	Develop delisting monitoring plan	TBD	FWS	10	0	0	0	0	0
Total for all actions for 30 years: $489.2 million										

Appendix A: Background

This section of the Recovery Plan is designed to provide information necessary to understand the Plan's strategy, goals, objectives, and criteria for the spotted owl. While it is not an exhaustive review, information on the spotted owl's status, basic ecology, demography, and past and current threats is included. Detailed accounts of the taxonomy, ecology, and reproductive characteristics of the spotted owl were presented in the 1987 and 1990 Status Reviews (USFWS 1987, 1990a), 1989 Status Review Supplement (USFWS 1989), Interagency Scientific Committee Report (Thomas *et al.* 1990), Forest Ecosystem Management Assessment Team (FEMAT) Report (USDA *et al.* 1993), final rule designating the spotted owl as a threatened species (USFWS 1990b), scientific evaluation of the status of the spotted owl (Courtney *et al.* 2004), and several key monographs (e.g, Anthony *et al.* 2006 and Forsman *et al.* 2004).

Species Description and Taxonomy

The northern spotted owl is a medium-sized owl and is the largest of the three subspecies of spotted owls (Gutiérrez *et al.* 1995). It is approximately 46 to 48 centimeters (18 inches to 19 inches) long and the sexes are dimorphic, with males averaging about 13 percent smaller than females. The mean mass of 971 males taken during 1,108 captures was 580.4 grams (1.28 pounds) (out of a range 430.0 to 690.0 grams) (0.95 pound to 1.52 pounds), and the mean mass of 874 females taken during 1,016 captures was 664.5 grams (1.46 pounds) (out of a range 490.0 to 885.0 grams) (1.1 pounds to 1.95 pounds) (P. Loschl and E. Forsman 2006 pers. comm.). The northern spotted owl is dark brown with a barred tail and white spots on its head and breast, and it has dark brown eyes surrounded by prominent facial disks. Four age classes can be distinguished on the basis of plumage characteristics (Forsman 1981; Moen *et al.* 1991). The northern spotted owl superficially resembles the barred owl, a species with which it occasionally hybridizes (Kelly and Forsman 2004). Hybrids exhibit physical and vocal characteristics of both species (Hamer *et al.* 1994).

The northern spotted owl is one of three subspecies of spotted owls recognized by the American Ornithologists' Union. The taxonomic separation of these three subspecies is supported by genetic (Barrowclough and Gutiérrez 1990; Barrowclough *et al.* 1999; Haig *et al.* 2004a), morphological (Gutiérrez *et al.* 1995), and biogeographic information (Barrowclough and Gutiérrez 1990). The distribution of the Mexican subspecies (*S. o. lucida*) is separate from those of the northern and California (*S. o. occidentalis*) subspecies (Gutiérrez *et al.* 1995). Recent studies analyzing mitochondrial DNA sequences (Haig *et al.* 2004a; Chi *et al.* 2005; Barrowclough *et al.* 2005) and microsatellites (Henke *et al.* 2005) confirmed the validity of the current subspecies designations for northern and California spotted owls. The narrow hybrid zone between these two subspecies, which is located in the southern Cascades and northern Sierra Nevadas, appears to be stable (Barrowclough *et al.* 2005).

Population Trends and Distribution

There are no estimates of the size of the spotted owl population prior to settlement by Europeans. Spotted owls are believed to have inhabited most old-growth forests or stands throughout the Pacific Northwest, including northwestern California, prior to beginning of modern settlement in the mid-1800s (USFWS 1989).

The current range of the spotted owl extends from southwest British Columbia through the Cascade Mountains, coastal ranges, and intervening forested lands in Washington, Oregon, and California, as far south as Marin County (USFWS 1990b). The range of the spotted owl is partitioned into 12 physiographic Provinces (Figure A1) based on recognized landscape subdivisions exhibiting different physical and environmental features (Thomas *et al.* 1993). These Provinces are distributed across the species' range as follows:

- Four Provinces in Washington: Eastern Washington Cascades, Olympic Peninsula, Western Washington Cascades, Western Washington Lowlands
- Five Provinces in Oregon: Oregon Coast Range, Willamette Valley, Western Oregon Cascades, Eastern Oregon Cascades, Oregon Klamath
- Three Provinces in California: California Coast, California Klamath, California Cascades

The spotted owl has become rare in certain areas, such as British Columbia, southwestern Washington, and the northern coastal ranges of Oregon.

As of July 1, 1994, there were 5,431 known site-centers of spotted owl pairs or resident singles: 851 sites (16 percent) in Washington, 2,893 sites (53 percent) in Oregon, and 1,687 sites (31 percent) in California (USFWS 1995). By June 2004, the number of territorial spotted owl sites recognized by Washington Department of Fish and Wildlife was 1,044 (Buchanan and Swedeen 2005). The actual number of currently occupied spotted owl locations across the range is unknown because not all areas have been or can be surveyed on an annual basis (USFWS 1992a; Thomas *et al.* 1993). In addition, many historical sites are no longer occupied because spotted owls have been displaced by barred owls, timber harvest, or severe fires, and it is possible that some new sites have been established due to recruitment of new areas into suitable habitat since 1994. The totals in USFWS (1995) represent the cumulative number of locations recorded in the three States, not population estimates.

Many historical spotted owl site-centers are no longer occupied because spotted owls have been displaced by barred owls, timber harvest, or fires.

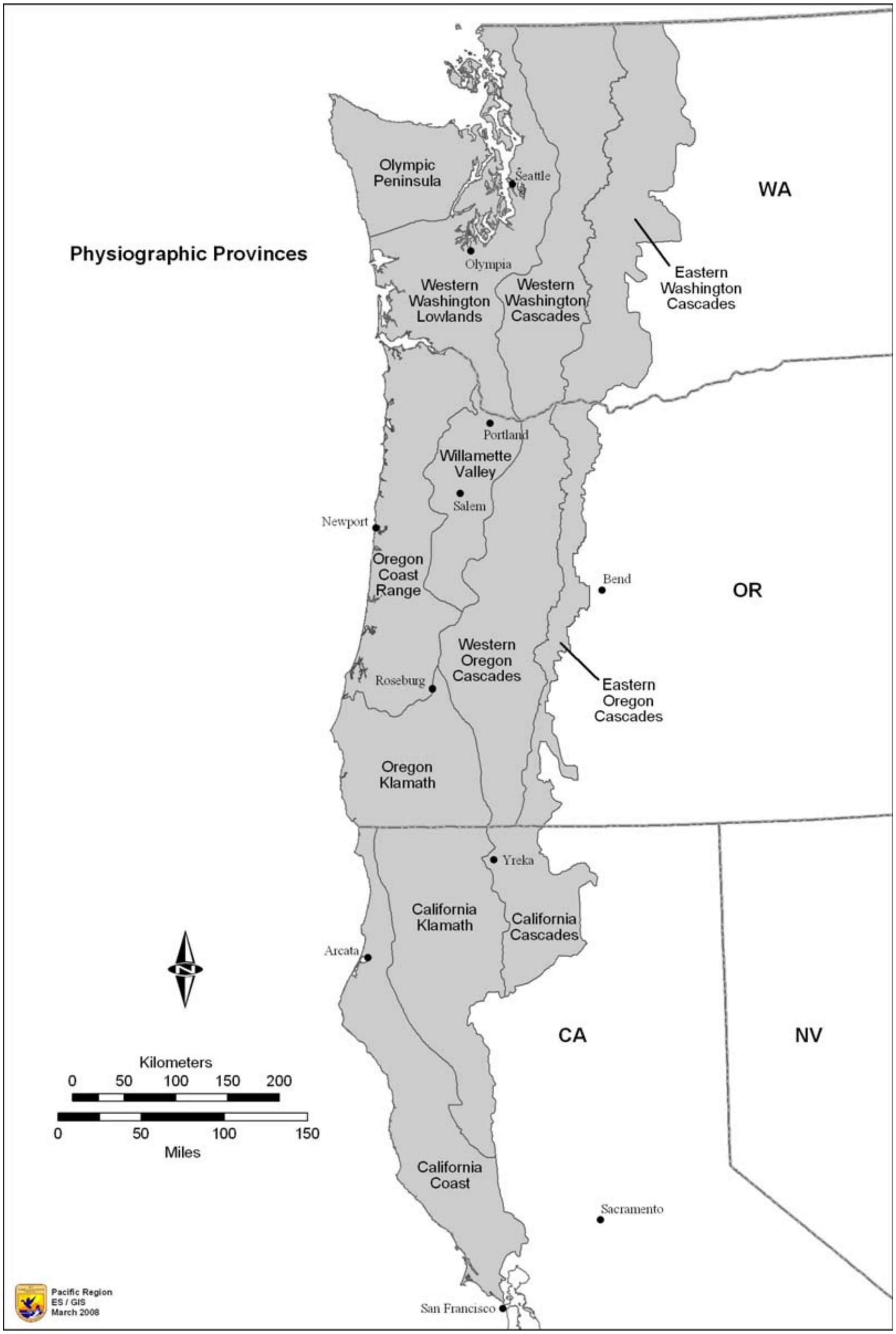


Figure A1. Physiographic Provinces in the range of the spotted owl in the United States.

Because the existing survey coverage and effort are insufficient to produce reliable range-wide estimates of population size, demographic data are used to evaluate trends in spotted owl populations. Analysis of demographic data can provide an estimate of the finite rate of population change (λ), which provides information on the direction and magnitude of population change. A λ of 1.0 indicates a stationary population, meaning the population is neither increasing nor decreasing. A λ of less than 1.0 indicates a decreasing population, and a λ of greater than 1.0 indicates a growing population. Demographic data, derived from studies initiated as early as 1985, have been analyzed periodically (Anderson and Burnham 1992; Burnham *et al.* 1994: Forsman *et al.* 1996; Anthony *et al.* 2006) to estimate trends in the populations of the spotted owl.

In January 2004, two meta-analyses modeled rates of population change for up to 18 years using the re-parameterized Jolly-Seber method (λ_{RJS}). One meta-analysis modeled all 13 long-term study areas excluding the Marin study area (Table A1), while the other modeled the eight study areas that are part of the effectiveness monitoring program of the NWFP (Anthony *et al.* 2006). Data were analyzed separately for individual study areas, as well as across all study areas in a meta-analysis.

Point estimates of λ_{RJS} ranged from 0.896 to 1.005 for the 13 long-term study areas, and in all study areas but one—the Tyee study area—these estimates were less than 1.0 (Anthony *et al.* 2006). There was strong evidence that populations in the Wenatchee, Cle Elum, Warm Springs, and Simpson study areas decreased during the period of study. There also was evidence that populations in the Rainier, Olympic, Oregon Coast Range, and HJ Andrews study areas were decreasing. The precision of the λ_{RJS} estimates for Rainier and Olympic study areas was poor and not sufficient to detect a statistically significant difference from 1.00; however, the estimate of λ_{RJS} for the Rainier study area (0.896) was the lowest of all of the areas. Populations in the Tyee, Klamath, South Oregon Cascades, Northwest California, and Hoopa study areas appeared to be stationary during the study, but there was some evidence that the spotted owl population in the Northwest California study area was decreasing (λ_{RJS} = 0.959 to 1.011).

Demographic data suggest that populations over the 13 long-term demographic study areas decreased by about 3.7 percent from 1985 to 2003.

The weighted mean λ_{RJS} for all of the study areas was 0.963 (standard error [SE] = 0.009, 95 percent confidence interval [CI] = 0.945 to 0.981), suggesting that populations over all of the study areas decreased by about 3.7 percent per year from 1985 to 2003. Anthony *et al.* (2006) explains that the indication populations were declining was based on the fact that the 95 percent confidence intervals around the estimate of mean lambda did not overlap 1.0 (stable) or barely included 1.0.

Table A1. Spotted owl demographic study areas (adapted from Anthony *et al.* 2004).

Area	Fecundity	Survival	λ_{RJS}	Population change
Wenatchee	Declining	Declining	0.917	Declining
Cle Elum	Declining	Declining?	0.938	Declining
Rainier	Stable	Declining	0.896	Declining
Olympic	Stable	Declining	0.956	Declining
Coast Ranges	Declining?	Stable	0.968	Declining
HJ Andrews	Stable?	Stable	0.978	Declining
Warm Springs	Stable	Stable	0.908	Declining
Tyee	Increasing	Stable	1.005	Stationary
Klamath	Stable	Stable	0.997	Stationary
S. Cascades	Declining	Stable	0.974	Stationary
NW California	Declining	Declining	0.985	Declining?
Hoopa	Increasing	Stable	0.98	Stationary
Simpson	Declining	Stable	0.97	Declining
Marin	Stable	Stable	NA	NA

The mean λ_{RJS} for the eight demographic monitoring areas that are part of the effectiveness monitoring program of the NWFP was 0.976 (SE = 0.007, 95 percent CI = 0.962 to 0.990), and the mean λ_{RJS} for the other five study areas was 0.942 (SE = 0.016, 95 percent CI = 0.910 to 0.974), yielding average declines of 2.4 and 5.8 percent per year, respectively. These data suggest that demographic rates for spotted owl populations on Federal lands were better than elsewhere; however, this comparison is confounded by the interspersion of non-Federal land in study areas and the likelihood that spotted owls use habitat on multiple ownerships in some demography study areas.

Decreases in apparent adult survival rates were an important factor contributing to decreasing population trends.

The number of populations that declined and the rate at which they have declined are noteworthy, particularly the precipitous declines in the Wenatchee, Cle Elum, and Rainier study areas in Washington and the Warm Springs study area in Oregon. Estimates of population declines in these areas ranged from 40 to 60 percent during the study period of 1990 to 2003 (Anthony *et al.* 2006). Decreases in apparent adult survival rates were an important factor contributing to decreasing population trends. Survival rates decreased over time in five of the 14 study areas: four study areas in Washington, which showed the sharpest declines, and one study area in the California Klamath Province of northwest California (Anthony *et al.* 2006). In Oregon, there were no time trends in apparent survival for four of six study areas, and remaining areas had weak, non-linear trends. In California, three study areas showed no trend and one showed a significant linear decrease (Anthony *et al.* 2006). Like the trends in annual rate of population change, trends in the rate of adult survival showed clear decreases in some areas but not in others.

There are few spotted owls remaining in British Columbia. Chutter *et al.* (2004) suggested immediate action was required to improve the likelihood of recovering the spotted owl population in British Columbia. So, in 2007, personnel in British Columbia captured and brought into captivity the remaining 16 known wild spotted owls. Prior to initiating the captive-breeding program, the population of spotted owls in Canada was declining by as much as 35 percent per year (Chutter *et al.* 2004). The amount of previous interaction between spotted owls in Canada and the United States is unknown (Chutter *et al.* 2004).

Life History and Ecology

Spotted owls are territorial and usually monogamous. Home-range sizes vary geographically, generally increasing from south to north (USFWS 1990b). Estimates of median size of their annual home range vary from 2,955 acres in the Oregon Cascades (Thomas *et al.* 1990) to 14,211 acres on the Olympic Peninsula (USFWS 1994a). Zabel *et al.* (1995) showed that spotted owl home ranges are larger where flying squirrels are the predominant prey and smaller where wood rats are the predominant prey. Home ranges of adjacent pairs overlap (Forsman *et al.* 1984; Solis and Gutiérrez 1990), suggesting that the defended area is smaller than the area used for foraging. The Service uses a circle of 0.7-mile radius (984 acres) from the activity center to delineate the most heavily used area during the nesting season. The portion of the home range used during the breeding season is smaller than that used in the remainder of the year (Forsman *et al.* 1984; Sisco 1990).

The spotted owl is relatively long-lived, has a long reproductive life span, invests significantly in parental care, and exhibits high adult survivorship relative to other North American owls (Forsman *et al.* 1984; Gutiérrez *et al.* 1995). Spotted owls are sexually mature at 1 year of age, but rarely breed until they are 2 to 5 years of age (Miller *et al.* 1985; Franklin 1992; Forsman *et al.* 2002). Breeding females lay one to four eggs per clutch, with the average clutch size being two eggs; however, most spotted owl pairs do not nest every year, nor are nesting pairs successful every year (USFWS 1990b; Forsman *et al.* 1984; Anthony *et al.* 2006). The small clutch size, temporal variability in nesting success, and delayed onset of breeding all contribute to the relatively low fecundity of this species (Gutiérrez 1996).

The spotted owl is relatively long-lived, has a long reproductive life span, invests significantly in parental care, and exhibits high adult survivorship relative to other North American owls.

Courtship behavior usually begins in February or March, and females typically lay eggs in late March or April. The timing of nesting and fledging varies with latitude and elevation (Forsman *et al.* 1984). After they leave the nest in late May or June, juvenile spotted owls depend on their parents until they are able to fly and hunt on their own. Parental care continues after fledging into September (USFWS 1990b; Forsman *et al.* 1984). During the first few weeks after the young leave the nest, the adults often roost with them during the day. By late summer, the adults are rarely found roosting with their young and usually only visit the juveniles to feed them at night (Forsman *et al.* 1984).

Natal dispersal of spotted owls typically begins in September and October with a few individuals dispersing in November and December (Miller *et al.* 1997; Forsman *et al.* 2002). Natal dispersal occurs in stages, with juveniles settling in temporary locations between periods of more pronounced movement (Forsman *et al.* 2002; Miller *et al.* 1997). The median natal dispersal distance is about 10 miles for males and 15.5 miles for females (Forsman *et al.* 2002). Dispersing juvenile spotted owls experience high mortality rates, exceeding 70 percent in some studies (USFWS 1990b; Miller 1989). Known or suspected causes of mortality during dispersal include starvation, predation, and accidents (Miller 1989; USFWS 1990b; Forsman *et al.* 2002). Parasitic infection may contribute to these causes of mortality, but the relationship between parasite loads and survival is poorly understood (Hoberg *et al.* 1989; Gutiérrez 1989; Forsman *et al.* 2002).

Dispersing juvenile spotted owls experience high mortality rates, exceeding 70 percent in some studies. Known or suspected causes of mortality during dispersal include starvation, predation, and accidents.

Analysis of the genetic structure of spotted owl populations suggests that gene flow may have been adequate between the Olympic Mountains and the Washington Cascades, and between the Olympic Mountains and the Oregon Coast Range (Haig *et al.* 2001). Although telemetry and genetic studies indicate that close inbreeding between siblings or parents and their offspring is rare (Haig *et al.* 2001; Forsman *et al.* 2002), inbreeding between more distant relatives is fairly common (E. Forsman 2006 pers. comm.).

Spotted owls are mostly nocturnal, although they also forage opportunistically during the day (Forsman *et al.* 1984; Sovern *et al.* 1994). The composition of the spotted owl's diet varies geographically and by forest type. Generally, flying squirrels are the most prominent prey for spotted owls in Douglas-fir and western hemlock forests (Forsman *et al.* 1984) in Washington and Oregon, while dusky-footed wood rats are a major part of the diet in the Oregon Klamath, California Klamath, and California Coastal Provinces (Forsman *et al.* 1984, 2001, 2004; Ward *et al.* 1998; Hamer *et al.* 2001). Depending on location, other important prey include deer mice, tree voles, red-backed voles, gophers, snowshoe hare, bushy-tailed wood rats, birds, and insects, although these species comprise a small portion of the spotted owl diet (Forsman *et al.* 1984, 2004; Ward *et al.* 1998; Hamer *et al.* 2001).

Effects to spotted owls from barred owls are described above in Listing Factor E.

Habitat Characteristics

Forsman *et al.* (1984) reported that spotted owls have been observed in the following forest types: Douglas-fir, western hemlock, grand fir, white fir, ponderosa pine, Shasta red fir, mixed evergreen, mixed conifer hardwood (Klamath montane, Marin County), and redwood. In addition, spotted owls in Marin County, California use Bishop pine forests and mixed evergreen-deciduous hardwood forests. The upper elevation limit at which spotted owls occur corresponds to the transition to subalpine forest, which is characterized by relatively simple structure and severe winter weather (Forsman 1975; Forsman *et al.* 1984).

Spotted owls generally rely on older forested habitats (Carroll and Johnson In Press) because such forests contain the structures and characteristics required for nesting, roosting, and foraging. Features that support nesting and roosting typically include a moderate to high canopy closure (60 to 90 percent); a multi-layered, multi-species canopy with large overstory trees (with diameter at breast height [dbh] of greater than 30 inches); a high incidence of large trees with various deformities (large cavities, broken tops, mistletoe infections, and other evidence of decadence); large snags; large accumulations of fallen trees and other woody debris on the ground; and sufficient open space below the canopy for spotted owls to fly (Thomas *et al.* 1990). Forested stands with high canopy closure also provide thermal cover (Weathers *et al.* 2001) and protection from predators.

Foraging habitat generally has attributes similar to those of nesting and roosting habitat, but such habitat may not always support successfully nesting pairs (USFWS 1992b). Dispersal habitat, at a minimum, consists of stands with adequate tree size and canopy closure to provide protection from avian predators and at least minimal foraging opportunities (USFWS 1992b). Forsman *et al.* (2002) found that spotted owls could disperse through highly fragmented forest landscapes, yet the stand-level and landscape-level attributes of forests needed to facilitate successful dispersal have not been thoroughly evaluated (Buchanan 2004). Therefore, a more complete description of dispersal habitat may be determined in the future. There is little evidence that small openings in forest habitat influence the dispersal of spotted owls, but large, non-forested valleys such as the Willamette Valley apparently are barriers to both natal and breeding dispersal (Forsman *et al.* 2002). The degree to which water bodies, such as the Columbia River and Puget Sound, function as barriers to dispersal is unclear, although radio telemetry data indicate that spotted owls move around large water bodies rather than cross them (Forsman *et al.* 2002).

Recent landscape-level analyses in portions of Oregon Coast and California Klamath Provinces suggest that a mosaic of late-successional habitat interspersed with other seral conditions may benefit spotted owls more than large, homogeneous expanses of older forests (Zabel *et al.* 2003; Franklin *et al.* 2000; Meyer *et al.* 1998). In Oregon Klamath and Western Oregon Cascade Provinces, Dugger *et al.* (2005) found that apparent survival and reproduction was positively associated with the proportion of older forest near the territory center (within 730 meters) (2,395 feet). Survival decreased dramatically when the amount of non-habitat (non-forest areas, sapling stands, etc.) exceeded approximately 50 percent of the home range (Dugger *et al.* 2005). The authors concluded they found no support for either a positive or negative direct effect of intermediate-aged forest—that is, all forest stages between sapling and mature, with total canopy cover greater than 40 percent—on either the survival or reproduction of spotted owls. It is unknown how these results were affected by the low habitat fitness potential in their study area, which Dugger *et al.* (2005) stated was generally much lower than those in Franklin *et al.* (2000) and Olson *et al.* (2004), and the low reproductive rate and survival in their study area, which they reported were generally lower than those studied by Anthony *et al.* (2006). Olson *et al.* (2004) found that reproductive rates fluctuated biennially and were positively related to the amount of edge between late-seral and mid-seral forests and other habitat classes in the central Oregon Coast Range. Olson *et al.* (2004) concluded that their results indicate that while mid-seral and late-seral forests are important to spotted owls, a mixture of these forest types with younger forest and non-forest may be best for spotted owl survival and reproduction in their study area.

One study indicated that while mid-seral and late-seral forests are important to spotted owls, a mixture of these forest types with younger forest and non-forest may be best for spotted owl survival and reproduction in certain parts of the range.

While the effects of wildfire on spotted owls and their habitat vary, in the fire-adapted portions of the spotted owl's range, low- to moderate-severity fires may contribute to this mixture of habitats. Bond *et al.* (2002) examined the demography of the three spotted owl subspecies after wildfires, in which wildfire burned through spotted owl nest and roost sites in varying degrees of severity[3]. Post-fire demography parameters for the three subspecies were similar or better than long-term demographic parameters for each of the three subspecies in those same areas (Bond *et al.* 2002). In a preliminary study conducted by Anthony and Andrews (2004) in the Oregon Klamath Province, their sample of spotted owls appeared to be using a variety of habitats within area of the Timbered Rock fire, including areas where burning had been moderate. In 1994, the Hatchery Complex fire burned 17,603 hectares in the Wenatchee National Forest in Washington's eastern Cascades, affecting six spotted owl activity centers (Gaines *et al.* 1997). Spotted owl habitat within a 2.9 1.8 mile of the activity centers was reduced by 8 to 45 percent (mean = 31

[3] Fire severity is defined in several ways. See the individual studies cited for further information on the definitions of fire severity.

percent) as a result of the direct effects of the fire and by 10 to 85 percent (mean = 55 percent) as a result of delayed mortality of fire-damaged trees and insects. Direct mortality of spotted owls was assumed to have occurred at one site, and spotted owls were present at only one of the six sites 1 year after the fire. In 1994, two wildfires burned in the Yakama Indian Reservation in Washington's eastern Cascades, affecting the home ranges of two radio-tagged spotted owls (King *et al.* 1997). Although the amount of home ranges burned was not quantified, spotted owls were observed using areas that burned at low and medium intensities. No direct mortality of spotted owls was observed, even though thick smoke covered several spotted owl site-centers for a week. It appears that, at least in the short term, spotted owls may be resilient to the effects of wildfire—a process with which they have evolved. More research is needed to further understand the relationship between fire and spotted owl habitat use.

It appears that, at least in the short term, spotted owls may be resilient to the effects of wildfire—a process they have evolved with.

Spotted owls may be found in younger forest stands that have the structural characteristics of older forests or retained structural elements from the previous forest. In redwood forests and mixed conifer-hardwood forests along the coast of northwestern California, considerable numbers of spotted owls also occur in younger forest stands, particularly in areas where hardwoods provide a multi-layered structure at an early age (Thomas *et al.* 1990; Diller and Thome 1999). In mixed conifer forests in the eastern Cascades in Washington, 27 percent of nest sites were in old-growth forests, 57 percent were in the understory reinitiation phase of stand development, and 17 percent were in the stem exclusion phase (Buchanan *et al.* 1995). In the western Cascades of Oregon, 50 percent of spotted owl nests were in late-seral/old-growth stands (greater than 80 years old), and none were found in stands of less than 40 years old (Irwin *et al.* 2000).

In the Western Washington Cascades, spotted owls roosted in mature forests dominated by trees greater than 50 centimeters (19.7 inches) dbh with greater than 60 percent canopy closure more often than expected for roosting during the non-breeding season. Spotted owls also used young forest (trees of 20 to 50 centimeters (7.9 inches to 19.7 inches) dbh with greater than 60 percent canopy closure) less often than expected based on this habitat's availability (Herter *et al.* 2002). In the Coast Ranges, Western Oregon Cascades and the Olympic Peninsula, radio-marked spotted owls selected for old-growth and mature forests for foraging and roosting and used young forests less than predicted based on availability (Forsman *et al.* 1984; Carey *et al.* 1990; 1992; Thomas *et al.* 1990). Glenn *et al.* (2004) studied spotted owls in young forests in western Oregon and found little preference among age classes of young forest.

Habitat use also is influenced by prey availability. Ward (1990) found that spotted owls foraged in areas with lower variance in prey densities (that is, where the occurrence of prey was more predictable) within older forests and near ecotones of old forest and brush seral stages. Zabel *et al.* (1995) showed that spotted owl home ranges are larger and smaller where flying squirrels and wood rats, respectively, are the predominant prey.

Critical Habitat

On January 15, 1992, the Service designated critical habitat for the spotted owl within 190 Critical Habitat Units (CHUs), which encompass a total of nearly 6.9 million acres. CHUs total 2.2 million acres in Washington, 3.3 million acres in Oregon, and 1.4 million acres in California (USFWS 1992b). Primary constituent elements of CHUs are the physical and biological features of critical habitat essential to a species' conservation. Primary constituent elements identified in the spotted owl critical habitat final rule include those physical and biological features that support nesting, roosting, foraging, and dispersal (USFWS 1992b).

Spotted owl critical habitat was designated based on the identification of large blocks (the mean size was 41,432 acres) of suitable habitat that were well distributed across the range of the spotted owl, although not all critical habitat acres were or are suitable habitat. CHUs were intended to identify a network of habitats that provided the functions considered important to maintaining stable, self-sustaining, and interconnected populations over the range of the spotted owl, with each CHU having a local, provincial, and range-wide role in spotted owl conservation. Most CHUs were expected to provide suitable habitat for population support, some were designated primarily for connectivity, and others were designated to provide for both population support and connectivity.

Since 1994, the Service has conducted Section 7 consultations under the ESA across the range of the spotted owl on the removal or downgrading of 46,945 acres (0.68 percent) of critical habitat as a result of management-related activities, primarily on Federally managed lands. ("Downgraded" habitat is habitat that is changed from suitable nesting, roosting, or foraging habitat to unsuitable habitat.) The majority of the effects in these consultations—33,008 acres—has been concentrated in the Western Oregon Cascades and Oregon Klamath Provinces. In addition, natural events such as fire and insect outbreaks have resulted in the removal or downgrading of approximately 42,679 acres (0.62 percent) of critical habitat that existed in 1994. In general, fires have had more of a temporal impact to spotted owl critical habitat in the interior Provinces of Washington and California and the southern and interior Provinces of Oregon than in the coastal Provinces. More than 50 percent of the spotted owl critical habitat that was removed or downgraded because of fire can be attributed to the 1999 Megram fire that burned in north-central California and the 2002 Biscuit fire that burned in southwestern Oregon and northern California.

Although some degree of habitat alteration has occurred in most Provinces within the range of the spotted owl since 1994, total effects have been disproportionately distributed. Approximately 97 percent of the effects to critical habitat have been concentrated in six physiographic Provinces (Eastern Washington Cascades, Western Washington Cascades, Oregon Klamath, Eastern Oregon Cascades, Western Oregon Cascades, and California Klamath [USFWS

2006]). While losses were recorded on 1.3 percent of the critical habitat base, habitat conditions on the remaining 98.7 percent continued to improve through forest succession. There is no quantification of the acres that transitioned from one seral stage to another over the 16 years since critical habitat designation. However, it is evident that for the undisturbed portion, tree growth resulted in existing older stands becoming more structurally diverse and younger stands advancing toward the forest condition that will, in the future, make them useful as habitat for the spotted owl.

The Service is in the process of revising critical habitat for the spotted owl.

Conservation Efforts and Regulations

Federal Lands

Since it was signed on April 13, 1994, the NWFP has guided the management of Federal forest lands within the range of the spotted owl (USDA and USDI 1994a, 1994b). The NWFP was designed to protect large blocks of late-successional forest and provide habitat for species that depend on those forests including the spotted owl, as well as to "produce a predictable and sustainable level of timber sales and non timber resources that will not degrade or destroy the environment" (USDA and USDI 1994a). The NWFP included land-use allocations that would provide for population clusters of spotted owls (*i.e.,* demographic support) and maintain connectivity between population clusters. Certain land-use allocations in the plan contribute to supporting population clusters: LSRs, Managed Late-Successional Areas, and Congressionally Reserved Areas. Riparian Reserves, Adaptive Management Areas and Administratively Withdrawn Areas can provide both demographic support and connectivity/dispersal between the larger blocks, but were not necessarily designed for that purpose. Matrix areas were to support timber production while also retaining biological legacy components important to old-growth obligate species that would persist into future managed timber stands.

The NWFP amended the 19 National Forest and seven BLM district LRMPs that guide management of individual national forests and BLM districts across the range of the spotted owl. The LRMPs adopted a set of reserves and standards and guidelines described in the Record of Decision for the NWFP.

The NWFP with its rangewide network of LSRs was adapted from work completed by three previous studies (Thomas *et al.* 2006): the 1990 ISC Report (Thomas *et al.* 1990), the 1991 report for the Conservation of Late-successional Forests and Aquatic Ecosystems (Johnson *et al.* 1991), and the 1993 report of the Scientific Assessment Team (Thomas *et al.* 1993). In addition, the 1992 Draft Recovery Plan for the Northern Spotted Owl (USFWS 1992b) was based on the ISC report.

The FEMAT predicted, based on expert opinion, the spotted owl population would decline in non-reserve lands over time, while the population would stabilize and eventually increase within LSRs as habitat conditions improved over the next 50 to 100 years (USDA *et al.* 1993; USDA and USDI 1994a, 1994b). Based on the results of the first decade of monitoring, Lint (2005) could not determine whether implementation of the NWFP would reverse the spotted owl's declining population trend because not enough time had passed to provide the necessary measure of certainty. However, the results from the first decade of monitoring do not provide any reason to depart from the objective of habitat maintenance and restoration as described in the NWFP and incorporated into LRMPs (Lint 2005; Noon and Blakesley 2006). Bigley and Franklin (2004) suggested that more fuels treatments are needed in east-side forests to preclude large-scale losses of habitat to stand-replacing wildfires. Other stressors that occur in suitable habitat, such as the range expansion of the barred owl (already in action) and infection with WNV (which may or may not occur) may complicate the conservation of the spotted owl. Recent reports about the status of the spotted owl offer few management recommendations to deal with these emerging threats.

Results from the first decade of monitoring do not provide any reason to depart from the objective of habitat maintenance and restoration as described in the NWFP.

Non-Federal Lands

In the report from the ISC (Thomas *et al.* 1990), the draft Recovery Plan (USFWS 1992b), and the report from the FEMAT (USDA *et al.* 1993), it was noted that limited Federal ownership in some areas constrained the ability to form a network of old-forest reserves to meet the conservation needs of the spotted owl. In these areas in particular, non-Federal lands would be important to the range-wide goal of achieving conservation and recovery of the spotted owl. The Service's primary expectations for private lands are for their contributions to demographic support (pair or cluster protection) to Federal lands, or their connectivity with Federal lands. In addition, timber harvest within each State is governed by rules that provide protection of spotted owls or their habitat to varying degrees.

The U.S. Fish and Wildlife Service's primary expectations for private lands are for their contributions to demographic support to Federal lands, or their connectivity with Federal lands.

There are 15 current or completed Habitat Conservation Plans (HCPs) that have incidental take permits issued for spotted owls—eight in Washington, three in Oregon, and four in California. The HCPs range in size from 40 acres to more than 1.6 million acres, although not all acres are included in the mitigation for spotted owls. In total, the HCPs cover approximately 2.9 million acres (9.1 percent) of the 32 million acres of non-Federal forest lands in the range of the spotted owl. The period of time that the HCPs will be in place ranges from 5 to 100 years; however, most of the HCPs are of fairly long duration. While each

HCP is unique, there are several general approaches to mitigation of incidental take:

- Reserves of various sizes, some associated with adjacent Federal reserves
- Forest harvest that maintains or develops suitable habitat
- Forest management that maintains or develops dispersal habitat
- Deferral of harvest near specific sites

Washington. In 1996, the State Forest Practices Board adopted rules (Washington Forest Practices Board 1996) that would contribute to protection of spotted owls on strategic areas of non-Federal lands. Adoption of the rules was based in part on recommendations from a Science Advisory Group that identified important non-Federal lands and recommended roles for those lands in spotted owl conservation (Hanson *et al.* 1993; Buchanan *et al.* 1994). The 1996 rule package was developed by a stakeholder policy group and then reviewed, modified, and approved by the Forest Practices Board (Buchanan and Swedeen 2005). Spotted owl-related HCPs in Washington generally were intended to provide demographic or connectivity support (USFWS 1992b).

Oregon. The Oregon Forest Practices Act provides for protection of 70-acre core areas around sites occupied by an adult pair of spotted owls capable of breeding (as determined by recent protocol surveys), but it does not provide for protection of spotted owl habitat beyond these areas (ODF 2006). The three spotted owl-related HCPs currently in effect cover more than 300,000 acres of non-Federal lands. These HCPs are intended to provide some nesting habitat and connectivity over the next few decades.

California. In 1990, State Forest Practice Rules, which govern timber harvest on private lands, were amended to require surveys for spotted owls in suitable habitat and to provide protection around activity centers (CDF 2001). Under the Forest Practice Rules, no timber harvest plan can be approved if it is likely to result in incidental take of Federally listed species, unless the take is authorized by a Federal HCP. The California Department of Fish and Game initially reviewed all timber harvest plans to ensure that take was not likely to occur; the Service took over that review function in 2000. Several large industrial owners operate under spotted owl management plans that have been reviewed by the FWS and that specify basic measures for spotted owl protection. Four HCPs authorizing take of spotted owls have been approved; these HCPs cover more than 669,000 acres of non-Federal lands. Implementation of these plans is intended to provide for spotted owl demographic and connectivity support to NWFP lands.

Appendix B. Threats

Loss of Habitat

Historical Levels of Old-Growth/Mature Forest and Rates of Loss

In 1990, the Service estimated spotted owl habitat had declined 60 to 88 percent since the early 1800s (USFWS 1990b). This loss, which was concentrated mostly at lower elevations and in the Coast Ranges, was attributed primarily to timber harvest and land-conversion activities, and to a lesser degree to natural perturbations (USFWS 1990a). Davis and Lint (2005) compared the current condition of forests throughout the range of the species to maps from the 1930s and 1940s and found that, in Oregon and Washington, fragmentation of forests had increased substantially; in some physiographic Provinces, the increase was more than five-fold. However, fragmentation in California decreased, which the authors speculate may be due to fire suppression in fire-dependent Provinces (Davis and Lint 2005).

Current Rates of Loss of Suitable Habitat as a Result of Timber Harvest

Until 1990, the annual rate of removal of spotted owl habitat on national forests as a result of logging was approximately 1 percent per year in California and 1.5 percent per year in Oregon and Washington. Anticipated future rates of habitat removal on BLM lands in Oregon at that time were projected to eliminate all suitable habitat on non-protected BLM lands (except the Medford District) within 26 years (USFWS 1990b).

Since 1990, there have been only a few efforts that have produced indices or more direct estimates of trends or change in the amount of suitable habitat for spotted owls. A recent study (Cohen *et al.* 2002) reported landscape-level changes in forest cover across the Pacific Northwest using remote sensing technology. According to the study, there was "a steep decline in harvest rates between the late 1980s and the early 1990s on State and Federal and private industrial forest lands" (Bigley and Franklin 2004:6-11). Not all forested land is necessarily suitable habitat for spotted owls, so the area of forest that is cut does not necessarily equate to the area of spotted owl habitat removed. However, although these estimates of harvest rates do not translate directly to changes in the amount of spotted owl habitat, they do provide some insight into harvest trends since 1980 (Bigley and Franklin 2004).

The trend analysis for habitat of the spotted owl conducted by the Service (USFWS 2004a) and reported in Bigley and Franklin (2004) indicated an overall decline of approximately 2.11 percent in the amount of suitable habitat on Federal lands as a result of range-wide management activities from 1994 to 2003 (Table B1). This rate of loss is lower than the 2.5 percent-per-decade estimate of habitat loss resulting from management activities that was predicted in the NWFP (USDA and USDI 1994a). The majority of management-related habitat loss was in Oregon, which contributed more than 75 percent of the habitat removed range-wide (121,735 acres). In particular, the amount of habitat in the Oregon Klamath Province has declined by 6.8 percent (53,468 acres) since 1994, which represents an average annual rate of 0.76 percent (Table B1). The California Cascades Province, where the amount of habitat has declined by 5.77 percent (5,091 acres, which represents an average annual decline of 0.64 percent), is the only other area that has shown a relatively high rate of habitat loss during the 9 years of record. Because this Province has a smaller habitat baseline, it contributes less to the range-wide rate.

Table B1. Summary of lost habitat acres and percent change in northern spotted owl habitat on Federal lands as a result of management activities from 1994 to 2003 (Bigley and Franklin 2004).

Physiographic Province	Forest Plan Baseline (acres)	Management Changes (acres)	Percent Change	Average Annual Rate of Change
Olympic Peninsula	560,217	-87	-0.02	-0.002
Eastern WA Cascades	706,849	-5,024	-0.71	-0.08
Western WA Cascades	1,112,480	-11,139	-1.00	-0.11
Western WA Lowlands	0	0	0	0
OR Coast Range	516,577	-3,278	-0.63	-0.07
OR Klamath	786,298	-53,468	-6.80	-0.76
Eastern OR Cascades	443,659	-13,867	-3.13	-0.35
Western OR Cascades	2,045,763	-51,122	-2.50	-0.28
Willamette Valley	5,658	0	0	0
CA Coast	51,494	-250	-0.49	-0.05
CA Cascades	88,237	-5,091	-5.77	-0.64
CA Klamath	1,079,866	-12,673	-1.17	-0.13
Range-wide total	7,397,098	-155,999	-2.11	-0.23

Raphael (2006) estimates that approximately 7.5 million acres of spotted owl habitat existed on non-Federal lands within California, Oregon, and Washington in 1994 (Table B2). Cohen *et al.* (2002) reported that, from the early 1970s through the mid-1990s, the harvest rates on private industrial lands were consistently about twice the average rate of harvest on public land. “In the late 1980s and early 1990s the harvest rate was estimated at 2.4 percent per year for private industrial land. An increase in non-industrial private landowner’s harvest rates started in the 1970s when the rate was 0.2 percent per year and continued to increase to the early 1990s when the rate was similar to that of the private industrial lands" (Bigley and Franklin 2004:6-11). Again, these estimates can only be used to infer rates of forest removal on Federal and non-Federal lands and may or may not translate into the same comparisons with respect to habitat loss (*i.e.,* the harvest may not have removed spotted owl habitat). The estimates may also provide some insight into the potential differences in the rates of habitat loss on different land ownerships (Bigley and Franklin 2004). Raphael (2006) estimates that, since 1994, losses of spotted owl habitat from non-Federal timber harvest have far outpaced losses from Federal land, with the range-wide loss at 8.0 percent (12.0 percent in Washington, 10.7 percent in Oregon, and 2.2 percent in California).

Table B2. Estimated amount of spotted owl habitat[1] at the start of the Northwest Forest Plan (baseline) and losses owing to regeneration harvest from 1994 to 2004, by State and ownership (adapted from Raphael 2006).

Land class	Baseline (1994) (thousands of acres)	Harvest (thousands of acres)	Percent change 1994–2004
Federal reserved			
Washington	1964.5	0.4	0.02
Oregon	3002.5	1.6	0.05
California	1754.4	0.9	0.05
Range-wide total	6721.4	2.9	0.04
Federal non-reserved			
Washington	531.4	3.2	0.6
Oregon	1944.4	15.7	0.8
California	1104.8	4.1	0.4
Range-wide total	3580.6	23	0.6
Non-Federal			
Washington	1748.3	209.6	12.0
Oregon	2906.0	310.6	10.6
California	2910.7	63.3	2.2
Range-wide total	7565.0	583.5	7.7
Range-wide total	17,867	609.4	8.34

[1] See Davis and Lint (2005) for methods of defining habitat suitability (HS).

Raphael (2006) conducted a different analysis of habitat loss, this time looking solely at losses due to regeneration harvest. His analysis estimates that nearly 3,000 acres of higher-suitability spotted owl nesting habitat (see Davis and Lint 2005) were harvested on Federal reserved and nearly 26,000 acres of such habitat were harvested on non-reserved lands between 1994 and 2004. This represents less than 1 percent of the over 10 million acres of higher-suitability spotted owl nesting habitat believed to have existed in 1994.

Current Rates of Loss of Suitable Habitat as a Result of Natural Events

Habitat loss resulting from natural events in the 10-year period from 1994 to 2003 was 224,041 acres, which equates to a 3.03 percent decline in available habitat range-wide (USFWS 2004a). Most natural loss of habitat resulted from wildfires (75% of natural event losses), followed by insects and disease (25%). Very little loss from wind throw was reported (Table B3).

Table B3. Federal habitat lost resulting from natural disturbances from 1994 to 2002 (acres).

Physiographic Provinces	Fire	Wind	Insects and disease	Provincial total	Percent change	Annual rate of change
Olympic Peninsula	-299			-299	-0.05	-0.01
Eastern WA Cascades	-5,754			-5,754	-0.81	-0.09
Western WA Cascades			-250	-250	-0.02	-0.002
Western WA Lowlands				0	0	0
OR Coast Range	-66			-66	-0.01	0
OR Klamath	-117,622			-117,622	-14.96	-1.66
Eastern OR Cascades	-4,008		-55,000	-59,008	-13.30	-1.48
Western OR Cascades	-24,583			-24,583	-1.20	-0.13
Willamette Valley				0	0	0
CA Coast	-100			-100	-0.19	-0.02
CA Cascades				0	0	0
CA Klamath	-15,869	-100	-390	-16,359	-1.51	-0.17
Range-wide total	-168,301	-100	-55,640	-224,041	-3.03	-0.34

The effects of wildfire on spotted owls and their habitat vary by location and by fire intensity. Low-severity fires often result in habitat mosaics improving spotted owl habitat, while high-severity fires commonly result in the loss of spotted owl habitat. Mixed-severity fires vary in their impact to spotted owl habitat and may result in delayed mortality of trees, making impacts difficult to determine until well after the fire is over (USFWS 2004a).

Seventy different fires contributed to the loss of habitat as a result of natural disturbances, with the amount of loss from individual fires ranging from 66 to 113,667 acres. Only 14 of 70 fires resulted in losses of suitable nesting and roosting habitat that exceeded 1,000 acres. In general, the Oregon Klamath Province suffered the highest losses of habitat from natural events, all of which were due to wildfire. Ninety-six percent of habitat loss in this Province can be attributed to the Biscuit fire that burned approximately 113,667 acres of habitat on three administrative units of the Rogue River basin in 2002 (USFWS 2004a).

Information on the loss of spotted owl habitat as a result of natural disturbances on non-Federal lands was not available.

Habitat Recruitment

As with habitat loss, development of suitable habitat contributes to overall trends in habitat availability and distribution. Estimates of late-successional habitat development were calculated at the regional scale using a modeled projection approach (USDA *et al.* 1993; USFWS 2004a). This approach estimated 600,000 acres of in-growth per decade on Federal lands, representing about an 8 percent decadal increase in forest over 80 years of age on Federal lands relative to the NWFP baseline. In reality, projecting the transition of a forest's age and size classes to different levels of habitat function requires extensive field verification. Estimates of late-successional habitat development are approximations to be used on range-wide scales. Given the uncertainty about the rate of complex forest structure development in the stands older than 80 years, it is likely that habitat development was overestimated, although the extent of overestimation cannot be determined (Bigley and Franklin 2004).

This approach estimated 600,000 acres of in-growth per decade on Federal lands, representing about an 8 percent decadal increase in forest over 80 years of age on Federal lands relative to the NWFP baseline.

Moeur *et al.* (2005) measured the rate of forest stand change in medium and large older-forest classes (defined as containing trees at least 20 inches dbh) on BLM, USDA Forest Service, and National Park Service lands during the first decade following adoption of the NWFP. They estimated the net change in these types of forests (which includes the loss of these forest classes to regeneration harvest and stand-replacing fires) as a gain of 1.25 to 1.5 million acres.

Comparison of Current Rates of Habitat Loss Resulting from Management Activities to Rates in 1990

Average annual rates of the harvest of spotted owl habitat on Federal lands have declined substantially since 1990 (Table B4). Harvest rates on national forests in Oregon and Washington dropped from 1.5 percent (64,000 acres) per year at the time of listing to an average of 0.21 percent (10,341 acres) per year from 1994 to 2003. Harvest rates for spotted owl habitat on national forests in California dropped from 0.6 percent per year (calculated at approximately 4,700 acres) to an average of 0.14 percent (1,653 acres) per year. Harvest rates for spotted owl habitat on BLM lands in Oregon dropped from 3 percent (22,000 acres) per year in 1990 to 0.52 percent (4,911 acres) per year in 2003 (Table B4).

Table B4. Comparison of estimates of the amount of spotted owl habitat annually harvested on lands in the 10-year period prior to the listing of the northern spotted owl with the anticipated and actual rates of harvest of spotted owl habitat after the listing of the spotted owl. Values represent acres, with the average annual percentage in parentheses.

Management Agency and State	Final Listing Document[1]		5-Year Review[2]
	Pre-Listing Period (about 1981 to 1990)[3]	Anticipated Rates (about 1991 to 2000)[4]	Calculated Rates[5] (1994 to 2003)
Forest Service in WA and OR	64,000 (1.5)	39,400 (1)	10,341 (0.21)
Forest Service in CA	Not reported[6]	4,700 (0.6)	1,653 (0.14)
Bureau of Land Management in OR	22,000 (3)	23,400 (3)	4,911 (0.52)
	Total	67,500 (1)	16,905 (0.24)

[1] Habitat change values were presented in the listing document in units of acres per year, rather than as a percentage of total available habitat per year. We converted these values to annual percentage rates by dividing by the habitat amount in the Northwest Forest Plan's baseline for each management agency and geographic group and multiplying by 100. Annual percentages in parentheses indicate negative changes.
[2] USFWS (2004b).
[3] Reported in USFWS (1990b) as observed trends from 1981 to 1990.
[4] Estimated in USFWS (1990b) as trends expected in the next decade (1991 to 2001).
[5] Annual acreage totals calculated as the sum of effects from 1994 to 2003 divided by 9 years of record. Annual percentage rates calculated as described above.
[6] The listing document references a rate of 12,000 acres of habitat loss per year in California, but it was unclear what time period this rate represented so it was not included here.

Disease

WNV has killed millions of wild birds in North America since it arrived in 1999 (McLean *et al.* 2001; Fitzgerald *et al.* 2003; Caffrey 2003; Marra *et al.* 2004). Although birds are the primary hosts of WNV, mosquitoes are the primary carriers of this virus that causes encephalitis in humans, horses, and birds. Mammalian prey may play a role in spreading WNV, if predators like spotted owls contract the disease by eating infected prey (Garmendia *et al.* 2000; Komar *et al.* 2001). One captive spotted owl in Ontario, Canada, is known to have contracted WNV and died (Gancz *et al.* 2004), but there are no documented cases of the virus in wild spotted owls.

Health officials expect that WNV eventually will spread throughout the range of the spotted owl (Blakesley *et al.* 2004), but it is unknown how the virus will ultimately affect spotted owl populations. Susceptibility to infection and the mortality rates of infected individuals vary among bird species (Blakesley *et al.* 2004), but most owls appear to be quite susceptible. For example, eastern screech-owls breeding in Ohio that were exposed to WNV experienced 100 percent mortality (T. Grubb pers. comm. in Blakesley *et al.* 2004). Barred owls, in contrast, showed lower susceptibility (B. Hunter pers. comm. in Blakesley *et al.* 2004). Wild birds may develop resistance to WNV through immune responses (Deubel *et al.* 2001).

Blakesley *et al.* (2004) offer competing scenarios for the likely outcome of spotted owl populations being infected by WNV. One scenario is that spotted owls can tolerate severe, short-term population reductions caused by the virus because spotted owl populations are widely distributed and number in the several thousands. An alternative scenario is that the virus will cause unsustainable mortality because of the frequency and/or magnitude of infection, thereby resulting in long-term population declines and extirpation from parts of the spotted owl's current range.

Inadequacy of Regulatory Mechanisms

The original listing document (USFWS 1990b), Franklin and Courtney (2004), and the 5-year review (USFWS 2004b) noted some inadequacies in existing regulatory mechanisms. The 1990 listing rule concluded that current State regulations and policies did not provide adequate protection for spotted owls; less than 1 percent of the non-Federal lands provided long-term protection for spotted owls (USFWS 1990b). The listing rule stated that the rate of harvest on Federal lands, the limited amount of permanently reserved habitat, and the management of spotted owls based on a network of individually protected spotted owl sites did not provide adequate protection for the spotted owl. If continued, these management practices would result in an estimated 60 percent decline in the remaining spotted owl habitat, and the resulting amount of habitat might not be sufficient to ensure long-term viability of the spotted owl.

When it was adopted in 1994, the NWFP significantly altered management of Federal lands (USDA and USDI 1994a, 1994b; Noon and Blakesley 2006; Thomas *et al.* 2006). The substantial increase in reserved areas and associated reduced harvest (ranging from approximately 1 percent per year to 0.24 percent per year) has substantially lowered the timber-harvest threat to spotted owls. However, the NWFP allows some loss of habitat and assumed some unspecified level of continued decline in spotted owls. Franklin and Courtney (2004) noted that many, but not all, of the scientific building blocks of the NWFP have been confirmed or validated in the decade since the plan was adopted. One major limitation appears to be the inability of the reserve strategy presented in the plan to deal with invasive species. However, this deficiency does not diminish the important contribution of the relevant LRMPs to spotted owl conservation (Franklin and Courtney 2004).

As the Federal agencies develop new LRMPs, they will consider the conservation needs of the northern spotted owl and the goals and objectives of the Recovery Plan. If needed, actions to implement Federal land use plans will be accompanied with either plan or project level consultations to assure management actions align with recovery goals.

Barred Owls

With its recent expansion to as far south as Marin County, California (Gutiérrez *et al.* 2004), the barred owl's range now completely overlaps that of their slightly smaller congener, the northern spotted owl. To what extent the barred owl range expansion is a result of humans altering the environment is unknown (Monahan and Hijmans 2007; Livezey *et al.* 2008). Barred owls appear to be competing with spotted owls for prey (Hamer *et al.* 2001) and habitat (Hamer *et al.* 1989, 2007; Dunbar *et al.* 1991; Herter and Hicks 2000; Pearson and Livezey 2003, 2007). In addition, barred owls have been observed physically attacking spotted owls (pers. comm's in Pearson and Livezey 2003) and circumstantial evidence indicated that a barred owl killed a spotted owl (Leskiw and Gutiérrez 1998).

Barred owls were thought by some to be more closely associated with early successional forests than spotted owls are, based on studies conducted on the west slope of the Cascades in Washington (Hamer 1988; Iverson 1993). However, barred owls throughout North America use, and in some cases, prefer older forest (Pearson and Livezey 2003; Gremel 2005; Schmidt 2006; Hamer *et al.* 2007; Livezey 2007).

The only study comparing food habits of sympatric spotted and barred owls reported that the diets of these two species overlapped by 76 percent (Hamer *et al.* 2001). However, barred owl diets (Livezey 2007; Livezey *et al.* In Press) are more diverse than spotted owl diets (Forsman *et al.* 2004) and include more species associated with riparian and other moist habitats, along with more terrestrial and diurnal species (Hamer *et al.* 2001). The more-diverse food habits of barred owls appears to be the reason that barred owls have much smaller home-ranges than spotted owls do (Hamer *et al.* 2007). Gutiérrez *et al.* (2007:189) stated: "We predict that the barred owl will have negative impacts on the threatened spotted owl through competitive exclusion. …Dietary relationships suggest that interference competition would…be the mode of this relationship."

Barred owls reportedly have reduced detectability (response behavior), site occupancy, reproduction, and survival of spotted owls.

- In Washington, Oregon, and California, Olson *et al.* (2005) and Crozier *et al.* (2006) found that the presence of barred owls significantly reduced the detectability of spotted owls during surveys.
- In Washington and Oregon, Kelly *et al.* (2003:51) reported that the occupancy of historical territories by spotted owls was significantly lower after barred owls were detected within 0.5 miles of the territory center but was "only marginally lower" if barred owls were located more than 0.5 miles from the spotted owl territory center. In Gifford Pinchot National Forest, Pearson and Livezey (2003) found there were significantly more barred owl site-centers in unoccupied spotted owl circles than in occupied spotted owl circles with radii of 0.5 miles, 1 mile, and 1.8 miles. In Olympic National Park, Gremel (2005) found a significant decline in spotted owl pair occupancy at sites where barred owls had been detected,

while pair occupancy remained stable at spotted owl sites without barred owls. In some areas at least, barred owls appear to be appropriating spotted owl sites in flatter, lower-elevation forests (Pearson and Livezey 2003, Gremel 2005, Hamer *et al.* 2007) and individual spotted owls, apparently in response to barred owls, have moved higher up slopes (Gremel 2005). According to one study, "the trade-off for living in high elevation forests could be reduced survival or fecundity in years with severe winters" (Hamer *et al.* 2007:764). In addition, In Washington State at least, NWFP reserves typically include large percentages of forests in flatter, lower-elevation areas, and these areas are supporting many barred owls. For example, throughout one Ranger District of the Gifford Pinchot National Forest in 2006, there were 34 percent more barred owl sites (n = 94) than spotted owl sites (n = 70) in reserves set aside by the NWFP, whereas in non-reserves there were 33 percent more spotted owl sites (n = 79) than barred owl sites (n = 53; Pearson and Livezey 2007). It is unknown: whether this slope/elevation tendency found in two study areas in Washington is prevalent throughout the range of the spotted owl, how long spotted owls can persist in landscapes where they are relegated to only steep, higher-elevation areas, and whether barred owls will continue to move upslope and eventually supplant the remaining spotted owls in these areas. Olson *et al.* (2005) found that the annual probability that a spotted owl territory would be occupied by a pair of spotted owls after barred owls were detected at the site declined by 5 percent in the HJ Andrews study area, 12 percent in the Coast Range study area, and 15 percent in the Tyee study area.

- In the Roseburg study area located in the central Coast Range of Oregon, Olson *et al.* (2004) found the presence of barred owls had a significant negative effect on the reproduction of spotted owls.
- In two of 14 study areas (Olympic and Wenatchee), Anthony *et al.* (2006) found evidence for negative effects of barred owls on apparent survival of spotted owls. They attributed the equivocal results for most of their study areas to the coarse nature of their barred owl covariate. It is likely that this study underestimated the effects of barred owls on the reproduction of spotted owls because spotted owls often cannot be relocated after they are displaced by barred owls (E. Forsman 2006 pers. comm.). The conclusion by Iverson (2004) that barred owls had no significant effect on the reproduction of spotted owls in one study in the western Washington Cascades was unfounded because of small sample sizes (Livezey 2005).

In a recent analysis of more than 9,000 banded spotted owls throughout their range, only 47 spotted owl/barred owl hybrids were detected (Kelly and Forsman 2004). Consequently, hybridization with the barred owl is considered to be "an interesting biological phenomenon that is probably inconsequential, compared with the real threat—direct competition between the two species for food and space" (Kelly and Forsman 2004:808). However, at very small population sizes, hybridization between the two owl species could be come a significant issue.

Data indicating negative effects of barred owls on spotted owls are largely correlational and are almost exclusively gathered incidentally to data collected on spotted owls (Gutiérrez *et al.* 2004; Livezey and Fleming 2007). Because there has been no research to quantitatively evaluate the strength of different types of competitive interactions, such as resource partitioning and competitive interference, the particular mechanism by which the two owl species appear to be competing is not known. Competition theory predicts that barred owls will compete with spotted owls because they are similar in size and have overlapping diet and habitat requirements (Hamer *et al.* 2001, 2007; Gutiérrez *et al.* 2007). Limited experimental evidence (Olson *et al.* 2005; Crozier *et al.* 2006), an experiment controlling barred owls (L. Diller pers. comm.), correlational studies (Kelly *et al.* 2003; Pearson and Livezey 2003; Gremel 2005; Olson *et al.* 2005), and copious anecdotal information (Leskiw and Gutiérrez 1998; Gutiérrez *et al.* 2004) all strongly suggest competition through reduction of site occupancy by spotted owls, interference competition, and possible predation. The preponderance of evidence suggests barred owls are exacerbating the spotted owl population decline, particularly in Washington, portions of Oregon, and the northern coast of California (Gutiérrez *et al.* 2004; Olson *et al.* 2005). Although there are few efforts designed to track trends in barred owl abundance, there is no evidence that the increasing trend in barred owls has stabilized in any portion of the spotted owl's range (*e.g.*, Pearson and Livezey 2007; Herter *et al.* 2008), and "there are no grounds for optimistic views suggesting that barred owl impacts on northern spotted owls have been already fully realized" (Gutiérrez *et al.* 2004:7-38).

Loss of Genetic Variation

One possible threat to northern spotted owls is a loss of genetic variation from population bottlenecks which could lead to increased inbreeding depression and decreased adaptive potential. SEI (2008) reviewed a presentation and two unpublished manuscripts, provided by Dr. Susan Haig, on the evidence for genetic bottlenecks in northern spotted owl populations. Using microsatellite markers and a computer program called "Bottleneck," Haig provided evidence of recent genetic bottlenecks at several spatial scales (individual "populations" [demographic study areas], regions, and subspecies). Haig explicitly stated she could not conclude these bottlenecks were the cause for, nor were they necessarily related to, the recently documented declines in spotted owl populations. However, she did present a "cross-walk" of her results with a table depicting the status of northern spotted owl populations from Anthony *et al.* (2006).

SEI (2008) concluded Haig's observed bottlenecks are likely the result of population declines and not the cause of it; they are signatures of something that occurred in the past. SEI (2008) advises the population dynamics of the spotted owl likely will be more important to its short-term survival than will be its genetic makeup, regardless of the evidence for bottlenecks having occurred in the past (Barrowclough and Coats 1985). SEI (2008) stated the data and manuscript results presented by Dr. Haig did not currently warrant re-evaluation of genetic concerns as threats to the spotted owl. Based on this analysis by SEI (2008), this Recovery Plan does not list additional recovery actions to address genetic threats to the spotted owl, although a modification to this conclusion may be warranted at a later time.

Appendix C: Basis for MOCA and CSA Strategy

Interagency Scientific Committee (1990)

The ISC (Thomas *et al.* 1990) delineated and mapped a network of 193 HCAs thought necessary to ensure a viable, well-distributed population of spotted owls. Wherever possible, each HCA was designed with the goal of being able to support a minimum of 20 pairs of spotted owls. The maximum distance between these HCAs was 12 miles. The criterion of 20 pairs was based on models of population persistence and empirical studies of bird populations. Twelve miles was chosen as the maximum distance between HCAs because this value was within the known dispersal distance of about two-thirds of all radio-marked juvenile spotted owls studied up to that time.

Each HCA was designed with the goal of being able to support a minimum of 20 pairs of spotted owls. The maximum distance between these HCAs was 12 miles.

The HCA concept applied primarily to BLM, FS, and NPS lands. The ISC strongly recommended that HCAs be established on State-owned lands in certain key areas to ensure population connectivity. The committee also recommended that resource managers of other State lands, Tribal lands, other Federal lands, and private lands use forestry and silvicultural techniques and practices that maintain or enhance habitat characteristics associated with spotted owls.

To facilitate the movement of spotted owls, the ISC also recommended that 50 percent of the land base between HCAs (by quarter township) be maintained in stands of timber with an average diameter of 11 inches or greater and at least 40 percent canopy closure, even though modeling to estimate the efficacy of the HCAs assumed that the forests between the HCAs was entirely unsuitable for spotted owl territories (Thomas *et al.* 1990:AM 253).

Draft Recovery Plan (1992)

The 192 Designated Conservation Areas (DCAs) in the 1992 Draft Recovery Plan were modifications of the HCAs from the ISC. The 1992 recovery team's objective in remapping the HCAs was to provide a level of habitat protection in the DCAs that was at least equal to that provided by HCAs, while increasing the biological and economic efficiency of the network. The 1992 recovery team also attempted to address deficiencies identified in the HCA network. The fundamental sizing and

In 1992, HCAs were modified to create DCAs to increase the biological and economic efficiency of the network and address deficiencies identified in the HCA network.

spacing criteria from Thomas *et al.* (1990) were applied during mapping of the DCAs.

The following additional criteria were used in the 1992 effort to establish DCAs based on HCAs (USFWS 1992b):

- Areas were mapped to include as much high-quality habitat and as many spotted owl locations as possible to achieve an effective and efficient network. Where more effective acres were added to DCAs (meaning acres with more spotted owl locations or better habitat), opportunities were sought to drop less effective areas so that the total area did not increase.
- 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 spotted owl conservation.
- Areas were mapped to include as high a proportion of Federal reserved lands and other lands unsuitable for timber production as possible when consistent with mapping criteria from Thomas *et al.* (1990).
- 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.
- In areas where the existing network was identified to be deficient for supporting the desired number of reproducing spotted owls, attempts were made to provide for new spotted owl clusters and populations with the least possible economic impact.
- Where possible, boundaries were refined to avoid conflict with other economic development proposals.

Following the HCA system, DCAs were established that contained approximately 7.6 million acres of Federal forest lands as the primary habitat for the spotted owl. Two categories of DCAs were identified: Category 1 DCAs were established to be large enough to support "20 pairs of owls with contiguous or nearly contiguous home ranges" (USFWS 1992b). Category 1 DCAs were to be spaced no more than 12 miles apart. Category 2 DCAs were established to be large enough to support 2 to 19 pairs of spotted owls. Given their smaller size, category 2 DCAs were to be spaced no more than 7 miles apart.

The process of mapping DCAs was organized by the 1992 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
- Allocation maps from national forest land management plans

- BLM timber production capability maps
- Sensitive soils maps
- HCA maps
- Maps of other species associated with old forests, and streams with fish species at risk

Northwest Forest Plan (1994)

The NWFP was established in 1994, 2 years after the 1992 Final Draft Recovery Plan was prepared. The NWFP amended the 19 national forest and seven BLM district land and resource management plans (LRMPs) that guide management of individual national forests and BLM districts across the range of the spotted owl. The NWFP provides a network of reserves identified as Late-Successional Reserves to provide habitat for late-successional forest species, including the spotted owl. Davis and Lint (2005) state:

> "The primary contribution of the Northwest Forest Plan (the Plan) to conserving the northern spotted owl (the owl) was the Federal network of reserved land use allocations designed to support clusters of reproducing owl pairs across the species' range. These 'reserves' include late-successional reserves, adaptive management reserves, congressionally reserved lands, managed late-successional areas, and larger blocks of administratively withdrawn lands… Federal lands between these reserves were designed to provide habitat to allow movement, or dispersal, of owls from one reserve to another. The 'between' lands are a combination of matrix, riparian reserves, smaller tracts of administratively withdrawn lands and other smaller reserved areas such as 100-acre owl core areas."

MOCAs in Final Recovery Plan (2008)

This Recovery Plan builds on concepts and information presented by the ISC (Thomas *et al.* 1990), the 1992 draft Recovery Plan (USFWS 1992), and the NWFP (USDA and USDI 1994a). While the 1992 draft Recovery Plan was never finalized, the plan remains the most-recent spotted owl-specific analysis of habitat needed to provide for a sustainable population of spotted owls across the species' range. This Recovery Plan's MOCA strategy focuses:

- Managing large blocks of habitat in designated conservation areas throughout the range of the spotted owl that could support self-sustaining populations of 15 to 20 pairs of spotted owls and
- Spacing the blocks and managing the areas between them to permit movement of spotted owls between and among the blocks.

Overall Distribution of MOCAs

> "Ideally, blocks of habitat should be dispersed in a pattern corresponding to a species' full geographic distribution. This distribution is the key hedge against major catastrophes that could otherwise extinguish the sole

remaining population of a once wide-spread species…" (Thomas *et al.* 1990:285).

The Willamette Valley and Western Washington Lowland Provinces are excluded from the MOCA network; given their low population numbers it is assumed they can not play an essential role in recovering the species. Further, because of the recommended landscape approach in the fire-prone Provinces, these Provinces are not included in the MOCA network.

Size of MOCAs

Lamberson *et al.* (1994) modeled patch size and patch spacing relative to persistence of spotted owls, and an "earlier version" (Lamberson *et al.* 1990:186) of that work was used as the basis for Thomas *et al.* (1990) for the sizes of HCAs and the distances between them. Both of these publications used a range of values for five parameters; those in Lamberson *et al.* (1994) included a wider range of values (Table C1).

Table C1. Values of parameters used in simulations in Lamberson *et al.* (1994:table 2).

Parameter	Range of values
Percentage of total landscape within the clusters	5–40
Spotted owl cluster size	5–45
Percentage of sites within clusters that are suitable	20–100
Number of sites searched by dispersing females per cluster	0.2, 0.4, and 0.8 times cluster size
Dispersal coefficient	0.0004–0.30

The major assumptions included in this model were: (1) clusters were circular and every territory within a cluster was of equal size; (2) land between clusters was assumed to be entirely unsuitable for territories; (3) suitability of sites within clusters varied; and (4) all clusters had exactly the same number of neighboring clusters (there were no edges).

Following are quotations and results from Thomas *et al.* (1990) and Lamberson *et al.* (1994) used to determine the number of pairs of spotted owls large habitat blocks in this Recovery Plan are intended to support.

> "Within the structure of our model, clusters [of] $\geq$ 15 sites appeared stable; if all sites were initially suitable, at least moderate connectivity existed among clusters, and dispersing owls searched preferentially within their natal cluster. Under more realistic conditions where many spotted owl HCAs would not be continuous habitat, either initially, or ever, stability seemed to require at least 20-pair clusters and low to moderate connectivity" (Thomas *et al.* 1990:265).

> "Assuming 60% of the sites in each cluster to be suitable (approximately the current condition), the number of sites sampled [by dispersing females] per cluster to be 40% of cluster size, and a maximum of 22 sites searched, we did not observe a stabilization of mean occupancy within 100 years until each cluster contained at least 15 sites (Fig. 5). Clusters of 20 sites stabilized at approximately 77% occupancy" (Lamberson *et al.* 1994:191).

> "Within the structure of our model simulations—60% of the sites suitable, moderate connectivity among clusters (Table 4), preferential search within the natal cluster before dispersal, equilibrium conditions, and no edge effects—clusters of 20 or more sites appear to support stable populations. ... Further, our results suggest that a reserve design that provides only for individual pairs or small clusters of pairs has a low likelihood of sustaining the species" (Lamberson *et al.* 1993:193).

> "Ours is an all-female model. This simplification eliminated the complication of mate finding... the inclusion of search for mates will further reduce mean occupancies when cluster sizes are small, certainly when they contain less than 20 sites" (Lamberson *et al.* 1994:193).

Following the results of Thomas *et al.* (1990) and Lamberson *et al.* (1994), large habitat blocks (MOCA 1s) in this Recovery Plan are designed to support 20 or more pairs of spotted owls. Small habitat blocks (MOCA 2s) are by definition those that can support at least one pair, but less than 20 pairs of spotted owls.

> "The size of the HCA was established by delineating an area to support the target number of pairs using median annual home-range and density information as a guide" (Thomas *et al.* 1990:318).

The amount of habitat needed per pair of spotted owls was determined using median annual home-range size within each Province as obtained from the literature and simplified into circles of various radii. Recommended median annual home-range sizes to be used are presented in Table C2, which are the median home-range sizes currently being used in ESA Section 7 consultations between the Service and the FS and BLM (USFWS 1994b). New information may revise these home-range sizes.

Table C2. Estimated home-range sizes of spotted owls by Province.

State/Province	Radius of home-range circle (miles)	Area of home-range circle (acres)
Washington		
East Cascades and West Cascades	1.8	6,514
Olympic Peninsula	2.7	14,657
Oregon		
East Cascades and West Cascades	1.2	2,895
Coast Range	1.5	4,524
Klamath	1.3	3,398
California		
Cascades, Coast, and Klamath	1.3	3,398

To estimate the area of a 20-pair habitat block, we followed the methods in Thomas *et al.* (1990:320) which used provincial home-range sizes and assumed 25 percent overlap of territories. Their formula was: (20 pairs) X (acres in provincial home-range circle) X (0.75) = acres in 20-pair habitat block. Following that formula resulted in the acreages presented in Table C3.

Lamberson *et al.* (1994) modeled their results using 20,000 ha (49,420 acres) of blocks with 60 percent suitable habitat and 20 pairs of spotted owls per cluster. The large blocks in this Recovery Plan for the Olympic Peninsula, West Cascades, and East Cascades of Washington and Coast Range of Oregon are larger than those in Lamberson *et al.* (1994), while those in the other Provinces are similar in size to those in Lamberson *et al.* (1994).

Table C3. Calculated sizes of 20-pair habitat blocks by Province, assuming 25 percent overlap of territories.

State/Province	Calculated size of 20-pair habitat blocks (acres)	Rounded size of 20-pair habitat blocks (acres)
Washington		
East Cascades and West Cascades	97,716	98,000
Olympic Peninsula	219,861	220,000
Oregon		
East Cascades and West Cascades	43,429	45,000
Coast Range	67,858	70,000
Klamath	50,969	51,000
California		
Cascades, Coast, and Klamath	50,969	51,000

Raphael (2006:118-119) states:

> "The FEMAT (1993) [USDA *et al.* (1993)] used an expert panel to assess the sufficiency of habitat on federal land to support a viable population of the northern spotted owl for 100 years. The panel considered four possible outcomes, labeled A through D. Under outcome A, habitat was judged to be of sufficient quality, distribution, and abundance to allow the owl population to stabilize, well-distributed across federal lands over the next 100 years. Note that this outcome does not imply a constant population, but rather one that might vary around some nondeclining mean population. Under outcome B, habitat would allow the owl population to stabilize but with significant gaps in the historical distribution that could cause some limitation in interactions among local populations. Under outcome C, habitat would be so limited as to allow owl persistence only in refugia with strong limitations on interactions among local populations. Outcome D represented extirpation of owls from federal land. The expert panel assigned an 83-percent likelihood to outcome A and an 18-percent likelihood for outcome B with no likelihood of outcomes C or D for option 9, the option that eventually was developed as the [Northwest Forest] Plan…Note also that additional features added to option 9 after FEMAT in the Record of Decision (USDA and USDI 1994b), such as an increase in the width of riparian buffers on intermittent streams and protection of 100-acre areas around owl activity centers in the matrix, would likely provide for an even higher likelihood in outcome A had these features been evaluated by the expert panel…I emphasize, however, that this projection was based on whether habitat conditions on federal lands would support owls. The panels recognized that the cumulative effects of habitat conditions on nonfederal lands, interactions with the barred owl, and other factors outside the scope of the Plan, would produce much greater uncertainty in the projected likelihood of owl persistence. The FEMAT also assessed option 7, an option that was based on provisions of the draft recovery plan for the owl and which was very similar to the proposals of the ISC. Outcomes for that option were lower than option 9, with likelihood scores of 71, 25, 4, and 0 for outcomes A, B, C, and D. "

Further, Noon and McKelvey (1996:157) state:

> "Subsequent modeling suggests that reserves with a carrying capacity of 20 pairs are stable only if juvenile search efficiency is high and edge effects are minimal (54, 55). To achieve local stability within the constraints of real landscapes, more recent modeling suggests that carrying capacities of perhaps 30–40 pairs per HCA are needed. In addition, a few large reserves (> 100 pairs) significantly safeguard against population extinction. For these reasons, the original reserve design proposed by the ISC represents a minimum system, with greater risks to persistence then initially envisioned."

The MOCA network identified in this Recovery Plan most closely resembles Option 7 and the 20-pair system described in Noon and McKelvey (1996). Following the 1992 proposed DCA network, two categories of MOCAs were created to match the category 1 and category 2 DCAs. Each MOCA 1 has the capacity to support 20 or more reproducing pairs of spotted owls, and each MOCA 2 has the capacity to support 1 to 19 pairs of reproducing spotted owls.

Distance Between MOCAs

The maximum distances allowed between MOCAs followed Thomas *et al.* (1990), which was 12 miles (from closest edge to closest edge) between MOCA 1s and 7 miles between MOCA 2s.

> "...we believe the distances between HCAs should be well within the known dispersal distances of at least 50% of all juveniles. After lengthy discussions of this matter among all members of the Committee and advisors, and consultation with other authorities not closely affiliated with our efforts, we believe the distances between HCAs should be within the known dispersal distances of at least 2/3rds (67%) of all juveniles" (Thomas *et al.* 1990:307).

> "Based on available data from 56 juvenile northern spotted owls equipped with radio transmitters, we set the maximum distance between HCAs with at least 20 territory sites (at their nearest point of separation) at 12 miles (appendix P). This distance is within the known dispersal distance of about 66% of the owls studied..." (Thomas *et al.* 1990:26).

> "To provide an additional measure of security for small HCAs, we opted to increase the likelihood of successful dispersal from one to another by setting shorter distances between them. ...The distance selected, 7 miles, is less than the median distanced estimated from banded birds (table P2) and is within the dispersal range of more than 75% of all radio-marked juveniles (table P1)" (Thomas *et al.* 1990:308).

Forsman *et al.* (2002) reported dispersal distances of 1,475 northern spotted owls in Oregon and Washington from 1985 to 1996, 324 of which were radio-marked and 1,151 of which were banded. Data from radio-marked spotted owls are more representative than data from banded owls because banding data underestimate maximum dispersal distances (Thomas *et al.* 2000, Forsman *et al.* 2002). Median maximum dispersal distance (the straight-line distance between the natal site and the farthest location) for radio-marked juvenile male spotted owls was 12.7 miles, and that of female spotted owls was 17.2 miles (Forsman *et al.* 2002:table 2).

Data reported in Forsman *et al.* (2002) did not permit estimating distances dispersed by certain percentages of juvenile owls as was done for the five studies analyzed by Thomas *et al.* (1990). To allow the Service to do this, E. Forsman (2007 pers. comm.) provided the data for maximum dispersal distances of juvenile radio-marked spotted owls used in Forsman *et al.* (2002). Analysis of these data (USFWS 2007a) resulted in the information presented in Table C4.

Table C4. Maximum distances dispersed by 50 percent, 66 percent, and 75 percent of radio-marked juvenile spotted owls in Forsman *et al.* (2002).

Percent of spotted owls	Distances dispersed (mi)		
	Males (n = 114)	Females (n = 122)	All (n = 236)
50	12.7	17.4	14.5
66	9.6	13.7	11.4
75	7.9	11.1	9.4

2008 modeling of size of MOCAs and distances between MOCAs

In late 2007, the Service asked M. Raphael and B. Marcot (U.S. Forest Service, Pacific Northwest Research Station) to determine if the findings from Lamberson *et al.* (1994) concerning the influence of spotted owl habitat patch (cluster) size and spacing on spotted owl occupancy were still relevant using the most-recent data and modeling programs. Their modeling was completed in April 2008 (M. Raphael and B. Marcot 2008 pers. comm.).

They used a spatially-explicit, individual-based (female-only) population model, HexSim (version 1.2.1.5), which is a simulation modeling shell developed by N. Schumaker (Environmental Protection Agency, Corvallis, Oregon[4]). They parameterized HexSim with empirical data on stage-class specific dispersal distances (derived from Forsman *et al.* 2002) and stage-class specific reproduction and survival rates (derived from Anthony *et al.* 2006). They consulted directly with: HexSim model author N. Schumaker; previous modelers R. Lamberson, K. McKelvey, and B. Noon; and spotted owl biologists R. Anthony and E. Forsman to ensure correct model operation and parameterization. Their analysis tested and passed a number of aspects of model behavior to ensure it was parameterized correctly, including:

- the most appropriate means of varying landscape designs (keeping the number of suitable habitat sites constant across scenarios)
- total size of the modeled landscapes to avoid bias of boundary effects in the model (approximately 1800 suitable-habitat sites per landscape)
- number of years to simulate in the model to achieve long-term stability (100 years per run)
- number of model replicates to stabilize variation among model runs (20 replicates per scenario)
- number of simulated years required for the model to correctly initialize (5 years)
- resulting lognormal distributions of resulting simulated dispersal distances (to match empirically reported findings), and

[4] HexSim is the current name of what previously was called the PATCH model by the same author. HexSim improves the user interface and provides for greater manipulation of simulation outcomes. PATCH and HexSim are formally produced and authorized under auspices of EPA. Applications of PATCH to a variety of habitat and species evaluation projects have appeared in at least 20 peer-reviewed publications (*e.g.,* Schumaker *et al.* 2004, Rustigian *et al.* 2003).

- whether using the fixed initial seed in the model produced results comparable to a random initial seed (so that results could be duplicated)

They developed 31 artificial landscapes representing combinations of habitat cluster size (4, 9, 25, 36, and 49 owl pairs) and cluster spacing (7, 15, 29, 52, 74, and 101 km, or approximately 4, 9, 18, 32, 46, and 63 miles), and an all-habitat landscape, each under two sets of demographic vital rates representing (1) average population conditions throughout the range of the subspecies (lambda = 0.95, derived from Anthony *et al.* 2006) and (2) stable population conditions with lambda = 1.00 by boosting adult survival rate in the same manner as was done by Lamberson *et al.* (1994). This boosting was necessary because if lambda remained unchanged, spotted owls would go to extinction no matter how large the reserves are. (The cluster sizes and cluster spacings were dictated by the sizes of the hexagons in the model. That is, they could not test round numbers such as 5, 10, 15, 20.) In total, they modeled 62 scenarios combining landscape designs and demographic vital rates. For each of the modeled scenarios, they produced summary statistics and graphs displaying (1) expected occupancy rates of habitat sites by female spotted owls (Figs. 1–4) and (2) realized lambda (annual finite rate of population change), by time step (up to 100 years), cluster size, and cluster spacing (Fig 5).

Model results, which used the best-available demographic and dispersal data, suggested outcomes similar to those reported by Lamberson *et al.* (1994) in the following way:

- Occupancy rates are greater with larger cluster sizes.
- Occupancy rates are greater with close cluster spacing.
- Neither the current modeling effort nor that of Lamberson *et al.* (1994) suggested thresholds of cluster sizes or spacing that clearly distinguished viable from non-viable population conditions. Both efforts suggest a gradient in increasing occupancy rates with larger clusters and closer spacing of clusters.
- However, the current modeling effort suggested that, with initially stable populations, greater long-term (100-year) stability is achieved with cluster sizes of at least 25 territories/cluster, and is far lower with cluster sizes of 9 territories/cluster or less (again, current modeling did not evaluate cluster sizes between 9 and 25, so simple interpolation suggests that a cluster size of 20 territories/cluster would fare only slightly worse than that of 25).
- Both modeling efforts suggest that occupancy rate drops more precipitously in landscapes consisting of less than approximately 35–40 percent habitat.
- Current modeling efforts suggested an overall lower expected occupancy rate than did the previous effort.

On the final point above, both the current modeling work and that of Lamberson *et al.* (1994) based the simulations on entirely hypothetical, geometrically-designed landscapes of habitat clusters, so that the resulting occupancy rates and lambda values should not be interpreted as predictions of real-world outcomes.

Differences in absolute levels of occupancy between the current model results and those of Lamberson *et al.* (1994) likely are, in part, due to several factors:

- The current modeling effort uses updated data on stage-class specific reproduction and survival rates, which different somewhat from the previous effort.
- The current modeling effort uses stage-class specific data on dispersal distances and proportions of each stage class dispersing per time step (simulated year), whereas the previous effort apparently used just one set of dispersal distance data for all stage classes and did not account for differential dispersal propensities among stage classes.
- The current modeling effort uses the most updated version available of an individual-based spatially-explicit simulation model.
- Lamberson *et al.* (1994) decremented occupancy of each habitat cluster whereas the current modeling effort did not and presumed all habitats are equally suitable.

B. Marcot and M. Raphael are preparing a manuscript with full methods and results of this effort for submission to a scientific journal.

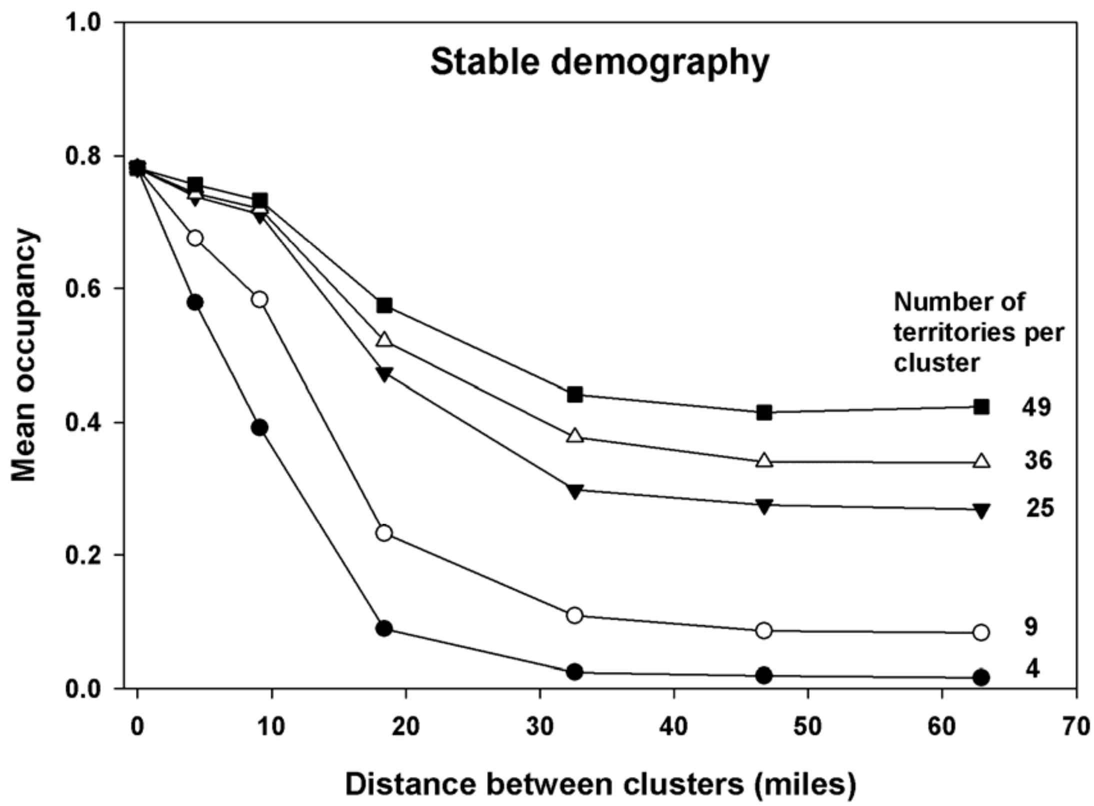


Figure C1. Results of HexSim model simulation showing mean occupancy as a function of distance between habitat clusters and cluster size (number of potential territories per cluster), summarized at year 100 and using adult survival rates for a stable population (lambda = 1.0). These are the modeling conditions and form of results that match those reported in Lamberson *et al.* (1994:figure 9).

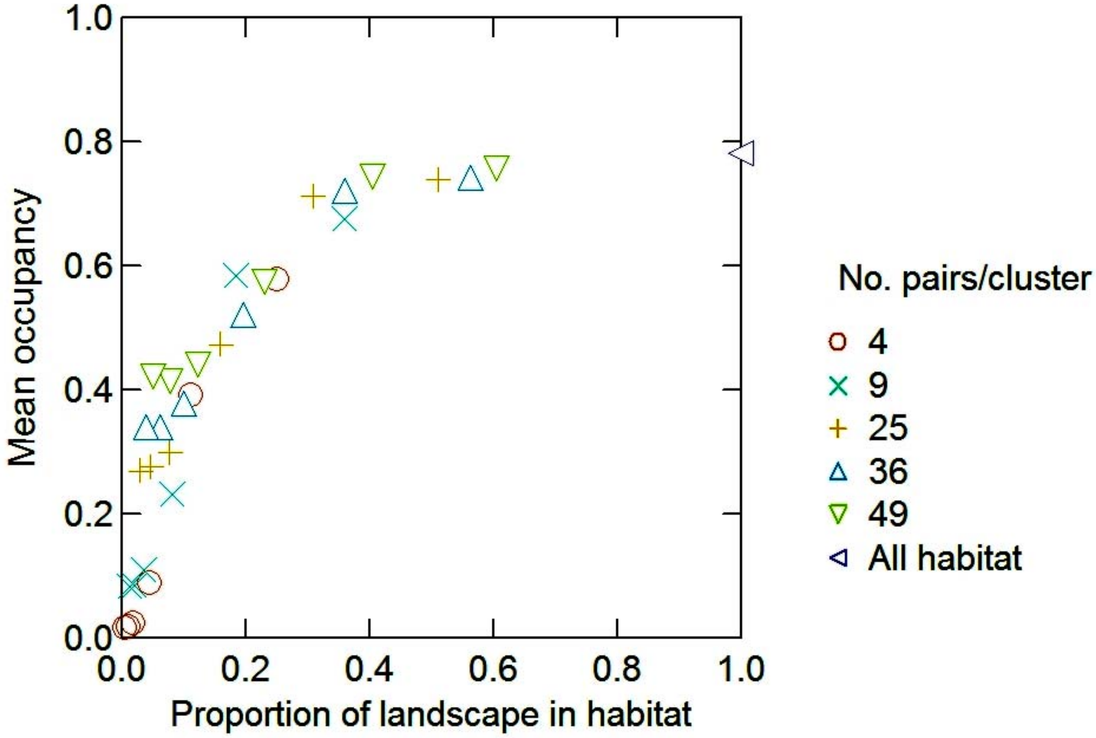


Figure C2. Results of HexSim model simulation showing mean occupancy as a function of proportion of the sites that are 100% suitable habitat and cluster size (number of potential territories per cluster), summarized at year 100 and using adult survival rates for a stable population (lambda = 1.0). These are the modeling conditions and form of results that match those reported in Lamberson *et al.* (1994:figure 8).

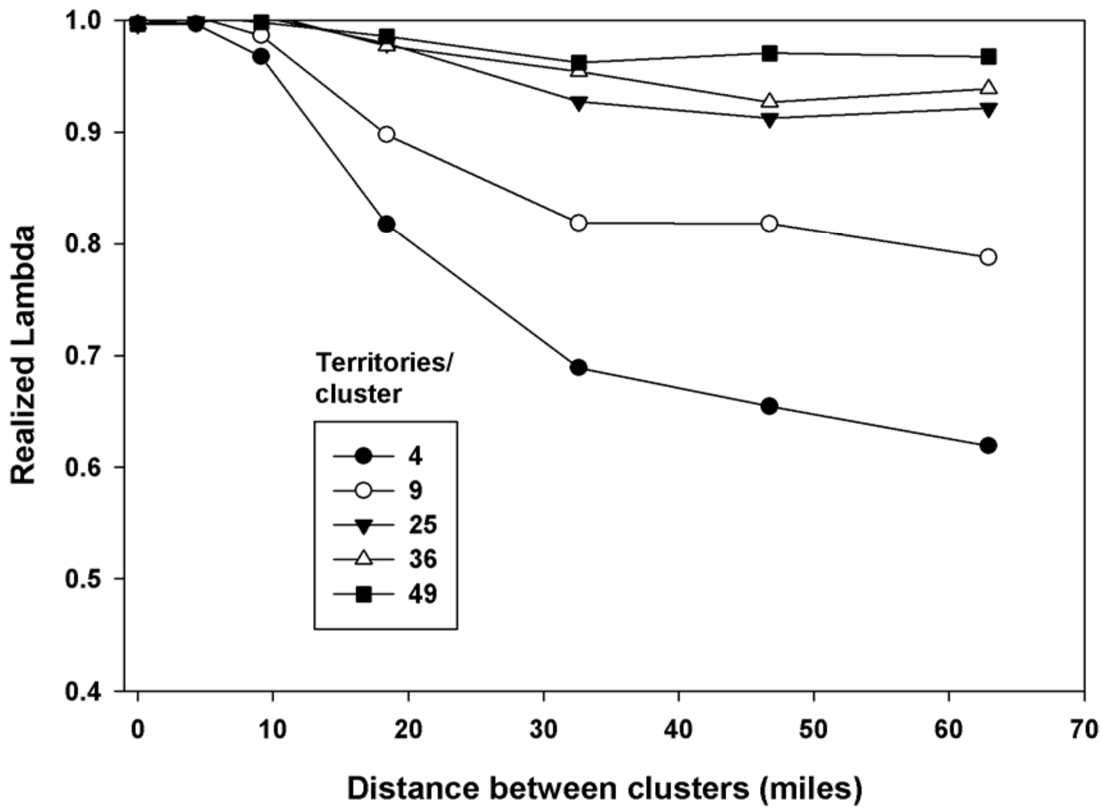


Figure C3. Results of HexSim model simulation showing realized lambda (calculated from model simulation results) as a function of distance between habitat clusters and cluster size (number of potential territories per cluster), summarized at year 100 and using adult survival rates for a stable population (lambda = 1.0).

MOCA Size and Spacing Summary

In summary, the sizes of the MOCAs and the distances between MOCAs used in this Recovery Plan allow for a reasonable level of owl dispersal and persistence. The Service reached this conclusion through interpretation of Thomas *et al.* (1990), USDA (1993), Lamberson *et al.* (1994), Noon and McKelvey (1996), Forsman *et al.* (2002), and the 2008 modeling effort by M. Raphael and B. Marcot (2008 pers. comm.). That is not to say the MOCA network exactly matches the risk tolerances expressed in all of these publications. For example, the MOCA network does not fully satisfy Noon and McKelvey's (1996:157) suggestion that "more recent modeling suggests that carrying capacities of perhaps 30–40 pairs per HCA are needed." However, given the other publications, the MOCA network embodies a reasonable level of risk at this time. This conclusion will need to be revisited in the future.

Delineation of MOCAs

Given the thorough analysis supporting the HCAs in Thomas *et al.* (1990) and the DCAs in the 1992 Draft Recovery Plan (see especially Chapter III E), the DCAs served as the default habitat network for the MOCAs. This Recovery Plan maps 45 MOCA 1s and 88 MOCA 2s (Tables C5 and C6).

The DCAs served as the default habitat network for the MOCAs.

Because the LRMPs are designed and implemented, in part, to be the Federal contribution to recovery for the spotted owl (USDA and USDI 1994a), the Service looked first to the DCAs on Federal lands, and specifically lands within the LRMP reserves, for the habitat-capable acres needed to support the recovery objectives under this Recovery Plan. In some cases, Federal lands outside the large block reserves of the LRMPs (NWFP matrix lands, for example) were included in the MOCA network to incorporate areas particularly important to spotted owl recovery and to ensure that the size, spacing, and distribution criteria were met (see below). Only Federal lands were included in the MOCAs. CSAs were designated to support MOCAs (see below).

In the process of delineating the MOCAs, the 1992 DCAs were adopted as is, reconfigured into a new MOCA, redesignated as a CSA (see below), or eliminated. For the DCAs that were retained as MOCAs, the original DCA's overall size, number of habitat-capable acres, and proximity to its closest neighbor were retained to the maximum extent practicable. Where DCAs were modified, the new MOCA's size was kept as close as possible to that of the old DCA while also attempting to eliminate conflicts between the new MOCA and the underlying Federal land use allocation. MOCA sizes vary based on regional ecological differences; therefore some MOCA 2s may be larger than some MOCA 1s. In addition, modeled information on potential development of future habitat blocks in checkerboard ownership patterns in western Oregon provided by the BLM was used to position MOCAs in areas where DCAs were not designated. In this modeling, the BLM used its updated forest inventory and modeling techniques in a "let it grow" scenario to see how the delineation of a MOCA could be changed to grow it into more suitable nesting, roosting, and foraging habitat in a shorter amount of time.

We also considered the boundaries of LSMA proposed by BLM in their Western Oregon Plan Revision when establishing MOCAs. Delineation of MOCAs[5] followed these rules:

- The original DCA was retained with no boundary change under one of the following conditions:
  - The original DCA boundary fell completely within a LRMP reserve and no revision of the DCA adjustment of the boundary was needed

---

[5] Numbers of MOCA 1s and 2s in the Final Plan are fewer than those in the Draft Plan because MOCAs are not designated in eastern Provinces in the Final Plan.

  - The original DCA boundary did not fall completely within a LRMP reserve, but there was no need to change the boundary to move all or a portion of the DCA into the reserve

- The original DCA was retained with a boundary change under one of the following conditions:
  - The DCA boundary fell completely within a LRMP reserve and a boundary adjustment was made to match all or a portion of the original DCA boundary with the boundary of the reserve
  - The DCA boundary fell completely within a LRMP reserve and a boundary adjustment was made to include current or future habitat conditions within the new MOCA boundary.
  - All or a portion of the DCA was outside a LRMP reserve and the DCA was moved to match the reserve as much as possible, resulting in fewer acres of non-reserve land in the DCA
  - All or a portion of the DCA was outside a LRMP reserve and the DCA was moved to match the reserve as much as possible, resulting in a decrease of non-reserve land in the DCA
  - Non-Federal lands within the DCA boundary were removed or redesignated as a CSA

- The original DCA was eliminated under one of the following conditions:
  - The original DCA was not needed to satisfy the maximum spacing of 12 miles (closest edge to closest edge) between category 1 DCAs and 7 miles between category 2 DCAs
  - The original DCA was not needed to provide for a cluster of reproducing spotted owls
  - The DCA was redesignated as a CSA

Table C5. Acres of MOCA by Federal ownership and Land Use Allocation in Washington, Oregon and California in westside Provinces. The "LSR" LUA includes the LSR, LSR3, LSR4 and AMR allocations. The "Matrix/RR" LUA includes both Matrix lands and Riparian Reserve allocations, and the "ND" (Not Determined) LUA includes Federal lands not designated in 1994. LUA: Land-use allocation; AMA: Adaptive Management Area; AWA: Administratively Withdrawn Area; CRA: Congressionally Reserved Area; LSR: Late-Successional Reserve; MLSA: Managed Late-Successional Area; RR: Riparian Reserve.

State	Agency	LUA*	Total LUA acres in MOCA	Total LUA acres in westside provinces	Percent (MOCA-LUA of total LUA)
Washington	Forest Service	AMA	0	283,853	0
		AWA	50,895	199,038	26
		CRA	331,612	1,080,275	31
		LSR	1,199,297	1,543,111	78
		Matrix/RR	0	497,620	0
		ND	0	14,805	0
	Fish Wildlife Service	CRA	152	11,266	1
	National Parks	CRA	575,103	1,657,523	35
	Dept. of Defense	CRA	0	110,451	0
		Washington total	2,157,059	5,397,943	40
Oregon	Bureau of Land Management	AMA	1,635	187,389	1
		AWA	54,191	79,421	68
		CRA	19,074	26,855	71
		LSR	497,210	912,692	54
		Matrix/RR	126,551	1,122,053	11
		ND	0	1,024	0
	Forest Service	AMA	0	356,127	0
		AWA	40,461	355,940	11
		CRA	494,226	920,791	54
		LSR	1,358,862	2,316,482	59
		Matrix/RR	0	1,689,785	0
		ND	163	6,987	2
	Fish Wildlife Service	CRA	0	9,929	0
	National Parks	CRA	863	89,324	1
	Dept. of Defense	CRA	0	727	0
		Oregon total	2,593,235	8,075,525	32
	Bureau of Land Management	AMA	0	1,807	0
		AWA	6,366	22,034	29
		CRA	16,584	19,299	86
		LSR	108,364	117,524	92
		Matrix/RR	0	214,793	0
		ND	5,716	6,336	90

State	Agency	LUA*	Total LUA acres in MOCA	Total LUA acres in westside provinces	Percent (MOCA-LUA of total LUA)
California	Forest Service	AMA	0	378,845	0
		AWA	43,894	339,000	13
		CRA	426,911	1,138,484	37
		LSR	898,460	1,288,684	70
		Matrix/RR	0	1,304,861	0
	Fish Wildlife Service	CRA	0	145	0
	National Parks	CRA	104,563	226,614	46
	Dept. of Defense	CRA	0	22,260	0
California total			1,610,860	5,080,687	32
Range-wide total			6,361,154	18,554,155	34

Table C6. Summary of total acres, habitat-capable acres, and spotted owl habitat acres in MOCAs by State and Physiographic Province.

Province/ MOCA Number	MOCA type	Total acres in MOCA	Owl habitat capable acres in MOCA	Percent (capable of total)	Suitable owl habitat acres[1] in MOCA	Percent (suitable of capable)
Washington						
Western WA Cascades						
WMOCA-01	1	141,075	140,340	99	73,517	52
WMOCA-02	2	19,955	19,570	98	10,588	54
WMOCA-03	1	143,948	143,397	100	78,279	55
WMOCA-04	2	29,028	28,812	99	14,841	52
WMOCA-05	2	37,811	37,699	100	12,781	34
WMOCA-06	1	158,700	156,975	99	92,974	59
WMOCA-07	1	112,344	111,155	99	46,414	42
WMOCA-08	2	4,813	4,767	99	1,743	37
WMOCA-09	2	35,699	34,383	96	15,194	44
WMOCA-10	2	13,016	12,707	98	6,805	54
WMOCA-11	2	36,979	36,597	99	18,439	50
WMOCA-12	2	29,681	28,989	98	12,650	44
WMOCA-13	2	46,511	44,906	97	16,573	37
WMOCA-14	2	9,285	8,791	95	4,664	53
WMOCA-15	2	26,336	25,924	98	15,203	59
WMOCA-16	2	30,679	29,536	96	12,691	43
WMOCA-17	2	74,775	73,561	98	31,084	42
WMOCA-18	2	83,506	83,205	100	34,244	41
WMOCA-19	2	14,424	14,237	99	6,122	43

Province/ MOCA Number	MOCA type	Total acres in MOCA	Owl habitat capable acres in MOCA	Percent (capable of total)	Suitable owl habitat acres[1] in MOCA	Percent (suitable of capable)
WMOCA-20	2	27,015	26,577	98	12,471	47
WMOCA-21	1	101,811	99,755	98	41,030	41
WMOCA-22	2	37,618	36,932	98	14,202	38
WMOCA-23	2	14,405	13,944	97	4,513	32
WMOCA-24	2	77,248	75,352	98	29,325	39
WMOCA-25	2	3,457	3,407	99	757	22
Province total[2]	5/20	1,310,118	1,291,517	99	607,105	47
Olympic Peninsula						
WMOCA-26	1	803,443	761,027	95	406,065	53
WMOCA-27	2	4,650	4,650	100	2,521	54
WMOCA-28	2	4,001	4,001	100	2,034	51
WMOCA-29	2	34,847	33,590	96	7,230	22
Province total	1/3	846,941	803,268	95	417,850	52
Washington total	6/23	2,157,059	2,094,786	97	1,024,956	49
Oregon						
Western Oregon Cascades						
OMOCA-01	1	100,084	98,015	98	56,245	57
OMOCA-02	1	115,781	115,195	99	73,188	64
OMOCA-03	1	88,113	87,825	100	58,213	66
OMOCA-04	1	76,147	74,853	98	44,246	59
OMOCA-05	1	51,386	51,325	100	30,919	60
OMOCA-06	2	34,423	34,236	99	18,779	55
OMOCA-07	1	133,604	132,387	99	99,856	75
OMOCA-08	1	67,759	67,651	100	32,689	48
OMOCA-09	1	102,418	101,513	99	49,078	48
OMOCA-10	1	65,405	65,132	100	37,434	57
OMOCA-11	1	60,681	60,652	100	23,171	38
OMOCA-12	1	68,908	68,706	100	38,486	56
OMOCA-13	1	77,733	77,658	100	45,231	58
OMOCA-14	1	67,054	66,847	100	38,885	58
OMOCA-15	1	49,706	49,664	100	29,148	59
OMOCA-16	1	70,624	70,562	100	38,805	55
OMOCA-17	1	49,367	48,786	99	17,986	37
OMOCA-18	1	51,778	50,883	98	10,442	21
Province total	17/1	1,330,970	1,321,891	99	742,801	56
Oregon Klamath						
OMOCA-19	1	45,434	44,636	98	12,675	28

Province/ MOCA Number	MOCA type	Total acres in MOCA	Owl habitat capable acres in MOCA	Percent (capable of total)	Suitable owl habitat acres[1] in MOCA	Percent (suitable of capable)
OMOCA-20	1	2,008	2,007	100	956	48
OMOCA-21	2	45,024	44,696	99	17,607	39
OMOCA-22	1	71,805	71,561	100	27,972	39
OMOCA-23	1	129,836	128,394	99	48,846	38
OMOCA-24	1	119,276	118,394	99	63,554	54
OMOCA-25	1	67,638	67,217	99	35,542	53
OMOCA-26	2	49,172	49,100	100	21,194	43
OMOCA-27	2	24,378	24,272	100	12,882	53
OMOCA-28	2	29,904	29,670	99	15,508	52
OMOCA-29	2	14,426	14,410	100	10,298	71
Province total	6/5	598,901	594,358	99	267,034	45
Oregon Coast Range						
OMOCA-30	2	55,816	55,809	100	22,443	40
OMOCA-31	2	51,620	51,613	100	25,310	49
OMOCA-32	2	8,554	8,554	100	5,048	59
OMOCA-33	2	46,723	46,669	100	27,268	58
OMOCA-34	2	49,279	49,252	100	27,216	55
OMOCA-35	2	59,145	59,127	100	29,124	49
OMOCA-36	2	57,372	56,997	99	27,893	49
OMOCA-37	1	80,664	80,569	100	40,331	50
OMOCA-38	2	48,242	45,050	93	24,219	54
OMOCA-39	2	42,631	42,593	100	20,731	49
OMOCA-40	2	7,930	7,930	100	3,555	45
OMOCA-41	2	27,252	27,216	100	10,296	38
OMOCA-42	2	45,636	45,404	99	21,171	47
OMOCA-43	1	74,101	74,079	100	30,725	41
OMOCA-44	2	8,397	8,393	100	3,093	37
Province total	2/13	663,363	659,254	99	318,423	48
Oregon total	25/19	2,593,235	2,575,502	99	1,328,258	52
California						
California Coast						
CMOCA-01	1	5,789	5,475	95	4,186	76
CMOCA-02	2	14,253	13,058	92	9,456	72
CMOCA-03	1	67,333	64,932	96	51,012	79
CMOCA-04	2	4,126	4,086	99	3,582	88
CMOCA-05	2	7,493	7,385	99	6,436	87
CMOCA-06	2	1,111	1,108	100	937	85

Province/ MOCA Number	MOCA type	Total acres in MOCA	Owl habitat capable acres in MOCA	Percent (capable of total)	Suitable owl habitat acres[1] in MOCA	Percent (suitable of capable)
CMOCA-07	2	2,270	2,259	99	1,960	87
CMOCA-08	2	40,308	36,255	90	28,102	78
CMOCA-09	2	4,138	4,097	99	3,765	92
CMOCA-10	2	1,097	1,094	100	634	58
CMOCA-11	2	1,926	1,833	95	1,285	70
CMOCA-12	2	2,982	2,797	94	1,734	62
CMOCA-13	2	930	785	84	364	46
CMOCA-14	2	2,747	2,577	94	1,663	65
CMOCA-15	2	2,639	2,488	94	1,770	71
CMOCA-16	2	8,941	8,713	97	3,232	37
CMOCA-17	2	9,813	9,721	99	7,287	75
CMOCA-18	2	6,843	6,701	98	3,754	56
CMOCA-19	2	2,013	1,574	78	765	49
CMOCA-20	2	1,564	1,266	81	657	52
CMOCA-21	2	3,726	2,265	61	1,592	70
CMOCA-22	2	4,457	4,009	90	2,009	50
CMOCA-23	2	6,858	5,452	80	2,495	46
CMOCA-24	2	1,043	676	65	612	91
CMOCA-25	2	3,260	2,416	74	1,559	65
CMOCA-26	2	30,669	21,053	69	16,701	79
Province total	2/24	238,328	214,074	90	157,548	74
California Klamath						
CMOCA-27	1	102,031	98,364	96	66,136	67
CMOCA-28	1	79,515	76,507	96	47,771	62
CMOCA-29	1	6,136	6,014	98	4,223	70
CMOCA-30	2	49,230	48,612	99	30,202	62
CMOCA-31	2	14,687	14,505	99	10,473	72
CMOCA-32	1	140,834	138,791	99	87,826	63
CMOCA-33	2	6,294	6,056	96	2,458	41
CMOCA-34	1	52,240	51,406	98	32,614	63
CMOCA-35	1	73,976	70,894	96	38,704	55
CMOCA-36	2	8,788	8,670	99	5,516	64
CMOCA-37	2	3,314	3,262	98	1,594	49
CMOCA-38	2	4,043	3,987	99	995	25
CMOCA-39	2	1,400	1,392	99	282	20
CMOCA-40	2	2,283	2,201	96	1,084	49
CMOCA-41	2	2,656	2,596	98	2,156	83

Province/ MOCA Number	MOCA type	Total acres in MOCA	Owl habitat capable acres in MOCA	Percent (capable of total)	Suitable owl habitat acres[1] in MOCA	Percent (suitable of capable)
CMOCA-42	2	3,885	3,854	99	3,259	85
CMOCA-43	2	7,304	7,189	98	5,743	80
CMOCA-44	1	95,485	92,668	97	68,589	74
CMOCA-45	1	100,925	98,329	97	70,627	72
CMOCA-46	2	23,433	22,500	96	19,407	86
CMOCA-47	2	11,788	11,549	98	9,556	83
CMOCA-48	2	32,637	31,860	98	27,322	86
CMOCA-49	2	38,081	37,371	98	22,701	61
CMOCA-50	1	50,931	50,743	100	39,063	77
CMOCA-51	1	60,163	58,399	97	35,331	60
CMOCA-52	2	42,977	42,638	99	36,259	85
CMOCA-53	2	30,523	29,358	96	23,998	82
CMOCA-54	1	116,304	108,646	93	82,637	76
CMOCA-55	1	65,890	62,288	95	41,158	66
CMOCA-56	2	35,960	33,069	92	20,660	62
CMOCA-57	2	25,739	23,467	91	11,695	50
CMOCA-58	2	43,805	40,623	93	24,660	61
CMOCA-59	2	11,460	10,802	94	7,188	67
CMOCA-60	2	27,813	24,800	89	17,666	71
Province total	12/22	1,372,531	1,323,411	96	899,555	68
California total	14/46	1,610,860	1,537,485	95	1,057,104	69
Range-wide total	45/88	6,361,154	6,207,773	98	3,410,317	55

[1] BioMapper-generated suitable habitat based on Davis and Lint (2005:table 3-4)
[2] MOCA totals are MOCA 1s/MOCA 2s

CSAs in Final Recovery Plan (2008)

Mapped or described CSAs (Table C7) are areas between or adjacent to MOCAs where habitat contributions by private, State, and some Federal land managers are expected to increase the likelihood that spotted owl recovery is achieved, shorten the time needed to achieve recovery, and/or reduce management risks associated with the Recovery Strategy and Actions. The Service delineated or described CSAs in areas that can provide important contributions to recovery and where private, State, or Federal management regimes support owl habitat (for example, Section 10 Habitat Conservation Plans, State forest practices rules, certain Federal adaptive management areas). CSAs may function to provide demographic support to core spotted owl populations in the MOCA network or dry-forest landscape management areas, facilitate dispersal of juvenile spotted owls among MOCAs, or serve both of these functions.

CSAs may function to provide demographic support to core spotted owl populations in the MOCA network or facilitate dispersal of juvenile spotted owls among MOCAs.

Table C7. Description of CSAs by State.

State/ CSA number	Total CSA acres	Name	Function[1]	Current management regime	Notes
Washington					
WCSA-01	85,400	Columbia Gorge	DS	Mixed private and State ownership	Includes "Columbia Gorge" Spotted Owl Special Emphasis Area (SOSEA)[2]
WCSA-02	425,114	Klickitat	DS	Mixed private, State and Federal (NWFP Matrix) ownership	Includes "White Salmon" SOSEA; E. boundary extends to Klickitat River
WCSA-03	35,146	Siouxon	DS	Mixed private and State ownership	Includes "Siouxon" SOSEA
WCSA-04	316,663	Mineral	DP, DS	Mixed private and State ownership	Includes "Mineral Block/Link" SOSEA
WCSA-05	513,520	I-90	DP, DS	Mixed private and State ownership	Includes "I-90 West", "I-90 East"
WCSA-06	54,647	Blewett	DP, DS	Mixed private and State ownership	Includes "North Blewett" SOSEA
WCSA-07	76,411	Entiat	DP, DS	Mixed private and State ownership	Includes "Entiat" SOSEA
WCSA-08	259,256	Finney	DP, DS	Mixed private and State ownership	Includes "Finney Block" SOSEA
WCSA-09	397,295	West Olympic	DS	Mixed private, State and Federal (AMA) ownership	Includes "Hoh-Clearwater/Coastal Link" SOSEA
	2,163,453	Washington total			

State/ CSA number	Total CSA acres	Name	Function[1]	Current management regime	Notes
Oregon					
OCSA-01	43,586	Central Cascades	DP, DS	Federal AMA	
OCSA-02	10,501	Lower Applegate	DP	Federal AMA	
OCSA-03	8,971	Upper Applegate	DP, DS	Federal AMA	
OCSA-04	Unmapped	Coquille	DP	Mixed Federal, State and private ownership (not to include Tribal lands)	North from OMOCA-25 and OMOCA-26 to OMOCA-29, East of Myrtle Point and Port Orford, and West of OMOCA-27
OCSA-05	Unmapped	Yaquina	DP	Mixed Federal, State and private ownership (not to include Tribal lands)	North from OMOCA-38 and OMOCA-39 to OMOCA-41 and OMOCA-42
	63,058	Oregon mapped total			
California					
CCSA-01	26,845	Green Diamond Resource Co.	DS	Private Land HCP	Oregon border to Jedediah Smith SP
CCSA-02	10,191	Jedediah Smith Redwoods SP	DS	State Park	
CCSA-03	32,331	Mill Creek State Park	DS	State Park	
CCSA-04	175,708	Green Diamond Resource Co.	DS	Private Land HCP	South of Mill Creek SP to Bald Hills; Straddles Klamath River
CCSA-05	13,186	Prairie Creek SP	DS	State Park	
CCSA-06	147,862	Green Diamond Resource Co.	DS	Private Land HCP	South of Bald Hills to Jacoby Creek/Arcata Bay; Straddles CA-299
CCSA-07	221,089	Pacific Lumber & Green Diamond Resource Co's	DS	Private Land HCP	South of Eureka, CA to Humboldt Redwoods SP
CCSA-08	405	Grizzly Creek Redwoods SP	DS	State Park	Two parcels straddling CA-36

State/ CSA number	Total CSA acres	Name	Function[1]	Current management regime	Notes
CCSA-09	53,528	Humboldt Redwoods SP	DS	State Park	
CCSA-10	4,126	Angelo Coast Range Reserve	DS	University of California Natural Reserve System	
CCSA-11	48,443	Jackson State Demon. Forest	DS	State Land HCP	
CCSA-12	16,420	Dept. of Defense	DS	Federal Non-designated	
CCSA-13	38,698	Tomales Bay SP and Marin County	DS	State Parks, County Park, Marin County Open Space, Marin Municipal Water District	
CCSA-14	230,693	Mendocino Redwoods	DS	HCP in draft	
	1,019,523	California total			
	3,246,034	Range-wide total			

[1]DP = Dispersal, DS = Demographic Support
[2]See the Washington State Forest Practices Rules

Appendix D. Maps of MOCAs and CSAs

Figure D1. MOCAs and CSAs in Washington.

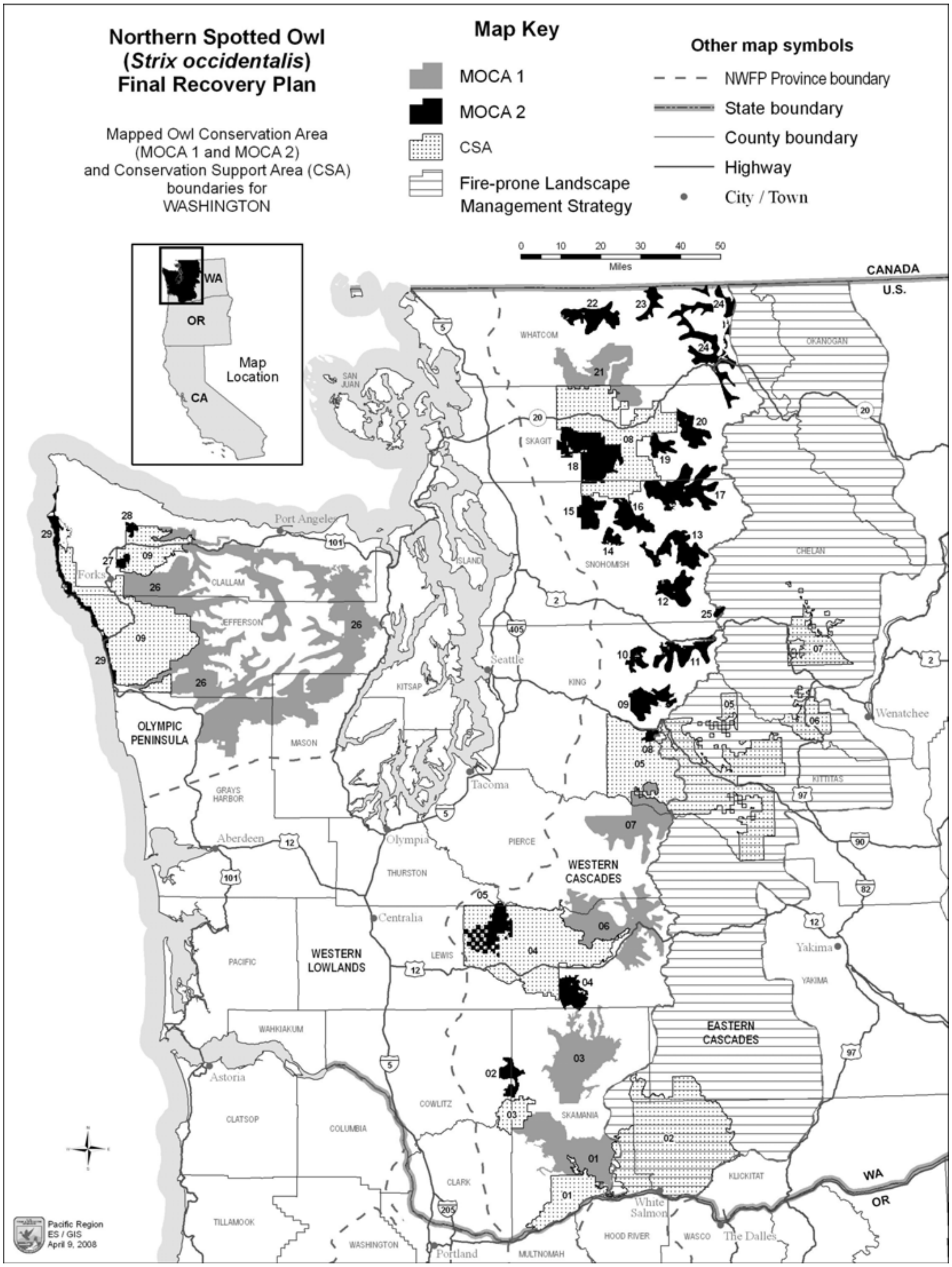


Figure D2. MOCAs and CSAs in Oregon.

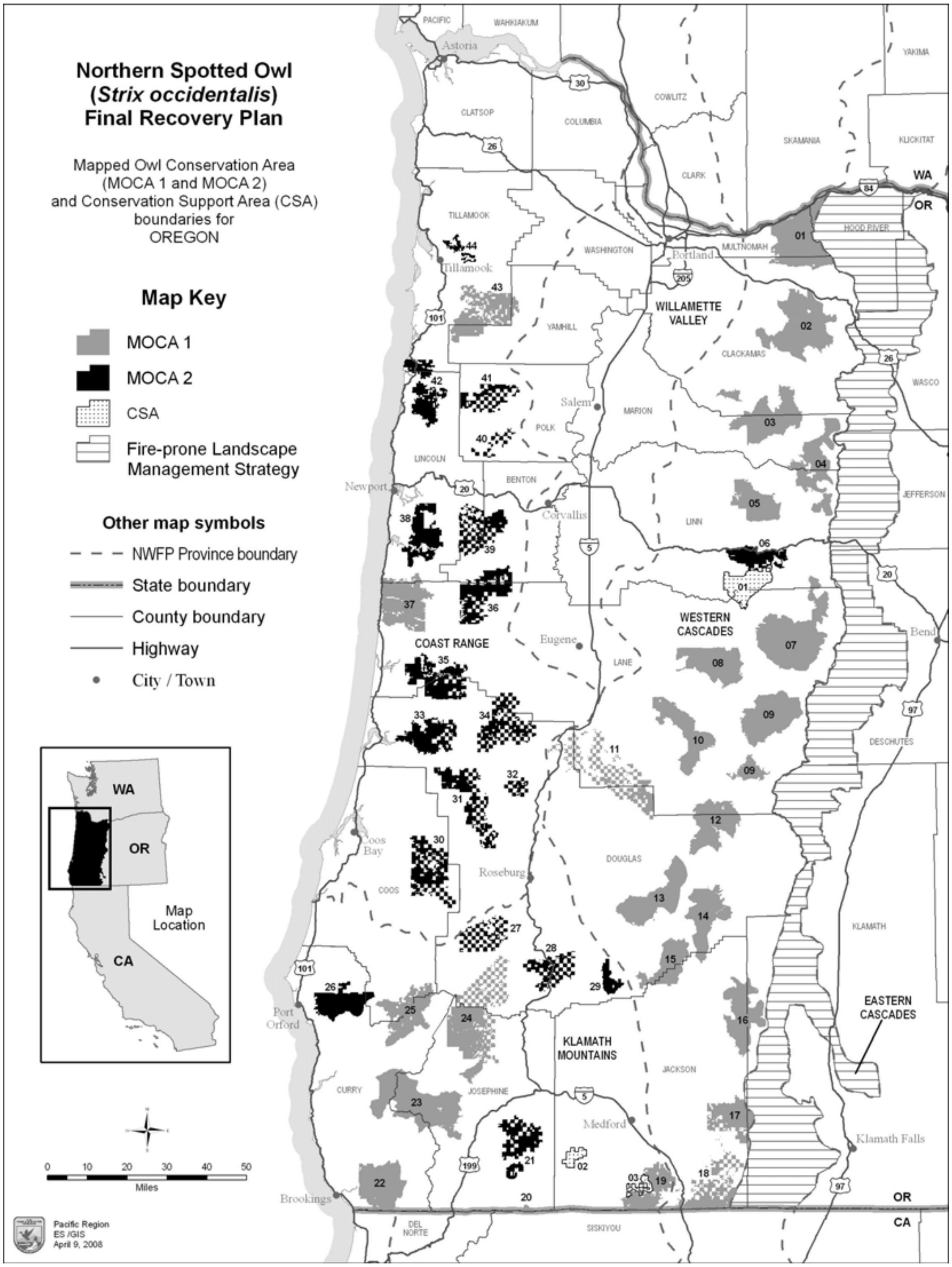
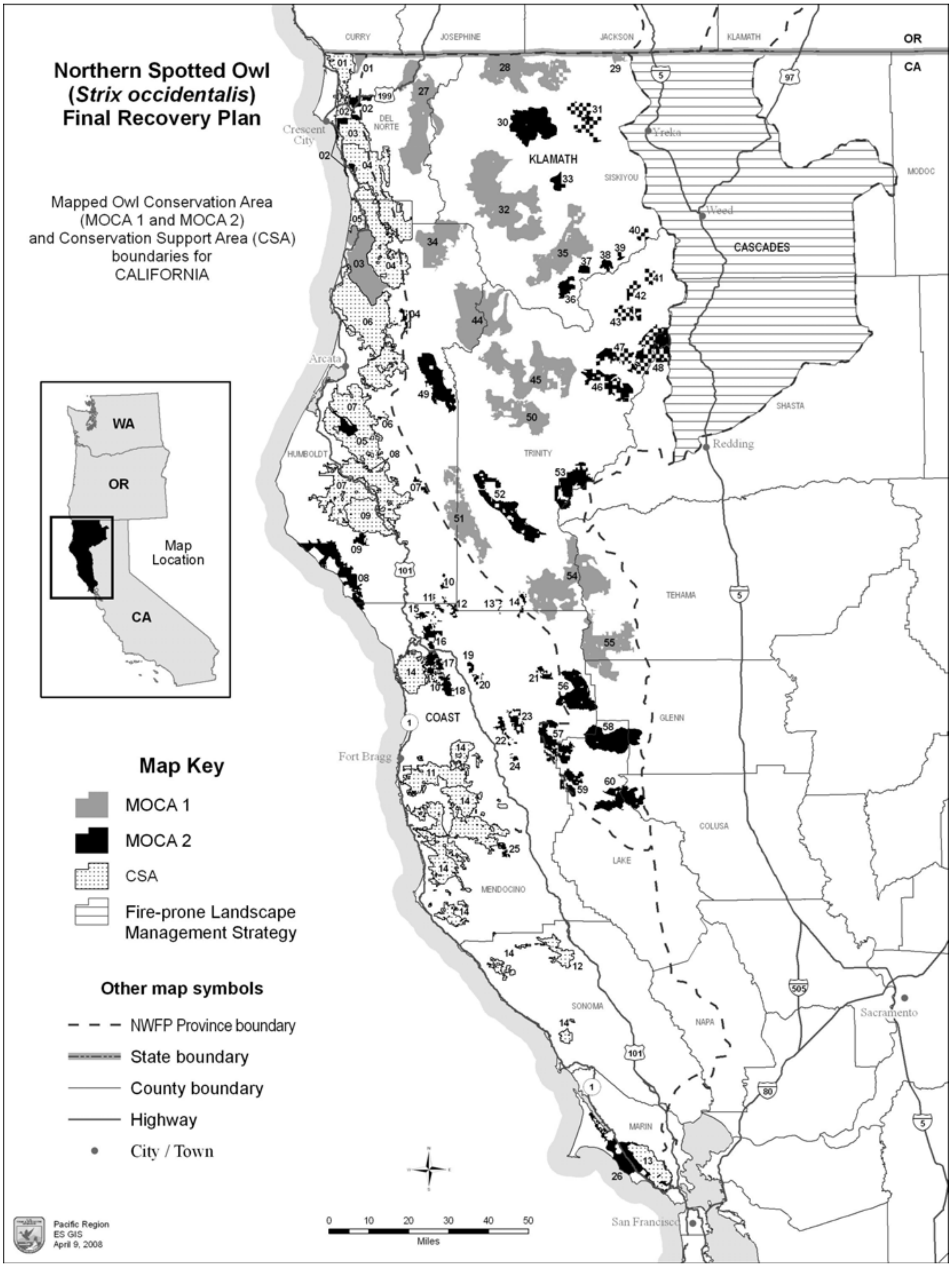


Figure D3. MOCAs and CSAs in California.



Appendix E. Managing for Sustainable Spotted Owl Habitat in Dry Eastern Cascades Forests of the Inland Northwest (from SEI 2008)

The text for this Appendix is excerpted from SEI (2008) and is provided as general guidance and information. See the main body of the Recovery Plan for the specific Recovery Actions that apply to the dry-forest Provinces.

Fire

Fire Modeling and Climate Change

Wildfire in Northern Spotted Owl habitat

Habitat loss by high severity wildfire is an important consideration related to the viability of the Northern Spotted Owl, particularly in the drier forest types in the Cascades and Klamath regions of California, Oregon, and Washington. Many of the Cascades and Klamath forests were once dominated by ponderosa pine in the overstory and experienced relatively frequent, low-to-moderate intensity fires (fire return intervals less than 20 years) (Taylor and Skinner 1998, Heyerdahl *et al.* 2001, 2002, Skinner and Taylor 2006, Skinner *et al.* 2006). Fire was effectively excluded from these forests by the 1930's and 1940's and this resulted in changes in forest structure, and canopy and surface fuel loads making these forests more susceptible to large, mixed and high severity wildfires, with stand replacement components dominating (Graham *et al.* 2004, Agee and Skinner 2005).

Several recent analyses have investigated whether wildfire has become more common in US forests. Stephens (2005) analyzed USFS fire records from 1940–2000 for the entire US and found that wildfire area had significantly increased in the western US, with the exception of California and Alaska, where no change was detected. In a more recent paper by Westerling *et al.* (2006), they determined that wildfire area has increased since the mid 1980's in the western US, and changing climates are likely contributing to this change. Most recently Rhodes and Baker (In Press) analyzed data from USFS burned area emergency rehabilitation reports (BAER) in the western US and argued that high severity wildfire was not as common in ponderosa pine forests as many have reported. Three recent papers have discussed the strengths and weaknesses of using BAER data in such an analysis (Odion and Hansen 2006, Safford *et al.* In Press, Odion and Hansen In Press). A new technique that analyzes remotely sensed data before and after wildfire (Collins *et al.* 2007) provides a more direct assessment of forest fire severity and the heterogeneity of fire effects. A similar analysis could be done in the Cascade and Klamath province to fully assess fire effects over the last 2 decades.

Recent research has documented the amount of high severity wildfire in Northern Spotted Owl habitat. Moeur *et al.* (2005) reported that the highest losses from wildfire occurred in the dry provinces (Klamath and Cascades). In the first decade of the Northwest Forest Plan (1994–2003) older forest (late-successional + old forest) losses to wildfire Plan-wide were about 1.3% but there was high variation between provinces. The highest losses of older forest were in the Oregon Klamath (21% of the administratively withdrawn/congressionally reserved group and 7% of the late succession reserve group), California Klamath (3% in administratively withdrawn/congressionally reserved group and 1% of the late succession reserve group), and Washington eastern Cascades (3% of administratively withdrawn/congressionally reserved group and 2% of the late succession reserve group).

In another recent report Haynes *et al.* (2006) wrote that the Oregon Klamath province had a decadal rate of loss of about 9.5% regarding high severity wildfire, compared to a region wide average of 1.8%. If we assume that this percentage loss was similar for the province as a whole, then the high severity fire rotation would be about 105 years for this province (Haynes *et al.* 2006). This burning rate would result in a landscape with approximately 15% in a state with large ponderosa pine and Douglas-fir trees over 200 years old. The eastern Cascades province in Oregon had experienced relatively low losses to high severity wildfire up to 2002 but in 2003 the B and B fire burned, resulting in a fire rotation estimate for high severity fire in this province of 69 years. At the scale of an individual USFS Ranger Unit (The Sisters District) one-third of the Northern Spotted Owl habitat has burned by high severity wildfire since 2002 and this has reduced the number of Spotted Owl pairs from 23 to 6 on this District. High amounts of Spotted Owl habitat loss during the last decade in the Cascades province also agrees with comments provided by Dr. James Agee, Emeritus Professor of Forest Ecology at the University of Washington (Agee 2007). In his written comments, Dr. Agee provides estimates of acres lost to high severity wildfire and the percent of habitat that would be lost in 100 years if current burning rates continue; the amount of habitat loss from high severity fire varied from 52 to 100% in the next century which would significantly affect the Spotted Owl. Care should be taken when interpreting the losses of forests to high severity wildfire over only a decade but the trend is very troubling.

Regarding the disagreement (Rhodes and Baker In Press versus Moeur *et al.* 2005, Haynes *et al.* 2006, Agee 2007) in the amount of forests burning by high severity wildfire--there are three issues to discuss. The first is the spatial scale of the analysis; the scale of analysis matters. Rhodes and Baker (In Press) conduct their analysis at large spatial scales similar to that done by Stephens (2005) and Westerling *et al.* (2006). None of these analyzes at large spatial scales could answer questions at the Northern Spotted Owl province scale. The second issue concerns possible problems associated with estimating forest fire severity with BAER data versus a more direct assessment of remotely sensed data discussed above. Lastly, the analyses of Moeur *et al.* (2005) and Haynes *et al.* (2006) were targeted to Northern Spotted Owl provinces in California, Oregon, and Washington and are therefore the most appropriate for this assessment.

Forest management in an era of changing climates (Adapted from Millar et al. 2007).

During the last several decades, forest managers have relied on paradigms of ecological sustainability, historical range of variability, and ecological integrity to set goals and inform management decisions. These concepts commonly use historical forest conditions – usually defined as those that occurred before Euro-Americans dominated North American landscapes – as a means of gaining information about how healthy forests should be structured. By managing forests within the range of historic conditions, managers have assumed they were maximizing chances of maintaining ecosystems—their goods, services, amenity values, and biodiversity—sustainably into the future. The pervasiveness of natural climatic variability, as well as novel anthropogenic effects on climate, mean that environments are not static (IPCC 2007). Novel anthropogenic stressors such as pollution, habitat fragmentation, land-use changes, invasive plants and animals, and altered fire regimes interact with climate change at local to global scales. The premise of an uncertain and variable future can be addressed with approaches that embrace strategic flexibility, characterized by experimentation and calculated risk-taking (including decisions of no action), capacity to re-assess conditions frequently, and willingness to change course as conditions change (Hobbs *et al.* 2006). Some specific ideas that could be used to manage forests under changing climates are:

Adaptation Options

Create Resistance to Change. One set of adaptive options is to manage forest ecosystems so that they are better able to resist the influence of climate change or to forestall undesired effects of change. From high-value plantations near harvest to high-priority endangered species with limited available habitat, maintaining the status quo for a short time may be the only or best option (Stephens and Moghaddas 2005a,b). Resistance practices seek to improve forest defenses against direct as well as indirect effects of rapid environmental changes. In western North America these will commonly include reducing undesirable or extreme effects of fires, insects, and diseases (Graham *et al.* 2004, Agee and Skinner 2005). Treatments might include fuel breaks around highest risk or highest value areas (forests with high amenity or commodity values, or at-risk species); intensive removal of invasives; or interventions such as those used in high-value agricultural situations (*i.e.,* resistance breeding or novel pheromone applications). Abrupt invasions, changes in population dynamics, and long-distance movements of native and non-native species are expected in response to changing climates (Keeley 2006). Climate changes may also catalyze conversion of native insects or disease species into invasive species in new environments, such as with mountain pine beetle (*Dendroctonus ponderosae*) east of the Continental Divide in Canada (Carroll *et al.* 2006). Taking early defensive actions at key migration points to remove and block invasions are important to increase resistance.

Promote Resilience to Change. Resilient forests are those that not only accommodate gradual changes related to climate but tend to return toward a prior condition after disturbance either naturally or with management assistance.

Promoting resilience is the most commonly suggested adaptive option discussed in a climate-change context (Price and Neville 2006), but like resistance, is not a panacea. Resilience in forest ecosystems can be increased through practices similar to those described for resisting change but applied more broadly, and specifically aimed at coping with disturbance. Decisions that emphasize ecological process, such as increased use of managed wildfire in remote areas (Collins and Stephens 2007), along with structure and composition become critical, just as institutional flexibility is likely more effective than rigid or highly structured decision-making (Harris *et al.* 2006).

Enable Forests to Respond to Change. This suite of adaptation options intentionally plans for change rather than resisting it, with a goal of enabling or facilitating forest ecosystems to respond adaptively as environmental changes accrue. Treatments implemented would mimic, assist, or at least accommodate ongoing natural adaptive processes such as species dispersal and migration, population mortality and colonization, changes in species' dominances and community composition, and changing disturbance regimes. The strategic goal is to encourage gradual adaptation and transition to inevitable change, and thereby to avoid rapid threshold or catastrophic conversion that may occur otherwise.

Capacity to move (migrate) in response to changing climates has been key to adaptation and long-term survival of plants and animals in historic ecosystems. Plants migrate (shift ranges) by dying in unfavorable sites and colonizing favorable sites, including internal species' margins. Capacity to do this is aided by managing for connected landscapes, that is, landscapes that contain continuous habitat with few physical or biotic impediments to migration, and through which species can move readily (Noss 2001). Promoting large forested landscapes with flexible management goals that can be modified as conditions change may assist species to respond naturally to changing climates (Noss 2001). Desired goals include reducing fragmentation and planning at large landscape scales to maximize habitat connectivity.

Note that one of the predicted consequences of climate change is for an increase in fire frequency in previously mesic habitats. If the west-side mesic forests begin to show higher fire frequencies (and/or intensities), this may affect the capability of the west-side reserve network to recover Spotted Owls. This possibility could be addressed by the ongoing Spotted Owl Work Group.

Managing for Sustainable Northern Spotted Owl Habitat in Dry Eastern Cascades Forests of the Inland Northwest

Background

According to the Draft Recovery Plan for the Northern Spotted Owl (USFWS 2007b), a significant portion of existing habitat for Northern Spotted Owl occurs in relatively dry forest environments east of the Cascade Crest in Oregon and

Washington and in the Klamath province. Lint (2005) found that habitat losses to wildfire and insect outbreaks were of concern for Spotted Owl persistence in dry forest areas within the range of the Northern Spotted Owl. Public comments received for the DRP indicated similar concerns. To examine the effects of natural disturbances on Spotted Owl habitat, the area within the range of the Northern Spotted Owl might be divided into three logical sections: 1) relatively moist environments in northwestern Oregon and western Washington (west-side), 2) drier environments east of the Cascade Crest (east-side), and 3) mixed and highly variable environments in the Klamath province (Klamath).

Though somewhat variable, especially farther south, natural disturbance regimes on the west-side were historically dominated, and continue to be dominated in the present-day, by high intensity wildfires with long return intervals (Agee 1993). West-side wildfires have return intervals ranging from less than 100 years to those many centuries long. Return intervals become shorter on drier sites and to the south. Due to longer fire return intervals, west-side forests have not suffered the consequences of fire suppression to the degree that east-side forests have. Wildfire risks have not increased dramatically in most west-side environments and dense old forests are relatively stable on the west-side. Given the relative stability of older forests and Spotted Owl habitat in west-side forests, the panel suggests that the current habitat reserve approach works well on the west-side, and that this is still the best supported conservation strategy in terms of likelihood of success. Despite relative stability, some loss of old forest to natural disturbances will occur and replacement over time will be necessary.

The Klamath province contains highly variable environments, forests, and fire regimes. Many areas in the western portion of the Klamath experience wildfire regimes like those of the west-side farther north. The eastern portion of the Klamath also exhibits forest types and fire regimes like the east-side. Unfortunately, local conditions are highly variable as a result of soils, climate, topography, and other influences. The panel suggests that the current reserve approach for Spotted Owl habitat is adequate for the short term, but that the area could be examined more closely for portions in which fire and other disturbance risks behave like those on the east-side. A province-scale analysis could be carried out to tailor habitat management approach to local conditions. We note the 2006 workshop sponsored by USFWS as an important step toward this goal.

East-side forests experience a variety of natural disturbance regimes, but were historically dominated by relatively frequent, low and mixed severity wildfire. This fire regime suggests that owl habitat in east-side forests be managed using a different approach, based on landscape-wide combinations of habitat and fuels treatments. This report addresses comments received during review of the DRP and provides recommendations for sustainable management of Northern Spotted Owl habitat in dry forest environments east of the Cascade Crest in Oregon and Washington.

This report discusses Northern Spotted Owl habitat in the context of the larger suite of dry, east-side forests that contain old forest attributes and characteristics. The broader range of old forest conditions in dry east-side environments includes both relatively open forests dominated by large trees of fire tolerant species and more dense forests with multiple canopy layers and abundant small trees of a variety of species. When we refer to Northern Spotted Owl habitat, we mean that subset of dry, east-side, old forest conditions that provide suitable owl habitat.

East-side Forest Environments and Disturbances

Natural disturbance regimes in dry east-side forests in the range of the Northern Spotted Owl vary with the climate, topography, surficial geology, landforms, and other factors. Potential vegetation types (Hall 1998) are often used as convenient environmental strata to discuss overall severity and frequency of wildfires and other natural disturbances, and we use them here to partition the landscape and disturbance ecology and habitat management within the dry forests. Hessburg and Agee (2003) described the historical wildfire regimes of interior Pacific Northwest forest potential vegetation types as low severity, low to mixed severity, mixed severity, or high severity (Table E1). They characterized low-severity regimes (those where <20–25% of the overstory crown cover or basal area was destroyed by the sum of all fire effects) as those that historically (*i.e.,* prior to 1900) were surface fire dominated, had frequent fire return intervals, low fireline intensity, small patch size, and relatively little edge. Mixed-severity regimes (those where 20–75% of the overstory crown cover or basal area was destroyed by the sum of all fire effects) exhibited less frequent fire return, a mix of fire intensities that included surface and stand-replacement fires, intermediate patch sizes, and significant edge between patches. In contrast, infrequent fire, generally high fireline intensity, large patch sizes, and intermediate amounts of edge were typical in high-severity regimes. High-severity wildfire regimes (those where >70–75% of the overstory crown cover or basal area was destroyed by the sum of all fire effects) are often called "stand replacement regimes" because most of the above ground vegetation is killed by infrequent, severe wildfires. Generally speaking, historical wildfires became less frequent with increasing elevation and in protected topographic locations (Camp *et al.* 1997). For simplicity, we categorize major forest types as having low, mixed, or high severity natural wildfire regimes. While we describe historical wildfire regimes for all east-side forest types, we focus on old forest structure and composition in dry forest environments that were dominated by relatively open, fire tolerant forests that experienced low and mixed severity historical fire regimes (Agee 1998, 2003, Hessburg and Agee 2003, Hessburg *et al.* 2007).

Several forest potential vegetation series with stand replacement fire regimes are important components of the east-side forested landscapes within the range of the Northern Spotted Owl. Engelmann spruce-subalpine fir forests occur at upper elevations in environments dominated by long winters, deep snow, and relatively continental climates throughout western North America (Barbour and Billings 2000, Hemstrom 2003). Extensions of several west-side forest types with stand replacement fire regimes occur near the Cascade crest and in the northeastern corner of Washington, including mountain hemlock, Pacific silver fir, western hemlock, and western redcedar-western hemlock forests. Historical fire return intervals typically exceeded 100 years and fires were usually of mixed and high severity in each these forest types, with stand replacement fire effects dominating. Old forest structures in these forest types were similar to those found in west-side Douglas-fir and western hemlock types and included multiple canopy layers, abundant large old trees, and abundant large standing and down dead wood. Consequently, the science panel assumes that a reserve-based approach to conserving Northern Spotted Owl habitat will suffice in these forest types where they exist east of the Cascade Crest in Oregon and Washington.

Lodgepole pine forests are extensive at middle to upper elevations east of the Cascade Crest and are often seral to other forest types. Most lodgepole pine forests experience fire return intervals of less than 100 years with mixed severity to stand replacement historical fire regimes (Hessburg and Agee 2003). Lodgepole pine forests within the Northern Spotted Owl range seldom exceed 200 years in age, in contrast to those found farther east in the Rocky Mountains and elsewhere (*e.g.,* Kaufmann 1996), due to relatively frequent stand replacement wildfire and insect outbreaks (Agee 1993). Consequently, old lodgepole pine forests within the Northern Spotted Owl range rarely contain many trees over 20 to 24 inches in diameter and are likely not important Northern Spotted Owl habitat.

Natural Disturbances Regimes of East-side Dry Forests

Fire regimes of the pre-settlement era maintained shifting landscape mosaics dominated by fire tolerant cover types and fire tolerant structures. Fire intolerant cover types and structures also existed, but they tended to be spatially isolated in a matrix of fire tolerant land cover and structure. (References to "matrix" in this appendix refer to matrix in a generic sense, not to NWFP matrix.) In this context, landscape functionality and resilience in the face of many types of disturbances came from dynamism, a mosaic of conditions shifting over space and time as a consequence of disturbances. Steady state conditions where they existed were temporary features in the dry forests. These broad insights would suggest that owls and owl habitat conservation may be better served by borrowing some key insights from historical landscape dynamics and their functionality. This does not imply restoration to historical conditions would provide optimal owl habitat, rather that historical conditions provide useful information about disturbance and recovery dynamics in dry forests.

Compared to west-side old forests (Franklin *et al.* 1981), late-successional and old forests in dry east-side forest environments historically had: 1) fewer large old trees per unit area and smaller old trees in general, 2) fewer large standing dead trees, 3) fewer down logs, and 4) simpler canopy structure (Agee 1993, Covington and Moore 1994, Arno *et al.* 1997, Hann *et al.* 1997, Hessburg *et al.* 1999, 2000, 2005, 2007, Hessburg and Agee 2003). In these relatively dry settings, large, old, widely spaced ponderosa pine, western larch, or Douglas-fir dominated in the overstory, and occasionally under mixed species conditions. Often (~5–40% of the time), patches would be dominated by the cover of these large older trees, where 30 to 80% of the canopy cover or more was contributed by large and very large trees (old forests patches). However, most patches (~60–90% of the time, depending upon the landscape) exhibited a lower crown cover (<30%) of large and very large trees. Understory conditions could be much more variable, ranging from understories completely absent (old park-like and stem exclusion stands), to multi-layered understories (old and young multi-story forest), and single-layered understories (understory re-initiation structures).

Large trees of the fire-tolerant species have thick bark and show the capacity to resist mortality associated with low and mixed severity wildfires. Frequent wildfire consumed most dead wood, so large snags and down logs were generally sparse, but not absent. In open park-like old forest and stem exclusion stands, wildfires typically killed a few large trees where fuels were locally high due to insect-related mortality, a skipped fire return interval, or some other factor, resulting in openings, patches of regenerating conifers, and dead wood. Most of the basal area in old single story park-like forests was in multiple-aged large trees, which existed in a fine-scale mosaic or patchwork dominated by open forests with patches of smaller trees (Youngblood *et al.* 2004). Both old single story and old multi-story forest patches tended to be strongly multi-cohort, representing many fine scale disturbance events within patches that contributed to continuous regeneration of fine scale patches within patches.

Dry east-side forests had different structure, composition, and landscape patterns under historical disturbance regimes (Agee 1993, Covington and Moore 1994, Arno *et al.* 1997, Hann *et al.* 1997, Hessburg and Agee 2003, Hessburg *et al.* 1999, 2000, 2005, 2007). Decades of fire suppression, forest management, wildfires, insect outbreaks, and other factors have altered the structure of the few remaining dry old forests. Compared to historical conditions, current old forests in dry east-side environments are: 1) much less abundant, 2) often have multiple canopy layers and dense forest structure, 3) often exist in homogeneous landscapes with continuous and high surface and ladder fuel levels, and, consequently, 4) are highly susceptible to loss from stand replacement from wildfire or insect outbreaks.

Several forest and woodland potential vegetation series with low to mixed severity fire regimes may also occur within the Northern Spotted Owl range east of the Cascade Crest, including those dominated by ponderosa pine, Douglas-fir, grand fir, white fir, and ponderosa pine-Oregon oak (Table E1). Within this range of dry forests, Northern Spotted Owl habitat occurs largely within the Douglas-fir, grand fir, and white fir vegetation series. Because Northern Spotted Owl habitat is embedded in larger landscapes that may pose risks for loss to insect outbreak and wildfire, it is important to consider both Northern Spotted Owl habitat and the larger landscape matrix it is embedded in as critical context. Managing for sustainable Northern Spotted Owl habitat will generally require managing large landscapes that include a variety of forest types. For purposes of simplicity, we collapsed the various forest vegetation series that may provide or surround Northern Spotted Owl habitat into three general categories (dry ponderosa pine, dry mixed conifer, and moist mixed conifer; Table E1) that reflect major environmental and old forest differences.

Table E1. Major east-side series by dominant fire regime for east-side forests in the range of the Northern Spotted Owl (Hessburg and Agee 2003).

Forest series	Potential Vegetation Group	Severity of fire regime	Range of fire return intervals from various studies (years)
Ponderosa pine[1]	Dry ponderosa pine	Low	16–38, 7–20, 11–16, 3–36
Douglas-fir[2]	Dry mixed conifer	Low to Mixed	7–11, 10, 10–24, 14, 8–18
Grand fir/white fir[3]	Dry to moist mixed conifer	Low to Mixed	16, 47, 33–100, 17, 100–200
Lodgepole pine[4]	Lodgepole pine	Mixed	60
Western hemlock/ western redcedar[5]	Moist mixed conifer	High	50–200+,50–100, 150–500
Subalpine fir[6]	Spruce-fir	High	25–75, 109–137, 140–340, 250, 50–300

[1] Bork (1985), Weaver (1959), Soeriaatmadja (1966), Heyerdahl *et al.* (2001)
[2] Wischnofske (1983), Hall (1976), Finch (1984), Everett *et al.* (2000)
[3] Weaver (1959), Wischnofske (1983), Arno (1976), Antos (1981)
[4] Agee (1981), Stuart (1984)
[5] Arno and Davis (1980), Davis *et al.* (1980)
[6] Barrett *et al.* (1991), Agee *et al.* (1990), Fahnestock (1976), Arno and Davis (1980), Morgan and Bunting (1990)

Dry ponderosa pine forests

Ponderosa pine is the dominant early and late seral conifer in the driest forest environments. Dry ponderosa pine forests are somewhat uncommon east of the Cascade Crest in Washington, but are abundant further south in Oregon and elsewhere (Hopkins 1979a, b, Williams and Lillybridge 1983, Volland 1985, Lillybridge *et al*. 1995). Hessburg and Agee (2003) describe historical wildfires in dry ponderosa pine forests as generally frequent and of low-severity, with 7 to 38 year fire return intervals (Table E1). However, most forest landscapes, even in dry ponderosa pine environments, included some level of mixed and high severity wildfire under natural conditions. In dry ponderosa pine and dry mixed conifer stands, this often resulted in a patchy landscape with stand level mosaics of dominated by open forests of large trees with patches of smaller trees (Hann *et al*. 1997, Hessburg *et al*. 1999). Northern Spotted Owl habitat is generally not found in dry ponderosa pine forests, but may exist in other environments within a landscape that contains abundant dry ponderosa pine forest.

The driest forest environments grade into woodlands of ponderosa pine, western juniper, and Oregon white oak, depending on location and environment. In the central portion of the east Cascades, particularly in the Columbia Gorge area, Oregon white oak and ponderosa pine often form locally extensive woodland plant communities. Under natural conditions, these woodlands were maintained in open structure by summer drought and frequent wildfire (Agee 1993). Burning by Indo-Americans may have been an important component of the fire regime prior to 1850 (Agee 1993).

Dry mixed conifer forests

Douglas-fir, grand fir, and (in more open sites) ponderosa pine can regenerate beneath open old ponderosa pine canopies in somewhat more moist dry mixed conifer sites. While Douglas-fir or grand fir easily regenerate in the understories of dry mixed conifer forests, frequent low-severity wildfire maintained generally open stand structures under historical conditions. Agee (1993), Agee (2003), and Hessburg and Agee (2003) characterized the historical wildfire regime as low- to mixed-severity with fire return intervals of less than 10 to 50 or more years, depending on local conditions. Since dry mixed conifer forests occur in somewhat more moist and productive sites than dry ponderosa pine forests, they likely contained somewhat larger trees and higher large tree basal under historical conditions. Otherwise, old forest structure and composition in dry ponderosa pine and dry mixed conifer sites were similar under historical conditions. There were important differences too. One important difference was that although fire regimes were surface fire dominated, both low and mixed severity regimes contributed to those fires. This resulted in more variable mosaic conditions of structure and composition than occurred in the dry ponderosa pine forests, including patches and patch clusters of late-successional forest that were vulnerable to stand-replacement fires and insect outbreaks. These conditions likely supported the Northern Spotted Owl historically, and these are the same conditions that owls appear to be found in today. This notion of spatial isolation of late-successional forest structure embedded in a matrix of more fire tolerant forest structures forms the underpinning of our later recommendations.

Moist mixed conifer forests

Grand fir and Douglas-fir are important stand components in moist mixed conifer forests (Table E1). Moist mixed conifer forests occur in areas of higher precipitation, at somewhat higher elevations, or on more northerly aspects compared to dry ponderosa pine and dry mixed conifer forests. Forest productivity tends to be higher as well and historical wildfire return intervals somewhat longer. Consequently, old forests in moist mixed conifer sites likely had larger trees, higher basal area of large trees, and more abundant small trees and standing and down dead wood compared to those in dry mixed conifer forest. At the most mesic end, moist mixed conifer forests grade into types in which old forest characteristics are best characterized by west-side old forest definitions (Table E1). Because fires were less frequent and fuel loads higher under historical conditions compared to drier forest types, moist mixed conifer forests typically experienced a higher proportion of mixed and high severity wildfire than compared to forests on drier sites. Hessburg and Agee (2003) described the historical wildfire regimes of the Douglas-fir and grand fir series (most of the moist mixed conifer forests) as low- to mixed-severity, with mixed severity fires dominating, and with fire return intervals that ranged from less than 10 to over 100 years. High severity fires that regenerated new patches of forest were also an important component of moist mixed conifer forests, and to a lesser extent the dry mixed conifer forests, but these sorts of fires were not the dominant influence.

Western larch often is an important component of relatively dry east-side forests at higher elevations (Williams and Lillybridge 1983, Lillybridge *et al.* 1995, Williams *et al.* 1995). Large, old western larch possess a thick, fire-resistant bark and frequently survive low- to moderate-intensity wildfires. Under historical conditions, western larch filled an ecological role at upper elevations similar to that of ponderosa pine at lower elevations. Because western larch forests occurred in mid- and upper montane environments, fire regimes tended to be mixed-severity because fuel loads were higher and fires less frequent. Otherwise, old forests dominated by western larch under historical conditions had structures similar to those found in east-side moist mixed conifer environments.

Changes in forest conditions during last 150 years

The structure and composition of old forests in dry east-side environments changed dramatically following Euro-American settlement in the nineteenth and early twentieth centuries (*e.g.,* Harrington and Sackett 1992, Covington and Moore 1994, Hessburg *et al.* 1994, 1999, 2000, Hemstrom *et al.* 2007, Vavra *et al.* 2007). Fire suppression, human settlement, timber harvest, livestock grazing, subdivision by land ownership, development of road and rail networks, introduced diseases, and other factors altered disturbance regimes, forest structure and composition, the mix of stand structures across landscapes, understory regeneration rates, and species mixes in regeneration following disturbance. Fire suppression and fire exclusion influences (livestock grazing, road and rail development, development of grasslands to agricultural uses) had an obvious effect on wildfire frequency and spatial extent, and consequently, on fuel levels and subsequent wildfire intensity. Fire suppression reduced wildfire frequency to the extent that nearly all dry east-side forests have missed one to as many as 7-10 expected wildfire returns since the early twentieth century. Decreased fire frequency allowed seedlings to survive, especially fire intolerant Douglas-fir, grand and white fir seedlings, and become dense understories of pole to small-sized trees in most stands.

In many cases, multi-layered stands developing in the present-day consist of a sparse to absent overstory of old ponderosa pine, western larch, or Douglas-fir with an increasingly dense understory of grand fir, Douglas-fir, or ponderosa pine. Increased stand density has several implications: 1) wildfires, when they do occur, are more intense due to high surface and canopy fuel levels, 2) a dense understory competes for moisture and nutrients with large old overstory trees which become stressed and increasingly susceptible to insect (especially tree-killing bark beetles) and disease-related mortality, and 3) forest cover and structure across large landscapes have become more homogeneous, leading to larger and more contiguous wildfires and insect outbreaks. As a result of changed disturbance regimes and human activities, east-side old forests have become increasingly uncommon, especially in dry ponderosa pine and dry mixed conifer environments. Old forests dominated by widely spaced, large ponderosa pine and western larch were once more abundant in east-side forested landscapes prior to 1850, but have become minor components today (Hessburg *et* *al*. 1999, 2000). Many present-day dry forest landscapes contain very little old forest structure at all since the large old ponderosa pine and larch trees were logged, burned in severe wildfires, or succumbed to insect attack over the last 100 years or more. Those stands that do contain large old ponderosa pine and larch generally also contain dense understories that put the large old trees at risk to wildfire or insect attack.

Early seral ponderosa pine and western larch do not regenerate or differentiate well in closed forests or those where overstory canopy cover exceeds 30–40% (Lillybridge *et al*. 1995), and they often require 200 or more years to become large enough to contribute to late-successional or old forest structure. Unfortunately, these key old forest structures are easily lost to wildfire, insect attack, or disease and many stands that might otherwise have high old forest potential lack sufficient numbers of large old trees in the overstory. This situation highlights a key contrast to old forest definition and management in moist west-side environments: management may often be required to protect or restore old forest conditions in east-side environments. Most west-side old forests can persist without wildfire or management for many centuries, but rapid mortality of large, old ponderosa pine and western larch as a consequence of changes to disturbance regimes can result in the loss of old forest structure in dry east-side forests. Management to reduce the density of understory trees and restore both meso- and fine-scale forest patchiness can be critical to conserving existing dry east-side old forests. Suitable management can take many forms, including various combinations of low and free thinning, prescribed burning, and wildfire for resource use (prescribed natural fire). The key ingredients in all management to produce, conserve, or protect dry east-side old forest is the retention or generation of sufficient numbers of large and very large, old ponderosa pine, western larch, and (in some cases) Douglas-fir and the maintenance of both meso- and fine-scale patchiness among and within stands.

Restoring Old Forest Characteristics in Dry Environments

Based upon past and current research about the landscape and disturbance ecology of historical east-side forests, restoration of late-successional and old forests as part of the Northern Spotted Owl Recovery Plan must usefully consider three major objectives: 1) provision of sufficient Northern Spotted Owl habitat in the short term to allow owls to persist in the face of threats from Barred Owl expansion and habitat loss from wildland fires, 2) building a landscape that is resistant and resilient to fire disturbances in the short term and more resilient to alterations that might be induced by climatic warming and drying in this next century, and 3) provision for restored function of a variety of ecological services provided by late-successional and old forests.

The ability of Barred Owls to increase in dry forest environments is unknown (although we heard a presentation from Singleton that suggested that Barred Owls in one such area were at high numbers, albeit in 'greener' habitats) and some likelihood exists that Northern Spotted Owl habitat management in dry forests will have no beneficial effects on Barred Owl invasion. However, short-term Northern Spotted Owl habitat loss can be reduced by careful landscape-scale reduction of wildfire and insect outbreak risks. Management of these risks in the short term could begin near existing centers of Northern Spotted Owl habitat within Late Successional Reserves with the objective of buying time to implement landscape-wide risk management. Managing to reduce risks of loss of Northern Spotted Owl habitat to insects and wildfire also benefits other ecological conditions associated with old forests. The large old trees of fire tolerant species that anchor Northern Spotted Owl habitat in dry forests also are imperiled keystone structures for other species and ecosystem processes. In essence, landscape management to benefit Northern Spotted Owl habitat can also benefit many other ecosystem processes, ecosystem functions, and wildlife habitats.

Management of risks across larger landscapes

The contiguity and homogeneity of dense forest vegetation in dry environments in the current condition differs from historical patterns (Hessburg *et al.* 1999, 2000, 2005) and presents virtually continuous surface and canopy fuels that enable large-scale wildfires to eliminate or severely depreciate Northern Spotted Owl habitat (Camp *et al.* 1997, Everett *et al.* 2000). Management activities to reduce the contiguity of dense, relatively uniform forests can reduce the risks of Northern Spotted Owl habitat loss by isolating habitat patches and reducing the spread of wildfire into habitat patches (Agee *et al.* 2000, Ager *et al.* 2006). Agee *et al.* (2000) suggest the use of shaded fuel breaks to reduce the contiguity of landscape fuels. These could be modeled after the historical distribution of open forests, non-forest areas, and other lower-risk fuels using natural vegetation, landform, and topographic breaks, along with vegetation management. Such fuel breaks existed naturally in the historical landscape and were highly functional.

Mosaics of forest and other vegetation patches with variable sizes, composition, stand density, vegetation type, and fuel levels could provide resistance and variability of resistance to wildfire and other disturbances, thereby reinforcing similar patch size distributions in the future (Spies *et al.* 2006). Historically, these were represented by the negative exponential or J-shaped distribution of patch sizes (Hessburg *et al.* 2007). Patches might range in size from a tenth acre to thousands of acres with some few very large patches and more abundant smaller patches. For example, a few patches could be very large, perhaps ranging in size from 1,000 acres to 3 or 4 thousand acres, or more. Median size might be approximately 50–250 ac and most patches should range in size from parts of an acre to tens of acres. Historical conditions might provide lessons about the sustainable kinds and sizes of patches in individual landscapes. Emerging methods to examine fire and other disturbance risks could be used to examine effects of treatment patterns on reducing wildfire risks to Northern Spotted Owl habitat across many stands (*e.g.*, Finney 2004, Ager *et al.* 2006, Kennedy *et al.* 2008) and many watersheds or larger areas (*e.g.*, Hemstrom *et al.* 2007). Treatments to reduce fire and insect outbreak risks to Northern Spotted Owl habitat should be done in the broader context of restoring broader ecological functions and processes to landscapes.

Restoration of fire tolerance

Decades of fire suppression, forest management, and other changes have altered the composition and structure of dry forests so they can no longer tolerate low and moderate severity wildfire. Restoration of fire tolerance within forest stands is required to reduce landscape and stand-scale susceptibility to stand-replacing disturbance. Once treated, the landscapes surrounding Northern Spotted Owl habitat should act as retardants to wildfire and insect outbreaks rather than as conduits. Many recommendations exist about the kinds of management activities that can reduce fuels and fire risks in dry forests (*e.g.,* Agee 2002, Hessburg and Agee 2003, Hessburg *et al.* 2005, Brown *et al.* 2004, Agee and Skinner 2005, Peterson *et al.* 2005, Stephens and Moghaddas 2005a,b). The science panel recommend Agee's (2002) summary of *FireSafe* fuel treatment principles:

1. Reduce surface fuels—especially volume in the 1-hr (herbs, litter, round wood < ¼ " dia.), 10-hr (duff to 4" depth, and round wood ¼ - 1" dia.), 100-hr (round wood 1–3" dia.), and 1000-hr (3–6" dia.) time lag classes, decreases flame lengths and fireline intensity.
2. Increase the height to live crowns—eliminates fuel ladders, which means longer flame lengths are needed to facilitate tree torching. Amounts to removing the lower crown classes—seedlings, saplings, poles, small and sometimes medium sized trees.
3. Decrease crown density—reduces crown fuel continuity, the propensity for canopies to trap heat, and thereby, the likelihood of running crown fires. Decreasing crown density is the least important of all other principles are applied. This principle may be applied variably across the landscape and would appropriately be ignored in owl habitat to maintain prey habitat and provide closed canopy owl habitat.

Favor retention of fire tolerant tree species

In addition to simply treating fuels, restoration of fire tolerance should restore fire tolerant tree species to their former role in dry forest landscapes. Large, old trees of ponderosa pine, western larch, Douglas-fir, sugar pine, incense-cedar, Jeffrey pine and a few others (depending on location) have thick, fire-resistant bark and other attributes that allow them to withstand most low and mixed severity wildfires. Large, old trees of these species provide the anchors for Northern Spotted Owls and other species habitat in dry forests, often surviving for centuries while smaller trees in the lower and mid-canopy come and go with disturbance. Even sapling and pole sized ponderosa pine are more tolerant of low and mixed severity fires than Douglas-fir, grand fir, and white fir in equivalent sizes. Smaller size classes of fire tolerant tree species provide the recruitment resource for future large and very large fire tolerant trees. The panel recommends consideration of five additional stand restoration and fuel treatment principles:

1. Favor fire tolerant tree species during treatments, thereby steadily improving the fire tolerance of stands, especially where fires are typically low or mixed severity.
2. Retain the large and very large fire tolerant trees—existing old trees of fire tolerant species (ponderosa pine, western larch, Douglas-fir, sugar pine, incense-cedar, Jeffrey pine, and a few others depending on location) should be retained throughout the landscape managed for Northern Spotted Owl habitat. These trees take 150 or more years to grow and are not easily replaced. They are key habitat features that can persist for centuries. Large trees of other species (*e.g.,* grand fir and white fir) and younger, smaller trees (*e.g.,* <20" DBH) of fire tolerant species may be removed outside critical owl habitat to reduce canopy fuels. The panel recommends that visual criteria including bark and canopy characteristics and other indicators be developed to aid field recognition of old trees regardless of diameter.
3. Apply treatments unevenly within stands—creating fine-scale landscapes within stands. Fuel and other stand-scale restoration treatments should produce a fine-scale mosaic of open patches of large trees, denser patches with mid-canopy trees, and regeneration within a landscape that generally meets *FireSafe* principles (above). Creating fine-scale landscapes within stands, provides for species and processes that operate at a smaller patch scale (range from <0.1 acre to 100+ acres). Many plants, animals, and processes rely on a relatively fine scale pattern of patchiness than occurs at a tree, sub-patch, patch, patch-group, or neighborhood scale.
4. Apply treatments unevenly among stands—creating meso-scale landscape mosaics within regional landscapes.
5. Develop silviculture prescriptions for entire landscapes (landscape silviculture) that integrate the above fuel reduction objectives with those for maintaining or improving habitat for Northern Spotted Owl prey habitat, habitat for other species, and restoration of dry forest ecological process and function.

Management of the whole of the dry forest landscape to provide Northern Spotted Owl habitat

Northern Spotted Owl habitat in dry forests east of the Cascade Crest in Oregon and Washington exists in a larger landscape matrix containing a variety of forest types. It is important to manage entire, large landscapes for sustainable Northern Spotted Owl habitat. In the current condition, Northern Spotted Owl habitat is embedded in larger landscapes that are themselves susceptible to disturbances that originate elsewhere, carried by dense forests that serve as contiguous fuels or insect food. Regardless of management intentions, existing dry forest landscapes facilitate loss of Northern Spotted Owl habitat and will continue to do so until landscape fuel and risk management become effective. Even when landscape risk management has become effective, adverse fire weather and other factors may drive disturbances through designated Northern Spotted Owl habitat. The maintenance of Northern Spotted Owl habitat in dry forests cannot sustainably rely on designated reserves in risk-rich landscapes. Entire landscapes will have to be managed to sustain habitat and generate new Northern Spotted Owl habitat as disturbances inevitably remove existing habitat. In essence, all of the dry forest landscape area of several million acres would need to be managed to restore ecological process and function as well as embedded Northern Spotted Owl habitat. Landscape plans would identify existing Northern Spotted Owl habitat, disturbance risks, and viable strategies to provide sufficient Northern Spotted Owl habitat over decades and longer. Sustainable amounts of Northern Spotted Owl habitat and other forest types as well as management strategies to provide sufficient habitat will vary by landscape. The panel suggests that existing high quality habitat could be recognized as important habitat initially but with the expectation that some will cease to be habitat in the future as a result of disturbance. Such habitat should be reviewed and re-designated on a periodic (*e.g.,* 10 year) basis.

The Final Recovery Plan may call for higher levels of dense late-successional and old forest than historically occurred in many dry forest landscapes. Historical abundance of late-successional and old forests habitats in fire-prone forests ranged from about 5% to 40% of many dry forest landscapes, depending upon the landscape (Hessburg *et al.* 1999, 2000). This means that landscape management objectives may target levels of dense old forest that are on average difficult to retain in dry forest environments in the long term (100 years +), even though required by management policy. Active management to reduce wildfire and insect outbreak risks will be required to off-set risks of habitat loss. Ultimately, initial approaches for managing dry forests to sustain substantial amounts of dense conditions may fail. Monitoring and adaptive management are necessary to allow adjustment.

The panel recommends several considerations to aid in landscape planning for sustainable Northern Spotted Owl habitat:

1. **Identify high quality Northern Spotted Owl NRF habitat patches or neighboring groups of patches (patch clusters) throughout dry forest provinces**
    a) Local owl biologists should identify existing high quality Northern Spotted Owl habitat. Given that many Spotted Owls have been probably been displaced by Barred Owls, particularly in Washington, there will need to be two complementary efforts to identify i. areas currently occupied by Spotted Owls (highest priority) and ii. areas currently unoccupied but with high recovery potential (*e.g.,* if Barred Owls were removed). This is not a trivial effort - it will require extensive surveys, and will need to be current at the time that fire management decisions are made (that is, surveys may need to be repeated periodically).
    b) Start risk reduction treatments around key Northern Spotted Owl habitat. Much of the existing high quality Northern Spotted Owl habitat likely exists within late successional reserves (LSRs). High quality habitat should be identified and fuels management and other

restoration treatments should be applied adjacent to high quality habitat to reduce fire risks while maintaining medium and large tree structure and favoring fire tolerant tree species. The objective is to protect current high quality habitat *and* make recovery of habitat inevitably removed by disturbance a relatively quick process. High quality Northern Spotted Owl habitat should be in patch clusters of several hundred acres (+ or -) distributed across the landscape, especially in locations where fire refugia (Camp *et al.* 1997) might be expected to occur. Starting treatments around existing high quality Northern Spotted Owl habitat serves two purposes: 1) it attempts to conserve and protect from stand replacement wildfires the best existing important habitat and 2) it buys time to implement a larger landscape risk management and Northern Spotted Owl habitat plan.

c) Total area of owl habitat patches or patch clusters averages 30–35% of overall landscape area managed for Northern Spotted Owl habitat, but this should vary by landscape; *i.e.,* it will be lower in landscapes dominated by the driest forest types and somewhat higher in landscapes dominated by the moist forest habitats.

2. **Embed the high quality Northern Spotted Owl habitat patches in a matrix that has been treated to reduce the potential for significant losses by stand replacement fires.**
    a) A large portion (*e.g.,* 50 to 70%) of the landscape may be treated to reduce risks to high quality Northern Spotted Owl habitat and achieve other management objectives, depending on the particular landscape in question. In general, at least 20–25% of the landscape likely needs be treated if treatments are spatially optimized to constrain severe fire behavior (Finney 2004, Ager *et al.* 2006, Lehmkuhl *et al.* 2007). Because treatments will likely not be spatially optimized in this sense, most of the dry forest matrix outside critical Northern Spotted Owl habitat may need to be treated. Particular attention should be given to effective fuel treatments around existing high quality Northern Spotted Owl habitat.
    b) Consider the lessons from historical patterns when designing landscape fuel treatments. Incorporate spatial heterogeneity of dry forest stand structure in restoration treatments.
    c) It is critical to think of the matrix as the pool of structural conditions, from which future old forest and late-successional structure will derive to losses from fire and insects.
    d) In that light, the dry forest matrix can be managed for a full complement of all structural classes.

3. **Active management of the matrix as a high priority.**
    a) Treatments in dry forest landscapes should be motivated by a combination of Northern Spotted Owl habitat concerns and other ecological and management objectives.
    b) Treatment should be done in a way that deals with surface fuels, fuel ladders, and density, but maintains structural conditions supporting

prey occurrence and abundance in current or potential NRF habitat, maintains structural conditions conducive to Northern Spotted Owl foraging, and allows for rapid development of replacement NRF habitat.

c) Treatments should allow for a fine scale mosaic of open forests, denser patches with mid-canopy trees, and regeneration patches.
d) A substantial portion of the managed matrix (*e.g.,* 20 to 35%) might be treated so it could very rapidly develop as replacement habitat (*e.g.,* over 20–25 yr). These areas should be managed such that they are more naturally resistant to fire and insect disturbances and are adjacent to or in the near vicinity of existing high quality Northern Spotted Owl habitat.
e) Another substantial portion of the managed matrix (*e.g.,* 20 to 35%) could be more heavily treated so it could provide higher disturbance resistance and develop with moderate pace as replacement habitat (*e.g.,* over 40–50 yr).
f) The proportions of the landscape in the rapid and moderately developing Northern Spotted Owl habitat (d and e above) will necessarily vary with landscape characteristics such as topography, productivity, land allocations (*e.g.,* Wilderness), ownership patterns, and other factors. Establishing these objectives should be part of larger and longer term landscape planning for sustainable Northern Spotted Owl habitat.
g) Once surface and canopy fuels are treated the first time, follow up treatments should occur at regular intervals to maintain fuels in accord with the FireSafe principles above. Lack of follow-up treatments would likely increase fire risks quite dramatically (Ager *et al.* 2007, Huff *et al.* 1995).

4. **As a high priority, determine the effects of fuel treatment activities on Spotted Owls**
   a) Spotted Owls and their prey may be negatively affected by some fuels treatment activities. If so, these negative effects should be weighed in any decision to apply treatments on a particular site. We note that canopy closure is a key issue, and suggest that treatments affecting this be limited.
   b) Research in these areas would provide much needed information, to be applied through adaptive changes in management.

Monitoring of treatments is important

Given the uncertainties around sustaining Northern Spotted Owl habitat in dry forest landscapes, monitoring is key. The landscape plan developed in the process of designing landscape-specific habitat objectives, treatment strategies, and projected outcomes forms the conceptual model that defines how managers think the landscape in question works, key interactions, and assumed management tactics and results. The conceptual model also forms the basis of key characteristics to monitor. Several landscape characteristics are likely important to monitor in any dry forest landscape managed for Northern Spotted Owl habitat:

1. Total Northern Spotted Owl habitat area and condition
2. Matrix area and condition
3. Effectiveness of spatial isolation on Northern Spotted Owl habitat clusters
4. Pattern, amount, and timing of management activities and natural disturbances
5. Preferred timing of follow-up treatments by area
6. Patch recruitment potential and timing as replacement Northern Spotted Owl habitat
    - Fledging success
    - Interactions with Barred Owls
    - Stand-level prey response to treatments, including habitat elements that support prey (mistletoe, snags, down wood, forage lichens, truffles abundance)
7. Northern Spotted Owl response to habitat and matrix area and dispersion
8. Occupancy by breeding pairs or single owls

Adaptive management is important

The landscape plan, the conceptual model it represents, goals formulated, and monitoring could possibly form the basis of an adaptive management plan. Managing Northern Spotted Owl habitat in dry forest landscapes is a risky business. Trends of Northern Spotted Owl habitat or populations would be compared to those expected to result from the landscape plan, with an allowance for random variation. Trends counter to the expected outcomes, especially those well outside the expected variation in outcomes, could be cause for examining the effectiveness of management strategies in attaining objectives, the basic assumptions in the conceptual model underlying the landscape management plan, measurement error, and other factors. External factors, such as climate change influence, could be evaluated. Several possibilities exist when considering adaptive change:

1. The conceptual model underlying the landscape plan was wrong (*e.g.,* wildfire or insect outbreaks are not altering key habitat as anticipated, or to the degree anticipated). The model should be updated and objectives re-evaluated.
2. Management strategies or tactics did not work as anticipated. Management strategies and tactics should be re-visited to see if alternative methods might work better.
3. Measurement error has confounded the ability to detect meaningful change. Examine monitoring protocols for improvement or selection of alternative monitoring elements.
4. An external factor that was not anticipated has come into play, altering or introducing new relationships considered as background in the conceptual model (*e.g.,* climate change, Barred Owls). Revise conceptual model accordingly, re-evaluate landscape plan, and devise alternative management strategies.

The panel suggests several additional steps to facilitate adaptive management and monitoring:

1. Convene a formal regional adaptive management coordinating group of managers and researchers, similar to that proposed for Barred Owl adaptive management, to supervise a range-wide integrated and comprehensive program.
2. New prescriptions and treatments for fuel reduction and other dry forest management could be standardized to the extent possible to facilitate regional comparisons by meta-analysis and to maximize the scientific and management value of studies.
3. Experimental designs likewise could be standardized to the extent possible to ensure comparability across the region and to ensure statistically valid results.

The Klamath Provinces

The forest landscapes of the Klamath Mountains are unique and like few others because of complex interactions among topography, land surface forms, surface lithologies, forest types, and regional climate. Taylor and Skinner (1998, 2003) and Skinner *et al.* (2006) show that historical fire regimes of the dry and mesic forest types were influenced by the regional climate and the broader landscape context rather than by the vegetation type, which is fundamentally different than the eastern Cascades of Oregon and Washington. Summers in the Klamath Mountains are a dry Mediterranean-type, but thunderstorms are a relatively common event. This situation results in productive forests that support a fire regime where fires were historically quite frequent, could be quite large events, and spanned a spectrum of fire severity.

Recent work has documented the amount of high severity wildfire in northern spotted owl habitat; Moeur *et al.* (2005) reported that the highest losses occurred in dry forests of the Klamath and Cascade provinces. The most significant losses of older forest were in the Oregon Klamath, California Klamath, and Washington eastern Cascades. The loss of Northern Spotted Owl habitat to high severity wildfire in the Klamath and Cascade provinces has been relatively high over the last decade and if this trend continued, could significantly impact the owl in these drier forests. Care should be taken when interpreting the loss of forests to high severity wildfire over only a decade, but the trends are troublesome.

An important difference between the Klamath Mountains and dry forests of the eastern Cascades is the greater amount of annual precipitation occurring in the Klamath Mountains. Such precipitation accounts for highly productive Douglas-fir and sugar pine components to the mixed conifer forest, even under frequently burned historical conditions. The combination of relatively high precipitation and Mediterranean summers ensures that Klamath Mountain forests will continually be at high risk of wildfire. However, it is uncertain the extent to which understanding gained from wildfire studies of the eastern Cascades may be applied to these forests.

The science review team entertained much discussion about using spatially optimized patterns of fuels treatments (*sensu* Finney *et al.* 2007) in the landscape outside of spotted owl habitat patches. However, there was considerable uncertainty expressed about the advantages of such treatments overlaying (but disjunct from) large, spatially specified networks of owl patches. There was also much discussion of reducing surface and ladder fuels over large landscape areas outside of owl patches, but with little resolution. At the time of this report, the review panel could not agree on a clear direction for managing the dry forests of the Klamath Mountains because of limited information about the natural variability and changes in the landscape ecology of these forests, and due to the highly constrained timeline for the review. Scientists also expressed concerns about a shortage of province-relevant science, relative to fire ecology and owl biology. For these reasons, the panel made two specific recommendations: 1) that substantial new research focus, in the near term, on remedying scientific uncertainties, and 2) that knowledge gained from studies of the eastern Cascades dry forests or wet coastal forests not be applied directly to the Klamath Mountains forests.

In light of direction outlined in the DRP, the review panel also offers these more general recommendations:

1. Given trends in timber harvesting (especially regeneration cutting) over the last several decades, and the increasing evidence of both a warming global and regional climate, it may be important that more rather then fewer acres of owl habitat should be protected from regeneration cutting. This increase would allow for some measure of habitat redundancy in uncertain times;
2. Large and old trees, either living or dead, are important wherever they occur, and suggest landscape designs that promote the increased abundance of large trees of fire tolerant species using ecologically sound landscape design criteria;
3. Existing plantations are one major source of risk of high severity fires (Odion *et al.* 2004). The fire tolerance of existing plantations can be increased by actively manipulating species composition, reducing density, promoting spatial heterogeneity in forest structure (avoiding large areas of homogeneously fire-prone plantations), treating surface fuels, and favoring the development of large, fire tolerant trees. This may be accomplished through large scale thinning operations (that include treatment of activity fuels and increasing spatial variability at the multi-hectare scale) in plantations outside of owl habitat (where plantations are generally concentrated), or using a larger regional landscape strategy that prioritizes the risk of high severity fire outside of owl habitat; and
4. The establishment of new plantations is not favored, but rather activities in dry forest settings that improve overall fire tolerance of the landscape and decrease the likelihood that a few large fires will destroy a significant number of owl territories.

The Southern Cascades in California

The Southern Cascades province in California is bounded on the west by the Sacramento Valley and the Klamath Mountains, on the east by the Modoc Plateau and Great Basin, and to the north by the Cascade Mountains in southern Oregon. Similar to the Cascade Mountains in Oregon and Washington, the California Cascades have a Mediterranean climate but with wet and cool winters and dry, warm summers. Historically, the long summer drought period was conducive to frequent fire return before the advent of fire suppression.

West-to-east gradients in precipitation and temperature create different environments at similar elevations on the west side of the crest compared to the east side, albeit not as dramatically as in the Sierra Nevada (Skinner and Taylor 2006). Mixed-species conifer forests dominate the mid-montane zone on the west side of the Cascade Range. Any of six conifer species (ponderosa pine, Douglas-fir, incense-cedar, sugar pine, Jeffrey pine, and white fir) may co-occur and share dominance (Parker 1995, Beaty and Taylor 2001, Skinner and Taylor 2006). A subcanopy of the deciduous hardwoods (California black oak, bigleaf maple, mountain dogwood and canyon live oak) may occur beneath the conifer canopy. Extensive areas east of the Cascade crest are dominated by ponderosa pine, Jeffrey pine, or a combination of both. Other conifers, such as white fir and incense-cedar, may be locally important but do not usually attain dominance, especially on the drier sites (Rundel *et al.* 1977).

There are generally two periods with distinctly different fire regimes in the Southern Cascades of California. The first was before 1905, when fires were generally frequent (mean fire return interval 5–20 years). Frequent lightning ignitions, and the widespread use of fire by native people promoted frequent surface fires of mostly low to moderate intensity, with fire frequency decreasing with elevation (Skinner and Taylor 2006). Fires appeared to have burned quite heterogeneously through stands leaving a general characteristic of open, variably spaced large, old trees (Skinner and Taylor 2006). Pronounced local variations in fire frequency also occurred due to interruptions in fuel connectivity caused by volcanics (*e.g.,* lava flows, scoria depositions, debris flows, and the like; Taylor 2000). This period of high fire incidence was followed by the fire-suppression period and the establishment of the national forest reserves in 1905 when fire occurrence decreased (Skinner and Chang 1996; Taylor 1990, 1993, 2000; Beaty and Taylor 2001; Bekker and Taylor 2001; Norman and Taylor 2003, 2005).

Structurally diverse, old-growth conditions were likely mostly found in refugia similar to those described for the eastside of the Cascades in Oregon and Washington. The intervening matrix was often dominated by open forests of large, old trees with heterogeneous smaller patches of younger trees in various stages of regeneration (Skinner and Taylor 2006). Due to the gentle topography and contemporary density of forests coupled with high surface fuel loads, fires that escape initial attack today are usually driven by gradient winds and generate extensive high-severity burn patterns (*e.g.,* Pondosa Fire 1977; Lost Fire

1987; Fountain Fire 1992). In general, the forests in the Southern Cascades in California tend to be similar to those found in the eastern Cascades of Oregon and Washington, with some exceptions, and management recommendations for eastern Oregon and Washington would generally apply to Southern Cascades in California. Notable exceptions may include, for example, where occurring, mixed conifer stands with hardwood understories might be managed strategically within broad landscape designs to influence contemporary fire behavior.

West-side Forest

Moist forests dominated by dense stands of long-lived conifers, such as Douglas-fir, western hemlock, and western redcedar, characterize the forest landscapes in the Oregon Coast Ranges and Olympic Mountains and on the western slopes and at middle elevations in the Cascade Range of Washington and Oregon.

These forests belong primarily to the Western Hemlock, Sitka Spruce, and Pacific Silver Fir Plant Associations. They grow on sites with favorable environmental regimes, including mild temperatures and high annual precipitation, although a pronounced summer dry period is characteristic. Forest productivity is relatively high and typically results in development of stands that have large accumulations of biomass and, often, complex structure. The ability of many species to survive and grow for many centuries is a major factor in the massiveness of older stands.

The moist forests are characterized by infrequent, high severity, stand-replacement disturbance regimes, primarily by wildfire and windstorm. Wildfires are the most widespread stand-replacement disturbances with natural return intervals typically ranging from 200 to 500+ years along a gradient of increasing interval from south to north. Windstorms are the dominant natural stand-replacement disturbances in the near-coastal regions but also can affect inland areas, as demonstrated by the Columbia Day 1962 windstorm.

Natural forest development after stand-replacement disturbances involves: (1) creation of a post-disturbance environment that is rich in biological legacies, including large numbers of dead trees as either snags or down logs or both; (2) an early successional community of high diversity (in part, due to the legacies), during which tree regeneration is gradually established; (3) eventual tree canopy closure after several decades or more and, typically, development of dense young forests characterized by intense competitive interactions and biomass accumulation; (4) maturation of forests during a second century of development, at which time lower stories of shade-tolerant tree species develop and wind-, insect-, and pathogen-induced mortality begins creating significant canopy gaps; and, eventually, (5) development of an evolving old-growth condition characterized by high levels of structural complexity, including large old trees, snags, and logs, canopies that are continuous from ground to tree top, and significant horizontal spatial heterogeneity, reflecting a fine-scale, low-contrast structural mosaic in which all developmental processes are represented.

Natural patterns of development and diversity are dramatically altered by silvicultural practices focused on wood production. Specifically, activities such as salvage logging, artificial control of herbs, shrubs, and hardwood trees (such as by herbicides), and establishment of dense conifer plantations alter patterns of stand development, ecosystem processes, and biological diversity for many centuries. Similarly, silvicultural activities designed to reduce fuels and alter fire behavior in forests naturally subject to stand-replacement disturbance regimes will result in unnatural ecosystems that have no historic precedent and are incapable of providing habitat for characteristic biodiversity or of carrying on the normal array of ecosystem processes.

Habitat Restoration and Salvage

The Draft Recovery Plan and the panel's meetings received strong comments and opinions on salvage logging after fire (and possibly other disturbances). There is widespread debate over the merits of salvage logging, and salvage is controversial in the technical literature. Related to this issue is the practice of habitat restoration after either natural or anthropogenic disturbance (from acute short-term disturbances to chronic disturbances that have markedly changed ecosystem function). So what is the relationship between salvage and restoration, and what guidance is there on how to do restoration?

Assuming continued implementation of the Northwest Forest Plan and its LSRs, or equivalent conservation strategy, recovery and maintenance of the Spotted Owl populations may well depend on, in part, restoration of habitat lost (to timber harvests, wildfire, insects, disease, windstorms, and other natural catastrophic disturbances such as volcanic eruptions such as happened with Mt. St. Helens, glacial dam breaks (as happened recently on Mt. Rainier), lahars, and large-scale floods). Considerable guidance has been developed for the west-side forests of Washington and Oregon (see Carey 2007 for a comprehensive review). Methods include (1) retention of biological legacies, (2) ensuring multi-tree-species regeneration and multi-tree-species management through precommercial thinning, (3) managing for spatial heterogeneity in canopies and understory vegetation site types through commercial thinning or application of fire, (4) management of decadence processes, including maintaining dead and decadent trees, coarse woody debris, creating cavity trees, and maintenance of large old trees with significant decay, etc., (5) management of forests on long to indefinite rotations, and other methods; details of management and amounts of various ecosystem components to be sought vary with low conditions and within-region (provincial) variation; see Carey *et al.* (1999a) for a simulation exercise and Carey (2003a,b) for results of experimental application of these concepts.

The current condition of dry fire-prone forests on the east slopes of the Cascades does not seem sustainable and high risks of catastrophic fires in complex mixed-conifer forests threatens the persistence of Spotted Owls; significant amounts of Spotted Owl habitat have been lost to wildfire in the last few years. Managing fuel loads in fire-prone forests is a principal part of ecological restoration of natural patterns and processes to return those landscapes and ecosystems to states of resilience and sustainability; and return to such conditions is essential for recovery and maintenance of Spotted Owl populations, the owl's prey, and the ecosystem that supports both the owl and its prey. Fire management is discussed in full elsewhere in this document. Furthermore, there is considerable controversy over post-fire logging (such as salvage logging) and its role in ecosystem recovery. Because narrowly focused management often produces unintended consequences, guidance on conceptualizing and evaluating actions and alternatives can be helpful. The Society for Ecological Restoration provides good guidance.

The Society for Ecological Restoration Primer on Ecological Restoration (SERPER 2002) states, ''Ecological restoration is an intentional activity that initiates or accelerates the recovery of an ecosystem with respect to its health, integrity, and sustainability'' and attempts to return an ecosystem to its historic condition. However, SERPER also recognizes that changing environmental conditions such as global climate change, invasive species, pests, diseases, human-altered disturbance regimes, and widespread land-use changes may not allow return to historic conditions, but still may allow restoration of many of the patterns, processes, and biocomplexity that help the systems function as they did historically. SERPER says restoration is intentional management. Intentionality, by definition, is a concept that implies ''wholeness'' in intention; in other words, comprehensiveness (high intentionality) versus narrow or limited purpose (low intentionality) Thus, restoration of degraded ecological function is a goal of active intentional management, but promotion of ecosystem resiliency, adaptiveness, general sustainability are equally important goals (Carey 2006). SERPER proposes 10 criteria for achieving restoration goals (Table E2) and Carey (2006) provides an example of the application of these criteria to active, intentional management of west-side forests for the restoration of biocomplexity, including recovery of Spotted Owl populations. These criteria extend beyond a species, a species and its prey, and even the local biotic community that supports a species. They address both the ecosystem and the landscape and such a multiple-scale approach, from identifying extant complex forests that need protection by isolation from potentially rapidly spreading threats such as wildfire and deleterious insects, to managing ecosystems in landscapes on trajectories that will allow rapid replacement of the old and complex forests that are lost, seems especially important in dry east-side fire-prone forests.

Table E2. Ten attributes of restored ecosystems excerpted from the Society for Ecological Restoration Primer on Ecological Restoration (SERPER 2002).

1. The restored ecosystem contains a characteristic assemblage of the species that occur in the reference ecosystem and that provide appropriate community structure.
2. The ecosystem consists of indigenous species to the greatest possible extent.
3. All functional groups necessary for the continued development and/or stability of the restored ecosystem are represented or have the potential to colonize by natural means.

4. The physical environment of the restored ecosystem is capable of sustaining reproducing populations of the species necessary for its continued stability or development along the desired trajectory.
5. The restored ecosystem apparently functions normally for its ecological stage of development, and signs of dysfunction are absent.
6. The restored ecosystem is suitably integrated into a larger ecological matrix or landscape, with which it interacts through abiotic and biotic flows and exchanges.
7. Potential threats to the health and integrity of the restored ecosystem from the surrounding landscape have been eliminated or reduced as much as possible.
8. The restored ecosystem is sufficiently resilient to endure the normal periodic stress events in the local environment that serve to maintain the integrity of the ecosystem.
9. The restored ecosystem is self-sustaining to the same degree as the reference ecosystem, and has the potential to persist indefinitely under existing environmental conditions aspects of biodiversity and functioning may change as part of normal ecosystem development in response to stress and disturbance [and] evolve as environmental conditions change.
10. Ecosystems provide specified natural goods and services for society in a sustainable manner, including aesthetic amenities and accommodation of activities of social consequence.

These criteria argue that thinking in terms of fuels management to reduce the probability of fire or salvage or post-fire logging to extract soon-to-be-lost timber values is likely to lead a manager away from successful restoration of the ecosystem for multiple values, or even just for recovery of biodiversity or a single species such as the Spotted Owl. One cannot recover Spotted Owls without *recovering the biotic communities of plants, fungi, and animals* that support Spotted Owls (Carey *et al.* 2003a,b). This suggests that managers begin with ecosystem restoration, as described by SERPER, as the primary objective, which *might* deconstruct to include some logging, if unintended consequences are to be avoided.

Hence the panel holds that in a Final Recovery Plan for the Northern Spotted Owl, the salient issue regarding “salvage” (and other activities such as planting) is whether it will enhance Spotted Owl conservation (by restoration of habitat, or reduction in risks). Any such benefit would then have to be weighed against any presumed detrimental effect.

Appendix F: Responses to Comments on the 2007 Draft Recovery Plan

A complete list of responses and comments can be found at http://www.fws.gov/pacific/ecoservices/endangered/recovery/NSORecoveryPlanning.htm.

Appendix G. References Cited

Literature Cited

Agee, J.K. 1981. Initial effects of prescribed fire in a climax *Pinus contorta* forest: Crater Lake National Park. USDI National Park Service, Coop. Park Studies Unit Seattle, Washington.

Agee, J.K. 1993. Fire Ecology of Pacific Northwest Forests. Island Press, Washington, DC.

Agee, J.K. 1998. The landscape ecology of western forest fire regimes. Northwest Science 72: 24–34.

Agee, J.K. 2002. The fallacy of passive management: managing for firesafe forest reserves. Conservation Biology in Practice 3: 18–25.

Agee, J.K. 2003. Historical range of variability in eastern Cascades forests, Washington, USA. Landscape Ecol 18:725–740.

Agee, J.K. 2007. Comments on 2007 draft recovery plan for the northern spotted owl (*Strix occidentalis caurina*): Merged options 1 and 2 (April 2007).

Agee, J.K., M. Finney, R. deGouvenain. 1990. Forest fire history of Desolation Peak, Washington. Canadian Journal of Forest Research 20:350–356.

Agee, J.K., B. Bahro, M.A. Finney, P.N. Omi, D.B. Sapsis, C.N. Skinner, J.W. van Wagtendonk, and C. Phillip Weatherspoon. 2000. The use of shaded fuelbreaks in landscape fire management. Forest Ecology and Management 127:55–66.

Agee, J.K., and C.N. Skinner. 2005. Basic principals of forest fuel reduction treatments. Forest Ecology and Management 211:83–96.

Ager, A., M. Finney, and A. McMahan. 2006. A wildfire risk modeling system for evaluating landscape fuel treatment strategies. Pages 149–162 in Fuels Management – How to Measure Success: Conference Proceedings. March 28–30, 2006, Portland, Oregon. RMRS-P-41. USDA Forest Service, Rocky Mountain Research Station, Ft. Collins, Colorado.

Ager, A.A., A.J. McMahan, J.J. Barrett, and C.W. McHugh. 2007. A simulation study of thinning and fuel treatments on a wildland-urban interface in eastern Oregon, USA. Landscape and Urban Planning 80:292–300.

Anderson, D.R. and K.P. Burnham. 1992. Demographic analysis of northern spotted owl populations. Pages 319–328 *in* Draft final recovery plan for the northern spotted owl. USDI Fish and Wildlife Service, Portland, Oregon.

Anthony, R.G., E.D. Forsman, A.B. Franklin, D.R. Anderson, K.P. Burnham, G.C. White, C.J. Schwarz, J. Nichols, J.E. Hines, G.S. Olson, S.H. Ackers, S. Andrews, B.L. Biswell, P.C. Carlson, L.V. Diller, K.M. Dugger, K.E. Fehring, T.L. Fleming, R.P. Gerhardt, S.A. Gremel, R.J. Gutiérrez, P.J. Happe, D.R. Herter, J.M. Higley, R.B. Horn, L.L. Irwin, P.J. Loschl, J.A. Reid, and S.G. Sovern. 2004. Status and trends in demography of northern spotted owls, 1985–2003. Final Report to the Interagency Regional Monitoring Program, Portland, Oregon. September 2004. 179 pp.

Anthony, R.G., E.D. Forsman, A.B. Franklin, D.R. Anderson, K.P. Burnham, G.C. White, C.J. Schwarz, J. Nichols, J.E. Hines, G.S. Olson, S.H. Ackers, S. Andrews, B.L. Biswell, P.C. Carlson, L.V. Diller, K.M. Dugger, K.E. Fehring, T.L. Fleming, R.P. Gerhardt, S.A. Gremel, R.J. Gutiérrez, P.J. Happe, D.R. Herter, J.M. Higley, R.B. Horn, L.L. Irwin, P.J. Loschl, J.A. Reid, and S.G. Sovern. 2006. Status and trends in demography of northern spotted owls, 1985–2003. Wildlife Monograph No. 163.

Anthony, R.G. and L.S. Andrews. 2004. Summary Report: Winter habitat use by spotted owls on USDI Bureau of Land Management Medford District Lands within the boundaries of the Timbered Rock Fire. Unpublished report, Oregon Cooperative Wildlife Research Unit, Corvallis, Oregon. 29 pp.

Antos, J.A., and Habeck, J.R. 1981. Successional development in *Abies grandis* (Dougl.) 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. Page 29. US Department of Agriculture, Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Arno, S.F., and Davis, D.H. 1980. Fire history of western redcedar/hemlock forests in northern Idaho. Pages 21–26 in M.A. Stokes and J.H. Dieterich (editors), Fire History Workshop. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado.

Arno, S.F., Smith, H.Y., and Krebs, M.A. 1997. Old growth ponderosa pine and western larch stand structures: influences of pre-1900 fires and fire exclusion. Res. Pap. INT-RP-495, USDA Forest Service, Intermountain Research Station, Ogden, Utah.

Barbour, M.G., and W.D. Billings. 2000. North American terrestrial vegetation. 2nd edition. Cambridge University Press, Cambridge, England.

Barrett, S.W., S.F. Arno, and C.H. Key. 1991. Fire regimes of western larch-lodgepole pine forests in Glacier National Park, Montana. Canadian Journal of Forest Research 21:1711–1720.

Barrowclough, G.F., and S. Coats. 1985. The demography and population genetics of owls, with special reference to the conservation of the spotted owl (*Strix occidentalis*). Pages 74–85 in R.J. Gutiérrez and A.B. Carey (editors), Ecology and management of the Spotted Owl in the Pacific Northwest. General Technical Report PNW-185. USDA-Forest Service, Portland, Oregon. 119 pp.

Barrowclough, G.F. and R. J. Gutiérrez. 1990. Genetic variation and differentiation in the spotted owl. Auk 107:737–744.

Barrowclough, G.F., R.J. Gutiérrez, and J.G. Groth. 1999. Phylogeography of spotted owl (*Strix occidentalis*) populations based on mitochondrial DNA sequences; gene flow, genetic structure, and a novel biogeographic pattern. Evolution 53:919–931.

Barrowclough, G.F., J.G. Groth, and R.J. Gutiérrez. 2005. Genetic structure, introgression and a narrow hybrid zone between northern and California spotted owls (*Strix occidentalis*). Molecular Ecology 14:1109–1120.

Beaty, R.M., and A.H. Taylor. 2001. Spatial and temporal variation of fire regimes in a mixed conifer forest landscape, southern Cascades, California, USA. Journal of Biogeography 28:955–966.

Bekker, M.F., and A.H. Taylor. 2001. Gradient analysis of fire regimes in montane forests of the southern Cascade Range, Thousand Lakes Wilderness, California, USA. Plant Ecology 155:15–28.

Bigley, R. and J. Franklin. 2004. Habitat trends. Chapter 6 in S. Courtney (editor), Scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon.

Blakesley, J.A., W. LaHaye, J.M.M. Marzluff, B.R. Noon, and S. Courtney. 2004. Demography. Chapter 8 in S. Courtney (editor), Scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon.

Bond, M.L., R.J. Gutiérrez,, A.B. Franklin, W.S. LaHaye, C.A. May, and M.E. Seamans. 2002. Short-term effects of wildfires on spotted owl survival, site fidelity, mate fidelity, and reproductive success. Wildlife Society Bulletin 30:1022–1028.

Bork, J. 1985. Fire history in three vegetation types on the east side of the Oregon Cascades. Oregon State University, Corvallis, Oregon.

Brown, R.T., J.K. Agee, and J.F. Franklin. 2004. Forest restoration and fire: Principles in the context of place. Conservation Biology 18:903–912.

Buchanan, J.B. 2004. Managing habitat for dispersing northern spotted owls – are the current management strategies adequate? Wildlife Society Bulletin 32:1333–1345.

Buchanan, J.B. and P. Swedeen. 2005. Final briefing report to the Washington State Forest Practices Board regarding spotted owl status and forest practices rules. Washington Department of Fish and Wildlife, Olympia. 84 pp.

Buchanan, J., E. Hanson, D. Hays, and L. Young. 1994. An evaluation of the Washington Forest Practices Board Wildlife Committee preferred alternative for a spotted owl protection rule. Washington Forest Practices Board Spotted Owl Scientific Advisory Group. Washington Department of Fish and Wildlife, Olympia, Washington.

Buchanan, J.B., L.L. Irwin, and E.L. McCutchen. 1995. Within-stand nest site selection by spotted owls in the eastern Washington Cascades. Journal of Wildlife Management 59:301–310.

Buchanan, J. B. 2005. Barred Owl. Pages 218–219 in T. R. Wahl, B. Tweit, and S. G. Mlodinow (editors), Birds of Washington: status and distribution. Oregon State Univ. Press, Corvallis, Oregon.

Buchanan, J.B., R.J. Gutierrez, R.G. Anthony, T. Cullinan, L.V. Diller, E.D. Forsman, and A.B. Franklin. 2007. A synopsis of suggested approaches to address potential competitive interactions between Barred Owls (*Strix varia*) and Spotted Owls (*S. occidentalis*). Biological Invasions 9:679–691.

Burnham, K.P., D.R. Anderson, and G.C. White. 1994. Estimation of vital rates of the northern spotted owl. Colorado Cooperative Fish and Wildlife Research Unit, Colorado State University, Fort Collins, Colorado, USA.

Caffrey, C. 2003. Determining impacts of West Nile Virus on crows and other birds. American Birds 57:12–13.

Camp, A.E., C.D. Oliver, P.F. Hessburg, and R.L. Everett. 1997. Predicting late-successional fire refugia from physiography and topography. Forest Ecology and Management 95:63–77.

Carey, A.B. 2003a. Biocomplexity and restoration of biodiversity in temperate coniferous forest. Forestry 76:131–140.

Carey, A.B. 2003b. Restoration of landscape function: reserves or active management? Forestry 76:225–234.

Carey, A.B. 2006. AIMing to restore forests: evaluation with SER criteria. Northwestern Naturalist 87:31–42.

Carey, A.B. 2007. AIMing for Healthy Forests: active, intentional management for multiple values. USDA Forest Service General Technical Report PNW-GTR-721, 447 pp.

Carey, A.B., J.A. Reid, and S.P. Horton. 1990. Spotted owl home range and habitat use in southern Oregon coast ranges. Journal of Wildlife Management 54:11–17.

Carey, A.B., S.P. Horton, and B.L. Biswell. 1992. Northern spotted owls: influence of prey base and landscape character. Ecol. Monographs 62:223–250.

Carey, A.B., B.R. Lippke, and J. Sessions. 1999a. Intentional ecosystem management: managing forests for biodiversity. Journal of Sustainable Forestry 9:83–125.

Carroll, A.L., J. Regneire, J.A., Logan, S.W. Taylor, B. Bentz, and J.A. Powell. 2006. Impacts of climate change on range expansion by the mountain pine beetle. Mountain Pine Beetle Initiative Working Paper 2006-14. Canadian Forest Service. 20 pp.

Carroll, C. and D.S. Johnson. In Press. The importance of being spatial (and reserved): assessing northern spotted owl habitat relationships with hierarchical Bayesian models. Conservation Biology 22(3).

CDF (California Department of Forestry and Fire Protection). 2001. California Forest Practices Rules: 2001. Title 14, California Code of Regulations, Chapters 4, 4.5, and 10. CDF, Sacramento, California.

Chi, T., A. Henke, J. Smith, and C. Brinegar. 2005. Spotted owl mitochondrial DNA haplotyping. San Jose State University. Unpublished results submitted to U.S. Fish and Wildlife Service.

Chutter, M.J., I. Blackburn, D. Bonin, J. Buchanan, B. Costanzo, D. Cunnington, A. Harestad, T. Hayes, D. Heppner, L. Kiss, J. Surgenor, W. Wall, L. Waterhouse, and L. Williams. 2004. Recovery strategy for the northern spotted owl (*Strix occidentalis caurina*) in British Columbia. British Columbia Ministry of Environment, Victoria. 74 pp.

Cohen, W.B., T.A. Spies, R.J. Alig, D.R. Oetter, T.K. Maiersperger, and M. Fiorella. 2002. Characterizing 23 years (1972–95) of stand replacement disturbance in western Oregon forests with Landsat Imagery. Ecosystems 5:122–137.

Collins, B.M. and S.L. Stephens. 2007. Managing Natural Fires in Sierra Nevada Wilderness Areas. Frontiers in Ecology and the Environment 5:523–527.

Collins, B.M., N. K. Kelly, J.W. van Wagtendonk, and S.L. Stephens. 2007. Spatial patterns of large natural fires in Sierra Nevada wilderness areas. Landscape Ecology 22:545–557.

Courtney, S.P., J.A. Blakesley, R.E. Bigley, M.L. Cody, J.P. Dumbacher, R.C. Fleischer, A.B. Franklin, J.F. Franklin, R.J. Gutiérrez, J.M. Marzluff, and L. Sztukowski. 2004. Scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon.

Covington, W.W., and M.M. Moore. 1994. Southwestern ponderosa forest structure changes since Euro-American settlement. Journal of Forestry 92:39–47.

Crozier, M.L., M.E. Seamans, R.J. Gutiérrez, P.J. Loschl, R.B. Horn, S.G. Sovern, and E.D. Forsman. 2006. Does the presence of Barred Owls suppress the calling behavior of Spotted Owls? Condor 108:760–769.

Davis, K.M., B.D. Clayton, and W.C. Fischer. 1980. Fire ecology of Lolo National Forest habitat types. US Department of Agriculture Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Davis, R. and J. Lint. 2005. Habitat status and trends. Pages 21–82 in J. Lint (technical coordinator), Northwest Forest Plan—the first 10 years (1994–2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Deubel, V., L. Fiette, P. Gounon, M.T. Drouet, H. Khun, M. Huerre, C. Banet, M. Malkinson, and P. Despres. 2001. Variations in biological features of West Nile viruses. Annals of the New York Academy of Sciences 951:195–206.

Diller, L.V. and D.M. Thome. 1999. Population density of northern spotted owls in managed young-growth forests in coastal northern California. Journal of Raptor Research 33: 275–286.

Dugger, K.M., F. Wagner, R.G. Anthony, and G.S. Olson. 2005. The relationship between habitat characteristics and demographic performance of northern spotted owls in southern Oregon. Condor 107:863–878.

Dunbar, D.L., B.P. Booth, E.D. Forsman, A.E. Hetherington, and D.J. Wilson. 1991. Status of the spotted owl, *Strix occidentalis*, and barred owl, *Strix varia*, in southwestern British Columbia. Canadian Field-Naturalist 105:464–468.

Everett, R.L., R. Schellhaas, D. Keenum, D. Spurbeck, and P. Ohlson. 2000. Fire history in the ponderosa pine/Douglas-fir forests on the east slope of the Washington Cascades. Forest Ecology and Management 129:207–225.

Fahnestock, G.R. 1976. Fires, fuel, and flora as factors in wilderness management: the Pasayten case. Tall Timbers Fire Ecology Conference Proceedings 15:33–70.

Finch, R.B. 1984. Fire history of selected sites on the Okanogan National Forest. Page 22. USDA Forest Service, Okanogan National Forest, Okanogan, Washington.

Finney, M.A. 2004. Landscape Fire Simulation and Fuel Treatment Optimization. Pages 117–131 in J.L. Hayes, A. Ager, and R.J. Barbour (editors), Methods for integrated modeling of landscape change: Interior Northwest Landscape Analysis System. Gen. Tech. Rep. PNW-GTR-610. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Finney, M.A., R.C. Seli, C.W. Mchugh, A.A. Ager, B. Bahro, and J.K. Agee. 2007. Simulation of long-term landscape-level fuel treatment effects on large wildfires. International Journal of Wildland Fire 16:712–727.

Fitzgerald, S.D., J.S. Patterson, M. Kiupel, H.A. Simmons, S.D. Grimes, C.F. Sarver, R.M. Fulton, B.A. Fulton, B.A. Steficek, T.M. Cooley, J.P. Massey, and J.G. Sikarskie. 2003. Clinical and pathological features of West Nile Virus infection in native North American owls (family *Strigidae*). Avian Diseases 47:602–610.

Forsman, E.D. 1975. A preliminary investigation of the spotted owl in Oregon. M.S. thesis, Oregon State University, Corvallis. 127 pp.

Forsman, E.D. 1981. Molt of the spotted owl. Auk 98:735–742.

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

Forsman, E.D., S. DeStefano, M.G. Raphael, and R.J. Gutiérrez (editors). 1996. Demography of the northern spotted owl. Studies in Avian Biology No. 17.

Forsman, E.D., I.A. Otto, S.G. Sovern, M. Taylor, D.W. Hays, H. Allen, S.L. Roberts, and D.E. Seaman. 2001. Spatial and temporal variation in diets of spotted owls in Washington. Journal of Raptor Research 35:141–150.

Forsman, E.D., R.G. Anthony, J.A. Reid, P.J. Loschl, S.G. Sovern, M. Taylor, B.L. Biswell, A. Ellingson, E.C. Meslow, G.S. Miller, K.A. Swindle, J.A. Thrailkill, F.F. Wagner, and D. E. Seaman. 2002. Natal and breeding dispersal of northern spotted owls. Wildlife Monographs 149:1–35.

Forsman, E.D., R.G. Anthony, E.C. Meslow, and C.J. Zabel. 2004. Diets and foraging behavior of northern spotted owls in Oregon. Journal of Raptor Research 38:214–230.

Franklin, A.B. 1992. Population regulation in northern spotted owls: theoretical implications for management. Pages 815–827 in D.R. McCullough and R.H. Barrett (editors), Wildlife 2001: populations. Elsevier Applied Sciences, London, England.

Franklin, A.B., D.R. Anderson, R.J. Gutiérrez, and K.P. Burnham. 2000. Climate, habitat quality, and fitness in northern spotted owl populations in northwestern California. Ecological Monographs 70:539–590.

Franklin, J. and J.K. Agee. 2003. Forging a science-based national forest fire policy. Issues in Science and Technology.

Franklin, J. and S. Courtney. 2004. Evolution and effectiveness of strategies for conservation of northern spotted owl. Chapter 9 in S. Courtney (editor), Scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon.

Gaines, W.L., R.A. Strand, and S.D. Piper. 1997. Effects of the Hatchery Complex Fires on northern spotted owls in the eastern Washington Cascades. Pages 123–129 in J.M. Greenlee (editor), Proceedings of the First Conference on Fire Effects on Rare and Endangered Species and Habitats. International Association of Wildland Fire, Coeur d'Alene, Idaho.

Gancz, A., I.K. Barker, R. Lindsay, A. Dibernardo, K. McKeever, and B. Hunter. 2004. West Nile Virus outbreak in North American owls, Ontario, 2002. Emerging Infectious Diseases 10:2135–2142.

Garmendia, A.E., H.J. Van Kruiningen, R.A. French, J.F. Anderson, T.G. Andreadis, A. Kumar, and A.B. West. 2000. Recovery and identification of West Nile virus from a hawk in winter. Journal of Clinical Microbiology 38:3110–3111.

Glenn, E.M, M.C. Hansen, and R.G. Anthony. 2004. Spotted owl home-range and habitat use in young forests of western Oregon. Journal of Wildlife Management 68:33–50.

Goheen, E.M., E. Hansen, A. Kanaskie, N. Osterbauer, J. Parke, J. Pscheidt, and G. Chastagner. 2006. Sudden oak death and *Phytopthora ramorum*: a guide for forest managers, Christmas tree growers, and forest-tree nursery operators in Oregon and Washington. Oregon State University Extension Service, Central Point, Oregon.

Graham, R.T., S. McCaffrey, and T.B. Jain. 2004. Science basis for changing forest structure to modify wildfire behavior and severity. USDA Forest Service General Technical Report RMRS-120 Rocky Mountain Research Station, Ogden, Utah.

Gremel, S. 2005. Factors controlling distribution and demography of northern spotted owls in a reserved landscape. M.S. thesis, University of Washington, Seattle. 49 pp.

Gutiérrez, R.J. 1989. Hematozoa from the spotted owl. Journal of Wildlife Diseases 24:614–618.

Gutiérrez, R.J. 1994. Changes in the distribution and abundance of spotted owls during the past century. Studies in Avian Biology 15:293–300.

Gutiérrez, R.J. 1996. Biology and distribution of the northern spotted owl. Studies in Avian Biology 17:2–5.

Gutiérrez, R.J., A.B. Franklin, and W.S. LaHaye. 1995. Spotted owl (*Strix occidentalis*) in A. Poole and F. Gill (editors), The birds of North America, No. 179. The Academy of Natural Sciences and The American Ornithologists' Union, Washington, D.C. 28 pp.

Gutiérrez, R. J., M. Cody, S. Courtney, and D. Kennedy. 2004. Assessment of the potential threat of the northern barred owl. Chapter 7 in S. Courtney (editor), Scientific evaluation of the status of the northern spotted owl. Sustainable Ecosystems Institute, Portland, Oregon.

Gutiérrez, R. J., M. Cody, S. Courtney, and A.B. Franklin. 2007. The invasion of barred owls and its potential effect on the spotted owl: a conservation conundrum. Biological Invasions 9:181–196.

Haig, S.M., R.S. Wagner, E.D. Forsman, E.D., and T.D. Mullins. 2001. Geographic variation and genetic structure in spotted owls. Conservation Genetics 2:25–40.

Haig, S.M., T.D. Mullins, and E.D. Forsman. 2004a. Subspecific relationships and genetic structure in the spotted owl. Conservation Genetics 5:683–705.

Haig, S.M., T.D. Mullins, E.D. Forsman, P. Trail, and L. Wennerberg. 2004b. Genetic identification of spotted owls, barred owls, and their hybrids: legal implications of hybrid identity. Conservation Biology 18:1347–1357.

Hall, F.C. 1976. Fire and vegetation in the Blue Mountains – implications for land managers. Pages 155–170 in Tall Timbers Fire Ecology Conference.

Hall, F.C. 1998. Pacific Northwest ecoclass codes for seral and potential natural plant communities. General Technical Report PNW-GTR-418, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Hamer, T.E. 1988. Home range size of the northern barred owl and northern spotted owl in western Washington. M.S. Thesis. Western Washington University, Bellingham.

Hamer, T.E., S.G. Seim, and K.R. Dixon. 1989. Northern spotted owl and northern barred owl habitat use and home range size in Washington: preliminary report. Washington Department of Wildlife, Olympia.

Hamer, T.E., E.D. Forsman, A.D. Fuchs, and M.L. Walters. 1994. Hybridization between barred and spotted owls. Auk 111:487–492.

Hamer, T.E., D.L. Hays, C.M. Senger, and E.D. Forsman. 2001. Diets of northern barred owls and northern spotted owls in an area of sympatry. Journal of Raptor Research 35:221–227.

Hamer, T.E., E.D. Forsman, and E.M Glenn. 2007. Home range attributes and habitat selection of barred owls and spotted owls in an area of sympatry. Condor 109:750–768.

Hann, W.J., J.L. Jones, M.G. Karl, P.F. Hessburg, R.E. Keane, D.G. Long, J.P. Menakis, C.H. McNicoll, S.G. Leonard, R.A. Gravenmier, and B.G. Smith. 1997. Landscape dynamics of the basin. Pages 337–1055 in T. M. Quigley and S. J. Arbelbide (editors), An Assessment of Ecosystem Components in the Interior Columbia Basin and Portions of the Klamath and Great Basins. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Hanson, E., D. Hays, L. Hicks, L. Young, and J. Buchanan. 1993. Spotted owl habitat in Washington: a report to the Washington Forest Practices Board. Washington Forest Practices Board, Spotted Owl Advisory Group. Washington Department of Wildlife, Olympia, Washington. 116 pp.

Hardy, C.C., K.M. Schmidt, J.P. Menakis, and K.R.N. Sampson. 2001. Spatial data for national fire planning and fuel management. International Journal of Wildlife Fire 10:353–372.

Harestad, A., J. Hobbs, and I. Blackburn. 2004. Précis of the northern spotted owl in British Columbia. Pages 12–14 in K. Zimmerman, K. Welstead, E. Williams, and J. Turner (editors), Northern Spotted Owl Workshop Proceedings. Forest Research Extension Partnership (Forrex) Series No. 14, Vancouver, British Columbia.

Harrington, M.G., and S.S. Sackett. 1992. Past and present fire influences on southwestern ponderosa pine old growth. General Technical Report RM-GTR-213, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado.

Harris, J.A., R.J. Hobbs, E. Higgs, and J. Aronson. 2006. Ecological restoration and global climate change. Restoration Ecology 14:170–176.

Haynes, R., B. Bormann, D. Lee, and J. Martin. 2006. A synthesis of monitoring and research results. PNW-GTR-651. Portland, Oregon.

Hemstrom, M.A. 2003. Forests and woodlands of western North America. Pages 9–40 in C. J. Zabel and R.G. Anthony (editors), Mammal Community Dynamics. Cambridge University Press, Cambridge, United Kingdom.

Hemstrom, M.A., J. Merzenich, A. Reger, and B. Wales. 2007. Integrated analysis of landscape management scenarios using state and transition models in the upper Grande Ronde River Subbasin, Oregon, USA. Landscape and Urban Planning 80:198–211.

Henke, A.L., T.Y. Chi, J. Smith, and C. Brinegar. 2005. Spotted owl (*Strix occidentalis*) microsatellite variation in California. Department of Biological Sciences, San Jose State University, San Jose, California. 23 pp.

Herter, D.R. and L.L. Hicks. 2000. Barred owl and spotted owl populations and habitat in the central Cascade Range of Washington. Journal of Raptor Research 34:279–286.

Herter, D.R., L.L. Hicks, H.C. Stabins, J.J. Millspaugh, A.J. Stabins, and L.D. Melampy. 2002. Roost site characteristics of northern spotted owls in the nonbreeding season in central Washington. Forest Science 48:437–446.

Herter, D.R., J. Schaberl, and E. Myers. 2008. Rainier spotted owl demography study area: 2007 annual report. Raedeke Associates, Seattle, Washington. 14 pp.

Hessburg, P.F., and J.K. Agee. 2003. An environmental narrative of Inland Northwest United States forests, 1800–2000. Forest Ecology and Management 178:23–59.

Hessburg, P.F., R.G. Mitchell, and G.M. Filip. 1994. Historical and current roles of insects and pathogens in eastern Oregon and Washington forested landscapes. General Technical Report PNW-GTR-327, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Hessburg, P.F., B.G. Smith, S.D. Kreiter, C.A. Miller, R.B. Salter, C.H. McNicoll, and W.J. Hann. 1999. Historical and Current Forest and Range Landscapes in the Interior Columbia River Basin and Portions of the Klamath and Great Basins, Part I: Linking Vegetation Patterns and Landscape Vulnerability to Potential Insect and Pathogen Disturbances. General Technical Report PNW-GTR-458, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Hessburg, P.F., B.G. Smith, R.B. Salter, R.D. Ottmar, and E. Alvarado. 2000. Recent changes (1930s–1990s) in spatial patterns of interior northwest forests, USA. Forest Ecology and Management 136:53–83.

Hessburg, P.F., J.K. Agee and J.F. Franklin. 2005. Dry Mixed Conifer Forests and Wildland Fires of the Inland Northwest: Contrasting the Landscape Ecology of the Pre-settlement and Modern Eras. Forest Ecology and Management 211:117–139.

Hessburg, P.F., K.M. James, and R.B. Salter. 2007. Re-examining fire severity relations in pre-management era mixed conifer forests: Inferences from landscape patterns of forest structure. Landscape Ecology 22:5–24.

Heyerdahl, E.K., L.B. Brubaker, and J.K. Agee. 2001. Spatial controls of historical fire regimes: A multiscale example from the interior west, USA. Ecology 82: 660–678.

Heyerdahl, E.K., L.B. Brubaker, and J.K. Agee. 2002. Annual and decadal climate forcing of historical fire regimes in the interior Pacific Northwest, USA. The Holocene 12: 597–604.

Hobbs, R., S. Arico, J. Aronson, J. Baron, P. Bridgewater, A. Cramer, P. Epstein, J.J. Ewel, C. Klink, A. Lugo, D. Norton, D. Ojima, D. Richardson, E. Sanderson, R. Valladares, M. Vila, R. Zamora, R., and M. Zobel. 2006. Novel ecosystems: Theoretical and management aspects of the new ecological world order. Global Ecology and Biogeography 15:1–7.

Hoberg, E.P., G.S. Miller, E. Wallner-Pendleton, and O.R. Hedstrom. 1989. Helminth parasites of northern spotted owls (*Strix occidentalis caurina*). Journal of Wildlife Diseases 25:246–251.

Hopkins, W.E. 1979a. Plant associations of the Fremont National Forest. R6 Ecol 79-004, USDA Forest Service, Pacific Northwest Region, Portland, Oregon.

Hopkins, W.E. 1979b. Plant associations of the south Chiloquin and Klamath Ranger Districts, Winema National Forest. R6 Ecol 79-005, USDA Forest Service, Pacific Northwest Region, Portland, Oregon.

Huff, M.H., R.D. Ottmar, J.F. Lehmkuhl, P.F. Hessburg, R.L. Everett, E. Alvarado, and R.H. Vihanek. 1995. Historical and current forest landscapes of eastern Oregon and Washington. Part II: potential fire behaviour and smoke production. In P.F. Hessburg (editor), Eastside Forest Ecosystem Health Assessment: Volume III: Assessment. Gen. Tech. Rep. PNW-GTR-355. Portland, Oregon: USDA, Forest Service, Pacific Northwest Research Station. 43 pp.

IPCC (Intergovernmental Panel on Climate Change). 2007. Climate change 2007: The physical science basis. Summary for Policymakers. Contribution of Working Group 1 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC Secretariat, World Meteorological Organization, Geneva, Switzerland.

Irwin, L.L., D.F. Rock, and G.P. Miller. 2000. Stand structures used by northern spotted owls in managed forests. Journal of Raptor Research 34:175–186.

Iverson, W.F. 1993. Is the barred owl displacing the spotted owl in western Washington? M.S. thesis, Western Washington University, Bellingham.

Iverson, W.F. 2004. Reproductive success of spotted owls sympatric with barred owls in western Washington. Journal of Raptor Research 38:88–91.

Johnson, K. N., J. F. Franklin, J. W. Thomas, and J. Gordon. 1991. Alternatives for management of late successional forests of the Pacific Northwest. A report to the Agriculture and Merchant and Marine Fisheries Committees of the U.S. House of Representative. Scientific Panel on Late Successional Forest Ecosystems, Washington, D.C.

Kaufmann, M.R. 1996. To live fast or not: growth, vigor and longevity of old-growth ponderosa pine and lodgepole pine trees. Tree Physiology 16:139–144.

Keeley, J.E. 2006. Fire management impacts on invasive plants in the western United States. Conservation Biology 20:375–384.

Kelly, E.G. and E.D. Forsman. 2003. Barred owl. Pages 320–322 in D. B. Marshall, M.G. Hunter, and A.L. Contreras (editors), Birds of Oregon: a general reference. Oregon State University, Corvallis, Oregon.

Kelly, E.G., and E.D. Forsman. 2004. Recent records of hybridization between barred owls (*Strix varia*) and northern spotted owls (*S. occidentalis caurina*). Auk 121:806–810.

Kelly, E.G., E.D. Forsman, and R.G. Anthony. 2003. Are barred owls displacing spotted owls? Condor 105:45–53.

Kelly, E.G. and E.D. Forsman. 2004. Recent records of hybridization between barred owls (*Strix varia*) and northern spotted owls (*S. occidentalis caurina*). Auk 121:806–810.

Kennedy, M.C., E.D. Ford, P. Singleton, M. Finney, and J.K. Agee. 2008. Informed multi-objective decision-making in environmental management using Pareto optimality. Journal of Applied Ecology 45:181–192.

King, G.M., K.R. Bevis, M.A. Rowe, and E.E. Hanson. 1997. Spotted owls use of habitat impacted by 1994 fires on the Yakama Indian Reservation: three years post fire. Journal of Forestry 95:21–25.

Komar, N., N.A. Panella, J.E. Burns, S.W. Dusza, T.M. Mascarenhas, and T.O. Talbot. 2001. Serologic evidence for West Nile virus infection in birds in the New York City vicinity during an outbreak in 1999. Emerging Infectious Diseases 7:621–625.

Lamberson, R.H., B.R. Noon, C. Voss, K.S. McKelvey. 1994. Reserve design for terrestrial species: The effects of patch size and spacing on the viability of the northern spotted owl. Conservation Biology 8:185–195.

Lehmkuhl, J.F., M. Kennedy, E.D. Ford, P.H. Singleton, W.L. Gaines, and R.L. Lind. 2007. Seeing the forest for the fuel: Integrating ecological values and fuels management. Forest Ecology and Management 246:73–80.

Leskiw, T. and R.J. Gutiérrez. 1998. Possible predation of a spotted owl by a barred owl. Western Birds 29:225–226.

Lillybridge, T.R., B.L. Kovalchik, C.K. Williams, and B.G. Smith. 1995. Field guide for forested plant associations of the Wenatchee National Forest. General Technical Report PNW-GTR-359, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Lint, J. 2005. Population status and trends. Pages 7–19 in J. Lint (technical coordinator), Northwest Forest Plan—the first 10 years (1994–2003): status and trends of northern spotted owl populations and habitat. Gen. Tech. Rep. PNW-GTR-648, USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Livezey, K.B. 2005. Iverson (2004) on spotted owls and barred owls: comments on methods and conclusion. Journal of Raptor Research 39:102–103.

Livezey, K.B. 2007. Barred Owl habitat and prey: a review and synthesis of the literature. Journal of Raptor Research 41:177–201.

Livezey, K.B. and T.L. Fleming. 2007. Effects of Barred Owls on Spotted Owls: the need for more than incidental detections and correlational analyses. Journal of Raptor Research 41:319–325.

Livezey, K.B., T.L. Root, S.A. Gremel, and C. Johnson. 2008. Natural range expansion of Barred Owls? A critique of Monahan and Hijmans (2007). Auk 125:230–232.

Livezey, K.B., M.F. Elderkin, P.A. Cott, J. Hobbs, and J.P. Hudson. In Press. Barred Owls eating worms and slugs: the advantage in not being picky eaters. Northwestern Naturalist 89(3).

Marra, P.P., S. Griffing, C. Caffrey, A.M. Kilpatrick, R. McLean, C. Brand, E. Saito, A.P. Dupuis, L. Kramer, and R. Novak. 2004. West Nile Virus and wildlife. BioScience 54:393–402.

McKenzie, D, Z. Gedalof, D.L. Peterson, and P. Mote. 2004. Climate change, wildfire, and conservation. Conservation Biology 18:890–902.

McLean, R.G., S.R. Ubico, S.E. Docherty, W.R. Hansen, L. Sileo, and T.S. McNamara. 2001. West Nile Virus and transmission and ecology in birds. Annals of the New York Academy of Sciences 951:54–57.

Meyer, J.S., L.L. Irwin, and M.S. Boyce. 1998. Influence of habitat abundance and fragmentation on northern spotted owls in western Oregon. Wildlife Monographs 139:1–51.

Miller, G.S. 1989. Dispersal of juvenile spotted owls in western Oregon. M.S. thesis, Oregon State University, Corvallis. 139 pp.

Miller, G.S., S.K. Nelson, and W.C. Wright. 1985. Two-year-old female spotted owl breeds successfully. Western Birds 16:69–73.

Miller, G.S., R.J. Small, and E.C. Meslow. 1997. Habitat selection by spotted owls during natal dispersal in western Oregon. Journal of Wildlife Management 61:140–150.

Moen, C.A., A.B. Franklin, and R.J. Gutiérrez. 1991. Age determination of subadult northern spotted owls in northwest California. Wildlife Society Bulletin 19:489–493.

Moeur, M., T.A. Spies, M. Hemstrom, J.R. Martin, J. Alegria, J. Browning, J. Cissel, W.B. Cohen, T.E. Demeo, S. Healey, and R. Warbington. 2005. Northwest Forest Plan—the first 10 years (1994–2003): status and trend of late-successional and old-growth forest. Gen. Tech. Rep. PNW-GTR-646. U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Monahan, W. B. and R. J. Hijmans. 2007. Distributional dynamics of invasion and hybridization by *Strix* spp. in western North America. Ornithological Monographs 63:55–66.

Morgan, P., and S.C. Bunting. 1990. Fire effects in whitebark pine forests. Pages 166–170 in W. C. Schmidt, K.J. McDonald, and K.J. (editors), Symposium on Whitebark Pine Ecosystems: Ecology and Management of a High-Mountain Resource. US Department of Agriculture Forest Service, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Noon, B.R. and J.A. Blakesley. 2006. Conservation of the northern spotted owl under the Northwest Forest Plan. Conservation Biology 20:288–296.

Noon, B.R. and K.S. McKelvey. 1996. Management of the spotted owl: a case history in conservation biology. Annual Review of Ecological Systems 27:135–162.

Norman, S.P., and A.H. Taylor. 2003. Tropical and north Pacific teleconnections influence fire regimes in pine-dominated forests of north-eastern California, USA. Journal of Biogeography 30:1081–1092.

Norman, S.P., and A.H. Taylor. 2005. Pine forest expansion along a forest-meadow ecotone in northeastern California, USA. Forest Ecology & Management 215: 51–68.

Noss, R.F. 2001. Beyond Kyoto: Forest management in a time of rapid climate change. Conservation Biology 15: 578–590.

Odion, D.C., and C.T. Hanson. 2006. Fire severity in conifer forests of the Sierra Nevada, California. Ecosystems 9:1177–1189.

Odion, D.C., and C.T. Hanson. In Press. Fire severity in the Sierra Nevada revisited: Conclusions robust to further analysis. Ecosystems.

Odion, D.C., J.R. Strittholt, H. Jiang, E. Frost, D.A. DellaSala, and M. Moritz. 2004. Fire severity patterns and forest management in the Klamath National Forest, northwest California, USA. Conservation Biology 18: 927–936.

Olson, G.S., E.M. Glenn, R.G. Anthony, E.D. Forsman, J.A. Reid, P.J. Loschl, and W.J. Ripple. 2004. Modeling demographic performance of northern spotted owls relative to forest habitat in Oregon. Journal of Wildlife Management 68:1039–1053.

Olson, G.S., R.G. Anthony, E.D. Forsman, S.H. Ackers, P.J. Loschl, J.A. Reid, K.M Dugger, E.M. Glenn, and W.J. Ripple. 2005. Modeling of site occupancy dynamics for northern spotted owls, with emphasis on the effects of barred owls. Journal of Wildlife Management 69:918–932.

ODF (Oregon Department of Forestry). 2006. Forest Practices Administrative Rules and Forest Practices Act. Oregon Department of Forestry, Salem, Oregon.

Parker, A.J. 1995. Comparative gradient structure and forest cover types in Lassen Volcanic and Yosemite National Parks, California. Bulletin of the Torrey Botanical Club 122:58–68.

Pearson, R.R. and K.B. Livezey. 2003. Distribution, numbers, and site characteristics of spotted owls and barred owls in the Cascade Mountains of Washington. Journal of Raptor Research 37:265–276.

Pearson, R.R. and K.B. Livezey. 2007. Spotted Owls, Barred Owls, and Late-Successional Reserves. Journal of Raptor Research 41:156–161.

Peterson, D.L., M.C. Johnson, J.K. Agee, T.B. Jain, D. McKenzie, and E.D. Reinhardt. 2005. Forest structure and fire hazard in dry forests of the Western United States. General Technical Report PNW-GTR-628., USDA Forest Service, Pacific Northwest Research Station, Seattle, Washington.

Price, M.F., and G.R. Neville. 2006. Designing strategies to increase the resilience of alpine/montane systems to climate changes. Chapter 3: Montane in L.J. Hansen, J.L. Biringer, and J.R. Hoffman (editors), Restoration Ecology 14:170–176.

Raphael, M.G. 2006. Conservation of listed species: the northern spotted owl and marbled murrelet. Chapter 7 in R.W. Haynes, B.T. Bormann, D.C. Lee, and J.R. Martin (technical editors), Northwest Forest Plan—the first 10 Years (1994–2003): synthesis of monitoring and research results. Gen. Tech. Rep. PNW-GTR. USDA Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Rhodes, J.J., and W.L. Baker. In Press. Fire probability, fuel treatment effectiveness and ecological tradeoffs in the western US public forests. Open Forest Science Journal.

Rundel, P.W., D.J. Parsons, and D.T. Gordon. 1977. Montane and subalpine vegetation of the Sierra Nevada and Cascade ranges. Pages 559–599 in M.G. Barbour and J. Major (editors), Terrestrial vegetation of California. Wiley, New York.

Rustigian, H. L., M. V. Santelmann, and N. H. Schumaker. 2003. Assessing the potential impacts of alternative landscape designs on amphibian population dynamics. Landscape Ecology 18:65–81.

Safford, H.D., J. Miller, D. Schmidt, B. Roath, and A. Parsons. In Press. BEAR soil burn severity maps do not measure fire effects to vegetation: A comment on Odion and Hanson (2006). Ecosystems.

Schmidt, K. 2006. Northern spotted owl monitoring and inventory, Redwood National and State Parks, 2005 annual report. Redwood National and State Parks, Orick, California.

Schumaker, N. H., T. Ernst, D. White, J. Baker, and P. Haggerty. 2004. Projecting wildlife responses to alternative future landscapes in Oregon's Willamette Basin. Ecological Applications 14:381–400.

SEI (Sustainable Ecosystems Institute). 2008. Scientific review of the draft northern spotted owl Recovery Plan and reviewer comments. Sustainable Ecosystems Institute, Portland, Oregon. 150 pp.

SERPER (Society for Ecological Restoration Science & Policy Working Group). 2002. The SER Primer on Ecological Restoration.

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

Skinner, C.N., and C. Chang. 1996. Fire regimes, past and present. P. 1041–1069 in Sierra Nevada Ecosystem Project: final report to Congress. Volume II:

Assessments and scientific basis for management options. Centers for Water and Wildland Resources, University of California, Davis, Water Resources Center Report No. 37.

Skinner, C.N., and A.H. Taylor. 2006. Southern Cascades bioregion. Pages 195–223 in Fire in N.G. Sugihara, J.W. van Wagtendonk, K.E. Shaffer, J. Fites-Kaufman, and A.E. Thode (editors), California's Ecosystems. University of California Press, Berkeley.

Skinner, C.N., A.H. Taylor, and J.K. Agee. 2006. Klamath Mountains bioregion. Pages 170–193 I in N.G. Sugihara, J.W. van Wagtendonk, K.E. Shaffer, J. Fites-Kaufman, and A.E. Thode (editors), Fire in California's Ecosystems. University of California Press, Berkeley.

Soeriaatmadja, R.E. 1966. Fire history of the ponderosa pine forests of the Warm Springs Indian Reservation, Oregon. Oregon State University, Corvallis, Oregon.

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

Sovern, S.G., E.D. Forsman, B.L. Biswell, D.N. Rolph, and M. Taylor. 1994. Diurnal behavior of the spotted owl in Washington. Condor 96:200–202.

Spies, T.A., M.A. Hemstrom, A. Youngblood, and S. Hummel. 2006. Conserving Old-Growth Forest Diversity in Disturbance-Prone Landscapes. Conservation Biology 20:351–362.

Stephens, S.L., 2005. Forest fire causes and extent on United States Forest Service lands. International Journal of Wildland Fire 14: 213–222.

Stephens, S.L., and J.J Moghaddas. 2005a. Silvicultural and reserve impacts on potential fire behavior and forest conservation: 25 years of experience from Sierra Nevada mixed conifer forests. Biological Conservation 25:369–379.

Stephens, S.L., and J.J. Moghaddas. 2005b. Experimental fuel treatment impacts on forest structure, potential fire behavior, and predicted tree mortality in a California mixed conifer forest. Forest Ecology and Management 215:21–36.

Stuart, J.D. 1984. Hazard rating of lodgepole pine stands to mountain pine beetle outbreaks in southcentral Oregon. Forest Ecology and Management 5:207–214.

Taylor, A.H. 1990. Habitat segregation and regeneration patterns of red fir and mountain hemlock in ecotonal forests, Lassen Volcanic National Park, California. Physical Geography 11:36–48.

Taylor, A.H. 1993. Fire history and structure of red fir (*Abies magnifica*) forests, Swain Mountain Experimental Forest, Cascade Range, northeastern California. Canadian Journal of Forest Research 23:1672–1678.

Taylor, A.H. 2000. Fire regimes and forest changes along a montane forest gradient, Lassen Volcanic National Park, southern Cascade Mountains, USA. Journal of Biogeography 27:87–104.

Taylor, A.H., and C.N. Skinner. 1998. Fire history and landscape dynamics in a late-successional reserve in the Klamath Mountains, California, USA. Forest Ecology and Management 111:285–301.

Taylor, A.H., and C.N. Skinner. 2003. Spatial patterns and controls on historical fire regimes and forest structure in the Klamath Mountains. Ecological Applications 13:704–719.

Thomas, J.W., E.D. Forsman, J.B. Lint, E.C. Meslow, B.R. Noon, and J. Verner. 1990. A conservation strategy for the northern spotted owl. Interagency Scientific Committee to Address the Conservation of the Northern Spotted Owl. USDA Forest Service, USDI Bureau of Land Management, USDI Fish and Wildlife Service, and USDI National Park Service. Portland, Oregon. 458 pp.

Thomas, J.W., M.G. Raphael, R.G. Anthony, E.D. Forsman, A.G. Gunderson, R.S. Holthausen, B.G. Marcot, G.H. Reeves, J.R. Sedell, and D.M. Solis. 1993. Viability assessments and management considerations for species associated with late-successional and old-growth forests of the Pacific Northwest. USDA Forest Service, Portland, Oregon.

Thomas, J.W., J.F. Franklin, J. Gordon, and K.N. Johnson. 2006. The Northwest Forest Plan: origins, components, implementation experience, and suggestions for change. Conservation Biology 20:277–287.

USDA (U.S. Department of Agriculture), U.S. Department of the Interior, U.S. Department of Commerce, and U.S. Environmental Protection Agency. 1993. Forest ecosystem management: an ecological, economic and social assessment. Report of the Forest Ecosystem Management Assessment Team. U.S. Forest Service, Portland, Oregon.

USDA (U.S. Department of Agriculture), and USDI (U.S. Department of the Interior). 1994a. Record of decision for amendments to Forest Service and Bureau of Land Management planning documents within the range of the northern spotted owl; standards and guidelines for management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. USDA Forest Service, Portland, Oregon, and USDI Bureau of Land Management, Portland, Oregon.

USDA (U.S. Department of Agriculture), and USDI (U.S. Department of the Interior). 1994b. Final supplemental environmental impact statement on management of habitat for late-successional and old-growth forest related species within the range of the northern spotted owl. USDA Forest Service, Portland, Oregon, and USDI Bureau of Land Management, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1983a. Endangered and threatened species listing and recovery priority guidelines. Federal Register 48:43098–43105.

USFWS (U.S. Fish and Wildlife Service). 1983b. Endangered and threatened species listing and recovery priority guidelines: correction. Federal Register 48:51985.

USFWS (U.S. Fish and Wildlife Service). 1987. The northern spotted owl status review. USDI Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1989. The northern spotted owl; a status review supplement. USDI Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1990a. The 1990 status review: northern spotted owl: *Strix occidentalis caurina*. USDI Fish and Wildlife Service, Portland, Oregon. 95 pp.

USFWS (U.S. Fish and Wildlife Service). 1990b. Endangered and threatened wildlife and plants; determination of threatened status for the northern spotted owl. Federal Register 55:26114–26194.

USFWS (U.S. Fish and Wildlife Service). 1992a. Endangered and threatened wildlife and plants; determination of critical habitat for the northern spotted owl. Federal Register 57:1796–1838.

USFWS (U.S. Fish and Wildlife Service). 1992b. Draft final recovery plan for the northern spotted owl. USDI Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1994a. Letter from D.C. Frederick (USFWS) to J. Belcher (Washington Department of Natural Resources) dated February 1, 1994, regarding correction to spotted owl home-range data for the Olympic Peninsula. USFWS, Olympia, Washington.

USFWS (U.S. Fish and Wildlife Service). 1994b. Letter from Curt Smitch (USFWS) to U.S. Forest Service and Bureau of Land Management regarding ESA Section 7 consultation guidance for the Northwest Forest Plan. USFWS, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1995. Endangered and threatened wildlife and plants; proposed special rule for the conservation of the northern spotted owl on non-federal lands. Federal Register 60:9483–9527.

USFWS (U.S. Fish and Wildlife Service). 2004a. Trends in suitable habitat for the northern spotted owl (*Strix occidentalis caurina*) on federal lands from 1994 to 2003. For use by: Sustainable Ecosystems Institute for the northern spotted owl 5-year review. USDI Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2004b. Northern spotted owl: Five Year Review Summary and Evaluation. USDI Fish and Wildlife Service, Portland, Oregon. 73 pp.

USFWS (U.S. Fish and Wildlife Service). 2006. Data compiled in the northern spotted owl consultation effects tracking system USFWS internal database. July 24, 2006.

USFWS (U.S. Fish and Wildlife Service). 2007a. Analysis of distances dispersed by juvenile spotted owls in Forsman *et al.* (2002) using data supplied by E. Forsman (2007 pers. comm.). USDI Fish and Wildlife Service, Lacey, Washington.

USFWS (U.S. Fish and Wildlife Service). 2007b. 2007 Draft Recovery Plan for the Northern Spotted Owl, *Strix occidentalis caurina*: Merged Options 1 and 2. Portland, Oregon. 170 pp.

USFWS (U.S. Fish and Wildlife Service). 2007c. Draft recovery plan for the northern spotted owl (*Strix occidentalis caurina*): notice of document availability for review and comment. Federal Register 72:20865–20866.

USFWS (U.S. Fish and Wildlife Service). 2007d. Draft recovery plan for the northern spotted owl (*Strix occidentalis caurina*): notice of document availability for review and comment. Federal Register 72:32857–32858.

USFWS (U.S. Fish and Wildlife Service). 2007e. Endangered and threatened wildlife and plants; designation of critical habitat for the marbled murrelet (*Brachyramphus marmoratus*), designation of critical habitat for the northern spotted owl (*Strix occidentalis caurina*), draft recovery plan for the northern spotted owl: reopening of comment periods for two proposed revised critical habitat rules and a draft recovery plan. Federal Register 72:50929–50930.

Vavra, M., M.A. Hemstrom, and M. Wisdom. 2007. Modeling the effects of herbivores on the abundance of forest overstory states using a state-transition approach in the upper Grande Ronde River Basin, Oregon, USA. Landscape and Urban Planning 80:212–222.

Volland, L.A. 1985. Plant associations of the central Oregon Pumice zone. R6 Ecol 104-1985, USDA Forest Service, Pacific Northwest Region, Portland, Oregon.

Ward, J.W. Jr. 1990. Spotted owl reproduction, diet and prey abundance in northwest California. M.S. thesis, Humboldt State University, Arcata, California.

Ward, J.W. Jr., R.J. Gutiérrez, and B.R. Noon. 1998. Habitat selection by northern spotted owls: the consequences of prey selection and distribution. Condor 100:79–92.

Washington Forest Practices Board. 1996. Permanent rules for the northern spotted owl. Washington Department of Natural Resources, Olympia.

Weathers, W.W., P.J. Hodum, and J.A. Blakesley. 2001. Thermal ecology and ecological energetics of the California spotted owl. Condor 103:678–690.

Weaver, H. 1959. Ecological changes in the ponderosa pine forest of the Warm Springs Indian Reservation in Oregon. Journal of Forestry 57:15–20.

Westerling, A.L., H.G. Hidalgo, D.R. Cayan, and T.W. Swetnam. 2006. Warming and Earlier Spring Increase Western U.S. Forest Fire Activity. Science 313(5789):940–943.

Williams, C.K. and T.R. Lillybridge. 1983. Forested plant associations of the Okanogan National Forest. R6 Ecol 132-1983, USDA Forest Service, Pacific Northwest Region, Portland, Oregon.

Williams, C.K., B. Kelly, B. Smith and T. Lillybridge. 1995. Forested plant associations of the Colville National Forest. Gen. Tech. Rep. PNW-GTR-360. Portland, Oregon: USDA Forest Service, Pacific Northwest Research Station. 375 pp.

Wischnofske, M.G., and D.W. Anderson. 1983. The natural role of fire in the Wenatchee Valley. Page 24 Undocumented Report. . USDA Forest Service, Pacific Northwest Experiment Station, Wenatchee National Forest, Wenatchee, Washington.

Youngblood, A., T. Max, and K. Coe. 2004. Stand structure in eastside old-growth ponderosa pine forests of Oregon and northern California. Forest Ecology and Management 199: 191–217.

Zabel, C. J., K.M. McKelvey, and J.P. Ward, Jr. 1995. Influence of primary prey on home-range size and habitat-use patterns of northern spotted owls (*Strix occidentalis caurina*). Canadian Journal of Zoology 73:433–439.

Zabel, C. J., J.R. Dunk, H.B. Stauffer, L.M. Roberts, B.S. Mulder, and A. Wright. 2003. Northern spotted owl habitat models for research and management application in California (USA). Ecological Applications 13:1027–1040.

Personal Communications Cited

Diller, Lowell. 2006. Preliminary observations of the feasibility and effectiveness of doing lethal Barred Owl control. Information provided to NSO Recovery Team. Green Diamond Resource Company, Korbel, California.

Forsman, Eric. 2006. U.S. Forest Service, Pacific Northwest Research Station, Corvallis, Oregon. Email to Paul Phifer, U.S. Fish and Wildlife Service, Regional Office, Portland, dated August 30, 2006.

Loschl, Peter, and Eric Forsman. 2006. U.S. Forest Service, Pacific Northwest Research Station, Corvallis, Oregon. Email addressed to Kent Livezey, U.S. Fish and Wildlife Service, Washington Fish and Wildlife Office, dated September 8, 2006.

Raphael, Martin, and Bruce Marcot. 2008. U.S. Forest Service, Pacific Northwest Research Station, Olympia, Washington. Email addressed to Paul Phifer, U.S. Fish and Wildlife Service, Region 1 Regional Office, Portland, Oregon, dated April 3, 2008.

Appendix H. Scientific Names for Common Names Used in the Text

Following is a list of scientific names for common names used in the text excluding *Strix* species which are identified in the text.

Trees	
ponderosa pine	*Pinus ponderosa*
sugar pine	*Pinus lambertiana*
Jeffrey pine	*Pinus jeffreyi*
Bishop pine	*Pinus muricata*
lodgepole pine	*Pinus contorta*
western larch	*Larix occidentalis*
Englemann spruce	*Picea englemannii*
western hemlock	*Tsuga heterophylla*
mountain hemlock	*Tsuga mertensiana*
Douglas-fir	*Pseudotsuga menziesii*
grand fir	*Abies grandis*
Pacific silver fir	*Abies amabilis*
white fir	*Abies concolor*
Shasta red fir	*Abies magnifica shastensis*
redwood	*Sequoia sempervirens*
incense-cedar	*Libocedrus decurrens*
western redcedar	*Thuja plicata*
tanoak	*Lithocarpus densiflorus*
Oregon white oak	*Quercus garryana*
California black oak	*Quercus kelloggii*
canyon live oak	*Quercus chrysolepis*
bigleaf maple	*Acer macrophyllum*
mountain dogwood	*Cornus nuttallii*
Mammals	
dusky-footed wood rat	*Neotoma fuscipes*
bushy-tailed wood rat	*Neotoma cinerea*
deer mouse	*Peromyscus maniculatus*
tree voles	*Arborimus longicaudus, A. pomo*
red-backed voles	*Clethrionomys* spp.
gophers	*Thomomys* spp.
flying squirrel	*Glaucomys sabrinus*
snowshoe hare	*Lepus americanus*
Birds	
eastern screech-owl	*Otus asio*
great horned owl	*Bubo virginianus*
northern goshawk	*Accipiter gentiles*
red-tailed hawk	*Buteo jamaicensis*

Region 1
U.S. Fish & Wildlife Service
Ecological Services
911 NE 11th Ave.
Portland, Oregon 97232-4181

http://www.fws.gov

May 2008