U.S. Fish & Wildlife Service

2010 Draft Revised Recovery Plan for the Northern Spotted Owl (*Strix occidentalis caurina*)

Cover photo:

2010 Draft Revised Recovery Plan for the Northern Spotted Owl (*Strix occidentalis caurina*)

September 8, 2010

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

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

Date: ____________________

Disclaimer

Recovery plans describe reasonable actions and criteria that are considered necessary to recover listed species. Recovery 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.

A Recovery Plan for the Northern Spotted Owl (2008 Recovery Plan or 2008 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) and published May 14, 2008. The Recovery Team members served as independent advisors to the Service for the development of the 2007 Draft Recovery Plan. The 2008 Plan did 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 this Plan will be achieved subject to availability of funding and the capability of the involved parties to participate while addressing other priorities.

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Citation

U.S. Fish and Wildlife Service. 2010. Draft revised recovery plan for the northern spotted owl, *Strix occidentalis caurina*. U.S. Fish and Wildlife Service, Portland, Oregon. xii + 163 pp.

Electronic copy

A copy of the draft revised Recovery Plan and other related materials can be found at http://www.fws.gov/species/nso

Acknowledgments

The Service gratefully acknowledges the effort and commitment of the many individuals involved in the conservation and recovery of the northern spotted owl who participated in the preparation of both the 2008 Plan and 2010 Draft Revised Recovery Plan (this revised Plan). Without their individual expertise and support, this revised Plan would not have been possible as it is the culmination of many years of labor.

This revised Plan is the culmination of many hours of discussion, research and analysis by a large number of scientific experts and managers over several years. The Service began preparing a recovery plan for the spotted owl in April 2006. To advise the Service, a Recovery Team was initially appointed which was supported by an Interagency Support Team (IST) and led by a Recovery Plan Project Manager. During the development of the 2007 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 Scientist and Implementer Panelists below). The Service is indebted to all of the individuals for the guidance provided during the preparation of the 2007 Draft Plan. Their names, affiliations, and roles are listed below.

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The 2007 Draft Recovery Plan generated more than 75,800 public comments. To evaluate scientific and management issues highlighted 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. Based on this input, and comments from the public, the FWS finalized the 2008 Plan. We thank all of these individuals; they are listed below.

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This draft Plan modifies portions of the 2008 Plan and relies heavily on that document as a foundation. The targeted revision to the 2008 Plan has been led by the Service and builds upon the efforts of numerous individuals from several different agencies, academia, state governments and private organizations. The Service is indebted to all of these individuals for the guidance provided during the preparation of this revised Plan. Their names, affiliations, and roles are listed below. Their participation in the revision process does not imply these contributors or their sponsoring agencies agree with the recommendations and conclusions of this revised Plan.

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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 1990*b*) 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 important 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 over the past two 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 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

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 uncharacteristic wildfire, and loss of amount and distribution of suitable habitat as a result of past activities and disturbances. To address these threats, this recovery strategy includes four basic steps:

1. Completion and application of rangewide habitat modeling
2. Habitat conservation and active forest management
3. Barred owl management
4. Research and monitoring

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.

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 recommended in the 2008 Plan that specific actions to address the barred owl threat begin immediately and in a coordinated manner. These actions are currently underway.

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

Maintaining and restoring sufficient habitat is important to address the threats the spotted owl faces from a loss of habitat due to harvest and uncharacteristic fire, loss of genetic diversity, and barred owl. The 2008 Plan established a network of Managed Owl Conservation Areas (MOCAs) across the range of the species. The peer review comments were critical of the MOCA network and recommended using updated modeling tools to plan and build a new habitat network. Based on those comments, the Service is withdrawing the previously recommended MOCA network until modeling can help assess its conservation value to the species. The Service initiated just such a modeling effort in October of 2009 which is currently in progress but is not complete. The Service intends to use the rangewide habitat model to evaluate a number of different habitat conservation network scenarios and present the results of those evaluations in the final Recovery Plan (anticipated to be completed by 2011.) The current reserve system in place for the spotted owl is that which was established under the Northwest Forest Plan (NWFP) and any state-designated conservation areas. In the interim, we recommend that land managers continue to implement the standards and guidelines of the Northwest Forest Plan as well fully consider other recommendations in this revised Plan.

The estimated time to delist the species is 30 years if all actions are implemented and effective. While the 2008 Plan identified a 10 year timeframe, this revision identifies several actions that will take many years to implement effectively and consequently, the Service considers this revised Plan to be fully implemented in 30 year timeframe. A longer time to delisting would be required if these assumptions are not met. Total cost for delisting over these 30 years is $147.1 million (see section IV – Implementation Schedule and Cost Estimates for specific costs).

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 implement this revised Plan aggressively and frequently revisit whether we are on the best path to recovering the species. The Service and other implementers of this revised Plan will have to employ an active adaptive management strategy to achieve results and focus on the most important actions for recovery.

After the 2008 Plan was finalized, an inter-organizational Northern Spotted Owl Recovery Plan implementation structure was established that included multiple interagency work groups and several management teams. This implementation structure is acknowledged in this revised Plan and is expected to continue operating both during and after development and completion of this revised Plan. These implementation work groups are essential to successfully implementing Recovery Actions and achieving recovery, and include a Barred Owl Work Group, a Dry-Forest Landscape Work Group, a Klamath Province Work Group, a Section 7 Work Group, and non-Federal lands groups in Washington, Oregon and in California. These work groups are overseen by an interagency team of managers (the Northern Spotted Owl Recovery Implementation Team) and an interagency team of directors (the Northern Spotted Owl Executive Team).

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 the spotted owl is the same.

Recovery Objectives

The objectives of this revised Plan are:

1. Spotted owl populations are sufficiently large and distributed such that the species no longer requires listing under the ESA.
2. Adequate habitat is available for spotted owls and will continue to exist to allow the species to persist without the protection of the ESA.
3. 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.

Recovery Criteria

There are four Recovery Criteria in this revised Plan. Given the draft nature of this revised Plan and the habitat network modeling effort we are conducting, additional criteria will need to be revised at a later date.

Recovery Criterion 1 - Stable Population Trend: The overall population trend of spotted owls throughout the range is stable or increasing over 10 years, as measured by a statistically reliable monitoring effort.

Recovery Criterion 2 – Adequate Population Distribution: Spotted owl subpopulations within each province (*i.e.*, recovery unit)(excluding the Willamette Valley Province) achieve viability, as measured by the HexSim population model or some other appropriate quantitative measure.

Recovery Criterion 3 – Continued Maintenance and Recruitment of Spotted Owl Habitat: There is no net loss in nesting/roosting or foraging habitat throughout the range, as measured by effectiveness monitoring efforts or other reliable habitat monitoring programs.

Recovery Criterion 4 – Post-delisting Monitoring: 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 revised 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.

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
LCC	Landscape Conservation Cooperative
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
NSOIT	Northern Spotted Owl Implementation Team
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

Development of this Draft Revised Recovery Plan

This revised Plan builds extensively on the 1992 Draft Recovery Plan for the Northern Spotted Owl (USFWS 1992*b*), the 1994 Northwest Forest Plan (USDA and USDI 1994*a*, *b*), and the 2008 Recovery Plan for the Northern Spotted Owl (USFWS 2008).

In 1993, President Clinton announced the Northwest Forest Plan which was intended to serve three roles: a program to manage forests to achieve both sustainable timber production and protection of biological diversity; a system for coordinating Federal agency implementation of the forest management efforts and receiving advice from non-Federal interests and an initiative for providing economic assistance for those individuals and communities who were adversely affected by the reduction in the timber program. The 1994 Northwest Forest Plan signaled a unique approach to Federal land management in that it sought to embody (Pipkin 1998):

1. A shift to an ecosystem approach that crosses jurisdictional boundaries;
2. Active and meaningful public participation;
3. A balancing of commodity production and ecosystem viability;
4. Increased adaptive management efforts that support reevaluation and adjustments based on science; and
5. A commitment to improved interagency processes;
6. Federal agencies sharing responsibility for the implementation of a set of standards and guidelines for managing a common resource.

Due to its broad, over-arching nature and comprehensive scientific information, the 1994 Northwest Forest Plan was widely viewed as the Federal government's contribution to the recovery of the spotted owl since it contained the information used to develop the draft 1992 Northern Spotted Owl Recovery Plan. The NWFP was directly incorporated into 4 National Forest land and resource management plans (LRMPs) and amended the LRMPs that guide the management of each of the 15 National Forests and six Bureau of Land Management (BLM) Districts across the range of the spotted owl to adopt a series of reserves and management guidelines that were intended to protect spotted owls and their habitat.

As time passed, the public and land managers expressed a desire for a spotted owl recovery plan that explicitly outlined and described the management actions and habitat needs of the species. The Service responded by publishing in May, 2008, the Recovery Plan for the Northern Spotted Owl, which was created after two years of scientific meetings, peer review, input from work groups and more than 70,000 public comments. The 2008 Plan was challenged in court and, on

September 1, 2010, remanded back to the Service to revise. *Carpenters' Industrial Council v. Salazar*, Case No. 1:08 cv 01409 EGS (D.D.C.).

The 2008 Plan identified two predominant threats: increasing competition from barred owls and habitat loss from timber harvest and fire. The main elements of the 2008 Plan included: 1) a network of conservation areas on Federal lands west of the Cascades; 2) a new approach to habitat management on Federal lands east of the Cascades that maintains spotted owl habitat in a fire-prone landscape; 3) large scale barred owl removal experiments; and 4) maintenance of substantially all older forests on Federal lands west of the Cascades to reduce spotted owl and barred owl competitive interactions as we evaluate barred owl management options.

As a result of the recommendations of the 2008 Plan, the Service established several recovery implementation work groups to actively implement the recovery actions which established the "framework for recovery." These activities have broad scientific support as actions that help meet the spotted owls conservation needs or are those where the peer reviewers identified the need for additional scientific discourse. These work groups include:

- **The Section 7 Work Group**- clarifies various questions associated with section 7 consultations and recovery plan implementation, such as how to apply Recovery Action 32.
- **The Dry-Forest Landscape Work Group and the Klamath Province Work Group**- addresses scientific and technical matters related to managing and recovering the spotted owl in dry-forest landscapes.
- **The Barred Owl Work Group**- seeks to understand and minimize the influence of barred owls on spotted owls, and
- **Ad hoc non-Federal lands work groups** for each state- represents the ongoing coordination between the Service, State officials, and other interested local parties on a variety of spotted owl conservation efforts.

The work groups' activities are actively implementing the 2008 Plan as well as aiding in the Plan revision process.

In June 2008, the Service received reviews of the 2008 Plan from the American Ornithologists' Union, Society for Conservation Biology and The Wildlife Society. These reviews were consistent in their comments, noting that the recovery plan provided a "solid conceptual framework for recovery." However, the comments were critical of several key aspects of the Plan, particularly addressing threats posed by habitat loss from fire and concerns regarding the adequacy of reserves and their management.

Both the recovery plan and the 2008 revised critical habitat designation for the northern spotted owl which is based on the recovery plan were challenged in court. *Carpenters' Industrial Council v. Salazar*, Case No. 1:08-cv-01409-EGS (D.D.C.). In addition, on December 15, 2008, the Inspector General of the Department of the Interior issued a report entitled "Investigative Report of the Endangered Species Act and the Conflict between Science and Policy" which concluded that the integrity of the agency decision-making process for the 2008 recovery plan was potentially jeopardized by improper political influence. As a result, the federal government filed a motion in the lawsuit for remand of the 2008 recovery plan and remand and vacature of the 2008 critical habitat designation. On September 1, 2010, the Court issued an opinion remanding the 2008 recovery plan to the FWS for issuance of a revised plan within nine months. The Court also indicated that it will remand the 2008 critical habitat designation pending resolution of a schedule for a new rulemaking. This draft revised recovery plan has been developed as part of the process to consider revisions to the 2008 recovery plan.

Not long after the peer review comments were received, litigation was brought against the 2008 critical habitat designation and 2008 Plan, citing a number of issues raised in the peer review comments. The Department of Interior requested that the court remand the 2008 Plan to the Service for revision in light of the peer review concerns and new scientific information.

On May 3, 2010, the Service issued a memo stating we were conducting a revision to address concerns cited about the 2008 Plan, with a final revision due at the end of December, 2010. Our goal is to complete a revision of the 2008 Plan by the end of December 2010 based on the best scientific information available, addressing the peer reviewers' comments and including more recent scientific information involving climate change and habitat modeling. The revised Plan will focus largely on four topics:

(a) Adequacy and management of the reserves,
(b) Adequacy of non-Federal lands' contribution to owl recovery,
(c) Protection of high quality habitat and occupied spotted owl sites, and
(d) Relation of fire/disease forest management to spotted owl recovery on "dynamic" landscapes

We have also addressed the implications of climate change on spotted owl conservation.

Because the Service is conducting a focused revision, the following document contains elements of the 2008 Plan, as well as revised and updated information. This presents the most comprehensive, up-to-date thinking on northern spotted owl science, conservation needs and management alternatives. With it, the Service seeks to engage Federal, State and private landowners in developing a comprehensive, landscape-level approach that furthers the recovery of the spotted owl.

In the document that follows, we propose to retain many aspects of the 2008 Plan in this revised Plan, such as the continuing use of established work groups, and the strategy to assess and address threats from the barred owl. Upon completion of the revised Plan, the Service will assess whether the designated Spotted Owl Critical Habitat also needs to be revised.

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

- 1994: The Record of Decision for the Northwest Forest Plan is signed, serving as the Federal contribution to recovery.
- April, 2006: Formation of 12-member multi-agency, multi-disciplinary Recovery Team
- April, 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, 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 work groups 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 2008 Final Recovery Plan; Implementation begins
- June, 2008: Peer review comments received on 2008 Final Recovery Plan
- July 30, 2009: The United States files a motion requesting the United States District Court for the District of Columbia to remand the 2008 Final Recovery Plan and proposing to complete a revised plan within nine months of a court order. *Carpenters Industrial Council v. Salazar*, Case No. 1:08-cv-01409-EGS (D.D.C.)
- May, 2010: The Service issues a memo stating the decision to conduct a scientific revision of the 2008 Recovery Plan in response to peer review comments received in summer 2008, as well as incorporate the latest science, including data on climate change and spotted owl demography.
- September 1, 2010: The district court in *Carpenters Industrial Council v. Salazar* grants the federal government's request to remand the 2008 recovery plan and complete a revised recovery plan within nine months.
- September, 2010: 2010 Draft Revised Recovery Plan released for public comment and peer review.

Recovery Planning 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:

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

Recovery plans are not regulatory documents; rather, they are created by the U.S. Fish and Wildlife Service as 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. 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 revised Plan.

Recovery Plan Objectives, Criteria, and Actions

The ultimate goal of this revised Plan is to delist the spotted owl. Its objectives describe a scenario 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.

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

The Recovery Criteria and Actions are at the front of the revised 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.

Five Year Reviews

A 5-year review of a listed species is required by section 4(c)(2) of the Endangered Species Act (ESA), and considers all new available information concerning the population status of the species and the threats that affect it. This process can serve as an integral component of tracking recovery implementation, updating scientific understanding, and evaluating status of the species. The U.S. Fish and Wildlife Service (Service) conducts these periodic reviews to ensure the listing classification of a species as threatened or endangered is accurate. A review considers the best scientific and commercial information that has become available since the original listing determination or last review, such as: species biology, habitat conditions, conservation measures, threat status and trends, and any other new information. The Service publishes a notice in the Federal Register announcing the initiation of these reviews and provides the public an opportunity to submit relevant information regarding the species and its threats. A 5-year review is intended to indicate whether a change in a species listing classification is warranted. Changes in classification recommended in a 5-year review could include delisting, reclassification from threatened to endangered (*i.e.*, uplisting), reclassification from endangered to threatened (*i.e.*, downlisting), or no change is warranted at this time. The 5-year review does not involve rule-making, so no change to a species classification is made at the time a review is completed. If a change is recommended in the completed review, the Service would need to initiate a separate rule-making process to propose the change.

Delisting Process

When sufficient progress toward recovery has been made, a separate effort 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). 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. These include:

1. The present or threatened destruction, modification, or curtailment of its habitat or range
2. Overutilization for commercial, recreational, scientific, or educational purposes
3. Disease or predation
4. The inadequacy of existing regulatory mechanisms, and
5. Other natural or manmade factors affecting its continued existence.

This subsequent review may be initiated without all of the Recovery Criteria in this revised 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 revised Plan was created. 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.

Assumptions Made in Drafting the Revised Plan

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

There are numerous land management plans and strategies being implemented to help recover the spotted owl. This revised Plan is not meant to negate the importance of these other plans. However, the success and implementation of these plans may be subject to change, so this revised Plan is meant to be a stand-alone document that describes what is necessary to recover the spotted owl. The steps described in the revised Plan are meant to be successful on their own; that is, they are not dependent on the continuance of any other conservation plan to be successful.

Listing History and Recovery Priority

The spotted owl was listed as threatened on June 26, 1990. On a scale of 1C (highest) to 18 (lowest) (USFWS 1983*a*, *b*) the Service recovery priority number for the spotted owl is 12C, which reflects a moderate degree of threat, a low potential for recovery, the spotted owl's taxonomic status as a subspecies and inherent conflicts with development, construction, or other economic activity given the economic value of older forest spotted owl habitat. A moderate degree of threat equates to a continual population decline and threat to its habitat, although extinction is not imminent. While the Service is optimistic regarding the potential for recovery, there is uncertainty

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.

regarding our ability to alleviate the barred owl impacts to spotted owls and the techniques are still experimental, which matches our guidelines "low recovery potential" definition (USFWS 1983*a*, *b*).

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 1990*b*: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 1992*b*). These threats were characterized for each province as severe, moderate, low or unknown (USFWS 1992*b*). 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 2004*b*), 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" (Gutiérrez *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" (Gutiérrez *et al.* 2004:7-38).

On June 1, 2006, a panel of seven experts was assembled to help 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 2007 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. West-side 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

It is the Service's position 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 2005). Consequently, the Service assumes barred owls are in all areas occupied by resident, dispersing, and displaced spotted owls. Addressing the threats associated with past and current habitat loss must be conducted

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.

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 hypothesizes spotted owls can persist in portions of their range due to the partitioning of habitat use by the two species (see Appendix B), but this may be overly optimistic. At this time, the long-term removal of significant numbers of barred owls, along with a suite of other recovery actions, will be assessed as a possible approach to recover the spotted owl. Before considering whether to fund and fully implement such an action, however, the Service needs to be confident this removal would benefit spotted owls. The Service is currently developing a draft Environmental Impact Statement to assess the effects of barred owl removal experiments proposed in this revised Plan.

Because spotted owls and barred owls compete for similar habitats and resources for breeding, feeding, and sheltering, ongoing loss of habitat has the potential to intensify competition as owl territories are constrained into closer proximity. In order to reduce or not increase this potential competitive pressure while the threat from barred owls is being addressed, this revised Plan now recommends retaining older, multi-layered forests on the dry-forest provinces and on non-Federal lands, in addition Federal lands across the range of the spotted owl.

Habitat Management

The Service believes a tiered approach of managing habitat to support the spotted owl and address the key threats it faces will most effectively achieve recovery. While the 2008 Plan recommended establishing MOCAs on Federal lands to provide the important habitat needed for the species to recover over the long-term, as a part of our response to peer review comments, the Service is not including this recommendation in this draft revised plan and is, instead, conducting a range-wide, multi-step modeling process that will help design, assess and inform designation of a habitat conservation network that will help address the recovery of the spotted owl.

In addition, given the continued decline of the species, the apparent increase in severity of the threat from barred owls, and information indicating a recent loss of genetic diversity for the species, this revised Plan also recommends retaining all occupied sites and unoccupied, high quality spotted owl habitat on all lands to the maximum extent possible. Management actions that may have short-term impacts but are beneficial to spotted owl occupied sites and unoccupied, high quality spotted owl habitat on all lands in the long-term meet the recovery intent of habitat conservation. Such actions may include silvicultural treatments that promote ecological restoration (Franklin *et al.* 2007)

In the more disturbance-prone provinces on the east side of the Cascade Mountains and in the Klamath Province, the Service is working with the Dry-Forest Landscape and Klamath Work Groups (established as recommended by the 2008 Plan) to develop a strategy that will incorporate the dynamic natural disturbance regime in a manner that provides for long-term ecological sustainability through the restoration of ecological processes, and retain spotted owl habitat over the long term.

Habitat Terms

This revised 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 1992*b*)
Nesting and roosting habitat	Suitable habitat that provides nesting and roosting 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).	
Foraging habitat	Suitable habitat that provides foraging opportunities for spotted owls, but without the structure to support nesting and roosting.	
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 and may vary due to climatic gradients across the range.	
Dispersal habitat	Optimally, forest stands with average tree diameters $\geq$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	USDA *et al.* (1993:IX-31)

Habitat term	Definition	Reference
	rapidly decrease in the stand.	
Late-seral forest	Stage in forest development that includes mature and old-growth forest.	USDA *et al.* (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 80–100 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 *et al.* (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)

Risk, Uncertainty and Changing Management

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 and type 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."

To be successful, Recovery Plans must describe goals the Service concludes are effective, 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 or desirable 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 the face of significant scientific uncertainty, we propose aggressive strategies to address the threats from habitat loss, barred owls and catastrophic wildfire. It is understood that this revised 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 revised Plan are necessary to achieve the plan's goal for the conservation and survival of the species.

In order to deal with uncertainty and risk the Service will employ an active program of adaptive management. Adaptive management includes identifying areas of uncertainty and risk, 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 1992*b*). There will be numerous opportunities to employ adaptive management to our spotted owl recovery approach. Some of the potential triggers for evaluating the efficacy of our approach may include the publishing of future demographic studies, revisions to state or Federal land management plans and upon receipt of the results of barred owl removal experiments, to name a few. Where possible, such an approach is recommended in this revised Plan.

Any amendments or revisions to existing, underlying Federal land use allocations and management plans that result from recommendations in this revised Plan will follow the process of public involvement as required under the National Environmental Policy Act (NEPA) of 1969, as amended (42 USC 4321 *et seq*.) and the consultation process under Section 7 of the ESA. The determination of the consistency of these approaches to meet the goals and objectives of this revised Plan would be conducted 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.

Ongoing Actions

After completion of the 2008 Plan, recovery actions were immediately implemented as coordinated by a Spotted Owl Recovery Coordinator. Under the Northern Spotted Owl Recovery Plan implementation structure, four specific topic work groups (Barred Owls, Klamath Province, Dry-Forest Landscape and Section 7), and a Non-Federal Landowners workgroup in each state were formed. These work groups are overseen by an interagency team of managers (the Northern Spotted Owl Recovery Implementation Team) and an interagency team of directors (the Northern Spotted Owl Executive Team). This revised Plan calls for the continuance of these work groups as they play a vital role in the successful implementation of recovery actions. For a more complete description of the implementation structure and progress to date, see the Northern Spotted Owl Recovery Information Portal at www.fws.gov/species/nso.

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 the spotted owl is the same.

Recovery Objectives

The objectives of this revised Plan are:

1. Spotted owl populations are sufficiently large and distributed such that the species no longer requires listing under the ESA.
2. 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.
3. 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.

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 uncharacteristic wildfire, and loss of amount and distribution of suitable habitat as a result of past activities and disturbances. To address these threats, this recovery strategy includes four basic steps:

1. Completion and application of rangewide habitat modeling
2. Habitat conservation and active forest management
3. Barred owl management
4. Research and monitoring

These four steps are described in detail below.

Completion and Application of Rangewide Habitat Modeling

Developing a mapped landscape "reserve" strategy as part of a spotted owl recovery plan remains a complex and controversial undertaking. Peer reviewers were highly critical of the 2008 Plan and its MOCA strategy. Likewise, the 2008 designated critical habitat, which was based in part on the MOCA strategy, has been challenged in Federal district court. The Service therefore initiated a spatially-explicit habitat modeling effort in October 2009 provides a more in-depth evaluation of various habitat features that affect spotted owl habitat use, when compared to the process used to develop the MOCAs. This effort, which is described in detail in Appendix C, has produced some important insights but as of this writing is not yet complete.

This draft revised Plan contains many site-specific management recommendations designed to advance the conservation and survival of the species. However, final recommendations relative to mapped high-value habitat areas associated with spotted owl recovery will occur after all phases of the current habitat modeling are completed. The first two stages of the process (*i.e.*, "MaxEnt" and "Zonation") have identified important areas with value for owl recovery. Mapping of a habitat conservation network, including any recommendations on potential refinements to existing long term land use allocations, will be deferred until the third and final step of the model effort (*i.e.*, "HexSim") is completed. In this final step, various land management scenarios can be evaluated for their relative potential contribution to spotted owl recovery. Results from this step, which will include evaluations of various existing and potential reserve scenarios, will be reported in the final Revised Recovery Plan, anticipated by 2011. Subsequent to this analysis and publication of a final Revised Plan, the Service will use these evaluations of various existing and potential habitat conservation network scenarios to inform possible revision of designated spotted owl critical habitat.

Habitat Conservation and Active Forest Management

The habitat modeling effort described above will provide an important geospatial perspective to spotted owl recovery. However, in addition to the modeling of habitat value across the landscape and its potential utility in refining critical habitat, spotted owl recovery will continue to require aggressive habitat conservation and active forest management on Federal and non-Federal lands. Therefore, we are also refining individual recovery actions that address these areas as described below.

Habitat Conservation on Federal Lands - We recommend retaining all occupied sites and unoccupied, high quality spotted owl habitat on all lands to the maximum extent possible. Management actions that may have short-term impacts but are beneficial to spotted owl occupied sites and unoccupied, high quality spotted owl habitat in the long-term meet the recovery intent of habitat conservation. Given the continued negative population trend of the spotted owl and the likely impact of barred owls, the Service recommends Federal land managers protect and manage extant high quality spotted owl habitat and occupied spotted owl sites throughout the species' range. Spotted owl populations continue to decline (Forsman *et al.* in press, Funk *et al.* 2010), likely due in large part to impacts from barred owls. Retention of all high quality habitat on Federal lands could ameliorate this impact as barred owl management options are considered and tested.

Active Forest Management – The Service continues to recommend an active forest management posture such as discussed below in many areas throughout the range of the spotted owl. The objective for active forest management is to restore ecosystem structure, composition, and processes so that they are sustainable and resilient under current and future conditions.

On the west side of the Cascades, Federal land managers should apply "ecological forestry" principles (Carey 2007, Franklin *et al*. 2007) where short-term and long-term spotted owl recovery will benefit. For example, managers should promote spatial heterogeneity within stands, restore lost species diversity, including hardwoods, with the historic range of variability, and restore ecological processes to historic levels and intensities. In some areas, we believe spotted owl recovery could benefit from extending the maximum age of stands eligible for management in Late Successional Reserves (LSRs). Some LSRs that are 80 years and older should be considered for treatments designed to encourage development of late-successional structural complexity in stands that are uniform and not likely to achieve the desired complexity on their own (Johnson and Franklin 2009). Likewise, in areas with regeneration harvest in moist forest Matrix lands, managers should design such harvest using ecological forestry principles that emphasize retention of larger and older trees, snags and down wood of varying size and decay classes, and live trees with decay and deformities. Applying these measures should promote spotted owl recovery by retaining important habitat features while also encouraging development of late-successional conditions as originally envisioned in the NWFP.

In drier forest landscapes of the eastern Cascades, California Cascades, and Klamath Provinces, dynamic, disturbance-prone forests should be actively managed in a way that addresses the complementary goals of spotted owl recovery, responding to climate change, and restoring dry-forest ecological structure, composition and processes. We support, as did the 2008 Plan peer reviewers, this overarching principle for managing dry-forest landscapes. Specific to the Eastern Washington Cascades, Eastern Oregon Cascades, and California Cascades Provinces, however, peer reviewers found the specific management recommendations in the 2008 Plan to be aggressive, untested, and not supported by analysis. We are modifying these recommendations based on our habitat modeling effort, the report of Johnson and Franklin (2009), SEI (2008), the ongoing debate as captured in Hanson *et al*. (2009, 2010) and Spies *et al*. (2010), the results of the vegetation-fire-owls research project (Kennedy *et al.* unpublished), and the continuing discussions of the Dry-Forest Landscape Work Group (DFLWG).

This ongoing debate seems to be one of degree rather than fundamental difference, and we would like to build on areas of agreement. We are working with the DFLWG to identify general areas of scientific agreement that would enable the Service to put forth defensible recommended actions that have broad support from land managers. We recognize these recommendations may generate some controversy, and we understand that spotted owl recovery is one of several goals -- sometimes competing, sometime complementary -- that land managers take into account when deciding how best to meet management objectives on their lands. While there is tremendous uncertainty about future landscape conditions due to fire risk, climate change, and dry-forest ecosystem dynamics, we agree with the following scientific opinions:

- "(U)ncertainty should motivate careful action that when coupled with scientifically sound monitoring can promote learning and improve conservation outcomes" (Spies *et al*. 2009:332);
- "In fire-prone forests, management inaction is not an option (North *et al*. 2010:33);
- We should prioritize implementation of adaptive management studies to understand owl response to treatments and natural processes with an emphasis on "no regrets" actions that address priority owl habitat needs (Hanson *et al*. 2010).

Given the need for action in the face of uncertainty, we recommend that Federal land managers implement a program of landscape-scale, science-based adaptive restoration treatments in disturbance-prone forests that will reconcile the complementary goals of conserving and developing spotted owl habitat while better enabling forests to (a) recover from past management measures and (b) respond positively to climate change concerns (Millar *et al*. 2007, North *et al*. 2010, Stephens *et al.* 2010). We recommend use of spatially-explicit models to identify and map spotted owl habitat as well as classify habitat value and function. We also recommend that actions affecting owls or owl habitat be designed as adaptive management projects at various landscape scales where evaluation of the following issues can be addressed quantitatively:

- Spotted owl dispersal;
- Spotted owl use of burned areas (by habitat function, such as nesting, foraging, roosting) with and without post-fire harvest;
- Effects of thinning and fuel reduction treatments on spotted owls;
- Occupancy of owl sites pre- and post-fire; and
- Effects of fuel reduction on fire behavior.

Although formal scientific inquiry into the above listed topics may be the most rigorous way to answer specific questions, it is not the only means of implementing adaptive management and acquiring new knowledge. Methods as simple as formulating a specific question, monitoring the results of the action, and recording the information in a manner that is retrievable and useful to inform future decision making will contribute to our learning; this is especially valuable if methods are coordinated across multiple administrative units so that they are comparable. As knowledge is obtained, management goals and measures should be modified as appropriate.

Non-Federal lands - This revised Plan acknowledges the important role State, private and Tribal lands can play toward recovering the spotted owl. The relative importance of this role to spotted owl recovery should be quantitatively assessed as step three of the rangewide habitat modeling effort is carried out. As stated earlier, we recommend retaining all occupied sites and unoccupied, high quality spotted owl habitat on all lands to the greatest feasible extent, and we recognize that this goal will be especially difficult to meet on nonfederal lands. Management actions that may have short-term impacts but are beneficial to spotted owl occupied sites and unoccupied, high quality spotted owl habitat on all lands in the long-term meet the recovery intent of habitat conservation.

In 1994, in its biological opinion on the NWFP, the Service concluded that the NWFP met or exceeded the standards expected for the Federal contribution to recovery of the spotted owl. The Service also concluded in that opinion that overall recovery of the species would be further evaluated to determine recovery needs on non-Federal lands. Since 1994, Federal lands have provided the majority of contribution to spotted owl recovery, and in many portions of the range it provides the sole contribution. However, there are other portions of the range where habitat on Federal lands is lacking or of low quality or where there is little Federal ownership, and non-Federal lands may be able to improve recovery potential in key areas. The Recovery Habitat Modeling Effort (Appendix C) currently underway will inform the potential value and contribution these lands may provide.

During the past 20 years, the Service has worked cooperatively with non-Federal land owners to minimize adverse impacts to spotted owls and to encourage conservation of spotted owl habitat. We recommend these efforts be continued and expanded in certain portions of the range to retain and recruit owl habitat on non-Federal land in areas with a lack of proximal high quality habitat on Federal lands and where future distribution of owls would improve long term recovery potential. The revised Plan identifies several Recovery Actions meant to encourage non-Federal landowners to voluntarily work toward recovery. These actions include using non-Federal work groups to evaluate the relative merits of regulatory, voluntary, and financial incentives to promote approaches that are economically and scientifically viable and that will maximize the likelihood of implementation for spotted owl recovery.

Barred Owl Management

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 revised 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 primary elements of this strategy will provide information required to evaluate progress toward the Recovery Criteria.

The monitoring and research results can be considered within the 5-yr review process to continually evaluate new information and the priorities for additional research and study and can contribute to a comprehensive evaluation of the status of recovery implementation, status of threats and make course adjustments as needed.

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.

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.

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. Assessing the demographic response will help the Service determine whether 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 (Recovery Objective 3).

Inventory of spotted owl distribution. The recovery of the spotted is predicated on maintaining the current rangewide distribution of the species within each of the 12 provinces (see Recovery Unit discussion). 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 if all provinces have spotted owls

Explicit consideration for climate change mitigation goals consistent with spotted owl recovery actions. There is significant overlap between many of the spotted owl recovery goals described in this revised plan and opportunities to mitigate impacts due to climate change. The Service is applying Secretarial Order No. 3289: *Addressing the Impacts of Climate Change on America's Water, Land, and Other Natural and Cultural Resources* into our forest management activities. This Secretarial Order directs DOI agencies to analyze potential climate change impacts when undertaking long-range planning exercises, developing multi-year management plans, and making major decisions regarding potential use of resources under the Service's purview. This direction applies to this revision of the 2008 Recovery Plan.

The highest densities of forest biomass carbon storage in North America occur in the conifer forests of the Pacific Northwest (Sundquist *et al.* 2009, Keith *et al.* 2010). Older forests with longer rotations may be more effective at sequestering carbon than younger, more intensively managed tree plantations (Schulze et al. 2000, Luyssaert 2008), but all forest lands may have value for the purpose of carbon sequestration. Effectiveness in this goal may depend on very specific prescriptions and locales. Preliminary research funded by the Service indicates that forests in Oregon have tremendous potential for carbon sequestration on state forest lands in the Coast Range, and nearby lands likely have similar potential. Likewise, managing for carbon sequestration means it is also necessary to manage forest biomass and the risks of catastrophic fire (Canadell and Raupach 2008). As of this writing it is unclear what role, if any, federal and state forest lands will ultimately play in mitigating climate change, but some policy analysts have begun to frame this issue (see Depro *et al.* 2008).

Therefore, to be consistent with the Secretarial Order as well as other Service initiatives (*e.g.*, Landscape Conservation Cooperatives (LCCs)), we are recommending that researchers emphasize ecological and economic overlap between spotted owl recovery actions and climate change mitigation actions. For example, more research should be conducted on the relative compatibility or conflict between thinning a forest to reduce fire risk, its impact on long term spotted owl habitat quality, and the action's mitigation of climate change impacts. Although thinning activity removes carbon from the forest system in the short term, it may reduce the risk of a subsequent catastrophic carbon release through fire or disease outbreak, and it also encourages carbon being concentrated in fewer, larger trees that approximate old-growth structure of pre-fire suppression forests (Hurteau *et al.* 2008). The validity of such a concept is not in dispute among mainstream scientists but, as discussed elsewhere in this document, there is significant disagreement regarding where, when, and how to implement such management measures to optimize the potential for positive outcomes.

III. Recovery Units, Criteria and Actions

Recovery Units

Unlike previous versions of the Spotted Owl recovery plan, this revised Plan includes a proposal to identify individual recovery units. Recovery units are special subunits of a listed entity that are geographically or otherwise identifiable and have been documented as necessary to both the survival and recovery of the species in a final recovery plan. (USFWS and NMFS 1998, 2002; NMFS 2007). Recovery units are individually necessary to conserve genetic robustness, demographic robustness, important life history stages, or some other feature necessary for the long-term sustainability of the entire listed entity. Therefore, recovery criteria for the listed entity should address each identified recovery unit. Recovery units are often delineated to assist managers in re-establishing or maintaining: 1) historical or current genetic flow; 2) current and historical population and habitat distribution; and 3) meta-population dynamics. Recovery units are generally delineated on a biological basis, although minor adjustments may be made to reflect different management regimes or other management purposes.

While not every species benefits from the identification of individual recovery units, they are a useful tool for assessing the recovery status of a wide-ranging species with multiple populations and varying ecological pressures in different parts of their range. Recovery units differ from management units, which are subsets of recovery units that might require different management, be managed by different entities, or encompass different populations. Recovery units are also not synonymous with critical habitat units; one is a unit of the listed species, the other is a unit of the species' habitat.

In 1990, the Interagency Scientific Committee decided to subdivide the range of the spotted owl into "smaller areas for practical and analytical purposes" and used the physiographic provinces as a basis for their analysis (Thomas *et al*. 1990: 61). The physiographic provinces (also referred to as "provinces") incorporate physical, biological and environmental factors that shape broad-scale landscapes. The provinces reflect differences in geology (*e.g.*, uplift rates, and recent volcanism, tectonic disruption) and climate (*e.g.*, precipitation, temperature, and glaciation). In turn, these factors result in broad-scale differences in soil development, natural plant communities and ultimately, forest zones. Studies have demonstrated biological differences shown in the numbers, distribution and habitat use patterns of spotted owls relative to the different forest zones that occur within its range (Thomas *et al*. 1990). The Northern Spotted Owl Recovery Team (USFWS 1992*b*) divided the range of the spotted owl into 12 provinces based on differences in vegetation, soils, geologic history, climate, land ownership, and political boundaries.

Given the above definitions and background information, the physiographic provinces meet the criteria for use as recovery units (Figure A1). The provinces collectively cover the range of the species, and each is essential for the conservation of the spotted owl (Thomas *et al*. 1990). The provinces are based on physical, biological and environmental factors that affect spotted owl numbers, distribution, habitat use patterns and habitat conditions. These provinces have been scientifically accepted, have been in use since 1990, and are integrated into management regimes and administrative purposes. In addition, most of the physiographic provinces contain spotted owl long-term monitoring sites, which yield robust scientific information to assess population dynamics and trends within each area and provide a good basis for analysis at recovery unit and range-wide scales. Their long-standing monitoring information, biological basis and accepted use by managers should lead to an efficient transition to their adoption as recovery units. Using this rationale, we are proposing to adopt the physiographic province designations in place since 1990 as recovery units and are soliciting feedback on this approach.

Recovery Criteria

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. These include:

1. the present or threatened destruction, modification, or curtailment of its habitat or range
2. overutilization for commercial, recreational, scientific, or educational purposes
3. disease or predation
4. the inadequacy of existing regulatory mechanisms, and
5. other natural or manmade factors affecting its continued existence.

Recovery Criteria in this revised 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. Recovery Actions are the Service's recommendations to guide the activities needed to accomplish the Recovery Criteria.

The first Recovery Criterion assesses the spotted owl's population status. The Service believes this criterion is 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 population-related Recovery Criterion.

Generally, this section follows the order of the listing factors. However, the first Recovery Criteria, and its associated Recovery Action does 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. In this Draft Revised Plan, we have retained many of the original Recovery Actions from the 2008 plan, we have introduced some new Recovery Actions, and we have revised many from the 2008 Plan to reflect new information, updated status, or to refine our intent. After each Recovery Action number we have included the word "new" or "revised" for those that have been introduced here for the first time or that have changed from the 2008 Plan. We have not added any words to those Recovery Actions that have not changed.

NSO Recovery Implementation Team

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

- ***Recovery Action 1. Establish an inter-organizational spotted owl implementation team ("Northern Spotted Owl Recovery Implementation Team") to oversee the implementation of the Recovery Plan.***

This interagency and intergovernmental Northern Spotted Owl Recovery Implementation Team (Implementation Team) was established shortly after the 2008 Plan was issued. The Implementation Team oversees implementation of the Plan, oversees the activities of the various work groups and issues management guidance related to spotted owl Recovery Actions to the field. For a current list of Implementation Team members go to http://www.fws.gov/species/nso

Recovery Criteria Concerning Population Trend and Distribution

The spotted owl listing decision 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. This will be accomplished when Recovery Criteria 1 is met.

Recovery Criterion 1 - Stable Population Trend: The overall population trend of spotted owls throughout the range is stable or increasing over 10 years, as measured by a statistically reliable monitoring effort.

Recovery Criterion 2 – Adequate Population Distribution: Spotted owl subpopulations within each province (*i.e.*, recovery unit)(excluding the

Willamette Valley Province) achieve viability, as measured by the HexSim population model or some other appropriate quantitative measure.

Recovery Criterion 3 – Continued Maintenance and Recruitment of Spotted Owl Habitat: There is no net loss in nesting/roosting or foraging habitat throughout the range, as measured by effectiveness monitoring efforts or other reliable habitat monitoring programs.

Monitoring and Inventory

- ***Recovery Action 2: Continue annual monitoring of 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 method 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 could potentially fulfill this Recovery Action.
- ***Recovery Action 3: Conduct occupancy inventory or predictive modeling needed to determine if Recovery Criteria 1 and 2 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 Criterion 1. Modeling techniques have improved recently, so predictive modeling may be part of the methodology 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). Therefore, this revised Plan recommends two basic strategies to address these threats: (1) retain occupied sites and unoccupied high quality habitat to the greatest possible extent, and (2) encourage and initiate active management actions that restore, enhance, and promote development of suitable high quality habitat. 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. The revised Plan includes a Recovery Action to standardize province-specific habitat definition across the range.

Habitat Management in West-side Forests

On the west side of the Cascades, the 2008 Plan identified a network of habitat blocks managed for spotted owls (MOCAs) as a fundamental component of the recovery strategy. The AOU, SCB and TWS peer-reviews were critical of the MOCA network, in part because of a) a perception that the network reduced the total amount of land set aside for spotted owls compared to the reserve network under the Northwest Forest Plan, and b) the Service conducted no formal modeling to demonstrate the potential efficacy of the MOCA network. We have considered this peer review critique and have decided to recommend withdrawal of the MOCA network until we re-evaluate the MOCA strategy, as well as other land management strategies, as part of the habitat modeling effort. We are currently conducting a range-wide modeling process using some of the latest modeling approaches to identify and map spotted owl habitat value range-wide, identify habitat conservation network scenarios, and test the efficacy of numerous scenarios at conserving the spotted owl. Once this modeling process is complete, the Service will use these results to inform possible revision of designated spotted owl critical habitat. In the interim, we recommend that land managers continue to implement the standards and guidelines of the Northwest Forest Plan as well as other recommendations in this revised Plan.

A future habitat conservation network is likely to build on multiple previous analyses including the Interagency Scientific Committee (Thomas *et al.* 1990), the 1992 Northern Spotted Owl Draft Recovery Plan (USFWS 1992*b*), the Northwest Forest Plan (USDA and USDI 1994*a*, *b*), and the spotted owl population modeling we are currently conducting. Although we are not recommending a habitat network at this time, spotted owl movement across the landscape is an important component of the spotted owl meta-population to maintain gene flow and to provide juveniles future nesting opportunities away from their natal sites.

While there is uncertainty regarding the precise forest conditions required for spotted owl dispersal, dispersal habitat, at a minimum, consists of stands with adequate tree size and canopy closure to provide protection from avian predators and minimal foraging opportunities (USFWS 1992*b*). It is assumed dispersal success rates are higher through habitat that more closely resembles suitable habitat. While the stand-level and landscape-level attributes of forests needed to facilitate successful dispersal have not been thoroughly evaluated (Buchanan 2004), the ISC Report (Thomas *et al*. 1990) recommended managing the forested landscape such that 50 percent of each ¼ township has a mean diameter at breast height of 11 inches and a canopy closure of 40 percent (the 50-11-40 rule). Existing land allocations and congressional designations (*e.g.*, wilderness areas, wild and scenic rivers, etc.) contribute significantly to spotted owl dispersal in many areas, and may provide the bulk of what is needed for successful dispersal across broad landscapes. Barriers to spotted owl dispersal do exist and likely include large tracts of unforested lands, such as the Willamette, Rogue and Umpqua valleys and Hood Canal and Puget Sound

(Forsman *et al*. 2002). However, spotted owls are able to successfully move through highly fragmented landscapes, including around these valley barriers.

- ***Recovery Action 4 (revised): Use the habitat modeling process described above and in Appendix C to identify, and test the efficacy of numerous habitat conservation network scenarios at conserving spotted owl habitat. Use the results from this effort to inform decisions concerning both the possible development of a habitat conservation network and potential revisions to spotted owl critical habitat.***
- ***Recovery Action 5(new): In west-side forests managed for spotted owl habitat we recommend land managers implement silvicultural techniques in plantations, overstocked naturally regenerated stands and modified younger stands to accelerate the development of structural complexity and biological diversity that will benefit spotted owl recovery.***

This recommendation includes consideration of extending the maximum age for thinning of plantations in Federal LSRs beyond 80 years of age, as recommended by Johnson and Franklin (2009), if these plantations are not yet suitable owl habitat and treatment will accelerate the development of suitable owl habitat. We also recommend that overstocked naturally regenerated stands and modified younger stands be considered for treatment if it will benefit spotted owl recovery. Any LSR thinning in plantations greater than 80-years old, if appropriate, should occur where nesting and roosting habitat is needed within LSRs to bolster spotted owl populations and should be designed and implemented within the interagency structure of the level one teams.

LSR thinning in plantations older than 80 years of age should only occur in cases where there are both near- and long-term beneficial effects to spotted owls to be realized from enhancing within-stand structural diversity. The treatment should emphasize the retention of the oldest and largest trees in the stands or any trees with characteristics that create stand diversity (*e.g.*, bole and limb deformities) and should focus on structural diversity in the mid-to upper story layers, but not at the expense of large snags or existing species diversity. We recommend the use of fungal inoculation, mechanical methods, or other tools as needed to create snags. The Service is available to participate in local or regional efforts to provide guidance on these sorts of prescriptions.

The use of tailhold, toehold, and other guyline trees and construction of new and reconstruction of existing roads in LSR thinning projects, regardless of stand age, should avoid impacts to existing larger/older trees, snags, and down wood. Cases where facilitating a thinning operation necessitates felling existing remnant trees over 120 years old should be very rare.

Likewise, in areas with regeneration harvest in moist forest Matrix lands, design such harvest using ecological forestry principles that emphasize retention of larger and older trees, snags and down wood of varying size and decay classes, and live trees with decay and deformities. Applying these measures should promote spotted owl recovery by retaining important habitat features while also encouraging development of late-successional conditions as originally envisioned in the NWFP.

Habitat Management in Dry Forests

Peer reviews of the 2008 Plan raised two primary issues regarding our strategy for managing dry-forest ecosystems, particularly with respect to recommending a reserveless approach in the Eastern Washington Cascades, Eastern Oregon Cascades, and California Cascades Provinces (hereafter referred to collectively as the dry Cascades provinces) and the potential for the Klamath Provinces to also move to a reserveless strategy. First, peer reviewers contended that our assessment of fire risk in dry-forest ecosystems was overstated, based on faulty analysis, and did not incorporate recruitment of old forest stands due to in-growth. Second, they argued that the 2008 Plan erroneously described all fires as causing habitat loss in dry-forest ecosystems. Thus, the peer reviewers believed that the risk of spotted owl habitat loss to fire was not sufficient to move to a reserveless approach, nor to warrant the magnitude and intensity of silvicultural treatments proposed by the 2008 Plan to reduce fire risk and restore forest stands, particularly in light of stated cautions regarding effects of thinning on owls (SEI 2008) and the paucity of information on this topic.

The assessment of fire risk in the dry-forest provinces within the range of the spotted owl and its implications for spotted owl recovery has recently been argued in the scientific literature (Hanson *et al.* 2009, 2010; Spies *et al.* 2010). The debate centers primarily on how fire rotation (the time to burn an area equivalent in size to the landscape of interest) was determined in the 2008 plan, particularly the methodology and sampling timeframe used. Hanson *et al.* (2009) also raised concerns that the 2008 Plan did not consider data showing recruitment of old-forest habitat and compare this recruitment to loss of old-forest habitat to fire. They argued that the fire rotations are much longer in the eastern Cascades and Klamath Provinces (746 and 575 years, respectively) than what was described in the 2008 Plan (69 and 105 years, respectively). Finally, Hanson *et al.* (2009), after comparing fire rotations they derived with the amount of late-seral forest recruitment published by Moeur *et al.* (2005), concluded that recruitment of old forest was outpacing loss of old forest to fires by a factor of 5.5 to 14.2, depending on the province and the recruitment estimate used. They further concluded that, given the low risk of high-severity fire, there is time to conduct needed research on the spotted owl response to proposed management actions before adopting a reserveless system.

Much energy has been expended recently on the debate determining fire rotations, and interpreting the rotation value and its implications on spotted owl management and recovery. It must be stressed that fire regimes are a complex interaction of vegetation, topography and climate that is not adequately represented by a single metric. Furthermore, dry-forest landscapes are a complex interaction of physical and biological properties, with multiple disturbance regimes that interact with floral and faunal communities as well as with each other in ways we have yet to understand. The complexities in interpreting fire rotation, as well as the effects of fire on owls, are summarized as follows.

There are limitations in using measures of fire history to describe a fire regime. In the fire rotations developed by the 2008 Plan and by Hanson *et al.* (2009), only one and two decades of data were used, respectively. Using such short time frames limits the ability to capture the range of fires that may occur and results may be biased by rare events that may occur during the sampling period. Although SEI (2008) found the fire rotation derived in the 2008 Plan "troubling," they explicitly expressed caution in interpreting the losses of forest to high severity fire because it was based on only a decade of data. Further confounding interpretation of fire rotation is the past and ongoing efforts of fire suppression and exclusion. Any estimate of fire return that is derived from data over the most recent 50-60 years when fire suppression has been most aggressive will be artificially inflated.

A final limitation in using any fire metric to describe a fire regime is its inability to capture the spatial and temporal heterogeneity (Heinselman 1973, Lertzman *et al.* 1998) of fires on a landscape, further compounding ecological interpretation. The dry-forest provinces within the range of the spotted owl comprise a diversity of vegetation types ranging from dry ponderosa pine to moist mountain hemlock and western red-cedar, each with their own unique fire regime (*e.g.*, dry ponderosa pine vegetation types primarily exhibit low-severity fires, whereas moister vegetation types exhibit mainly moderate- to high-severity fires) (Agee 1993, Hessburg and Agee 2003). The fire rotations described for the dry-forest provinces in the 2008 Plan and by Hanson *et al.* (2009) are single numbers that hide inherent variability in the system. This variability is of key relevance when making management decisions with respect to restoring dry-forest landscapes and managing to accommodate their inherent disturbances.

With respect to the effects of fire on spotted owl habitat, research on all three spotted owl subspecies indicates variability in the degree to which owls use post-fire sites, depending on fire severity and the function of the site for the owl (*i.e.* nesting, roosting, or foraging). Although owls have been observed reproducing in burned landscapes and nesting in core areas in which some portion has been burned by high-severity fires (*i.e.*, those that typically result in 70 – 100 percent overstory mortality), no spotted owls nests have been observed on sites burned by high-severity fires (Gaines *et al.* 1997, Bond *et al.* 2002, Jenness *et al.* 2004, Clark 2007, Bond *et al.* 2009). However, nesting has occurred in low to moderate severity burn patches (Gaines *et al.* 1997, Clark 2007, Bond *et al.* 2009). It is not known whether there is a maximum amount of high severity fire within a nesting core that would preclude nesting of spotted owls, and there have been no long-term studies to determine how long owls may remain in a burned-over area.

While spotted owls have been observed roosting in forests experiencing the full range of fire severity, most roosting owls were associated with low or moderate severity burns and roost sites from which stand measurements were taken had high levels of canopy closure (*i.e.* greater than 60%) and a large tree component, regardless of burn severity (Clark 2007, Bond *et al.* 2009). Spotted owls have been observed foraging in all fire severity categories, and seemed especially attracted to edges where burned forest met unburned stands (Clark 2007, Bond *et al.* 2009). Clark (2007) found that owls did not use large patch areas of high-severity burns, while Bond *et al.* (2009) found owls selecting burned areas, including high-severity burns, when they were within 1.5 km of a nest or roost site. Bond *et al.* (2009) postulated that greater foraging in burned patches may be due to increased presence of prey, such as the dusky-footed woodrats, which are more likely to occur in open stands with increased shrub and herbaceous cover. It is unknown whether this hypothesis would prove true in that portion of the spotted owl range where principal prey species differ and are more tied to closed canopy forest (*e.g.* northern flying squirrel, bushy-tailed woodrats) (Lehmkuhl *et al.* 2006*a*, *b*).

There is tremendous complexity in the fire regimes of the dry-forest provinces, driven by the variability in the vegetation, climate, and topography that shape these regimes. How fires influence spotted owl habitat depends on fire severity and the specific function that the post-fire site might provide for spotted owls. While not all burned areas result in loss of spotted owl habitat and some fires, including high severity burns, may even enhance certain habitat functions for spotted owls in certain parts of the range (*e.g.,* foraging habitat), there is still no evidence that large-scale areas experiencing a high-severity fire will contribute to spotted owl recovery in the short term. The concern about loss of spotted owl habitat to fire in the 2008 Plan stemmed from the recent losses of spotted owl habitat and nesting sites (*e.g.,* loss of 17 of 23 owl pairs on the Sisters Ranger District after significant canopy reductions from a combination of an outbreak of spruce budworm and fire). This concern also stems from the influence of past management practices (see Hessburg and Agee (2003) for summary), including fire exclusion and the removal of large trees and fire-dominated trees; such practices have resulted in direct habitat loss, as well as altered vegetation structure and composition which affects the activity of fires that do occur. Much of this activity has homogenized the landscape creating larger, contiguous blocks of either fuels for fire or host species for insects and pathogens. This increased homogeneity further increases the size and severity of disturbance events, reinforcing a fire's ability to burn large patches and continuing to simplify the landscape (Hessburg *et al.* 2005, 2007). The size of any single fire event may not be outside the range of events that have occurred historically (Walstad *et al.* 1990), and spotted owls may have evolved with these large-scale events. However, the combination of past management and its effects on ecosystem resiliency to these disturbances, decreased owl population and increased ecological pressures on them through habitat loss and barred owl competition, and impending habitat changes caused by climate change likely reduces owl resiliency to these habitat changes.

In addition to these concerns, we know that the frequency of large fires (>400 ha) has increased throughout the western U.S. over the past several decades. In some areas, fire severities may have increased as well (Westerling *et al.* 2006, Miller *et al.* 2009). This increase in large fire frequency is expected to continue with climate change (Westerling *et al.* 2006). Finally, recruitment rates of old-forest habitat established in Moeur *et al.* (2005) have been reanalyzed in light of new data and analysis methods (final report due out late 2010). New information indicates that while late-successional and old-growth forest recruitment is occurring at rates projected initially in the NWFP, that recruitment is being surpassed by late-successional and old-growth loss. Eighty five percent of the loss was due to wildfires, particularly in the dry-forest provinces (Moeur 2010).

Given the complexity of the disturbance regimes, response of owls to these regimes, and the projected influence that climate change will play on these regimes, this revised Plan recognizes that active management of fuels in overstocked stands within the dry-forest landscape may be needed to meet spotted owl conservation objectives. Restoration of forest ecosystems that are resilient to the endemic disturbance regimes and adaptive to impending climate change is a primary goal of any dry-forest recovery strategy and needs to include some form of active management to achieve that objective. Such a strategy could have short-term impacts on spotted owl habitat in order to achieve the long-term landscape strategy goal of creating a more sustainable, resilient landscape. More research is needed to understand if the costs of such short-term impacts are outweighed by the long-term gains. For example, more research is needed to determine the effects of forest thinning activities on spotted owls. Our knowledge is far from complete, and management to restore these systems will be challenging. These challenges need to be addressed through a well-defined adaptive management approach that reduces biological risk to the spotted owl. To address these challenges, the 2008 Plan called for establishing an interagency, science-based Dry-Forest Landscape Work Group (DFLWG) to assist the Service in designing a strategy for managing the Klamath Provinces and the dry Cascades provinces. The Service established two such work groups, one for the Klamath Provinces and one for the dry Cascades provinces, both of which are in the process of helping identify landscape-scale approaches to managing these areas that are based on the restoration of ecosystem processes. The Service will consider the input and feedback from these groups to our approach in these unique, dry-forest landscapes, including whether reserves would be an effective way to meet our goals in these areas.

- ***Recovery Action 6: 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.***
  As a result of this Recovery Action (RA9 in the 2008 Plan) the Service created a Dry-Forest Landscape Work Group to help the Service assess the feasibility and effectiveness of an integrated and comprehensive landscape management program for the Eastern Washington Cascades, Eastern Oregon Cascades, and California Cascades Provinces, and a Klamath Province Work Group (KPWG)to provide assistance to the Service in determining the most effective approach to managing the Oregon and California Klamath Provinces. Both these work groups

report to and coordinate with the Northern Spotted Owl Recovery Implementation Team (see Recovery Action 1). The DFLWG has met over the past year in an effort to evaluate landscape approaches to managing Federal forests in the eastern and California Cascades so as to create an ecologically sustainable environment in which spotted owls can recover. The DFLWG members represent a broad array of expertise in different technical fields from different geographical areas. Researchers and practitioners comprise the work group, and members bring forward different interpretations of the research in dry-forest systems. The Service is using this diverse array of expertise to find areas of agreement upon which a strategy for the dry Cascades provinces can be developed.

Currently, the DFLWG has established that key areas of agreement for a final strategy should include: 1) a landscape approach that not only addresses managing existing spotted owl habitat, but developing future habitat in areas capable of supporting such habitat; 2) monitoring and target thresholds that can be used to track changes in habitat and to revise management as necessary for adapting to dynamic processes, changing ecosystem conditions or new information; 3) an adaptive management framework for addressing key information gaps on which to inform future management; and 4) a systematic risk assessment of the completed strategy to determine whether and what type of risk reduction activities may be appropriate in particular areas or under particular conditions. The DFLWG will continue to assist the Service in developing such a strategy. The ongoing modeling effort conducted by the Service will be used to inform this strategy, which may be modified depending on the results of the vegetation-fire-owls study (Kennedy *et al.* unpublished) scheduled for completion in December 2011. Completion of this project should help managers reconcile conservation of spotted owl habitat with fire risk reduction at stand and landscape scales in dry, fire-prone forests.

- ***Recovery Action 7 (new): In Eastern Washington, Eastern Oregon and California Cascades Provinces, analyze existing data on spotted owl occupancy pre- and post-fire and establish a consistent database to track owl occupancy response to fires across the dry Cascades provinces.*** Data currently exist that may aid our understanding of spotted owl occupancy of sites after a fire. Most National Forest units in these provinces annually monitor known spotted owl sites for occupancy, and they have accumulated occupancy data sets in burned and unburned areas. Members of the DFLWG have begun compiling and analyzing existing data on occupancy rates of spotted owls in burned and unburned sites, as well as fire extent and severity in the burned sites, to determine how fire influences occupancy rates of spotted owls. Existing data on pre- and post-fire vegetation structure is also being analyzed to determine possible connections between pre-fire estimates of fuel loads, fire severity, and subsequent owl occupancy to inform risk analysis efforts. These data should be entered into a database to track future data on owl occupancy and fires. Data collection standards should be established to aid comparison of data among the provinces to aid in comparison across the provinces. This synthesis and analysis will inform land managers about how fuel loads in and adjacent to owl habitats can be managed, thereby sustaining owl habitat across the fire-prone dry Cascades provinces.

- ***Recovery Action 8 (new): For the Eastern Washington, Eastern Oregon and California Cascades Provinces, develop an Integrated Research Needs and Adaptive Management Strategy that prioritizes key management questions to address uncertainties of managing dry-forest system.***
  For research and adaptive management studies that may affect spotted owls or their habitat, this strategy will include an analysis of risk in doing studies that may affect owls but address a key management question. There are many complexities and unknowns in managing spotted owls in dry-forest landscapes. Resources needed to answer key management questions are limited. Some questions, such as effects of certain thinning treatments on spotted owl habitat, may pose short-term risks to owls that may or may not outweigh the benefit of the expected information to be gained from the study. FWS should work with management agencies to identify and prioritize key management questions and uncertainties that could be addressed by research or adaptive management studies. Upon completion of this list, FWS can work with the research community, through the DFLWG, to assess methodologies and resources needed to answer the key management questions and determine short-term risks to spotted owls. Such a strategy will help strategize how to efficiently use limited resources to inform spotted owl management and recovery.

This revised Plan also recognizes the unique importance of the Klamath Provinces in Oregon and California to the recovery of the spotted owl. The effective management of these provinces is essential to the long-term survival of the species. (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."

- ***Recovery Action 9 (new): Create an interagency Klamath Province Work Group to coordinate an integrated and comprehensive management framework for the Oregon and California Klamath physiographic provinces which includes a monitoring and an adaptive management program.***
  The Klamath Province Work Group (KPWG) was formed as a result of Recovery Action 8 in the 2008 Plan, and has been operating since 2008. During the course of several meetings and workshops in 2008 and 2009, the KPWG established a multi-step approach for evaluation of potential alternative conservation strategies for spotted owls in the Klamath Province, a combined view of the Oregon and California Klamath Provinces. The primary steps included; 1) Conduct a thorough review of the literature, spotted owl data sets, and spatial information and synthesize into a report describing spotted owl habitat in the Klamath Province, and the role of fire in developing, maintaining, modifying, and removing spotted owl habitat at multiple scales; 2) use spatially-explicit predictive models, developed and validated using current spotted owl location data from the Klamath Province, to identify areas of high-value spotted owl habitat based on forest composition and structure, climate variables, and topographic features; and 3) integrate spotted owl habitat models with models of fire occurrence and severity patterns to identify and prioritize areas for habitat protection, habitat restoration, and fuels treatment. Presently, the spotted owl habitat relationships report is nearing completion, and the development of spotted owl habitat models and fire models is underway.

Additional Habitat Actions for All Areas

Conserving occupied spotted owl habitat

The three main threats to the spotted owl are competition from barred owls, past habitat loss, and current habitat loss (2008 Recovery Plan). Recent research has suggested that fire is also affecting significant amounts of spotted owl habitat. The most recent demographic analysis (Forsman *et al*. in press) indicates the species is declining on seven of the eleven active demographic study areas at about 3 percent annually range-wide, and peer reviewers recommended that we address this downward demographic trend by protecting known spotted owl sites in addition to the retention of structurally complex forest habitat.

In the 2008 Plan, the Service made a general recommendation (Recovery Action 32) that high-quality habitat be maintained, including on non-Federal lands. This recommendation was primarily driven by the concern associated with the displacement of spotted owls by barred owls, and the need to retain high quality habitat as refugia for these displaced spotted owls.

In this draft Revised Plan, we reiterate Recovery Action 32 and provide additional specificity. The 2008 Plan emphasized applying a landscape and habitat-based approach to spotted owl conservation, instead of focusing on occupied habitat to accomplish this goal. One reason for this position was that a singular focus on occupied habitat could have negative consequences, such as requiring expensive long term surveys that may be subject to erroneous determinations of spotted owl absence due to depressed calling rates. Thus, high quality habitat could be lost due to errors in owl occupancy determinations.

The Service still supports this habitat-based approach for spotted owl habitat conservation. However, we also believe that retention of all occupied spotted owl sites to the greatest possible extent, especially those containing the habitat conditions to support successful reproduction, is important for recovery. This recommendation is especially crucial in the near term until spotted owl population trends improve.

Therefore, we conclude that conservation of important spotted owl habitat depends on application of a two-tiered approach to forest land management decisions as follows:

1. Retain known spotted owl sites to the greatest possible extent (see Recovery Action 10, below).
    a. This recommendation includes currently occupied as well as historically occupied sites.
    b. Work with land managers and spotted owl field scientists to develop prescriptions and approaches to implement this recommendation. At a minimum, this prescription should retain sufficient suitable habitat within the provincial core use area and within the provincial home range to support breeding, feeding and sheltering.
2. Maintain substantially all of the older and more structurally complex multilayered conifer forests on all lands to the grewatest possible extent (see Recovery Action 32).

> It is clear that these two recommendations overlap. It is our hope that their application on Federal and non-Federal lands will more effectively address the threats competition with and displacement by barred owls, as well as the impacts of past and current habitat loss.

This recommendation can be justified at several scales. At the scale of a territory, several studies have shown a positive association between spotted owl fitness and spotted owl habitat or a mosaic of habitat types (Franklin *et al*. 2000, Dugger *et al.* 2005, Olson *et al*. 2004). At the population scale, Forsman *et al*. (in press) found a positive relationship between recruitment of spotted owls into the overall population and the percent cover of spotted owl habitat within study areas. This multi-scale research suggests retention of spotted owl habitat within occupied spotted owl territories positively affects spotted owl demographic rates. Because spotted owls on established territories are likely to be more successful if they remain in those locations (Franklin *et al*. 2000), managing to retain spotted owls at existing sites should be the most effective approach to bolstering the demographic contribution of a habitat conservation network. Retention of long-term occupancy and reproduction at established spotted owl sites will require a coordinated and cooperative effort to craft management approaches tailored to regional, provincial or local conditions.

- ***Recovery Action 10 (new): Manage habitat-capable lands within occupied spotted owl sites across all ownerships to retain extant spotted owl pairs and resident singles.*** While there may be many approaches to meeting this recommendation, we believe that within the provincial core use area (*e.g.* about 500 acres around the nest site in the southern portion of the range (Zabel *et al.* 2003)) and within the provincial home range land managers should retain and, where necessary, improve a sufficient quality and quantity of suitable spotted owl habitat to support all life history functions.

Due to the tremendous variability in ecological conditions and land ownership patterns across the spotted owl's range, determining how to most effectively implement this Recovery Action will require a cooperative effort between the Service, land managers, and spotted owl researchers. It may be best approached at the Level 1 team, provincial team, State or Regional team, or range-wide team scale (*e.g.* a new Spotted owl Habitat work group). These teams will need to consider appropriate activities within spotted owl homeranges, what constitutes a site to be retained, what it means to "improve" habitat quality within varying provinces or regions, etc.

As a general rule, management activities in occupied habitat that tend to diminish that habitat's capability to support spotted owl occupancy, survival and productivity should be discouraged, and those activities that retain or improve the quality of the habitat in the long term should be encouraged. Some timber management may be necessary to maintain or improve long-term habitat conditions; these activities may have short-term adverse impacts on spotted owls but should be encouraged if their intent is to maintain or improve long term suitability or restore more natural ecological conditions. Likewise, some activities may have little or no adverse long-term impact to the site's ability to support spotted owl productivity. Given natural events such as fire, wind storms, and insect damage, not all habitat-capable lands in an occupied home range are likely to contain suitable habitat at any one time. In the drier and southern portions of the range, managing for dense older forest mixed with some younger or more structurally diverse stands may also be appropriate (Franklin *et al*. 2000, Olsen *et al*. 2004, but see Dugger *et al*. 2005). The Service recognizes there is tremendous variation across the species' range in such habitat conditions, and therefore, we expect to work closely with the BLM, FS and other land managers to define how to best meet the intent of this recommendation.

It is not uncommon for an occupied spotted owl site to be unoccupied in subsequent years, only to be re-occupied by the same or different spotted owls two, three or even more years later (Dugger *et al.* 2009). While temporarily unoccupied, these sites provide conservation value to the species by providing viable locations for future pairs or territorial singles absent changes to the habitat. While Dugger *et al.* (2009) provide evidence of spotted owl re-occupancy of historic sites over ten years after the last spotted owl detection, the demographic contribution of a site and the likelihood of re-occupancy diminishes with each passing year the site is unoccupied. The Service recently revised its spotted owl survey protocol based on much of this same information (available at www.fws.gov/species/nso) and with the assistance of inter-agency and inter-organizational spotted owl and barred owl experts. Similarly, the Service will seek input from other experts to help determine when the contribution of an unoccupied spotted owl site to spotted owl conservation is sufficiently small that the site can be considered abandoned.

Decisions to harvest timber after wildfires often are based on financial considerations, human safety, a desire to modify the composition and resource-production of forests, and a desire to "clean up the forest" (Foster and Orwig 2006, Noss and Lindenmayer 2006, Lindenmayer *et al*. 2008). Possible beneficial ecological effects of post-fire timber harvest include: decreased erosion due to placement of debris on the forest floor which intercepts surface water flow; decreased buildup of insect pests due to dead tree removal; decreased magnitude and extent of lethal soil temperatures around burning coarse woody debris; and, in stands where harvest-generated slash is treated, decreased fire risk due to removal of snags (McIver and Starr 2000, Lindenmayer *et al*. 2008, Monsanto and Agee 2008, Peterson *et al*. 2009). However, there is no support for the contention that reduction of fuels from post-fire harvest reduces the intensity of subsequent fires (McIver and Starr 2000). In fact, forests in southwest Oregon that were logged and planted after a 1987 fire burned more severely in a 2002 fire than areas that were not logged or planted due, evidently, to high fuel conditions in conifer plantations (Thompson *et al*. 2007).

Detrimental ecological effects of post-fire timber harvest include: increased erosion and sedimentation, especially due to construction of new roads; damage to soils and nutrient-cycling processes due to compaction and displacement of soils; reduction in soil-nutrient levels; removal of snags and, in many cases, live trees (both of which are habitat for spotted owls and their prey); decreased regeneration of trees; increased spread of weeds from vehicles; reduction in hiding cover and downed woody material used by spotted owl prey; altered composition of plant species; increased short-term fire risk when harvest-generated slash is not treated and medium-term fire risk due to creation of conifer plantations; reduction in shading; increase in soil and stream temperatures; and alterations of patterns of landscape heterogeneity (Perry *et al*. 1989, McIver and Starr 2000, Beschta *et al*. 2004, Karr *et al*. 2004, Donato *et al*. 2006, Lindenmeyer and Noss 2006, Reeves *et al*. 2006, Russell *et al*. 2006, Thompson *et al*. 2007, Lindenmayer *et al*. 2008, Johnson and Franklin 2009, Peterson *et al*. 2009). Soil damage and erosion are higher with traditional harvesting systems (*e.g.*, tractors) than they are with advanced systems (*e.g.*, helicopters) (Klock 1975, Peterson *et al*. 2009). After the 1988 Yellowstone fire, rates of soil loss were greatest where litter cover was minimal, percent silt content was high, and post-fire logging had been conducted (Marston and Haire 1990 in McIver and Starr 2000). Moreover, post-fire timber harvest activities "undermine many of the ecosystem benefits of major disturbances" (Lindenmayer *et al*. 2004:1303) and frequently "ignore important ecological lessons, especially the role of disturbances in diversifying and rejuvenating landscapes" (DellaSala *et al*. 2006:51). To avoid crisis-mode decision-making and minimize these detrimental effects, ecologically informed policies based on pre-fire management direction should be developed before fires take place (Lindenmayer *et al*. 2008, Johnson and Franklin 2009). Clark (2007) found that radio-tagged spotted owls in southwestern Oregon generally avoided areas that had been clear cut post-fire, and specific use of such areas by spotted owls was restricted to stands that retained live trees (*e.g.*, riparian areas, wildlife trees).

- ***Recovery Action 11 (revised RA10): In all areas of Federal and non-Federal lands where pre-fire management is focused towards the development of spotted owl habitat, post-fire silvicultural modifications should concentrate on spotted owl habitat restoration and conserving spotted owl habitat elements that take the most time to develop or recover (e.g., large trees, snags, downed wood).***

Post-fire management in these areas should promote the development of habitat elements that support spotted owls and their prey, especially those which require the most time to develop or recover (*e.g.*, large trees, snags, downed wood). There may be cases when the best approach to retain these features involves few management activities. Areas impacted by medium and low-severity fires often still function as spotted owl habitat and should be managed as such. The costs and benefits of post-fire harvest to the development of habitat for spotted owls and their prey should be evaluated by interagency teams (*e.g.*, level one teams) during the consultation process in these areas.

- ***Recovery Action 12 (revised RA 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, and the effects of various thinning prescriptions on spotted owls.***

Such forest management experiments should be given high-priority in non-reserved Federal lands (*i.e.*, "matrix" in NWFP), Adaptive Management Areas, and non-Federal lands in areas not having important conservation functions for spotted owls.

- ***Recovery Action 13: 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/roosting, 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, and may also incorporate spatial and abiotic features that help determine where spotted owls use these types of stands. As part of our habitat block network modeling process (Appendix C) we solicited information from spotted owl experts on the regional biotic and abiotic factors that dictated where on the landscape spotted owls nested and roosted, and on regional definitions of spotted owl foraging habitat. These data will provide a good starting point for this effort.

Non-Federal Lands

In 1994, in its biological opinion on the NWFP, the Service concluded that the NWFP met or exceeded the standards expected for the Federal contribution to recovery of the spotted owl. The Service also concluded in that opinion that overall recovery of the species would be further evaluated to determine recovery needs on non-Federal lands. Since 1994, Federal lands have provided the majority of contribution to spotted owl recovery, and in many portions of the range it provides the sole contribution. However, there are other portions of the range where habitat on Federal lands is lacking or of low quality or where there is little Federal ownership,, and non-Federal lands may be able to improve recovery potential in key areas.

Given the continued decline of the species, the apparent increase in severity of the threat from barred owls, and information indicating a recent loss of genetic diversity for the species, we recommend retaining all occupied sites and unoccupied, high quality spotted owl habitat on non-Federal lands wherever possible. Management actions that may have short-term impacts but are beneficial to spotted owl occupied sites and unoccupied, high quality spotted owl habitat on all lands in the long-term meet the recovery intent of habitat conservation. This recommendation is primarily driven by the concern associated with displacement of spotted owls by barred owls, and the need to retain good quality habitat to allow for displaced or recruited spotted owls to reoccupy such habitat. Because spotted owls on established territories are likely to be more successful if they remain in those locations (Franklin *et al*. 2000), managing to retain spotted owls at existing sites should be the most effective approach to bolstering the demographic contribution of a habitat conservation network. Retention of long-term occupancy and reproduction at established spotted owl sites will require a coordinated and cooperative effort to craft management approaches tailored to regional, provincial or local conditions. (Please see the **Conserving Spotted Owl Occupied Sites** section for more discussion.)

This revised Plan acknowledges the important role State, private and Tribal lands can play toward implementing a coordinated and cooperative effort to recover the spotted owl. The relative importance of this role to spotted owl recovery can be addressed in a variety of ways. Using the results of the rangewide habitat modeling will help identify areas where non-Federal lands can make the best contribution to recovery, and the Service will continue to work with non-Federal landowners to utilize a variety of voluntary incentives and approaches that will help contribute to spotted owl recovery through protection and development of unoccupied, high-quality habitat.

During the past 20 years, the Service has worked cooperatively with non-Federal land owners to minimize adverse impacts to spotted owls and to encourage conservation of spotted owl habitat. The Service has worked with a number of different applicants to implement habitat conservation plans and safe harbor agreements that minimize and mitigate impacts or provide for a net conservation benefit. Lands covered under these ESA Section 10 efforts provide for the conservation of key habitat areas and occupied sites. We recommend these efforts be continued and expanded in certain portions of the range to retain and recruit owl habitat on non-Federal land in areas with a lack of proximal high quality habitat on Federal lands and where future distribution of owls would improve long term recovery potential.

The revised Plan also seeks to identify several Recovery Actions meant to encourage non-Federal landowners to voluntarily work toward recovery through economic incentives. There are a number of established and emerging incentive-based options that currently exist for non-Federal landowners, including conservation banking and carbon sequestration that could provide valuable spotted owl habitat maintenance or restoration. Spotted owls could receive either directed or indirect benefits from ecosystem services market incentives.

In addition, current Federal programs could be expanded. For example, the endangered species tax deduction is included in the section of the Internal Revenue Service (IRS) code (26 USC Sec. 175) that currently allows taxpayers engaged in the business of farming a tax deduction for expenditures incurred for the purpose of soil and water conservation and for implementing certain recovery actions identified in approved recovery plans. For purposes of this current definition, forestry and timber production are not considered to be farming. However, this definition could be expanded in the future to better embrace the Healthy Forest Reserve Program implemented under the Farm Bill by the Natural Resource Conservation Service.

Since many of these are new fields, the Service will call for a non-Federal recovery work group to help develop, assess and implement various economic incentives and emerging market options to facilitate non-Federal landowners' involvement in spotted owl conservation. By using non-Federal work groups to evaluate the relative merits of regulatory, voluntary, and financial incentives to promote approaches that are economically and scientifically viable, we will maximize the likelihood of implementation for spotted owl recovery.

- ***Recovery Action: 14: 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. SHAs provide a net conservation benefit to the species, while allowing the landowner to return to baseline habitat conditions after a pre-defined period of time. The net conservation benefits are often direct contributions to recovery, even if of a limited temporal nature. On July 27, 2010, the Service finalized a SHA for small woodlot owners in Oregon that will enroll up to 50,000 acres of non-Federal lands within the state over a total of 50 years. The primary goal of this SHA is to increase the time between harvests (defer harvest), and to lightly to moderately thin younger forest stands that are currently not habitat to increase tree diameter size and stand diversity (species, canopy layers, presence of snags).

- ***Recovery Action 15 (new): As appropriate and within the boundaries of our authority, the Service encourages the establishment of a work group to develop a comprehensive set of business and economic incentives that facilitate 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. Incentives should be identified and developed as a means to reward landowners and land managers for implementing "ecological forestry" practices (Franklin *et al.* 2007) designed to recruit and retain higher quality spotted owl habitat. Such incentives may include extending tax credits for recovery –related activities that are carried out under the Farm Bill to timber production, development of State or

Federal subsidies for lands that meet carbon sequestration and habitat development goals, or conservation banks that facilitate mitigation for actions that impact the spotted owl. Many of the emerging ecosystem services incentives could allow landowners to receive financial compensation for providing co-benefits that include growing higher-quality spotted owl habitat. 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. Aspects of this Recovery Action may also be implemented more efficiently at the individual state levels as described below.

Table 2 - Summary of the forestry rules that provide northern spotted owl protections for California, Oregon and Washington

State	NSO Surveys Required	Habitat Requirements				Noise Disturbance Restrictions			NSO Forest Rules last updated	Exceptions
			Size-Location	Habitat	Duration	Zone size	Duration	Restricted Disturbance Includes		
California[1]	Yes	Coastal-Redwood	Within 0.5 – 1.3 miles of center	100-acre no cut, 100 acres of Nest-Roost[2] within 0.7-mile, 300 acres of Foraging[3] within 0.7- mile	All Year	0.25 mile	Breeding Season[4]	All timber harvest operations except planting and surveying	2008 – minor modifications to include FWS California "No Take Guidelines"	CFPRs allow for deviations with FWS review and other sec. 7 and 10
		Interior		72-acre no cut, 250 acres of Nest-Roost and 150 acres of Foraging within 0.5 miles						
				250 acres of Nest-Roost and 1235 acres of Foraging within 1.3 miles						
Oregon	No	All	Nest Site[5] is within 500' of timber operations	70-acre no cut Core around nest with the outer edge of the Core no less than 300' distance from the nest	Life of circle	0.25 mile	Critical Period[6]	Timber operations except log hauling, reforestation, road maintenance, research and monitoring, ground application of chemicals, aerial applications that do not require multiple passes, and burning	2006	
Washington	Yes	SOSEAs ~ 1.5 million acres private/state	Within 0.7-mile of activity center	retain all Suitable[7]	Life of circle	0.25 mile	Nesting Season[7]	Felling and bucking, yarding, slash disposal, prescribed burning, road construction, and other such activities (operation of heavy equipment and blasting)	1996	For plans ≤500 acres and >0.7 mile of known site and sec. 7, 10 and State planning
			Within home range of 1.8-2.7	retain 40% of Suitable[7]						
	No	Non-SOSEA	70 acres around known nest site	retain High quality	Nesting Season[8] Only					

1) California Forest Practice Rules (CFPRs) *per se* do not, but they rely on the Service's Guidelines as presented here.
2) Nest-Roost habitat in California is generally defined as 60-90% canopy closure, multi-layered/species canopy with trees >30" diameter, trees with deformities, woody debris on ground and open space below canopy to allow owls to fly.

3) Foraging Habitat in California is generally defined as a range of habitat types with older, denser, complex forest, may include Nest-Roost habitat at one end and younger more open habitats as defined in detail in the Service's CFPRs "No Take Guidelines."
4) Breeding Season for Coastal California is defined as February 1-July 30, Interior as February 1-August 31.
5) Nest Site requires a pair of owls.
6) Oregon defined the Critical Period as March 30 to September 30.
7) Suitable habitat in Washington are forest stands which meet the description of old forest habitat, sub-mature habitat, or young forest marginal habitat. Old forest habitat is the highest quality, followed in descending order by sub-mature habitat and young forest marginal habitat.
8) Nesting Season in Washington is defined as March 1 to August 31.

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), avian flu, or avian malaria (Ishak *et al.* 2008) will significantly affect spotted owls. Carrying out the following monitoring action would alert us if any disease becomes a threat.

- ***Recovery Action 16: Monitor for sudden oak death and avian diseases (e.g., WNV, avian flu, Plasmodium spp.) 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. Although there were regulatory mechanisms in place at the time, they offered variable levels of protection to spotted owls and, to a lesser extent, spotted owl habitat. Since 1994, the NWFP has been implemented on Federal lands throughout the range of the spotted owl. On Federal lands, the Service continues to support the implementation of the Northwest Forest Plan and its associated Standards and Guidelines, as well as the implementation of the Recovery Actions in the draft revised Plan. In light of the NWFP, this section will focus primarily on the State regulations that cover the approximately 21 million acres of private and State owned forest lands in Washington, Oregon and California.

State and private lands are regulated under various State authorities and timber harvest within each State is governed by rules that provide varying degrees of protection of spotted owls or their habitat. In Washington, logging practices on State, State trust, and private lands are regulated by the State Department of Natural Resources. In Oregon, the State Forest Practices Act regulates State and private lands. In California, timber harvest management plans are reviewed by the California Department Forestry. (See below for a more comprehensive treatment of each State.)

Since the listing of the spotted owl, there have been some regulatory changes that have reduced the rate of habitat decline on State and private lands. However, in light of the continued decline of the species, the apparent increase in severity of the threat from barred owls, and information indicating a recent loss of genetic diversity for the species, this revised Plan identifies a potentially more important recovery role for State, private and Tribal lands. The Service recommends retaining all occupied sites and unoccupied, high quality spotted owl habitat on non-Federal lands wherever feasible. Management actions that may have short-term impacts but are beneficial to spotted owl occupied sites and unoccupied, high quality spotted owl habitat in the long-term meet the recovery intent of habitat conservation. (See **Conserving Occupied Spotted Owl Habitat** and **Non-Federal Lands** under **Factor A: Habitat Loss** for a more comprehensive discussion.) As a result, the Service suggests States evaluate existing regulations affecting spotted owls and make changes where necessary and appropriate to meet recovery goals. We acknowledge the potential economic impacts such changes might have in certain parts of the spotted owl range, and we make several recommendations below to address these concerns.

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).

- ***Recovery Action 17 (new): In light of the declining spotted owl population in Washington, the Washington State Forest Practices Board should evaluate the recovery contribution from spotted owl sites on all private lands and design specific protections for those site centers, including sites where protocol surveys have not indicated occupancy by spotted owls for more than 3 years.***

Oregon. The Oregon Forest Practices Act provides for protection of 70-acre core areas around recently surveyed sites occupied by an adult pair of spotted owls capable of breeding (as determined by protocol surveys), but it does not provide for protection of resident single sites, nor of spotted owl habitat beyond these areas (ODF 2006). The Forest Practices Act does not require spotted owl surveys to identify potential nesting pair or resident single sites. The interim protection goals for spotted owl nesting sites initially adopted under Forest Practices Act at the time of listing have yet to be finalized. There is a process under the Forest Practices Act (*see* Oregon Administrative Rule 629-680) to update resource (*i.e.,* spotted owl) site protection measures. Every two years the Oregon Department of Forestry is to report to the Board of Forestry any recommended changes to the resource site protection rules and identify any research needed to further evaluate the protection levels. This on-going review has not been used to finalize the spotted owl resource site protection rules or to monitor their impact on spotted owls. Furthermore, due to issues related to confidentiality the Department of Forestry has been reluctant to share harvest locations within proximity of known spotted owl sites with Federal agencies interested in addressing potential harvest impacts.

- ***Recovery Action 18: The Service will request the cooperation of ODF in a scientific evaluation of (1) the potential role of non-Federal lands in Oregon to contribute to spotted owl recovery, and (2) the effectiveness of current Oregon Forest Practices in conserving spotted owl habitat and meeting the recovery goals identified in this draft revised Plan.***

Such an analysis is beyond the scope of this draft revised Plan and should be initiated as a cooperative effort between the Service and ODF. Among the issues this evaluation should address are the adequacy of the 70-acre core approach for spotted owl pair nest sites in contributing to recovery needs, an assessment of long-term residency and productivity of spotted owls in these territories, the potential implications the habitat modeling effort (Appendix C) to identify areas of high current or potential recovery value on non-Federal lands, and the potential application of these results to future land management decisions (*e.g,* critical habitat revisions, HCPs, etc.).

- ***Recovery Action 19: Based on the scientific evaluation described in the preceeding Recovery Action, the Service will work with ODF and other interested stakeholders to provide specific recommendations of how best to address spotted owl conservation needs on Oregon's non-Federal lands.***

Similar to the Washington Forest Practices Board's Northern Spotted Owl Policy Working Group, this group should identify voluntary and regulatory incentives that may improve spotted owl conservation on non-Federal lands, as well as areas where economic and other goals may be achieved while also benefiting spotted owls. The 2008 Plan recommended establishing Non-Federal Landowner Recovery Work Groups for each state, each of which operated with different goals and direction. The Washington group provides a strong model for critically examining the contribution of State forestry regulations to spotted owl recovery.

This Oregon group should focus on the identification of opportunities to address spotted owl recovery needs on non-Federal lands and an assessment of the various economic and social trade-offs necessary to meet this goal. Some specific issues this Oregon group should address are:

- potential recommendations to revise Forest Practice regulations, if appropriate and necessary;
- identification of specific opportunities to apply complimentary management goals that meet multiple economic, social, and ecological objectives compatible with spotted owl recovery, such as carbon sequestration, fuels treatment, silviculture, water quality, and recreation; and

- identification of incentives to non-Federal land managers that may encourage implementation of recovery actions on these lands, such as tax incentives, expansion of Farm Bill-type subsidies, and application of safe harbor provisions specific to Oregon (see RA 15).

California. State Forest Practice Rules, which govern timber harvest on private lands, were amended in 1990 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 Habitat Conservation Plan (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. In 2008, the Service provided additional technical guidance to the California Department of Forestry and Fire (CalFire) which are intended to add CalFire's review and approval of timber harvest plans.

Currently, the State of California considers it a crime to "take, possess, or destroy" birds of prey, including all owl species (California Fish and Game Code: CA FISH & G § 3500 – 3857). While some barred owl removal has occurred in California forest lands under special permits, this statute could hinder the ability to reduce the effects of barred owls on spotted owls in the southern portion of the range.

- ***Recovery Action 20 (new): If barred owl removal is determined to be most effectively and humanely implemented through shooting of individuals, work with the State of California to modify their regulations so this important recovery activity can occur in compliance with all applicable laws.***

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 spotted owls for nesting sites, roosting sites, and food, and possibly predate spotted owls. The threat posed by barred owls to

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

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 the Recovery Criteria. 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. The Service is the primary agent to oversee implementation of any strategy for the management of barred owls.

- ***Recovery Action 21: Establish a technical 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. The Barred Owl Work Group was informally convened prior to the adoption of the 2008 Plan and has since been formalized through the adoption of a charter. Currently, representatives from 14 Federal, State and non-governmental agencies and organizations comprise the work group helping to implement its technical and scientific functions.

This Barred Owl Work Group is chaired by the FWS and guided by its charter, along with the Implementation Team. The Barred Owl Work Group has guided implementation of numerous Recovery Actions addressing the barred owl threat to spotted owls.

- ***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.***
  Through implementation of this Recovery Action, many of the long-term demographic data sets have been studied, resulting in white papers and pending publications. Data mining has provided a greater understanding of the effects of barred owls on spotted owl detection rates, survival, site occupancy and the role of habitat in site occupancy. The Barred Owl Work Group and Principal Investigators of the demographic studies will continue to work collaboratively to mine data as appropriate.

- ***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, provide vital data needed to help manage the threat of the barred owl to spotted owls. A subgroup of the Barred Owl Work Group was formed in 2008 to develop a barred owl-specific survey protocol. The subgroup developed a draft protocol in 2009 with the purpose of providing a high likelihood of determining barred owl presence. During the 2009 field season, the draft protocol was tested in several areas with the objectives of determining barred owl detection rates and the survey effort needed to adequately detect barred owls. These data have been analyzed allowing the subgroup to refine the protocol based on the field tests.

- ***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, a subgroup of the Barred Owl Work Group enlisted scientific support and analysis from many spotted owl researchers from the Federal, state and private sectors across the range of the spotted owl. Data mining from demographic study areas focused on addressing the questions of: 1) what are the per visit detection rates of spotted owls with and without barred owls, and 2) what are the site occupancy rates of spotted owls at historic spotted owl sites, and has led to several white papers and pending publications. A draft revised spotted owl survey protocol (available at http://www.fws.gov/oregonfwo/Species/ Data/NorthernSpottedOwl/Recovery/Library/Documents/2010 %20DRAFT%20NSO%20protocol%20(2-18-2010).doc) was released for use and comment during the 2010 field season along with direction on how to transition from the 1992 protocol. Field testing of, and commenting on, several provision of the draft protocol will occur during the next several field seasons leading to finalization of a survey protocol.

- ***Recovery Action 25: Analyze resource partitioning of sympatric barred owls and spotted owls.***
  Radio-telemetry studies of sympatric spotted and barred owls help 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.

In anticipation of the need for this information, several research projects were initiated in 2007 and led by USGS, PNW, OSU and private industry researchers. This research is focused on interspecific competition and niche partition by spotted owls and barred owls. Results from the research are either incorporated in Appendix B or soon will be released in peer-review publications. This information will provide the opportunity for adaptive management of this revised Plan when it becomes available.

- ***Recovery Action 26: Create and implement an outreach strategy to educate the public about the threat of barred owls to spotted owls.***
  Since completion of the 2008 Plan, a Barred Owl Stakeholder Group (BOSG) has been formed. The BOSG, comprised of nearly 40 private and public stakeholders with interest in spotted owl and barred owl issues, met several times in 2009 with a professional ethicist to discuss the ethical considerations associated with permitting the experimental removal of barred owls. The results of these discussions will become part of the permitting documents created for any experimental removal proposals.

It is crucial that the general public be kept informed concerning this difficult aspect of spotted owl recovery and 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: Design and implement large-scale control experiments to assess the effects of barred owl removal on spotted owl site occupancy, reproduction, and survival.***
  Experimental removal 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).We believe removal of barred owls would provide local benefits to spotted owls. Given the rapidity and severity of the increasing threat from barred owls, barred owl removal should be initiated as soon as possible in the form of well-designed removal

experiments. These experiments will have the potential to substantially expand our knowledge of the ecological interactions between spotted owls and barred owls and the effectiveness of barred owl removal in recovering spotted owls. Removal experiments should be conducted in various parts of the spotted owl's range, including a range of barred owl/spotted owl densities, to provide the most useful scientific information.

In the fall of 2009 the Service initiated an Environmental Impact Statement for a proposed experimental removal of barred owls to determine if the removal benefits to spotted owls. Public scoping was completed in January 2010 and a draft EIS is in process.

- ***Recovery Action 29: Manage the negative effects of barred owls on spotted owls so that Recovery Criterion 1 can be met.*** Implement the results of research to adaptively manage the effects of barred owls in those areas required to meet Recovery Criterion 1. 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.

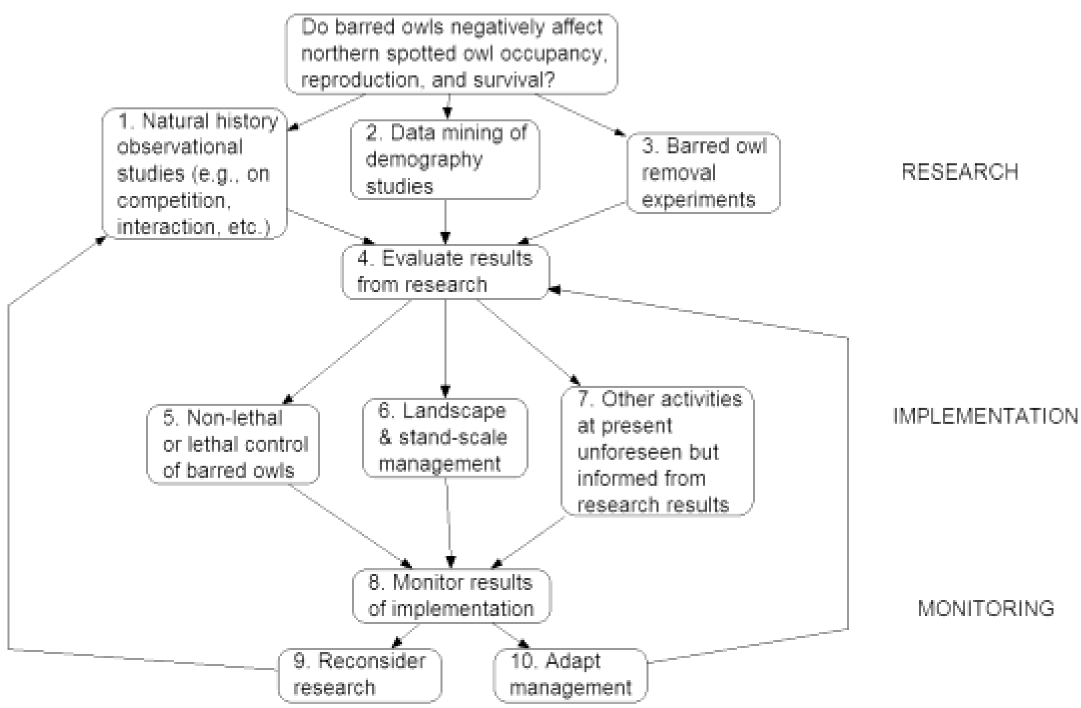

Figure 1. Flowchart of barred owl Recovery Actions.

Conducting natural history studies (step 1 in Figure 1) 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 (Dugger *et al*. 2009, Dugger *et al*. in review). Many Actions (*e.g.,* data mining, improving detection protocols for both species, outreach, identification of key spotted owl areas) have already begun. 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 the removal of barred owls (step 5) through non-lethal or lethal methods. If research indicates local or large-scale maintenance removal 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 30: 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 both 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 31 purposefully omitted)

- ***Recovery Action 32(revised): To the maximum extent practicable, maintain all of the older and more structurally complex multi-layered conifer forests on Federal and non-Federal lands across the range of the spotted owl, 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.***
  Maintaining forests with high-quality habitat will provide additional support for reducing key threats faced by spotted owls. Protecting these forests should provide spotted owls high-quality refugia habitat from the negative competitive interactions with barred owls that are likely occurring where the two species' home

ranges overlap. Maintaining these forests could support increased spotted owl populations in areas adjacent to habitat conservation blocks, and allow time to determine both the competitive effects of barred owls on spotted owls and the effectiveness of barred owl control measures.

Forest stands or patches meeting the described conditions are a subset of suitable habitat and actual stand conditions vary across the range. These stands or patches may be relatively small but important in a local area, may not be easily discernable using remote sensing techniques, and likely require project-level analysis and field verification to identify.

The peer reviewers were critical of this recovery action because it appeared "aspirational" instead of prescriptive, did not more thoroughly describe the stands targeted by this recovery action, and did not map these stands. However, the on-the-ground application of this action has been, and continues to be, on-going on the west side of the Cascades since shortly after the 2008 Plan was finalized as part of the level one team consultation process. Because the characteristics of the stands or patches targeted by this recovery action vary widely across the range of the species, the Service believes implementation and/or mapping of this recovery action is best left to interagency teams with localized expertise. Our recent experience reinforces that the BLM and Forest Service are aware of the conservation value of this recovery action and have been proactive and collaborative in the application of RA32.

To facilitate implementation of this Recovery Action, local, interagency Level 1 teams should continue to identify RA 32 stands or patches when necessary and evaluate the effects of proposed management activities in these areas on spotted owls, with assistance from management (Level 2) and Regional Technical Specialists, as needed. This approach will continue to ensure that interagency localized expertise will be utilized in identifying and managing RA32 stands or patches and will be the result of interagency cooperation.

Results and documentation of these interagency efforts should be forwarded to the Implementation Team for review, as needed. The Section 7 Work Group is available to assist the Level 1 teams.

The Dry-Forest Landscape and the Klamath Province Work Groups are both assisting the Service with multi-province-specific management strategies. Given the dynamic disturbance regimes of these provinces, the strategies developed by these two work groups may address the goals of this Recovery Action differently than outlined above when finalized. Consequently, the application of RA32 in these areas may also vary.

This Recovery Action may be temporary in nature, until such time as the competitive pressures of the barred owl on the spotted owl can be reduced to an extent that retention of these stands or patches is not necessary for spotted owl recovery. The Service is currently drafting an EIS to initiate a study testing the effects on spotted owls of removing barred owls from the forested landscape.

This study is expected to inform the ability to managing this barred owl threat at the landscape scale.

Climate Change

Addressing climate change implications in any significant detail was beyonf the scope of this revision. However, this topic is extremely important and relevant, and the Service is committed to identifying opportunities to dovetail climate change research and mitigation with spotted owl recovery efforts.

Potential changes in temperature and precipitation have profound implications for spotted owls. The Service expects forests in the Northwest to change both in the long-term from increased occurrences of drought during the growing season and in the short-term from large-scale disturbances such as wildfire and insect outbreaks, all of which can change structure and composition of forests.

In the Pacific Northwest, mean annual temperatures rose 0.8^{o} C (1.5^{o} F) in the 20th century and are expected to continue to warm from 0.1^{o} to 0.6^{o} C (0.2^{o} to 1^{o} F) per decade (Mote and Salathe 2009). Global climate models project an increase of 1 to 2 percent in annual average precipitation, with some predicting wetter autumns and winters with drier summers (Mote and Salathe 2009).

University of Washington researchers (Salathe *et al*. 2009) have developed finer-resolution, regional, predictive climate models, accounting for local terrain and other factors that affect weather (*e.g.* snow cover, cloudiness, soil moisture, and circulation patterns) in the Pacific Northwest. These models agree with the global climate models in projecting warmer, drier summers and warmer, wetter autumns and winters for the Pacific Northwest, resulting in diminished snowpack, earlier snowmelt, and an increase in extreme heat waves and precipitation events.

These changes in temperature and precipitation affect soil moisture. Soil moisture deficits arise in hot weather when the atmospheric demand for water is high and cannot be met by available moisture in soil, fuels, and plants. Increased periods of soil moisture deficits can make forests more vulnerable to multiple, synergistic disturbances such as insects, disease outbreaks, and wildfires (McKenzie *et al*. 2004). Soil moisture deficits would likely develop in a warming climate because hot weather greatly increases evaporative demand, particularly at lower elevations (Littell 2009) and more of the cool season precipitation falls as rain rather than snow (Littell *et al*. 2009b). Rain, particularly heavy events, is more likely to run off, rather than infiltrating into the soil.

On the cooler, moister west side of the Cascades, the summer water deficit is projected to increase two- to three- fold over current conditions (Littell 2009). East of the Cascades, summer soil deficits may not change as much or may even moderate slightly over current conditions (Elsner *et al*. 2009). Researchers expect some ecosystems to become more water-limited, more sensitive to variability in temperature, and more prone to disturbance (McKenzie *et al*. 2009).

There is evidence that the productivity of many high-elevation forests, where low summer temperature and winter snowpack limits the length of the growing season, is increasing in the Pacific Northwest as temperatures rise, potentially increasing the elevation of the tree line (Graumlich *et al*. 1989, Case and Peterson 2009). Conversely, productivity and tree growth in many low-elevation Pacific Northwest forests is likely to decrease due to the longer, warmer summers (Case and Peterson 2009). This may result in a change in species composition or reduction in the acreage of existing low-elevation forests.

Some patches of habitat may be more resistant to climate change effects than others. A study on the east side of the Cascade Mountains found that areas of high soil and fuel moisture had historically created fire refugia where late-successional forest persisted longer (Camp *et al*. 1997). These patches were often near streams or valley bottoms, had perched water tables, or were near headwalls where soil moisture was higher. They were also often at higher elevations where total precipitation was higher or on northern aspects of mountains where terrain was shaded longer. Daley *et al*. (2009) found that cold air pooling in some mountain valleys may decouple or shelter the local microclimate from regional climate conditions. These studies imply that some areas on the landscape may resist climate-driven disturbances that may affect spotted owls and their habitat.

Wildfire

Westerling *et al*. (2006) identified an increase in the frequency, duration, area and severity of wildfires in western forests in the mid-1980s, although much of this occurred outside of spotted owl range. Westerling *et al*. (2006) attributed this increase to warmer springs, a longer summer dry season, reduced winter precipitation and snowpack, and earlier snowmelt. Although fire suppression, fire exclusion, and fuel treatment has contributed to the increased magnitude of wildfires, the amount of wildfire area burned is substantially controlled by climate (Littell *et al*. 2009*a*). By the 2040s, the mean area burned in forested ecosystems in the western and eastern Cascades is projected to increase by a factor of 3.8 compared to 1980-2006 (Littell 2009).

Insect and Disease Outbreaks

Warming temperatures have led to mountain pine beetle outbreaks, with large-scale effects in some western forests, including in the Eastern Cascades. In warmer winters more mountain pine beetles survive and shorten their generation time, resulting in larger and more severe outbreaks. Drought can heighten the susceptibility of host trees to attack (Littell *et al*. 2009*b*). Littell *et al*. (2009*b)* suggest that the greatest likelihood of mountain pine beetle attack is when conditions are hot and dry combined with a fairly short period of extreme vapor pressure deficit, when trees are most vulnerable. In the future, outbreaks are projected to increase at higher elevations and decrease at lower elevations (Littell *et al*. 2009*b*), with uncertain implications for spotted owls. Littell *et al*.

(2009*b*) have projected that the combination of increased tree susceptibility and mountain pine beetle outbreaks could lead to the loss of pine species in the eastern Cascades as early as the 2040s. Mixed conifer stands in the eastern Cascades, which include pine species, provide den sites and food resources for bushy-tailed woodrats, an important prey species of spotted owls (Lehmkuhl *et al*. 2006*a*). Warmer winters have also been shown to increase the incidence of Swiss needle cast, a fungal disease in Douglas-fir on the Oregon coast (Manter *et al*. 2005) inhibiting tree growth, and causing severe chlorosis and defoliation. We are uncertain how significantly this will affect spotted owl habitat.

While a change in forest composition or extent is likely as the result of climate change, the rate of that change is uncertain. In forests with long-lived dominant species, mature individuals can survive these stresses, so direct effects of climate on forest composition and structure would most likely occur over a longer time scale (100 to 500 years) than disturbances such as wildfire or insect outbreaks (25 to 100 years)(McKenzie *et al*. 2009). Some changes appear to be already occurring. Regional warming and consequent drought stress appear to be the most likely drivers of an increase in the mortality rate of trees in recent decades in the western United States. The increase was evident across regions (Pacific Northwest, California), elevations (*i.e.*, topography), tree size, type of trees, and fire-return-intervals (van Mantgem *et al*. 2009).

Effects on Spotted Owl Demographic Rates

The influence of weather and climate on spotted owl populations was evidenced in northern California (Franklin *et al*. 2000), Oregon, and Washington (Glenn 2009). Climate accounted for 84 and 78percent of the temporal variation in population change of spotted owls in the Tyee and Oregon Coast Range study areas, respectively (Glenn 2009). Climate and barred owls together accounted for nearly all (~100%) of the changes in spotted owl survival in the Olympic Peninsula (Glenn 2009).

Wet, cold weather during the winter or nesting season, particularly the early nesting season, has been shown to negatively affect spotted owl reproduction (Olson *et al*. 2004, Dugger *et al.* 2005), survival (Franklin *et al*. 2000, Olson *et al*. 2004, Glenn 2009), and recruitment (Franklin *et al*. 2000). Cold, wet weather may reduce reproduction and/or survival during the breeding season due to declines or decreased activity in small mammal populations so that less food is available during reproduction when metabolic demands are high (Glenn 2009). Wet, cold springs or intense storms during this time may reduce the time it takes for an adult bird to starve (Franklin *et al*. 2000). Cold, wet weather may also inhibit the male spotted owl's ability to bring food to incubating females or nestlings (Franklin *et al*. 2000). Cold, wet nesting seasons may increase the mortality of nestlings due to chilling (Franklin *et al*. 2000) and reduce the number of young fledged per pair per year (Franklin *et al*. 2000, Glenn 2009). Wet, cold weather may decrease survival of dispersing juveniles during their first winter thereby reducing recruitment (Franklin *et al*. 2000).

Drought or hot temperatures during the previous summer have also reduced spotted owl recruitment and survival (Franklin *et al*. 2000, Glenn 2009). Drier, warmer summers and drought conditions during the growing season strongly influence primary production in forests, food availability, and the population sizes of small mammals (Glenn 2009). Northern flying squirrels, for example, forage primarily on ectomycorrhizal fungi (truffles), many of which grow better under mesic, or moist, conditions (Lehmkuhl *et al*. 2004). Drier, warmer summers, or the high-intensity fires such conditions support, may change the range or availability of these fungi, affecting northern flying squirrels and the spotted owls that prey on them. Periods of drought are associated with declines in annual survival rates for other raptors due to a presumed decrease in prey availability (Glenn 2009).

Survival, recruitment, and reproduction increased with precipitation in the late spring or summer (Olson *et al*. 2004, Glenn 2009). Olson *et al*. (2004) found that while survival decreased with early-nesting season precipitation, it increased with late-nesting season precipitation. This is probably due to reducing the potential for drought to occur.

In addition to effects on habitat, the heat itself may have physiological effects on spotted owls. Weathers *et al*. (2001) suggest California spotted owls (*Strix occidentalis occidentalis*) are less heat-tolerant than other owls responding to temperatures of 30 to 34 ^{o} C (86 ^{o}– 93 ^{o} F) with increased breathing rates, fluffing of feathers, and wing drooping. Northern spotted owls in an earlier study (Barrows 1981) showed signs of heat stress at even more modest temperatures of 27 to 31 ^{o} C (81 ^{o}–88 ^{o} F). We have no current information on how this affects survival or reproduction.

The presence of high-quality habitat appears to buffer the negative effects of cold, wet springs and winters on survival of spotted owls as well as ameliorate the effects of heat. High-quality spotted owl habitat was defined in a northern California study area as a mature or old growth core within a mosaic of different seral stages (Franklin *et al*. 2000). The high-quality habitat might help maintain a stable prey base, thereby reducing the cost of foraging during the early breeding season when energetic needs are high (Carey *et al*. 1992, Franklin *et al*. 2000).

Barred Owls, Spotted Owls, and Climate Change

Although the scientific literature has explored the link between the barred owls and climate change, climate is unlikely to have caused the invasion (Livezey (2009*b*). In general, climate change can increase the success of introduced or invasive species in colonizing new territory (Dale *et al*. 2001). Invasive animal species are more likely to be generalists, such as the barred owl, than specialists, such as the spotted owl and apt adapt more successfully to a new climate than natives (Dukes and Mooney 1999).

Scientists have observed spotted owls at higher elevations than expected and have speculated that this behavior may be avoidance of barred owls (Pearson and Livezey 2003). This behavior may also be related to increasing prey populations at higher elevations, which is attributed to a warming climate. Moritz *et al*. (2008) found that the range of many small mammals in Yosemite National Park had shifted upward in elevation consistent with warming temperatures. Although this study was outside the range of spotted owls, it showed evidence that the lower limits of bushy-tailed woodrats, an important prey species for spotted owls in some parts of its range, had increased in elevation by 609 meters (Moritz *et al*. 2008).

Implications for Spotted Owl Conservation

Millar *et al*. (2007) suggest a conceptual framework for managing forested ecosystems in a way that helps ecosystems accommodate changes adaptively. These "adaptation" strategies include: (1) resistance options (to forestall impacts and protect highly-valued resources), (2) resilience options (to improve the capacity of ecosystems to return to desired conditions after disturbance), and (3) response options (to facilitate transition of ecosystems from current to new conditions). This framework has value in planning actions to help spotted owls accommodate future climate changes.

Part of the Service-wide priority for responding to climate change is to conduct species and habitat vulnerability assessments, an analytical tool for determining how climate change will affect a species, habitat, or ecosystem and for developing strategies to safeguard these resources (USFWS 2009). Methodologies have been developed in recent years to conduct vulnerability assessments, some of which may be useful for determining appropriate recovery actions, given the climate change effects on the spotted owl and its habitat (Stein 2010).

- ***Recovery Action 33 (new): Convene an expert panel to develop a comprehensive vulnerability assessment (USFWS 2009) with recommendations for land managers and stakeholders engaged in spotted owl recovery. This interdisciplinary panel should include technical expertise on spotted owl and barred owl ecology, impacts of climate change in the Pacific Northwest, and the ecology of forested ecosystems.***

To address the effects of climate change on the spotted owl this panel should consider: (1) How reserve design modifications could account for areas where existing mature or old-growth forests are most likely to persist in a warming climate and how to effectively identify these areas on the landscape; and (2) how Federal, state and local government's climate change mitigation mandates and efforts (*e.g.*, carbon sequestration) can be conjoined with spotted owl recovery goals to maximize positive outcomes.

Recovery Criterion Concerning Post-delisting Monitoring

Recovery Criterion 4 – Post-delisting Monitoring: 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-delisting 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 draft revised Plan. It is a guide for planning and meeting the objectives discussed in this draft revised 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 effectively conducted. The Service and other implementers of this draft revised 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 $147.1 million. This is a substantial reduction from the $489.2 million estimated cost of implementing the 2008 Plan, primarily due to changes in two Recovery Actions. In both these cases the Recovery Actions have changed from providing recommended management in parts of the dry-forest landscape to relying on the input from the DFLWG and KPWG. Because we do not yet know what strategies will be suggested by these work groups we are unable to provide cost estimates of potential approaches at this time.

The actions identified in the implementation schedule are those that, in our opinion, should bring about the recovery of this species. However, these 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 not possible 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, such as these recovery actions, 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, expertise, 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 four 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.

For most of the actions identified in this draft revised 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 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 of existing practices, the cost of adjusting the action during planning was estimated, rather than the actual entire cost of implementing the project since the "existing practices" cost would already be incurred by the land manager. 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.

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.

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. For some Recovery Actions the interagency Northern Spotted Owl Implementation Team (NSOIT) is identified as a responsible party. In these cases it is likely the NSOIT will coordinate within their agencies to complete these actions as opposed to the NSOIT itself actually carrying out the activity.

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	2011	2012	2013	2014	2015
1	1	Establish Northern Spotted Implementation Team	Continuous	FWS	180	6	6	6	6	6
2	3	Monitor population trend	Ongoing	FWS, FS, BLM*, NPS, NSOIT	69,000	2,300	2,300	2,300	2,300	2,300
3	3	Monitor occupancy	Start TBD, intermittent thereafter	NSOIT	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	Utilize Habitat Modeling	2 years	FWS*, BLM, FS	140	80	60	0	0	0
5	1	West side: Manage to accelerate structural complexity	Continuous	FS, BLM, FWS	0	0	0	0	0	0
6	1	Create Dry Forest Landscape Work Group (DFLWG)	Continuous	FWS*, FS,BLM	180	6	6	6	6	6
7	3	Fire and occupancy data analysis	3 years	DFLWG	60	25	25	10	0	0
8	3	Research needs and management strategy development	2 years	DFLWG	40	20	20	0	0	0
9	1	Create Klamath Province Work Group (KPWG)	Continuous	FWS*, FS,BLM	180	6	6	6	6	6
10	1	Manage to retain occupied sites	Continuous	FS, BLM, FWS	1,520	60	60	50	50	50
11	2	Post-Fire Management approach	Continuous	FWS, FS, BLM	0	0	0	0	0	0
12	3	Design and conduct experiments concerning habitat, prey and	Continuous	FS, BLM, FWS, NPS, WDNR, ODF, CDF,	17,750	1,750	1,250	1,250	500	500

Action No.	Priority No.	Action Description	Action Duration	Resp. Parties (* = lead)	FY Cost Estimate (in $1,000s)					
					30-yr Total	2011	2012	2013	2014	2015
		spotted owl fitness and thinning		CDFG, landowners						
13	3	Standardize habitat definitions	2 years	NSOIT	120	60	60	0	0	0
14	3	Develop HCPs and SHAs that are consistent with spotted owl recovery	Continuous	FWS	4,000	200	200	200	200	200
15	3	Establish incentives workgroup/program	Continuous	FWS	6,000	200	200	200	200	200
Listing Factor C: Disease or predation										
16	3	Monitor and address diseases	Continuous	NSOIT	300	10	10	10	10	10
Listing Factor D: Inadequacy of existing regulatory mechanisms										
17	3	WA State Board evaluation of spotted owl sites	3 years	Washington Dept. of Fish and Wildlife	450	150	150	150	0	0
18	2	Cooperate with ODF on scientific evaluation	4 years	ODF*, FWS	400	100	100	100	100	0
19	2	Non-Federal land spotted owl conservation needs recommendations	3 years starting after previous RA	ODF*, FWS	150	0	0	0	50	50
20	2	Work with State of California to modify state law prohibiting shooting of owls	4 years	State of Cal*, FWS	150	50	50	50	0	0
Listing Factor E: Other natural or manmade factors affecting its continued existence										

Action No.	Priority No.	Action Description	Action Duration	Resp. Parties (* = lead)	FY Cost Estimate (in $1,000s)					
					30-yr Total	2011	2012	2013	2014	2015
21	2	Establish Barred Owl Work Group	Continuous	BOWG*, FWS, FS, BLM, NPS	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	3 years	BOWG*, FWS, FS, BLM, NPS	225	75	75	75	0	0
24	3	Ensure protocols adequately detect spotted owls	3 years	BOWG*, FWS, BLM, FS, NPS, States, landowners	300	100	100	100	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	Conduct experimental removal studies	10 years	BOWG*, TBD	3,000	600	600	600	600	600
29	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
30	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

Action No.	Priority No.	Action Description	Action Duration	Resp. Parties (* = lead)	FY Cost Estimate (in $1,000s)					
					30-yr Total	2011	2012	2013	2014	2015
31		Intentionally omitted								
32	1	Maintain high-quality habitat across all landscapes	Continuous	FWS, BLM, FS, States	0	0	0	0	0	0
33	3	Assess effects from climate change	5 years	FWS	220	50	50	40	40	40
34	3	Develop delisting monitoring plan	TBD	FWS	10	0	0	0	0	0
Estimated total cost for all actions for 30 years: $147.1 million										

Appendix A: Background

This section of the revised Plan is designed to provide information necessary to understand the revised 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, 1990*a*), 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 1990*b*), scientific evaluation of the status of the spotted owl (Courtney *et al*. 2004), and several key monographs (*e.g.*, Forsman *et al*. 2004, Anthony *et al*. 2006).

Species Description and Taxonomy

The 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 pers.comm. 2006). The 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 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*. 2004), 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*. 2004; 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 1990*b*). 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 1,070 (J. Buchanan pers. comm. 2010). 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 1992*a*, 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.

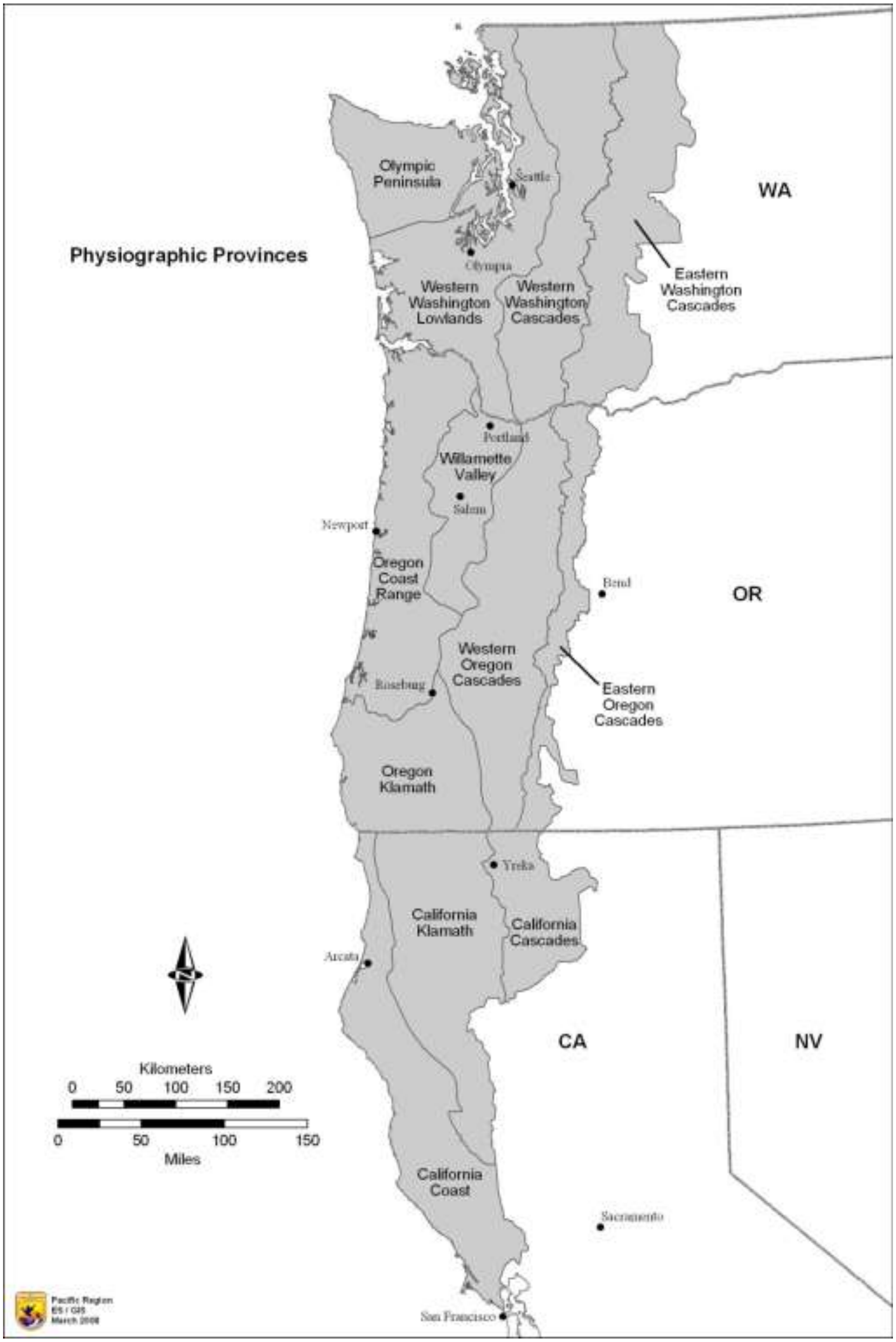

Figure A1. Physiographic provinces in the range of the spotted owl in the United States.

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) (lambda), 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, Forsman *et al*. in press) to estimate trends in the populations of the spotted owl.

In January 2009, two meta-analyses modeled rates of population change for up to 24 years using the re-parameterized Jolly-Seber method (λ_{RJS}). One meta-analysis modeled the 11 long-term study areas (Table A1), while the other modeled the eight study areas that are part of the effectiveness monitoring program of the NWFP (Forsman *et al*. in press).

Point estimates of λ_{RJS} were all below 1.0 and ranged from 0.929 to 0.996 for the 11 long-term study areas. There was strong evidence that populations declined on 7 of the 11 areas (Forsman *et al*. in press), these areas included Rainier, Olympic, Cle Elum, Coast Range, HJ Andrews, Northwest California and Green Diamond. On other four areas (Tyee, Klamath, Southern Cascades, and Hoopa), populations were either stable, or the precision of the estimates was not sufficient to detect declines.

The weighted mean λ_{RJS} for all of the 11 study areas was 0.971 (standard error [SE] = 0.007, 95 percent confidence interval [CI] = 0.960 to 0.983), which indicated an average population decline of 2.9 percent per year from 1985 to 2006. This is a lower rate of decline than the 3.7 percent reported by Anthony *et al*. (2006), but the rates are not directly comparable because Anthony *et al*. (2006) examined a different series of years and because two of the study areas in their analysis were discontinued and not included in Forsman *et al*. (in press). Forsman *et al*. (in press) 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.

Demographic data suggest that populations over the 11 long-term demographic study areas decreased by about 2.9 percent from 1985 to 2008.

Table A1. Spotted owl demographic parameters based on data from the spotted owl demographic study areas (adapted from Forsman *et al*. in press).

Study Area	Fecundity	Apparent Survival[1]	λ_{RJS}	Population change[2]
Cle Elum	Declining	Declining	0.937	Declining
Rainier	Increasing	Declining	0.929	Declining
Olympic	Stable	Declining	0.957	Declining
Coast Ranges	Increasing	Declining since 1998	0.966	Declining
HJ Andrews	Increasing	Declining since 1997	0.977	Declining
Tyee	Stable	Declining since 2000	0.996	Stationary
Klamath	Declining	Stable	0.990	Stationary
Southern Cascades	Declining	Declining since 2000	0.982	Stationary
NW California	Declining	Declining	0.983	Declining
Hoopa	Stable	Declining since 2004	0.989	Stationary
Green Diamond	Declining	Declining	0.972	Declining

[1]Apparent survival calculations are based on model average.
[2]Population trends are based on estimates of realized population change.

The mean λ_{RJS} for the eight demographic monitoring areas (Cle Elum, Olympic, Coast Range, HJ Andrews, Tyee, Klamath, Southern Cascades, and Northwest California) that are part of the effectiveness monitoring program of the NWFP was 0.972 (SE = 0.006, 95 percent CI = 0.958 to 0.985), which indicated an estimated decline of 2.8 percent per year on Federal lands with the range of the spotted owl. The weighted mean estimate λ_{RJS} for the other three study areas (Rainier, Hoopa, and Green Diamond) was 0.969 (SE = 0.016, 95 percent CI = 0.938 to 1.000), yielding an estimated average decline of 3.1 percent per year. These data suggest that demographic rates for spotted owl populations on Federal lands were somewhat 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.

The number of populations that declined and the rate at which they have declined are noteworthy, particularly the precipitous declines in the Olympic, Cle Elum, and Rainier study areas in Washington and the Coast Range study area in Oregon. Estimates of population declines in these areas ranged from 40 to 60 percent during the study

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

period through 2006 (Forsman *et al*. in press). Spotted owl populations on the HJ Andrews, Northwest California, and Green Diamond study areas declined by 20-30 percent whereas the Tyee, Klamath, Southern Cascades, and Hoopa study areas showed declines of 5 to 15 percent.

Decreases in adult apparent survival rates were an important factor contributing to decreasing population trends. Forsman *et al*. (in press) found apparent survival rates were declining on 10 of the study area with the Klamath study area in Oregon being the exception. Estimated declines in adult survival were most precipitous in Washington where apparent survival rates were less than 80 percent in recent years, a rate that may not allow for sustainable populations (Forsman *et al*. in press). In addition, declines in adult survival for study areas in Oregon have occurred predominately within the last five years and were not observed in the previous analysis by Anthony *et al*. 2006. Forsman *et al*. (in press) express concerns about the collective declines in adult survival across the subspecies range because spotted owl populations are most sensitive to changes in adult survival.

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 1990*b*). 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 1994). 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.

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 (Forsman *et al*. 1984, USFWS 1990*b*, 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).

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 (Forsman *et al*. 1984, USFWS 1990*b*). 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 (Miller *et al*. 1997, Forsman *et al*. 2002). 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 (Miller 1989, USFWS 1990*b*). Known or suspected causes of mortality during dispersal include starvation, predation, and accidents (Miller 1989, USFWS 1990*b*, Forsman *et al*. 2002). Parasitic infection may contribute to these causes of mortality, but the relationship between parasite loads and survival is poorly understood (Gutiérrez 1989, Hoberg *et al*. 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 pers. comm. 2006).

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 2008) 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 1992*b*). 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 1992*b*). 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 (Meyer *et al*. 1998, Franklin *et al*. 2000, Zabel *et al*. 2003). 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[1]. 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 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. Spotted owls have been observed foraging in areas burnt by fires of all severity categories (Clark 2007, Bond *et al.* 2009). While Clark (2007) found that owls did not use large patches of high-severity burns, Bond *et al.* (2009) found owls selecting burned areas, even high-severity burns, when they were within 1.5 km of a nest or roost site. 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.

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

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.

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

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 (*i.e.*, 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) encompassing nearly 6.9 million acres (2.2 million acres in Washington, 3.3 million acres in Oregon, and 1.4 million acres in California (USFWS 1992*b*)). Primary constituent elements (the physical and biological features of critical habitat essential to a species' conservation) identified in the spotted owl critical habitat final rule include those features that support nesting, roosting, foraging, and dispersal (USFWS 1992*b*). In 2008 the Service completed a revision of spotted owl critical habitat, designating 5.3 million acres (1.8 million acres in Washington, 2.3 million acres in Oregon, and 1.2 million acres in California). The primary constituent elements included suitable forest types and the areas within these containing nesting, roosting, foraging, or dispersal habitat.

Revised spotted owl critical habitat was designated based on large blocks of habitat identified for spotted owl conservation in the 2008 Plan (MOCAs) on the west side of the range. Because the 2008 Plan did not include mapped areas in the eastern Cascades of Oregon and Washington, focusing instead on a landscape approach, we relied on the areas mapped in the 2007 draft Recovery Plan in these provinces. The Service designated the Federal lands within these

MOCAs as critical habitat in 2008, excluding congressionally-reserved areas such as Wilderness Areas and National Parks,

The Service has initiated a habitat modeling effort which provides a more in-depth evaluation of various habitat features that affect spotted owl habitat use, when compared to the process used to develop the MOCAs. This information will be used to evaluate potential habitat conservation network scenarios. Following the completion of the final Revised Plan, the Service will evaluate the need to revise spotted owl critical habitat, and use the results of the modeling to inform this potential critical habitat revision.

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 1994*a*, *b*). 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 1994*a*). The NWFP includes 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 NWFP 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 are 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 1992*b*) 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 1994*a*, *b*). 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.

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.

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.

Non-Federal Lands

In the report from the ISC (Thomas *et al*. 1990), the draft Recovery Plan (USFWS 1992*b*), 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 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 17 current and ongoing conservation plans (CP) including Habitat Conservation Plans (HCPs) and Safe Harbor Agreements (SHA)that have incidental take permits issued for spotted owls—eight in Washington, three in Oregon, and six in California. The CPs range in size from 76 acres to more than 1.8 million acres, although not all acres are included in the mitigation for spotted owls. In total, the CPs cover approximately 3 million acres (9.4 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 20 to 100 years. While each CP is unique, there are several general approaches to mitigation of incidental take:

- Reserves of various sizes, some associated with adjacent Federal reserves

- Forest management that maintains or develops nesting habitat
- Forest management that maintains or develops foraging habitat
- Forest management that maintains or develops dispersal habitat
- Deferral of harvest near specific sites

Washington. In Washington State, there are over 2.1 million acres of land in conservation plans (6 HCPs and 2 SHAs). Some of these CPs focus on providing nesting, roosting habitat throughout the area or in strategic locations; while others focus on providing connectivity through foraging habitat and/or dispersal habitat. Most of the Washington HCPs have foraging as a minimal target for habitat quality. In addition, there is a long-term habitat management agreement covering 13,000 acres in which authorization of take was provided through an incidental take statement (section 7) associated with a Federal land exchange.

Two Washington HCPs are based upon municipal watershed management and will provide older forest conditions over time. One HCP occurs within checkerboard ownership in the central cascades and focuses on connectivity through a combination of nesting habitat in strategic locations as well as a distribution of nesting habitat and foraging habitat across the ownership and the planning area. Several HCPs, a Habitat Management Agreement (via section 7), and one Safe Harbor Agreement focus on connectivity from a dispersal standpoint, including providing foraging habitat and landscape conditions conducive to spotted owl movement and potential residence. The largest HCP in Washington State (WDNR State lands) was designed by a scientific advisory team which analyzed the manner in which State lands could contribute to support the NWFP reserves. That HCP has a system of designated areas designed to provide demographic support in some areas, and foraging and dispersal in other areas.

Oregon. 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. On July 27, 2010, the Service completed a Programmatic Safe Harbor Agreement with the Oregon Department of Forestry that will enroll up to 50,000 acres of non-Federal lands within the state over a total of 50 years. It is primarily intended to increase the time between harvests (defer harvest), and to lightly to moderately thin younger forest stands that are currently not habitat to increase tree diameter size and stand diversity (species, canopy layers, presence of snags).

California. Four HCPs and 2 SHAs authorizing take of spotted owls have been approved; these CPs cover more than 622,000 acres of non-Federal lands. Implementation of these plans is intended to provide for spotted owl demography 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 1990*b*). 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 1990*a*). 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 1990*b*).

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 2004*a*) 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 1994*a*). 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 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) estimated 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

The effects of wildfire on spotted owls and their habitat vary by location, fire severity, and habitat function. Although owls have been observed reproducing in burned landscapes and nesting has occurred in core areas burnt by high-severity fires, none have been observed nesting in actual forest patches burned by high severity fires (*i.e.*, typically 70 – 100 percent overstory mortality) (Gaines *et al.* 1997, Bond *et al.* 2002, Jenness *et al.* 2004, Clark 2007, Bond *et al.* 2009). However, low to moderate severity burn patches may function as nesting habitat (Gaines *et al*. 1997, Clark 2007, Bond *et al.* 2009). It is not known whether there is a maximum amount of high severity fire within a nesting core that would preclude nesting of spotted owls. In addition, there have been no long-term studies to determine how long owls may remain in an area after a fire.

While spotted owls have been observed roosting in forests experiencing the full range of fire severity, most were associated with low or moderate severity burns and all roost sites from which stand measurements have been taken had high levels of canopy closure (*i.e.*, greater than 60 percent) and a large tree component, regardless of burn severity (Clark 2007, Bond *et al.* 2009). Spotted owls were observed foraging in all fire severity categories, and seemed especially attracted to edges where burned forest met unburned stands (Clark 2007, Bond *et al.* 2009). Clark (2007) found that owls did not use large patches of high-severity burns, while Bond *et al.* (2009) found owls selecting burned areas, even high-severity burns, when they were within 1.5 km of a nest or roost site. Bond *et al.* (2009) postulated that greater foraging in burned patches may be due to increased presence of prey such as the dusky-footed woodrats, which are more likely to occur in open stands with increased shrub and herbaceous cover. It is unknown whether this hypothesis would prove true in that portion of the spotted owl range where principal prey species (*e.g.*, northern flying squirrel, bushy-tailed woodrats) differ and are more tied to closed canopy forest (Lehmkuhl *et al.* 2006*a*; Lehmkuhl *et al.* 2006*b*).

The following descriptions of spotted owl habitat loss due to natural disturbance events was derived from data as recorded in Biological Opinions and Biological Assessments used in Section 7 consultations required by Federal agencies under the Endangered Species Act. Estimating the effects of natural disturbances on spotted owl habitat is difficult to accurately assess for several reasons. First is the complex nature in which fire can affect owl habitat and the broad array of effects it can have on owl habitat depending on burn severity and how owl habitat is determined. Second, there are likely inconsistencies in how agencies determine habitat loss due to natural events and given the varied nature of how owls may use stands post-fire, the following descriptions may likely overestimate the acres that may not longer be usable by spotted owls.

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 2004*a*). 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 - Spotted owl habitat loss on Federal lands 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

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 2004*a*).

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 2004*a*). 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. However, new information indicates that while late-successional and old-growth (LSOG) forest recruitment is occurring at rates initially projected in the NWFP, that recruitment is being surpassed by LSOG loss. Eighty five percent of the LSOG loss was due to wildfires, particularly in the dry-forest provinces (Moeur 2010).

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 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 (2004*b*).
[3] Reported in USFWS (1990*b*) as observed trends from 1981 to 1990.
[4] Estimated in USFWS (1990*b*) 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, Caffrey 2003, Fitzgerald *et al*. 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.

Ishak *et al*. (2008) document Plasmodium spp. in a spotted owl. They also found 10 spotted owls with multiple infections (Ishak *et al.* 2008). It is unclear, however, if this rate of infection is significant and it might affect the recovery of the species.

Inadequacy of Regulatory Mechanisms

The original listing document (USFWS 1990*b*), Franklin and Courtney (2004), and the 5-year review (USFWS 2004*b*) 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 1990*b*). 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 1994*a*, *b*; 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 spotted owl and the goals and objectives of the final revised 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

Barred owls expanded their range from eastern to western North America during the past century. They were first documented in Montana in 1909 (Saunders 1911, 1921), Alberta in 1934 (Preble 1941), British Columbia in 1943 (Rand 1944, Munro and McTaggart-Cowan 1947), Saskatchewan in 1948 (R. Robertson in Houston and McGowan 1999), Washington in 1965 (Rogers 1966), Idaho in 1968 (Rogers 1970), Oregon in 1972 (E. Forsman in Livezey 2009*a*), California in 1976 (B. Marcot in Livezey 2009*a*), Alaska in 1967 (R. Gordon in Livezey 2009*a*), and Northwest Territories in 1977 (Scotter *et al*. 1985). This range expansion evidently was facilitated by increases in distribution of trees in the Great Plains due to exclusion of fires historically set by Native Americans, fire suppression, tree planting, and, during some periods and areas, extirpation of bison and other factors (Dark *et al*. 1998; R. Gutiérrez in Levy 1999, 2004; Mazur and James 2000; USFWS 2003; Livezey 2009*b*). The range of the barred owl (Livezey 2009*a*) now completely overlaps that of its slightly smaller congener, the spotted owl (Gutiérrez *et al*. 1995).

Barred owls have been observed physically attacking spotted owls (pers. comm's in Pearson and Livezey 2003) and circumstantial evidence indicates that a barred owl killed a spotted owl (Leskiw and Gutiérrez 1998). Based on early studies conducted on the west slope of the Washington Cascades (Hamer 1988, Iverson 1993), barred owls were thought by some to be more closely associated with early successional forests than spotted owls are. However, studies throughout North America (Livezey 2007) and recent studies in the Pacific Northwest (Herter and Hicks 2000, Pearson and Livezey 2003, Gremel 2005, Schmidt 2006, Hamer *et al*. 2007, Singleton *et al*. 2010) show that barred owls use, and in some cases, prefer old-growth forest and older forest. More recent studies of the ecological relationships between the two species demonstrated that barred owls nested more often, produced more young per nesting attempt, and suffered lower mortality rates than spotted owls did over a 3-year period (Wiens *et al*. 2009).

Diets of spotted and barred owls in the western Washington Cascades overlap by approximately 76 percent (Hamer *et al*. 2001). Barred owl diets (Livezey 2007, Livezey *et al*. 2008) are more diverse than those of spotted owls (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).

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

- The probability of detecting spotted owls during surveys in Washington, Oregon, and California was significantly reduced by the presence of barred owls (Olson *et al*. 2005, Crozier *et al*. 2006). In the eastern Cascades of Washington, probabilities of detecting any spotted owl or a pair of spotted owls were significantly lower when barred owls were detected during surveys than when no barred owls were detected (Kroll *et al*. 2010). In addition, studies in Oregon showed that detection of both species was negatively influenced by presence of the other (Bailey *et al*. 2009) and barred owls frequently were not detected during surveys for spotted owls (Bailey *et al*. 2009, Wiens *et al*. in press).

- Occupancy of historical territories by spotted owls in study areas in Washington and Oregon 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 (Kelly *et al*. 2003:51). In the Gifford Pinchot National Forest, 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 centered on spotted owl sites (Pearson and Livezey 2003). In the eastern Washington Cascades, barred owls had a significant negative effect on site occupancy by any spotted owl (both single and pair spotted owl detections combined); however, barred owls did not have a negative effect on site occupancy by spotted owl pairs (Kroll *et al*. 2010). Spotted owl simple extinction probabilities (probability that a site center changed from occupied to unoccupied) were significantly higher in the eastern Washington Cascades when barred owls were detected in a site center during the year (Kroll *et al*. 2010). In Olympic National Park, spotted owl pair occupancy declined significantly at sites where barred owls had been detected, whereas pair occupancy remained stable at spotted owl sites without barred owls (Gremel 2005). 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 five percent in the HJ Andrews study area, 12 percent in the Coast Range study area, and 15 percent in the Tyee study area (Olson *et al*. 2005). Barred owls evidently are appropriating spotted owl sites in flatter, lower-elevation forests in some areas (Pearson and Livezey 2003, Gremel 2005, Hamer *et al*. 2007). Apparently in response to barred owls, some marked spotted 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 Washington, 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 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 Washington is prevalent throughout the range of the spotted owl, how long spotted owls can persist 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.

- Reproduction of spotted owls in the Roseburg study area, Oregon, was negatively affected by the presence of barred owls (Olson *et al*. 2004).
- Apparent survival of spotted owls was negatively affected by barred owls in two (Olympic and Wenatchee) of 14 study areas throughout the range of the spotted owl (Anthony *et al*. 2006). The researchers 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 pers. comm. 2006). The conclusion that barred owls had no significant effect on the reproduction of spotted owls in a study area in the western Washington Cascades (Iverson 2004) was unfounded due to small sample sizes (Livezey 2005).

Only 47 spotted owl/barred owl hybrids were detected in an analysis of more than 9,000 banded spotted owls throughout their range (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).

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). 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 (Crozier *et al*. 2006), preliminary response by spotted owls to a scientific collection of barred owls (L. Diller pers. comm. 2010), correlational studies (Kelly *et al*. 2003, Pearson and Livezey 2003, Gremel 2005, Olson *et al*. 2005, Hamer *et al*. 2007), and anecdotal information (Leskiw and Gutiérrez 1998, Gutiérrez *et al*. 2004) suggest that barred owls are negatively affecting spotted owls through exploitive and interference competition. The preponderance of evidence suggests barred owls are contributing to the population decline of spotted owls, especially in Washington, portions of Oregon, and the northern coast of California (Gutiérrez *et al*. 2004, Olson *et al*. 2005).

Loss of Genetic Variation

One possible threat to spotted owls is a loss of genetic variation from population bottlenecks which could lead to increased inbreeding depression and decreased adaptive potential. Funk *et al*. (2010) found evidence of recent genetic bottlenecks in the spotted owl population, estimating these have occurred within the last few decades. They found the strongest evidence for recent bottlenecks in the Washington Cascades, which they correlate with data on significant population declines in the same area. However, they did not find strong evidence of bottlenecks in other areas that showed population declines. While they could not determine "whether inbreeding is contributing to vital rate reductions" (pg. 7), they do caution that "future efforts to conserve northern spotted owl populations will require greater consideration of genetic threats to persistence" (pg. 7).

SEI (2008) reviewed a presentation and two unpublished manuscripts, provided by Dr. Susan Haig, on the evidence for genetic bottlenecks in 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 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).

Appendix C: Habitat Block Network Modeling Process

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).

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

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.

deficiencies identified in the HCA network. The fundamental sizing and 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 1992*b*):

- 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 1992*b*). 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 (2005:21) 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."

Modeling procedures used to develop and evaluate spotted owl habitat conservation networks (2010)

The Service established a modeling team to design and evaluate habitat conservation networks for the spotted owl; the primary modeling team was assisted by an advisory group consisting of spotted owl researchers, agency advisors and modeling specialists.

Primary Modeling Team

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Brian Woodbridge (US Fish and Wildlife Service)
Bruce Marcot (US Forest Service, Pacific Northwest Research Station)
Nathan Schumaker (US Environmental Protection Agency)
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Modeling Advisory Group

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Katie Dugger (Oregon State University)
Marty Raphael (US Forest Service, Pacific Northwest Research Station)
Jim Thrailkill (US Fish and Wildlife Service)
Ray Davis (US Forest Service, Northwest Forest Plan Monitoring Group)
Eric Greenquist (Bureau of Land Management)
Brendan White (US Fish and Wildlife Service)
Jeffrey Dunk (Humboldt State University)
Brian Woodbridge (US Fish and Wildlife Service)
Bruce Marcot (US Forest Service, Pacific Northwest Research Station)

Technical Specialists

Craig Ducey (Bureau of Land Management)
Dan Hansen (Humboldt State University Foundation)
MJ Mazurek (Humboldt State University Foundation)
Karen West (US Fish and Wildlife Service)

General Approach

The Modeling Team employed a multi-step analysis similar to that proposed by Heinrichs *et al.* (2010) and Reed *et al.* (2006) for designing and evaluating habitat conservation networks. Our framework integrates a spotted owl habitat model, conservation reserve design program, and a population simulation model, allowing comparison of estimated spotted owl population performance among alternative habitat conservation network scenarios. This will enable the Service to use relative population viability as a criterion for recommending a habitat conservation network for the spotted owl.

The evaluation approach the modeling team developed consists of three main steps (Fig. C1):

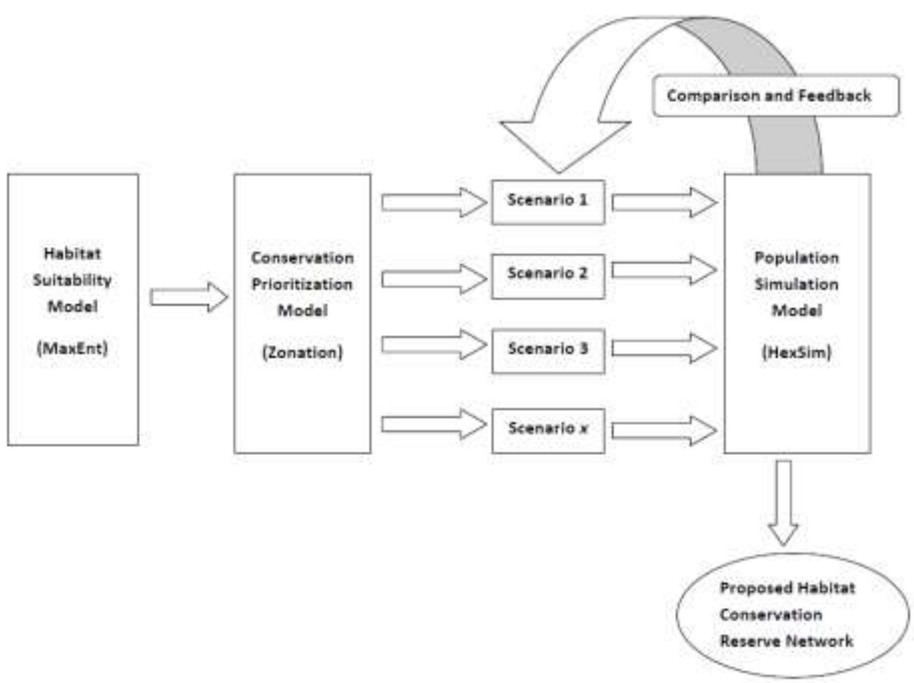
> **Step 1** –create a map of spotted owl habitat suitability throughout the species' U.S. range, based on a statistical model of spotted owl habitat associations.

Step 2 –use a conservation planning model to develop a series of habitat conservation network scenarios based on the habitat suitability map developed in Step 1.

Step 3 – use a population modeling program to test the effectiveness of these habitat conservation network scenarios to lead to recovery of the spotted owl. These simulations are not meant to be estimates of what will occur in the future, but provide information on trends predicted to occur under differing habitat conservation scenarios.

Each of the three steps mentioned above involves statistical and/or mathematical modeling. These models are not meant to be exact predictions of what currently exists or what will occur in the future, but represent our best estimates of current conditions and relationships. The use of these models allows the Service to use powerful, up-to-date, scientific tools in a repeatable, defensible, and scientifically accepted manner to develop and evaluate habitat conservation networks to recover the spotted owl. The Service views the benefit and utility of such models in the same way that Johnson (2001) articulated "*A model has value if it provides better insight, predictions, or control than would be available without the model*," and the modeling tools we've used for this effort meet this standard.

Fig. C1 – Schematic diagram of stepwise modeling process for developing and evaluating habitat conservation networks for the spotted owl.



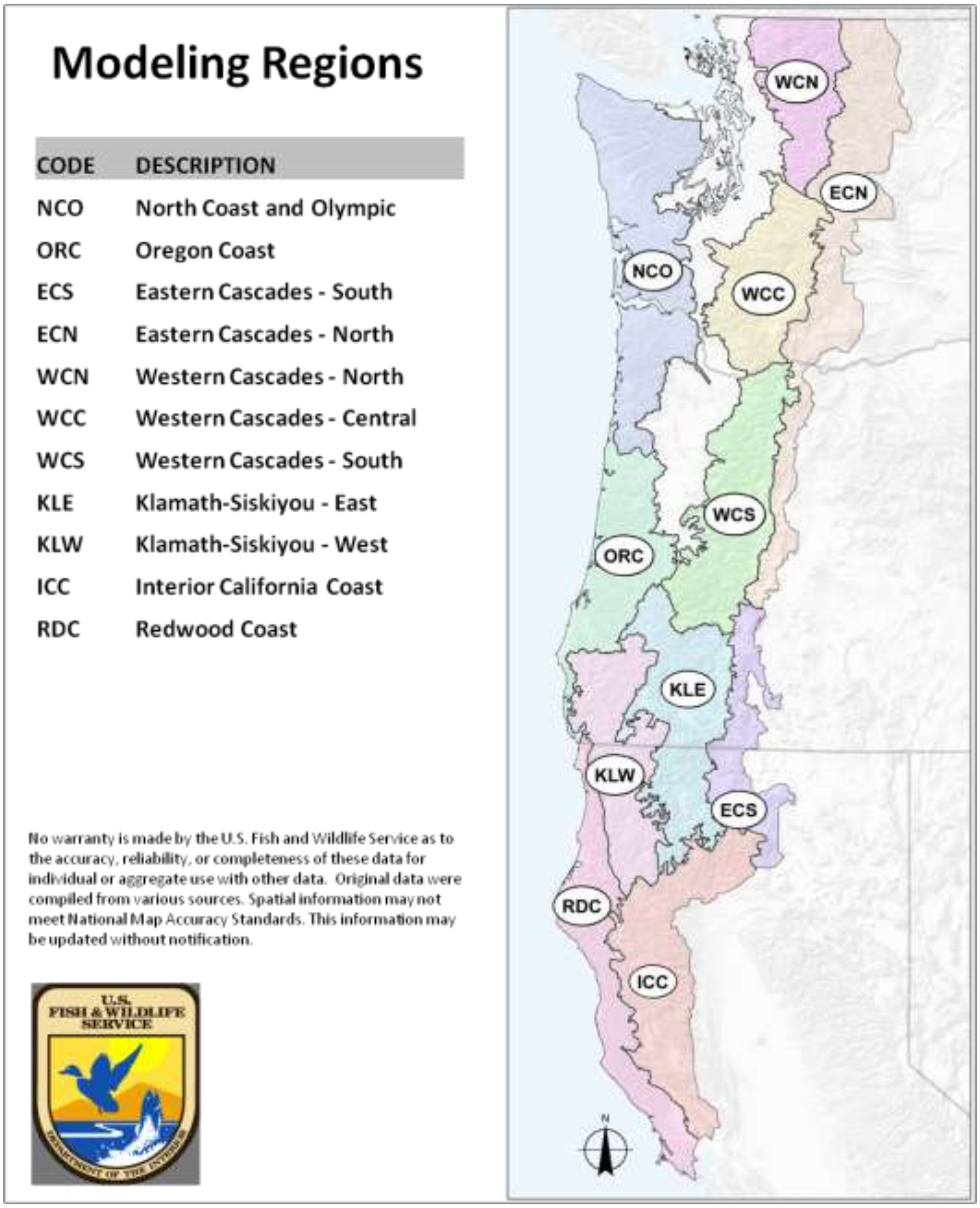
Explanation of each step

Modeling Process Step 1 – Create a spotted owl habitat suitability map covering the entire range of the species (in the U.S.), based on a statistical model of spotted owl habitat associations.

Because the spotted owl is among the most-studied birds in the world, there is a wealth of information on its ecology and habitat associations. To ensure that the modeling effort was based on this scientific foundation, our first step was to conduct an extensive review of published and unpublished information on the species, and convened a series of panel discussions among experts in spotted owl biology and forest ecology throughout the species' range to obtain regional descriptions of spotted owl habitat associations and ecology.

A large number of published studies on spotted owl habitat use and selection have provided insight into how they respond to different habitat conditions within different regions (*e.g.*, the Klamath Mountains vs. the Olympic Peninsula vs. the Cascade Mountains). Therefore, we saw a need to create a habitat suitability map that reflected these geographic differences. Based on our literature review and information gained from the expert panel discussions, we divided the spotted owl's range into 11 distinct "modeling regions" (Fig C2). These modeling regions reflect differences in forest type, elevation, climate, prey communities, and other factors that may influence the spotted owls' relationship to habitat conditions, and subsequently lead to different modeling region-specific models. Spotted owls *within* a modeling region respond to habitat conditions more similarly than do spotted owls in other modeling regions.

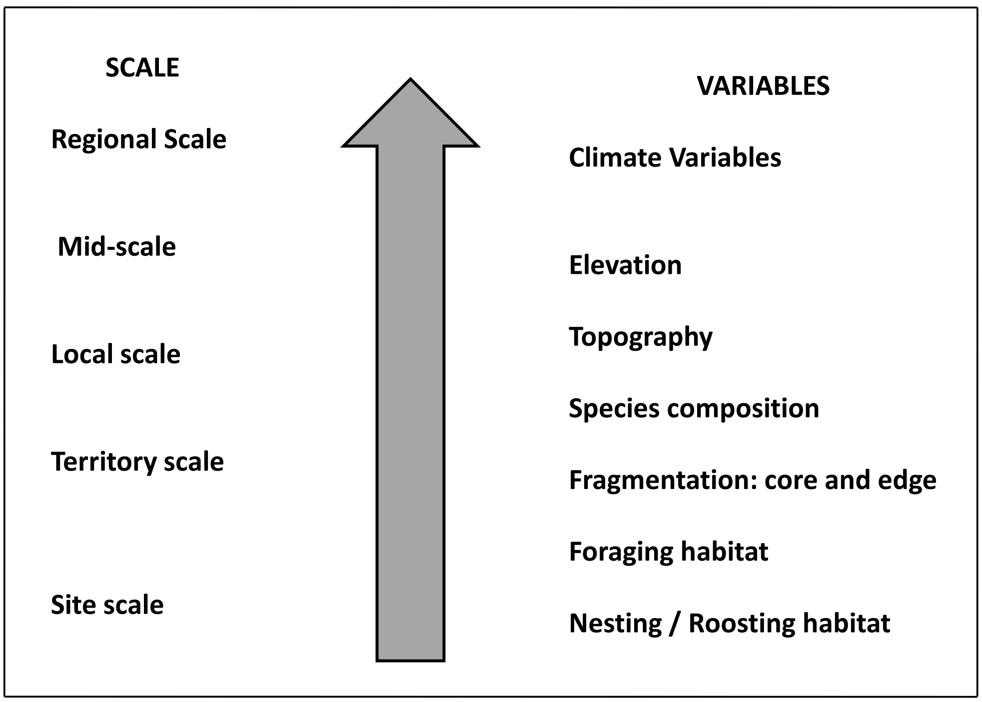
Figure C2 - Modeling regions used in development of habitat suitability models for the spotted owl.



Because spotted owl habitat use is influenced by factors occurring at different spatial scales, we developed a habitat suitability model in two stages. In the first stage we used information from our literature review and habitat expert panels to develop a series of alternative models of forest conditions corresponding to nesting-roosting and foraging habitat within each modeling region. We used a modeling program called "MaxEnt" (Phillips *et al.* 2006, Phillips and Dudik 2008) to test the effectiveness of these models and identify the forest structural models that best predicted the relative likelihood of a spotted owl territory being present. The amount of nesting-roosting habitat then became an important variable in the second stage of the model-building process.

In the second stage we refined the best nesting-roosting forest structure model for each modeling region by adding additional variables corresponding to tree species composition, habitat fragmentation, topography, elevation and climate (Fig. C3) and iteratively testing these new combinations of variables using the MaxEnt program.

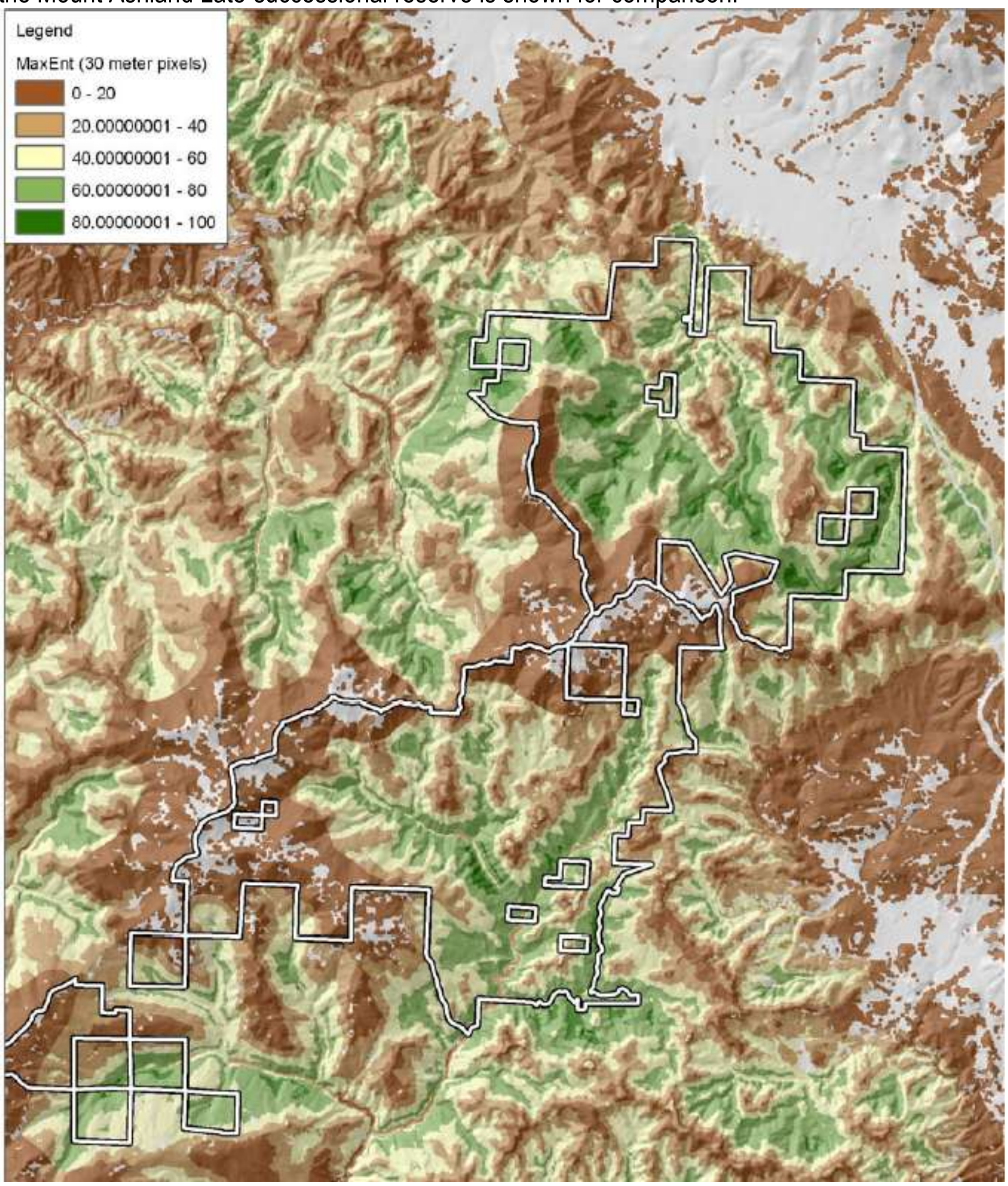
Figure C3 - Ecological scales and environmental variables used to model habitat suitability for spotted owl territories.



We modeled relative habitat suitability of spotted owls at the scale of a 500-acre territory. We obtained approximately 4,000 spotted owl nesting locations from monitoring studies, Federal, state and tribal agencies, and private land owners. MaxEnt compared spotted owl nesting locations to a random sample of ~10,000 random locations within each modeling region in order to distinguish nesting locations from the rest of the landscape. Once the best models were created for each modeling region, they were rigorously evaluated and found to provide reliable, robust predictions of habitat suitability. The MaxEnt models provide predictions of the relative habitat suitability of all locations within the landscape (not only the spotted owl locations and the ~10,000 random locations).

Once the best habitat models were created and evaluated for each of the modeling regions, we combined the individual modeling region maps into a single range-wide map of spotted owl habitat suitability. When displayed as a map with different colors representing different relative habitat suitability values (Fig. C4), the distribution of areas with varying habitat value to the spotted owl can be portrayed, as well as analyzed to evaluate differences among landowners (*e.g.*, BLM, USFS, private) or land use allocation (Wilderness, LSR, matrix).

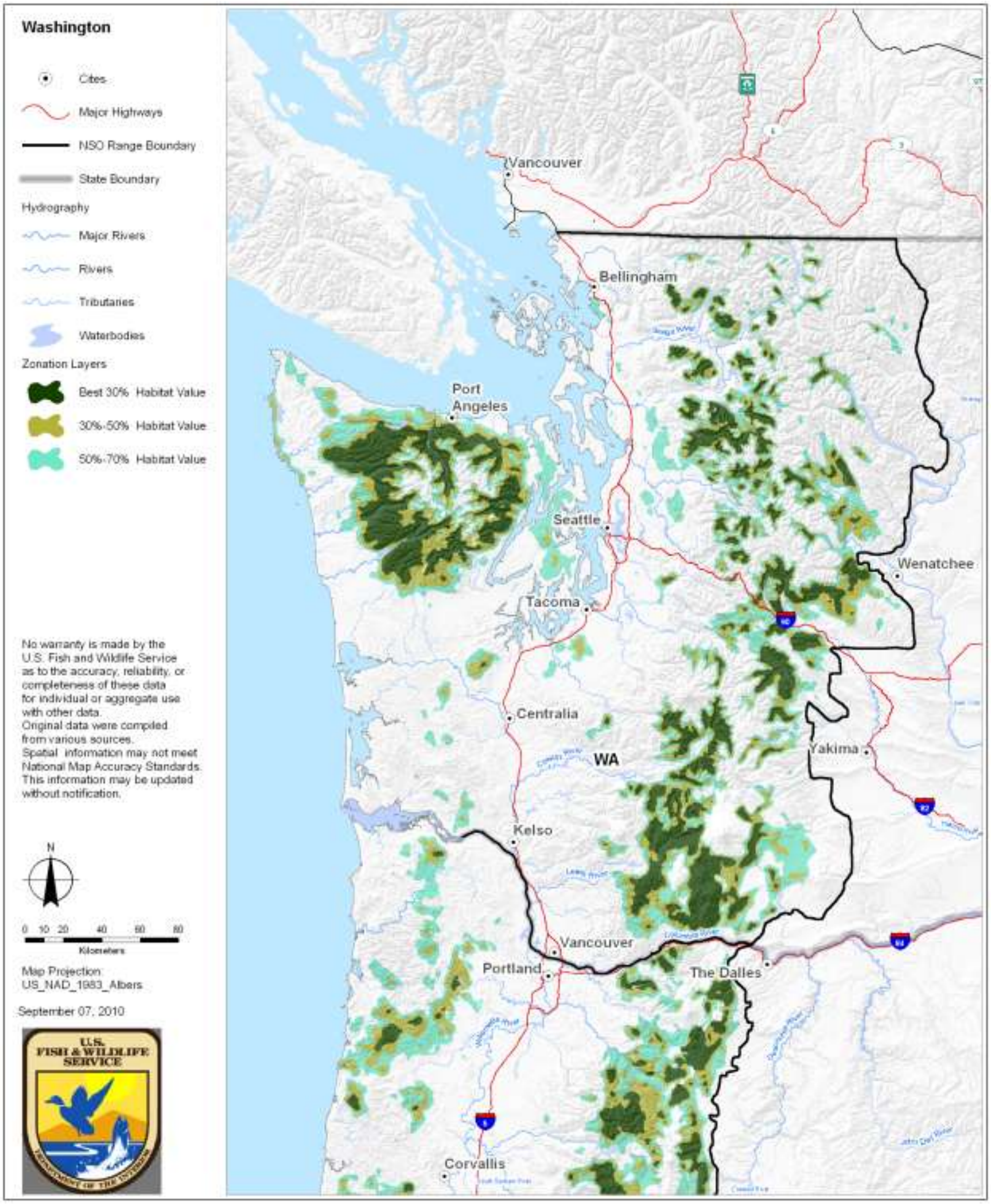
Figure C4 - Map depicting Relative Habitat Suitability from MaxEnt model. Higher suitability habitat conditions are indicated by darker green areas; brown colors denote lower suitability. Outline of the Mount Ashland Late-successional reserve is shown for comparison.

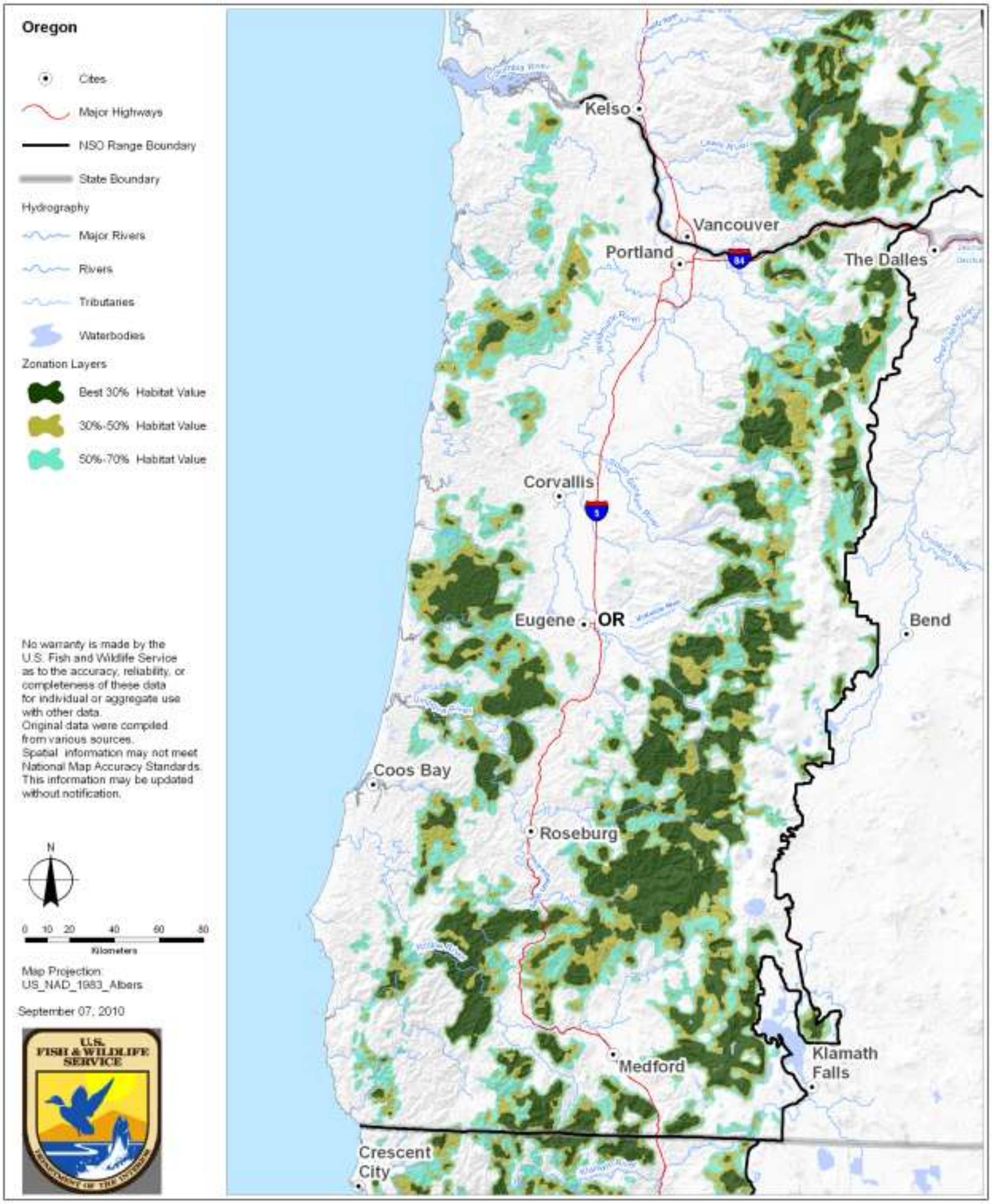


Modeling Process Step 2 – Use a conservation planning model to develop a series of habitat conservation network scenarios based on the habitat suitability map developed in Step 1.

Because the Relative Habitat Suitability maps from Step 1 consisted of finely-distributed patterns of habitat suitability across the owls' geographic range, the Service required a rigorous, repeatable method for aggregating habitat value into networks of habitat conservation priority areas or habitat blocks. We used the conservation planning model "Zonation" (Moilanen and Kujala 2008) to map a series of alternative spotted owl conservation priority area scenarios based on a series of rule-sets (*e.g.*, varying land ownership categories, the inclusion of existing reserves, identifying a specific amount of "habitat value" to include in the strategy). The primary output of a Zonation analysis of the landscape is a "hierarchical ranking" of conservation priority of all cells or pixels (Fig. 4) in the landscape. Zonation allows analysts to incorporate species-specific factors such as dispersal capabilities and response to habitat fragmentation into the ranking of cells. Zonation also allows the inclusion of political and social realities into various evaluations. For example it allows the analyst to identify areas that must be or must not be included in the conservation network. For example, existing reserves such as Wilderness Areas and National Parks can be "forced" into the priority areas, regardless of their habitat suitability. Similarly, various land ownership categories can be excluded from inclusion. The Zonation output includes the hierarchical ranking of habitat value across large landscapes (subject to restrictions as noted above) and allows analysts to identify specific areas of the landscape that represent a particular percentage of the total estimated habitat value to the species (Figs. 5a-f). In one Zonation scenario the modeling team estimated that 70% of the habitat value existed on ~40% of the landscape.

Fig. C5 a,b,c - Zonation maps displaying three habitat value groupings (best 30%, 30-50%, and 50-70%) as derived by modeling region in Washington (map C5a), Oregon (map C5b) and California (map C5c). These habitat value groupings are for display only and do not representation a proposed habitat conservation network.




Oregon
Cites
Major Highways
NSO Range Boundary
State Boundary
Hydrography
Major Rivers
Rivers
Tributaries
Waterbodies
Zonation Layers
Best 30% Habitat Value
30%-50% Habitat Value
50%-70% Habitat Value
No warranty is made by the U.S. Fish and Wildlife Service as to the accuracy, reliability, or completeness of these data for individual or aggregate use with other data.
Original data were compiled from various sources.
Spatial information may not meet National Map Accuracy Standards.
This information may be updated without notification.
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Coos Bay
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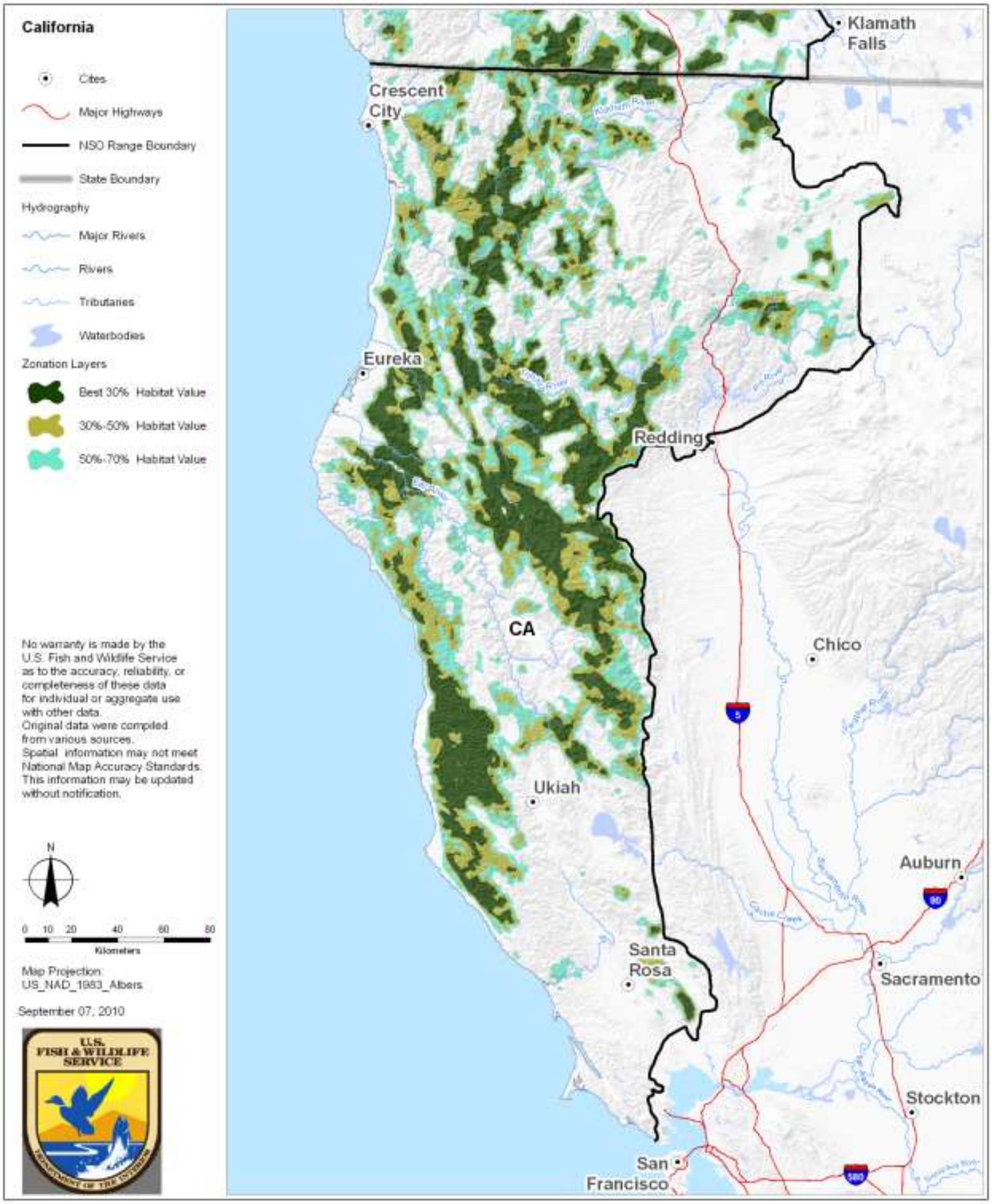
Medford
Klamath Falls
Crescent City


California
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Major Highways
NSO Range Boundary
State Boundary
Hydrography
Major Rivers
Rivers
Tributaries
Waterbodies
Zonation Layers
Best 30% Habitat Value
30%-50% Habitat Value
50%-70% Habitat Value
No warranty is made by the U.S. Fish and Wildlife Service as to the accuracy, reliability, or completeness of these data for individual or aggregate use with other data. Original data were compiled from various sources. Spatial information may not meet National Map Accuracy Standards. This information may be updated without notification.
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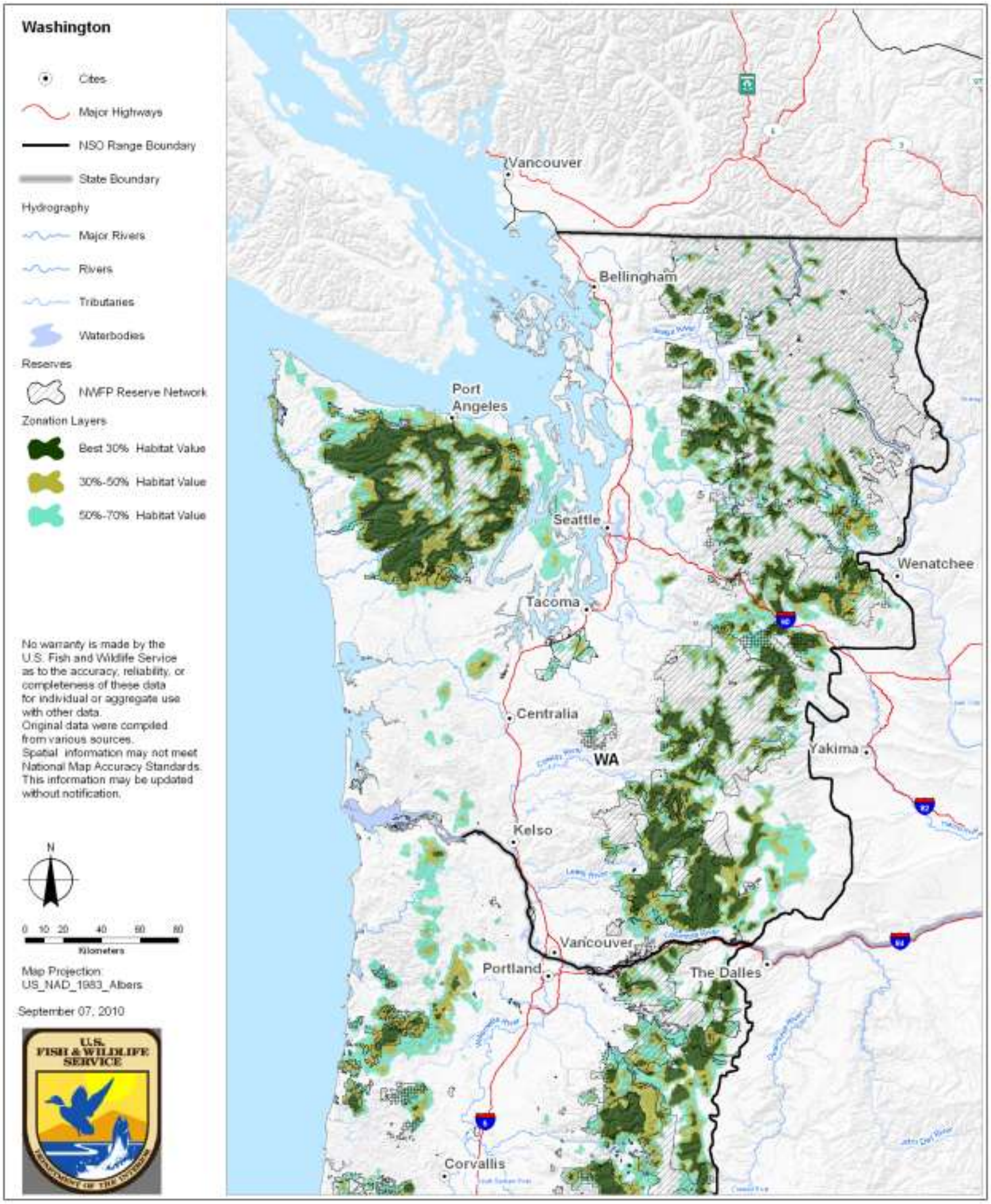
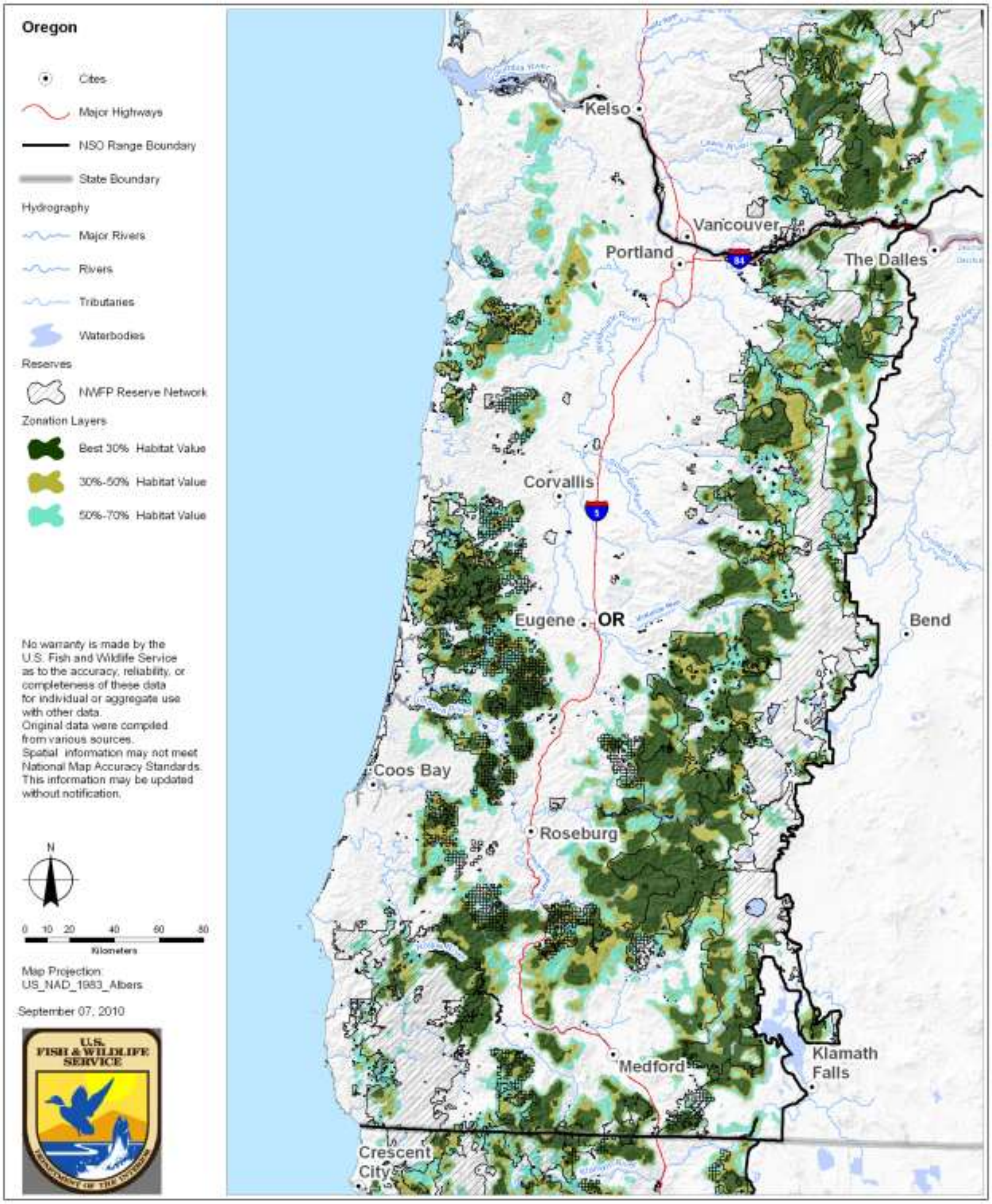
Auburn
Santa Rosa
Sacramento
Stockton
San Francisco

Fig. C5 d,e,f - Zonation maps displaying three habitat value groupings (best 30%, 30-50%, and 50-70%) as derived by modeling region in Washington (map C5d), Oregon (map C5e) and California (map C5f) with NWFP reserves overlaid for reference. These habitat value groupings are for display only and do not representation a proposed habitat conservation network.




Oregon
Cites
Major Highways
NSO Range Boundary
State Boundary
Hydrography
Major Rivers
Rivers
Tributaries
Waterbodies
Reserves
NWFP Reserve Network
Zonation Layers
Best 30% Habitat Value
30%-50% Habitat Value
50%-70% Habitat Value
No warranty is made by the
U.S. Fish and Wildlife Service
as to the accuracy, reliability, or
completeness of these data
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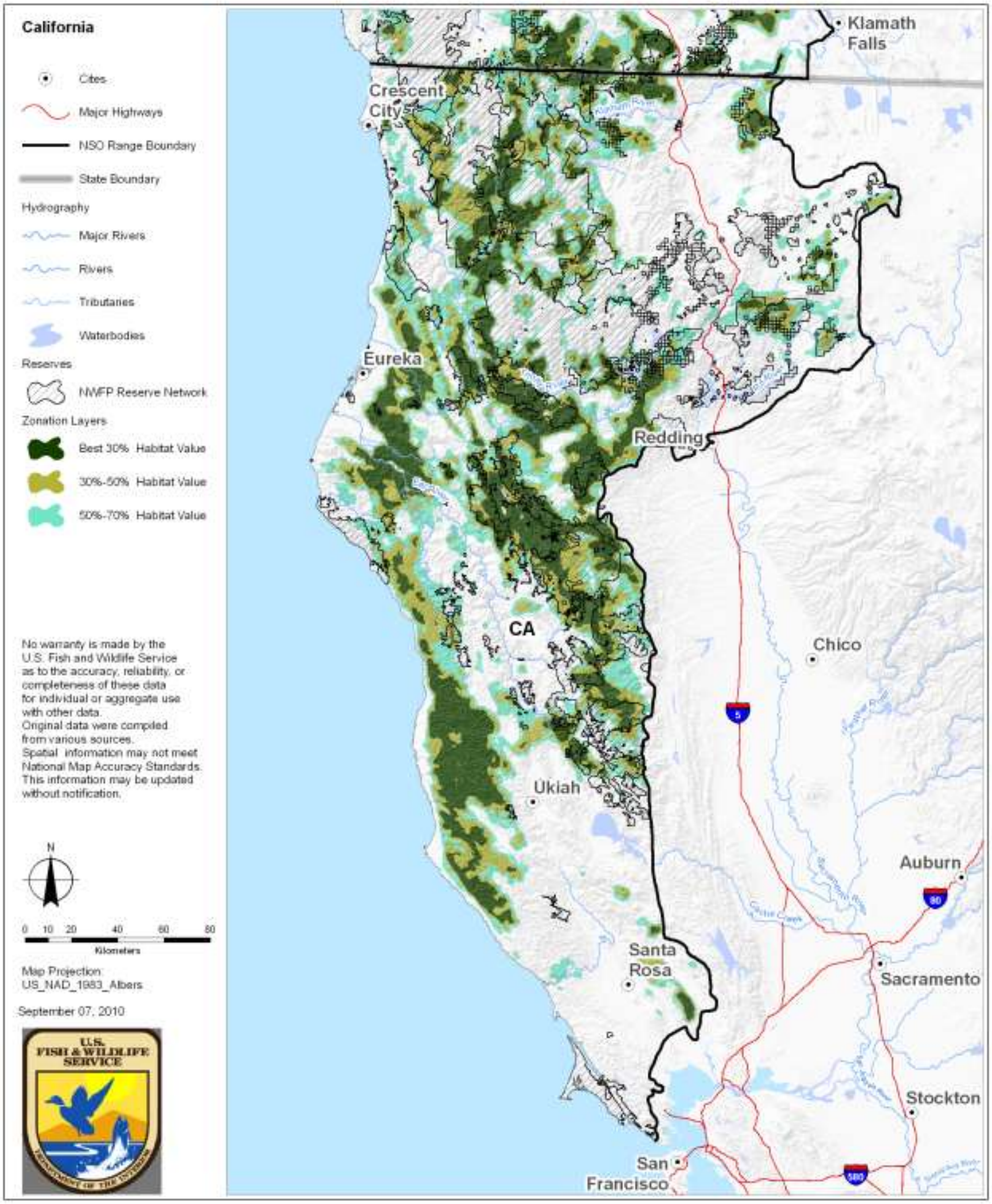
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Major Highways
NSO Range Boundary
State Boundary
Hydrography
Major Rivers
Rivers
Tributaries
Waterbodies
Reserves
NWFP Reserve Network
Zonation Layers
Best 30% Habitat Value
30%-50% Habitat Value
50%-70% Habitat Value
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Stockton
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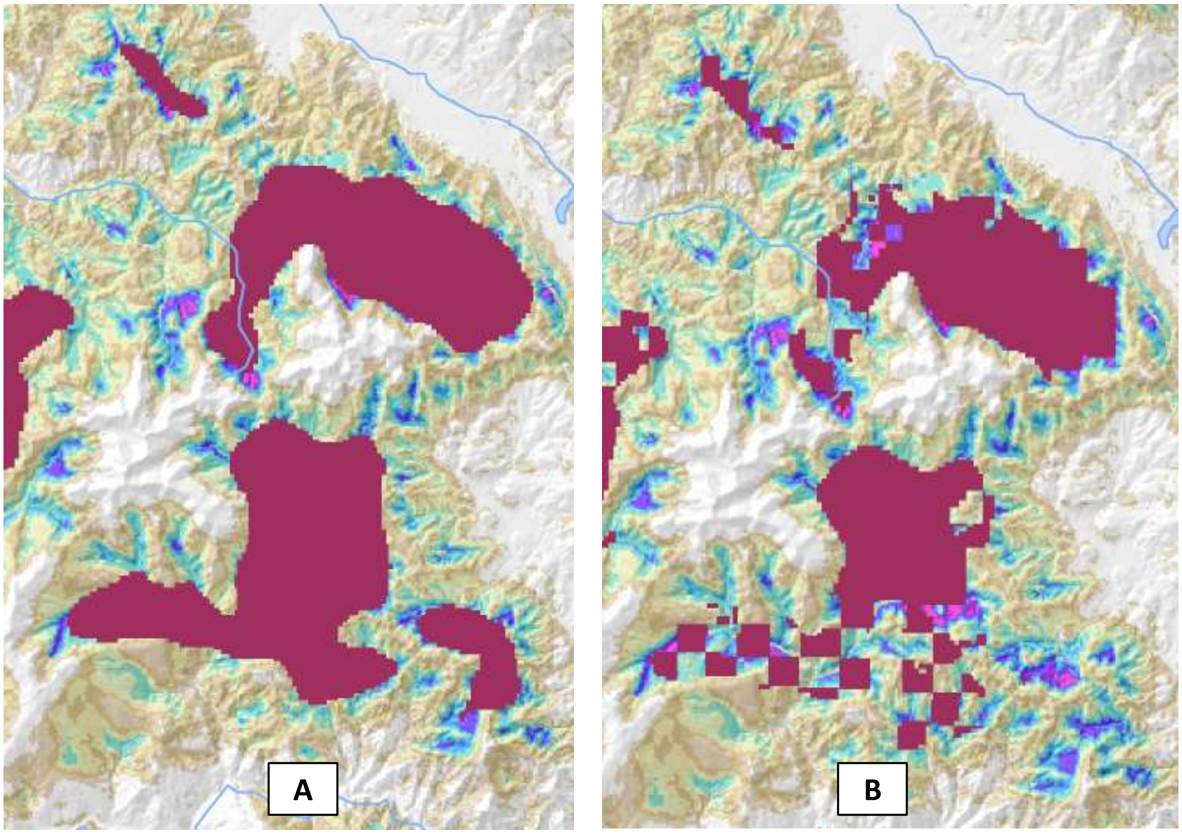
The Service used Zonation to develop a series of habitat conservation network scenarios based on different combinations of land ownership and proportion of total habitat value for spotted owls (Fig. C6). It is important to recall that these scenarios are not recommendations for habitat reserves – they are only scenarios for the purpose of comparing to other scenarios to evaluate how they influence spotted owl population performance (step 3). Land ownership scenarios evaluated include:

1) **No limit on inclusion** – All land ownerships were allowed to be included and existing reserves were not forced into the priority areas. This scenario was chosen to represent the potential of the entire area to provide for spotted owls.
2) **Public lands only** – Only publicly owned lands (Federal or State) were allowed to be included in the conservation priority areas.
3) **Federal lands only** – Only federally administered lands were allowed to be included in the conservation priority areas.

To incorporate geographic variability in the amount and distribution of habitat suitability across the owls' range, Zonation analyses were conducted separately for each modeling region. This modeling region decision also had the impact of ensuring that conservation areas would be better distributed across the range of the species. For each of the land ownership/land use allocation scenarios shown above, we evaluated habitat conservation networks that represented 30%, 50%, and 70% of the habitat value resulting in three habitat conservation network scenarios for each ownership/allocation scenario. The Service then evaluated a range of these scenarios to determine the subset that would be subjected to population modeling in Step 3.

Figure C6 - Example Zonation output map of the Mount Ashland, OR, area, depicting the best 30 percent of Relative Habitat Suitability in red on all lands (A) and on federal lands only (B).



Modeling Process Step 3 - Use a population modeling program to test the effectiveness of the habitat conservation network scenarios from Step 2 to lead to recovery of the spotted owl. These simulations are not meant to be estimates of what will occur in the future, but provide information on trends predicted to occur under differing habitat conservation network scenarios.

We are currently implementing this part of the modeling process and anticipate having preliminary results in the near future. We will use the habitat conservation network scenarios created during Step 2 as inputs into a population simulation program called HexSim (Schumaker 2008, Heinrichs *et al.* 2010).

This program was designed to simulate a population's response to various on-the-ground conditions over time by considering how those conditions influence the organism's survival, reproduction, and ability to move around the landscape. For a subset of the Modeling Process Step 2 habitat conservation network scenarios created, we will create several HexSim scenarios by varying how and where habitats change in value through time, and varying possible impacts of barred owls on spotted owl populations. These simulations are not meant to be estimates of what will necessarily occur in the future, but to provide information on spotted owl population trends that may occur under differing scenarios and to help evaluate the contribution of the varying conservation network scenarios to spotted owl recovery. For example, some scenarios may result in a much larger percentage of simulated spotted owl populations declining, or going extinct. The intention of the simulations is to evaluate the relative impact of variation in habitat conservation network size and distribution, habitat changes, and barred owl impact scenarios on spotted owl population performance. The resulting comparisons will inform the Service's proposal of a final habitat conservation network.

HexSim is a spatially-explicit, individual-based life history simulator. This means that analysts typically supply maps of landscape condition, data on birth and death rates, movement behavior, and other information known or surmised about a population or species. The model then simulates a population of individuals living, moving about, and dying within a computer landscape. The more that is known about an organism's life history, the more robust the model output generally is. Many species' biology is poorly known, and thus there aren't good estimates of their age-specific birth and death rates, or how those rates relate to habitat conditions. The spotted owl, in contrast, is well studied and we have reasonable estimates for these variables.

HexSim applications usually employ a habitat suitability map. In our case, this is the range-wide habitat suitability map created during Step 1. An initial spotted owl population is placed into this landscape when the model starts. Each of these owls then conducts its life cycle, as the model advances forward in time. There are feedbacks between the landscape condition and the spotted owl life history. For example, dispersing spotted owls attempt to construct territories in better habitats, but owl territories cannot overlap. Resources are acquired from spotted owl home ranges, and home ranges can overlap. Thus individuals compete for resources, and their annual survival rates are influenced by the outcome of this competition. The Modeling Team developed rules within HexSim based on published information, and several different analyses. Among other things, these rules determined: A) when an area was good enough to allow an individual to settle, B) how much area the owl would need within its home range (more area in poorer-quality habitats and less area in higher-quality habitats), and C) what the relationship between spotted owl survival and habitat quality was.

Our objective in step 3 is to evaluate spotted owl population performance relative to three primary sources of variation: size (area) of habitat conservation networks, trends in habitat conditions inside and outside of the habitat conservation networks, and trends in the influence of barred owls.

In order to evaluate the influence of habitat conservation network size (area) on spotted owl population performance, we will analyze a subset of the habitat conservation network scenarios from Step 2 representing a wide range of sizes (proportions of "habitat value"). We are also evaluating existing habitat conservation networks such as the Northwest Forest Plan land allocations, MOCAs from the 2008 Recovery Plan, and both 1992 and 2008 spotted owl critical habitat designations.

The Modeling Team evaluated the change in spotted owl habitat suitability between 1996 and 2006 to obtain estimates of how and where the landscape changed between 1996 and 2006. Although this 10-year time period may not be representative of "normal" changes, it at least provides an estimate of what *can* happen during a 10-year period.

Based on these changes in habitat suitability (1996 – 2006), the Modeling Team developed and is evaluating in HexSim a series of habitat change scenarios ranging from no change in habitat suitability (2006 conditions for 200 years), to increases in habitat suitability over time (with greater increases in reserves), to decreases in habitat suitability over time. These forecasts allow simulated spotted owls in the model to respond to various changes in habitat conditions in the simulated environment.

We will also evaluate the significance for the simulated owl populations of changes to the abundance, distribution, and impacts of barred owls. This will be done by evaluating several different barred owl scenarios, including: 1) our best approximation of the current condition; 2) a reduced impact of barred owls potentially resulting from efforts to control their numbers in portions of the spotted owls' range; and 3) an increased impact of barred owls as a result of their continued expansion in range and numbers. As with habitat change scenarios, simulated spotted owls will be allowed to respond to changes in barred owl numbers and influence through time.

The results of each HexSim simulation run will be estimates of population size, population trend, and probability of extinction, at both range-wide and regional scales.

Comparison of these population performance estimates across the range of scenarios incorporating variation in habitat conservation network sizes, habitat trends, and barred owl influence, will inform the Service's proposal of a habitat conservation network designed to lead to spotted owl recovery.

Appendix D. 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), which provided the scientific review for the draft spotted owl recovery plan of 2007. Although specific portions of this text present material that raised concerns by peer reviewers, such as some specific landscape management recommendations, we have retained much of this as background and general information to inform recovery of spotted owls in dry-forest provinces.

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 2007), 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 E: 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, Cooperative Park Studies Unit, Seattle, Washington.

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

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 Ecology 18:725–740.

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

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

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. U.S. Forest Service Proceedings RMRS-P-41, 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. 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.

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.

Antos, J.A., and J.R. Habeck. 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. U.S. Forest Service Research Paper INT-RP-187, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Arno, S.F., and D.H. Davis. 1980. Fire history of western redcedar/hemlock forests in northern Idaho. Pages 21–26 *in* M.A. Stokes and J.H. Dieterich, editors. Proceedings of the fire history workshop. U.S. Forest Service General Technical Report RM-GTR-81, Rocky Mountain Forest and Range Experiment Station, Ft. Collins, Colorado.

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

Bailey, L.L., J.A. Reid, E.D. Forsman, and J.D. Nichols. 2009. Modeling co-occurrence of northern spotted and barred owls: accounting for detection probability differences. Biological Conservation 142:2983–2989.

Barbour, M.G., and W.D. Billings. 2000. North American terrestrial vegetation. Second 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. Pacific Northwest Research Station, Portland, Oregon.

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.

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.

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

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.

Beschta R.L., J.J. Rhodes, J.B. Kauffman, R.E. Gresswell, G.W. Minshall, J.R. Karr, D.A. Perry, F.R. Hauer and C.A. Frissell. 2004. Postfire management on forested public lands of the western United States. Conservation Biology 18:957–967.

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.

Bond, M.L., D.E. Lee, R.B. Siegel, and J.P. Ward, Jr. 2009. Habitat use and selection by California spotted owls in a postfire landscape. Journal of Wildlife Management 73:1116-1124.

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

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

Buchanan, J.B., R.J. Gutiérrez, 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.

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. 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.

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, Ft. Collins, Colorado.

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.

Candell, J.G., and M.R. Raupch. 2008. Managing forests for climate change mitigation. Science 320: 1456-1457. Carey, A.B. 2003*a*. Biocomplexity and restoration of biodiversity in temperate coniferous forest. Forestry 76:131–140.

Carey, A.B. 2003*b*. 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. U.S. Forest Service General Technical Report PNW-GTR-721, Pacific Northwest Research Station, Portland, Oregon.

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

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

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.

Carroll, C. and D.S. Johnson. 2008. The importance of being spatial (and reserved): assessing northern spotted owl habitat relationships with hierarchical Bayesian models. Conservation Biology 22: 1026-1036.

Case, M.J. and D.L. Peterson. 2009. Growth-climate relations of lodgepole pine in the North Cascades National Park, Washington. Northwest Science 81:62–74.

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, Canada.

Clark, D.A. 2007. Demographic and habitat selection of northern spotted owls in post-fire landscapes of southwestern Oregon. Thesis. Oregon State University, Corvallis.

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.

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.

Courtney, S. and R. Gutiérrez. 2004. Chapter 11 *in* S. Courtney, editor. 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.

Dale, V.H., L.A. Joyce, S. McNulty, R.P. Neilson, M.P. Ayres, M.D. Flannigan, P.J. Hanson, L.C. Irland, A.E. Lugo, C.J. Peterson, D. Simberloff, F.J. Swanson, B.J. Stocks, and B.M. Wotton. 2001. Climate change and forest disturbances. BioScience 51: 723–734.

Daley, C., D.R. Conklin, and M.H. Unsworth. 2009. Short communication: local atmospheric decoupling in complex topography alters climate change impacts. International Journal of Climatology. <http://onlinelibrary.wiley.com/doi/10.1002/joc.2007/abstract>.

Dark, S.J., R.J. Gutiérrez, and G.I. Gould, Jr. 1998. The Barred Owl (*Strix varia*) invasion in California. Auk 115:50–56.

Davis, K.M., B.D. Clayton, and W.C. Fischer. 1980. Fire ecology of Lolo National Forest habitat types. U.S. Forest Service General Technical Report INT-GTR-79, 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. U.S. Forest Service General Technical Report PNW-GTR-648, Pacific Northwest Research Station, Portland, Oregon.

DellaSala, D.A., J.R. Karr, T. Schoennagel, D. Perry, R.F. Noss, D. Lindenmayer, R. Beschta, R.L. Hutto, M.E. Swanson and J. Evans. 2006. Post-fire logging debate ignores many issues. Science 314:51.

Depro, B.M., B.C. Murray, R.J. Alig and A. Shanks. 2008. Public land, timber harvests, and climate mitigation: Quantifying carbon sequestration potential on U.S. public timberlands. Forest Ecology and Management 255: 1122-1134.

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.

Donato, D.C., J.B. Fontaine, J.L. Campbell, W.D. Robinson, J.B. Kauffman and B.E. Law. 2006. Post-fire logging hinders regeneration and increases fire risk. Science 311:352.

Dugger, K.M., R.G. Anthony and L.S. Andrews. In Review. Transient dynamics of invasive competition: barred owls, spotted owls, habitat composition and the demons of competition present.

Dugger, K. and R.G. Anthony and E.D. Forsman. 2009. Estimating northern spotted owl detection probabilites: updating the USFWS Northern Spotted Owl Survey Protocol. Final Report. Dept. of Fisheries and Wildlife, Oregon State University, Corvallis.

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.

Dukes, J.S. and H.A. Mooney. 1999. Does global change increase the success of biological invaders? Tree 14:135–139.

Elsner, M.M., L. Cuo, N. Voisin, J.S. Deems, A.F. Hamlet, J.A Vano, K.E.B. Michelson, S. Lee, and D.P. Lettenmaier. 2009. Implications of 21st century climate change for the hydrology of Washington State. Pages 69–106 *in* M.M. Elsner, J. Littell, and L.W. Binder, editors. The Washington climate change impacts assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle.

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. Unpublished. U.S. 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. U.S. Forest Service General Technical Report PNW-GTR-610. 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. Thesis, Oregon State University, Corvallis.

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

Forsman, E.D., R.G. Anthony, K.M. Dugger, E.M. Glenn, A.B. Franklin, G.C. White, C.J. Schwarz, K.P. Burnham, D.R. Anderson, J.D. Nichols, J.E. Hines, J.B. Lint, R.J. Davis, S.H. Ackers, L.S. Andrews, B.L. Biswell, P.C. Carlson, L.V. Diller, S.A. Gremel, D.R. Herter, J.M. Higley, R.B. Horn, J.A. Reid, J. Rockweit, J. Schaberl, T.J. Snetsinger, and S.G. Sovern. 2010. Population demography of northern spotted owls: 1985–2008. Studies in Avian Biology. Cooper Ornithological Society. In press.

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.

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., 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., 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., 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.

Foster, D.R. and D.A. Orwig. 2006. Preemptive and salvage harvesting of new England forests: when doing nothing is a viable alternative. Conservation Biology 20:959–970.

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 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.

Franklin, J.F., K.J. Cromack, W. Dennison, A. McKee, C. Maser, J. Sedell, F.J. Swanson, and G. Juday. 1981. Ecological characteristics of old-growth Douglas-fir forests. U.S. Forest Service General Technical Report PNW-GTR-118, Pacific Northwest Research Station, Portland, Oregon.

Franklin, J.F., R.J. Mitchell, and B.J. Palik. 2007. Natural disturbance and stand development principles for ecological forestry. U.S. Forest Service General Technical Report NRS-GTR-19, Northern Research Station, Newtown Square, Pennsylvania.

Funk, W.C., E.D. Forsman, M. Johnson, T.D. Mullins, and S.M. Haig. 2010. Evidence for recent population bottlenecks in northern spotted owls (*Strix occidentalis caurina*). Conservation Genetics 11:1013-1021

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. 2009. Local weather, regional climate, and population dynamics of northern spotted owls in Washington and Oregon. Dissertation, Oregon State University, Corvallis.

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.

Graumlich, L.J., L.B. Brubaker, and C.C. Grier. 1989. Long-term trends in forest net primary productivity: Cascade Mountains, Washington. Ecology 70:405–410.

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

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

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

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.

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

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.

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

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

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. U.S. Forest Service General Technical Report PNW-GTR-418, 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. Thesis, Western Washington University, Bellingham.

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., 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.

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.

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. U.S. Forest Service General Technical Report PNW-GTR-405, Pacific Northwest Research Station, Portland, Oregon.

Hanson, C.T., D.C. Odion, D.A. DellaSala, and W.L. Baker. 2009. Overestimation of fire risk in the Northern Spotted Owl Recovery Plan. Conservation Biology 23:1314-1319.

Hanson, C.T., D.C. Odion, D.A. DellaSala, and W.L. Baker. 2010. More-comprehensive recovery actions for northern spotted owls in dry forests: reply to Spies *et al.* Conservation Biology 24:334-337.

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.

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

Heinrichs, J.H., D.H. Bender, D.L. Gummer, and N.H. Schumaker. 2010. Assessing critical habitat: evaluating the relative contributions of habitats to population persistence. Biological Conservation 143:2229-2237.

Heinselman, M.L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area, Minnesota. Quaternary Research 3:329-382.

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.

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.

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., 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.

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. U.S. Forest Service General Technical Report PNW-GTR-327, 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. U.S. Forest Service General Technical Report PNW-GTR-458, 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.

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.

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. 1979*a*. Plant associations of the Fremont National Forest. U.S. Forest Service R6-ECOL-79-004, Pacific Northwest Region, Portland, Oregon.

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

Houston, S. and K.J. McGowan. 1999. The westward spread of the Barred Owl. Blue Jay 57:190–195.

Huff, M.H., R.D. Ottmar, E. Alvarado, R.H. Vihanek, J.F. Lehmkuhl, P.F. Hessburg, and R.L. Everett. 1995. Historical and current forest landscapes of eastern Oregon and Washington. Part II: linking vegetation characteristics to potential fire behavior and related smoke production. *In* P.F. Hessburg, editor. Eastside Forest Ecosystem Health Assessment: Volume III: Assessment. U.S. Forest Service General Technical Report PNW-GTR-355, Pacific Northwest Research Station, Portland, Oregon.

Hurteau, M.D., G.W. Koch and B.A. Hungate. 2008. Carbon protection and fire risk reduction: toward a full accounting of forest carbon offsets. Front. Ecol. Environ. 6(9): 493-498.

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.

Ishak, H.D., J.P. Dumbacher, N.L. Anderson, J.J. Keane, G. Valkiunas, S.M. Haig, L.A. Tell, and R.N.M. Sehgal. 2008. Blood parasites in owls with conservation implications for the spotted owl (*Strix occidentalis*). PLoS ONE, 2008; 3 (5): e2304.

Iverson, W.F. 1993. Is the barred owl displacing the spotted owl in western Washington? 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.

Jenness, J.S., P. Beier, and J.L. Ganey. 2004. Associations between forest fire and Mexican spotted owls. Forest Science 50:765-772.

Johnson, D. H. 2001. Validating and evaluating models. Pages 105–119 *in* T. M. Shenk and A. B. Franklin, editors. Modeling in natural resource management. Island Press, Covelo, California.

Johnson, K.N. and J.F. Franklin. 2009. Restoration of federal forests in the Pacific Northwest: strategies and management implications. Oregon State University, Corvallis.

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.

Karr, J.R., J.J. Rhodes, G.W. Minshall, F.R. Hauer, R.L. Beschta, C.A. Frissell and D.A. Perry. 2004. The effects of postfire salvage logging on aquatic ecosystems in the American west. BioScience 54:1029–1033.

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.

Keith, H., B.G. Mackey and D.B. Lindenmayer. 2010. Re-evaluation of forest biomass carbon stocks and lessons form the world's most carbon-dense forests. Proceedings of the National Academy of Science (www.pnas.org/cgi/doi/10.1073/pnas.0901970106).

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.

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.

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.

Kennedy, R., P. Hessburg, J. Lehmkuhl, B. Marcot, M. Raphael, P. Singleton, and T. Spies. Unpublished. Assessing the compatibility of fuel treatments, wildfire risk, and conservation of northern spotted owl habitats and poplations in the eastern Cascades: a multi-scale analysis. Proposal submitted to the Joint Fire Science Program, Boise, Idaho.

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.

Klock, G.O. 1975. Impact of five postfire salvage logging systems on soils and vegetation. Journal of Soil and Water Conservation 30: 78–81.

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.

Kroll, A.J., T.L. Fleming, and L.L. Irwin. 2010. Site occupancy dynamics of northern spotted owls in the eastern Cascades, Washington, USA, 1990–2003. Journal of Wildlife Management 74:1264-1274.

Lehmkuhl, J.F., L.E. Gould, E. Cazares, D.R. Hosford. 2004. Truffle abundance and mycophagy by northern flying squirrels in eastern Washington forests. Forest Ecology and Management 200:49–65.

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.

Lehmkuhl, J.F., K.D. Kistler, and J.S. Begley. 2006a. Bushy-tailed woodrat abundance in dry forests of eastern Washington. Journal of Mammalogy 7:371-379.

Lehmkuhl, J.F., K.D. Kistler, J.S. Begley, and J. Boulanger. 2006*b*. Demography of northern flying squirrels informs ecosystem management of western interior forests. Ecological Applications 16:584–600.

Lertzman, K., J. Fall, and B. Dorner. 1998. Three kinds of heterogeneity in fire regimes: at the crossroads of fire history and landscape ecology. Northwest Science 72(Special Issue):4-23

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

Levy, S. 1999. Owl vs. owl. Natural History 108:28–32.

Levy, S. 2004. Native incursions: avian range expansions imperil threatened species. BioScience 54:94–98.

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. U.S. Forest Service General Technical Report PNW-GTR-359, Pacific Northwest Research Station, Portland, Oregon.

Lindenmayer, D.B., P.J. Burton, and J.F. Franklin. 2008. Salvage logging and its ecological consequences. Island Press, Washington, D.C.

Lindenmayer, D.B., D.R. Foster, J.F. Franklin, M.L. Hunter, R.F. Noss, F.A. Schmiegelow and D. Perry. 2004. Salvage harvesting policies after natural disturbance. Science 303:1303.

Lindenmayer, D.B., and R.F. Noss. 2006. Salvage logging, ecosystem processes, and biodiversity conservation. Conservation Biology 20:949–958.

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. U.S. Forest Service General Technical Report PNW-GTR-648, Pacific Northwest Research Station, Portland, Oregon.

Littell, J.S. 2009. "Climate change and the forest ecosystems of the Olympia Peninsula," a presentation given at Climate change impacts on Olympic Peninsula salmon, a workshop held at Olympic National Forest Headquarters in Olympia, Washington .

Littell, J.S., D. McKenzie, D.L. Peterson, and A.L. Westerling. 2009*a*. Climate and wildfire area burned in western U.S. ecoprovinces, 1916-2003. Ecological Applications 19:1003–1021.

Littell, J.S., E.E. Oneil, D. McKenzie, J.A. Kicke, J.A. Lutz, R.A. Norheim, M.M. Elsner. 2009*b*. Forest ecosystems, disturbances, and climatic change in Washington State, USA. Pages 255–284 *in* M.M. Elsner, J. Littell, and L.W. Binder, editors. The Washington climate change impacts assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle.

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. 2009*a*. Range expansion of Barred Owls, part I: chronology and distribution. American Midland Naturalist 161:49–56.

Livezey, K.B. 2009*b*. Range expansion of Barred Owls, part II: facilitating ecological changes. American Midland Naturalist 161:323–349.

Livezey, K.B. 2010. Killing barred owls to help spotted owls I: a global perspective. Northwestern Naturalist 91:107-133.

Livezey, K.B., M.F. Elderkin, P.A. Cott, J. Hobbs, and J.P. Hudson. 2008. Barred owls eating worms and slugs: the advantage in not being picky eaters. Northwestern Naturalist. 89:185-190.

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.

Luyssaert, S., E.-D. Schulze, A. Börner, A. Knohl, D. Hessenmöller, B.E. Law, P. Ciais and J. Grace. 2008. Old-growth forests as global carbon sinks. Nature 455:213-215.

Manter, D.K., P.W. Reeser, and J.K. Stone. 2005. A climate-based model for predicting geographic variation in Swiss needle cast severity in the Oregon Coast Range. Phytopathology 95:1256–1265.

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.

Marston, R.A. and D.H. Haire. 1990. Runoff and soil loss following the 1988 Yellowstone fires. Great Plains-Rocky Mountain Geographic Journal 18:1–8.

Mazur, K.M. and P. C. James. 2000. Barred owl (*Strix varia*). *In* A. Poole, editor. The Birds of North America Online, No. 508. Cornell Lab of Ornithology, Ithaca, New York.

McIver J.D and L. Starr, technical editors. 2000. Environmental effects of postfire logging: literature review and annotated bibliography. U.S. Forest Service General Technical Report PNW-GTR-486, Pacific Northwest Research Station, Portland, Oregon.

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

McKenzie, D., D.L. Peterson, and J.J. Littell. 2009. Global warming and stress complexes in forests of western North America. Pages 319–338 *In* A. Bytnerowicz, M.J. Araugh, A.R. Riebau, and C. Andersen, editors. Developments in Environmental Science, Volume 8. Elsevier, The Netherlands.

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.

Millar, C.I., N.L. Stephenson, and S.L Stephens. 2007. Climate change and forests of the future: managing in the face of uncertainty. Ecological Applications 17:2145–2151.

Miller, G.S. 1989. Dispersal of juvenile spotted owls in western Oregon. Thesis, Oregon State University, Corvallis.

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.

Miller, J.D., H.D. Safford, M. Crimmins, and A.E. Thode. 2009. Quantitative evidence for increasing forest fire severity in the Sierra Nevada and southern Cascade mountains, California and Nevada, USA. Ecosystems 12:16-32.

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. U.S. Forest Service General Technical Report PNW-GTR-646, Pacific Northwest Research Station, Portland, Oregon.

Moeur, M. 2010. Northwest Forest Plan interagency regional monitoring, 15-year report: status and trend of late-successional and old-growth forests. Unpublished briefing paper and presentation to U.S. Fish and Wildlife Service, Oregon Fish and Wildlife Office, Portland, Oregon, August 10, 2010.

Moilanen A., A.M.A. Franco, R. Early, R. Fox, B. Wintle, and C.D. Thomas. 2005. Prioritising multiple-use landscapes for conservation: methods for large multi-species planning problems. Proceedings Royal Society of London, Series B, 272:1885–1891.

Monsanto, P.G. and J.K. Agee. 2008. Long-term post-wildfire dynamics of coarse woody debris after salvage logging and implications for soil heating in dry forests of the eastern Cascades, Washington. Forest Ecology and Management 255:3952–3961.

Morgan, P., and S.C. Bunting. 1990. Fire effects in whitebark pine forests. Pages 166–170 *in* W. C. Schmidt, and K.J. McDonald, editors. Symposium on Whitebark Pine Ecosystems: Ecology and Management of a High-Mountain Resource. U.S. Forest Service General Technical Report INT-GTR-270, Intermountain Forest and Range Experiment Station, Ogden, Utah.

Moritz, C., J.L. Patton, and C.J. Conroy. 2008. Impact of a century of climate change on small-mammal communities in Yosemite National Park, U.S.A. Science 322:261–264.

Mote, P.W. and E.P. Salathe Jr. 2009. Future climate in the Pacific Northwest. Pages 21–43 *in* M.M. Elsner, J. Littell, and L.W. Binder, editors. The Washington climate change impacts assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle.

Munro, J.A. and I. McTaggart-Cowan. 1947. A review of the bird fauna of British Columbia. Special Publication Number 2. Provincial Museum, Victoria, British Columbia, Canada.

NMFS (National Marine Fisheries Service). 2007. Interim endangered and threatened species recovery planning guidance. Version 1.2. Silver Spring, Maryland.

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

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.

North, M., P. Stine, W. Zielinski, K. O'Hara, and S. Stephens. 2010. Harnessing fire for wildlife: fuels management in California's mixed-conifer forests. The Wildlife Professional. 4(1):30-33

Noss, R.F. and D.B. Lindenmayer. 2006. Special section: the ecological effects of salvage logging after natural disturbance. Conservation Biology 20:946-948.

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

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., 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.

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.

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.

Perry, D.A., M.P. Amaranthus, J.G. Borchers, S.L. Borchers and R.E. Brainerd. 1989. Bootstrapping in ecosystems. BioScience 39: 230–237.

Peterson, D.L., J.K. Agee, G.H. Aplet, D.P. Dykstra, R.T. Graham, J.F. Lehmkuhl, D.S. Pilliod, D.F. Potts, R.F. Powers and J.D. Stuart. 2009. Effects of timber harvest following wildfire in western North America. U.S. Forest Service General Technical Report PNW-GTR-776, Pacific Northwest Research Station, Portland, Oregon.

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. U.S. Forest Service General Technical Report PNW-GTR-628, Pacific Northwest Research Station, Seattle, Washington.

Phillips, S.J., R.P. Anderson, and R.E. Schapire. 2006. Maximum entropy modeling of species geographic distributions. Ecological Modeling 190:231–259.

Phillips S.J., and M. Dudik. 2008. Modeling of species distributions with Maxent: new extensions and a comprehensive evaluation. Ecography 31:161–175.

Pipkin, J. 1998. The Northwest Forest Plan revisited. U.S. Department of the Interior, Office of Policy Analysis, Washington, D.C., and Department of Forest Resources, Oregon State University, Corvallis.

Preble, E.A. 1941. Barred owl on Athabaska River, Alberta. Auk 58:407–408.

Rand, A.L. 1944. Birds of the Alaska highway in British Columbia. Canadian Field-Naturalist 58:111–125.

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. U.S. Forest Service General Technical Report PNW-GTR-651, Pacific Northwest Research Station, Portland, Oregon.

Reeves, G.H., P.A. Bisson, B.E. Rieman, and L.E. Benda. 2006. Postfire logging in riparian areas. Conservation Biology 20:994–1004.

Rogers, T.H. 1966. The fall migration: northern Rocky Mountain-Intermountain region. Audubon Field Notes 20:74.

Rogers, T.H. 1970. The fall migration: northern Rocky Mountain-Intermountain region. Audubon Field Notes 24:253.

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.

Russell, R.E., V.A. Saab, J.G. Dudley and J.J. Rotella. 2006. Snag longevity in relation to wildfire and postfire salvage logging. Forest Ecology and Management 232:179–187.

Salathe, E.P, L. R. Leung, Y. Qian, and Y. Zhang. 2009. Regional climate model projections for the State of Washington. Pages 45–67 in M. M. Elsner, J. Littell, and L.W. Binder, editors. The Washington climate change impacts assessment. Center for Science in the Earth System, Joint Institute for the Study of the Atmosphere and Oceans, University of Washington, Seattle.

Saunders, A.A. 1911. A preliminary list of the birds of Gallatin County, Montana. Auk 28:26–49.

Saunders, A.A. 1921. A distributional list of the birds of Montana, with notes on the migration and nesting of the better known species. Cooper Ornithological Club, Pacific Coast Avifauna 14:68.

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. 2008. HexSim (Version 1.3.6.9). U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon. <http://www.epa.gov/hexsim>

Schulze, E.-D., C. Wirth and M. Heimann. 2000. Managing forests after Kyoto. Science 289: 2058-2059.

Scotter, B.W., L.N. Carbyn, W.P. Neily, and J.D. Henry. 1985. Birds of Nahanni National Park, Northwest Territories. Saskatchewan Natural History Society, Regina, Saskatchewan, Canada.

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. The Society for Ecological Restoration, Tucson, Arizona.

Singleton, P.H., J.F. Lehmkuhl, W.L. Gaines, and S.A. Graham. 2010. Barred owl space use and habitat selection in the eastern Cascades, Washington. Journal of Wildlife Management 74:285–294.

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

Skinner, C.N., and C. Chang. 1996. Fire regimes, past and present. Pages 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, Davis.

Skinner, C.N., and A.H. Taylor. 2006. Southern Cascades bioregion. Pages 195–223 *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.

Skinner, C.N., A.H. Taylor, and J.K. Agee. 2006. Klamath Mountains bioregion. Pages 170–193 *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. Dissertaion, Oregon State University, Corvallis.

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.

Spies, T.A., J.D. Miller, J.B. Buchanan, J.F. Lehmkuhl, J.F. Franklin, S.P. Healey, P.F. Hessburg, H.D. Safford, W.B. Cohen, R.S.H. Kennedy, E.E. Knapp, J.K. Agee, and M. Moeur. 2010. Underestimating risks to the northern spotted owl in fire-prone forests: response to Hanson *et al.* Conservation Biology 24:330-333.

Stein, B.A. 2010. "Assessing vulnerability to climate change: , a key tool for adaptation planning," a webinar presentation given as part of the National Wildlife Federation-U.S. Fish and Wildlife Service climate change and wildlife webinar series, "Safeguarding Wildlife from Climate Change" January 28, 2010, National Conservation Training Center, U.S. Fish and Wildlife Service, Shepherdstown, WV.

Stephens, S.L., C.I. Millar, and B.M. Collins. 2010. Operational approaches to managing forests of the future in Mediterranean regions within a context of changing climates. Environmental Research Letters. <http://iopscience.iop.org/1748-9326/5/2/024003>.

Stephens, S.L., and J.J Moghaddas. 2005*a*. 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. 2005*b*. 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.

Sundquist, E.T., K.V. Ackerman, N.B. Bliss, J.M. Kellndorfer, M.C. Reeves and M.G. Rollins. 2009. Rapid assessment of U.S. forest and soil organic carbon storage and forest biomass carbon sequestration capacity. Open-file Report 2009-1283, U.S. Geological Survey.

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. U.S. Forest Service, U.S. Bureau of Land Management, U.S. Fish and Wildlife Service, and U.S. National Park 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.

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. U.S. Forest Service, Portland, Oregon.

Thompson J.R., T.A. Spies and L.M. Ganio. 2007. Reburn severity in managed and unmanaged vegetation in a large wildfire. Proceedings of the National Academy of Sciences 104:10743–10748.

USDA (U.S. Department of Agriculture), and USDI (U.S. Department of the Interior). 1994*a*. 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. U.S. Forest Service and U.S. Bureau of Land Management, Portland, Oregon.

USDA (U.S. Department of Agriculture), and USDI (U.S. Department of the Interior). 1994*b*. 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. U.S. Forest Service and U.S. Bureau of Land Management, Portland, Oregon.

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.

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

USFWS (U.S. Fish and Wildlife Service). 1983*b*. 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. U.S. Fish and Wildlife Service, Portland, Oregon.

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

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

USFWS (U.S. Fish and Wildlife Service). 1990*b*. 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). 1992*a*. 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). 1992*b*. Draft final recovery plan for the northern spotted owl. U.S. Fish and Wildlife Service, Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 1994. 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. U.S. Fish and Wildlife Service, Olympia, Washington.

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). 2003. Endangered and threatened wildlife and plants; 12-month finding for a petition to list the California Spotted Owl (*Strix occidentalis occidentalis*). Federal Register 68:7580–7608.

USFWS (U.S. Fish and Wildlife Service). 2004*a*. 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. U.S. Fish and Wildlife Service, Portland, Oregon.

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

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

USFWS (U.S. Fish and Wildlife Service). 2008. Final Recovery Plan for the Northern Spotted Owl (*Strix occidentalis caurina*). Portland, Oregon.

USFWS (U.S. Fish and Wildlife Service). 2009. (Draft) Rising to the challenge: strategic plan for responding to accelerating climate change. U.S. Fish and Wildlife Service, Washington D.C.

USFWS (U.S. Fish and Wildlife Service) and NMFS (National Marine Fisheries Service. 2002. Draft endangered species recovery handbook: procedures for conducting recovery planning activities for endangered and threatened species under section 4 of the Endangered Species Act. Washington, D.C.

van Mantgem, P.J., N.L. Stephenson, J.C. Byrne, L.D. Daniels, J.F. Franklin, P.Z. Fule, M.E. Harmon, A.J. Larson, J.M. Smith, A.H. Taylor, and T.T. Veblen. 2009. Widespread increase of tree mortality rates in the western United States. Science 323:521–524.

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. U.S. Forest Service R6-ECOL-104-1985, Pacific Northwest Region, Portland, Oregon.

Walstad, J.D., S.R. Radosevich, and D.V. Sandberg. 1990. Introduction to natural and prescribed fire in Pacific Northwest Forests. Pages 3-5 *in* J.D. Walstad, S.R. Radosevich, and D.V. Sandberg, editors. Natural and Prescribed Fire in Pacific Northwest Forests. Oregon State University Press, Corvallis.

Ward, J.W. Jr. 1990. Spotted owl reproduction, diet and prey abundance in northwest California. 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 313:940–943.

Wiens, J.D., R.G. Anthony, and E.D. Forsman. *In press*. Barred owl occupancy surveys within the range of the northern spotted owl. Journal of Wildlife Management.

Wiens, J.D., S.G. Graham, R.G. Anthony, E.D. Forsman, and M.R. Fuller. 2009. Competitive interactions and resource partitioning between northern spotted owls and barred owls in western Oregon: 2009 progress report. U.S. Geological Survey administrative report. U.S. Geological Survey, Reston, Virginia.

Williams, C.K., B. Kelly, B. Smith and T. Lillybridge. 1995. Forested plant associations of the Colville National Forest. U.S. Forest Service General Technical Report PNW-GTR-360. Pacific Northwest Research Station, Portland, Oregon.

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

Wischnofske, M.G., and D.W. Anderson. 1983. The natural role of fire in the Wenatchee Valley. Page 24 Undocumented Report. . U.S. 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., 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.

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.

Personal Communications Cited

Buchanan, Joe. 2010. Washington Department of Fish and Wildlife. Email to Brendan White, U.S. Fish and Wildlife Service, Oregon Fish and Wildlife Office, Portland, dated July 26, 2010.

Diller, Lowell. 2010. Green Diamond Resource Company. Email to Kent Livezey, U.S. Fish and Wildlife Service, Western Washington Fish and Wildlife Office, Lacey, dated April 1, 2010.

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.

Appendix F: 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*

Other species

Avian malaria	*Plasmodium* spp.
Mountain pine beetle	*Dendroctonus ponderosae*
Swiss needle cast	*Phaeocryptopus gaeumannii*

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