Sustainable Ecosystems Institute

Scientific Review of the Draft Northern Spotted Owl Recovery Plan and Reviewer Comments

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Sustainable Ecosystems Institute is a non-partisan organization of scientists dedicated to using their technical expertise to solve ecological problems. Headquartered in Portland, Oregon, the Institute works nationally and internationally. SEI specializes in independent scientific review. Visit http://sei.org and http://sei.org/peerrev.html for more details. Contact SEI at sei@sei.org

Cover photo by Katie Fehring

EXECUTIVE SUMMARY

Sustainable Ecosystems Institute (SEI) was charged with evaluating the Draft Recovery Plan (DRP) for the Northern Spotted Owl, as well as scientific comments on the DRP that had been received by US Fish and Wildlife Service (USFWS). SEI convened a scientific panel of 9 eminent owl and forest scientists to carry out the review. The panel was supported by 5 external reviewers, and SEI and other staff scientists. The review considered all written scientific comments received by the USFWS, as well as presentations at two public meetings, and additional information from scientists.

The SEI panel carefully considered all available information, and evaluated the strength of the evidence on every topic. There were many issues to consider, ranging from genetics to ecosystems dynamics, and the use of science in management. In general, the information available for evaluation is strong compared to that for other endangered species. We find that some parts of the DRP accurately reflect the currently best available science, however other parts of the DRP are less well-conceived, and do not use scientific information appropriately. Finally the SEI scientific panel differs with the DRP regarding its interpretation and opinion about some issues, based on recent information.

Despite the relative wealth of information on Northern Spotted Owls, there are still many important issues that are central to conservation and management for which we lack key information. As a consequence of these uncertainties, many conservation decisions regarding this species must be made from the standpoint of risk management. We identify numerous situations where new information may support changes to management in the future. A precautionary approach to risk management would keep 'options open'. This would entail maintaining Spotted Owl habitat, while taking concerted action against two pressing threats, Barred Owls and large-scale stand-replacing wildfires.

We anticipate that new information on key issues would become available in the short-term (3-10 years). We also anticipate the need for further resolution of many currently unresolved scientific issues related to management. Hence an important component of a successful Recovery Plan will be administrative and other support to ensure that new information is collected, analyzed, and applied in a meaningful adaptive process.

Major findings of the review are:

1. The major threats facing Northern Spotted Owls remain those identified at the time of the Status Review (2004), viz: loss of habitat to harvest and fire; Barred Owl competition.
2. There is considerable geographic variation in the ecology of Spotted Owls (notably its habitat and prey use). This is matched by similar variation in the threats faced by owl populations in different areas. A successful conservation strategy will need to fully address these differences across the entire spectrum of its range.

3. The DRP does not over-state the threat from Barred Owls, but does under-estimate the threat of habitat loss from fire and the harvest or 'salvage' of large and very large trees. The DRP threat assessment assumed that there would be no major loss of habitat currently conserved under the Northwest Forest Plan (NWFP). However this assumption may be incorrect because neither of the options proposed in the DRP either reference or require continuation of the Late Successional Reserves under the NWFP, which contain much of the remaining suitable owl habitat. It is difficult to determine the degree to which the DRP Options reduce protection of habitat. Conservation of habitat remains essential to Spotted Owl recovery.
4. The DRP's two options respectively propose a reserve network and a 'rule-set' for habitat identification and protection. We heard conflicting evidence as to whether a 'rule set' approach could adequately identify and protect habitat. Regardless of whether fixed reserves or 'rule sets' are used, two key factors determining success of a conservation strategy will be whether there is adequate long-term protection of occupied and other suitable habitat, and whether there is adequate recruitment of replacement habitats in the event of significant losses of suitable habitats due to wildfires, insect outbreaks, or other factors. It is not clear from the DRP how much of such habitat would be protected. This information is essential in order to determine whether the Final Recovery Plan will be as effective a conservation strategy as the existing NWFP. Currently there is no explicit explanation in the DRP as to any departure from the habitat provisions of the NWFP.
5. Current models of owls and their habitats are largely heuristic. Hence decisions on important issues such as reserve size, spacing, etc., must be made with relatively weak predictive tools.
6. The approach of the DRP for designating habitat goals (based on habitat fitness potential) is deeply flawed. However the need to set locally appropriate and sustainable habitat goals remains a valid goal.
7. In some circumstances, owls may remain in, or rapidly re-colonize habitats that have experienced a low intensity fire. Hence, it is incorrect to assume that all fires result in habitat loss. In other circumstances, owls or their habitats are lost as a consequence of intense or catastrophic fires. It is important to recognize such variation of fire effects when developing a conservation strategy.
8. Control of Barred Owls may be warranted (to be determined after experimentation and other research), and would be consistent with conservation actions for other endangered species.
9. The threat from wildfire is underestimated in the DRP for the dry forest provinces, and is inadequately addressed. This threat is likely to increase given both current forest conditions, and future climatic change.
10. In east-side habitats of the Washington and Oregon Cascades, the only viable conservation strategy will be to actively manage fire-prone forests and landscapes to sustain Spotted Owl habitat. However this needs to be closely monitored through an adaptive management process.

11. A simple reserve network is unsustainable in east-side fire-prone habitats. Conservation strategies, to be viable, must be designed and implemented at the landscape level.
12. Post-fire habitat modifications could most appropriately focus on habitat restoration and conserving habitat elements that take the most time to develop or recover.

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INTRODUCTION

SEI PROCESS AND REVIEW ORGANIZATION

Sustainable Ecosystems Institute (SEI) is a public-benefit non-profit organization dedicated to scientific resolution of issues. The Institute has carried out numerous peer review processes on endangered species, including the Scientific Evaluation of the Status of the Northern Spotted Owl (Courtney et al. 2004), and related resource management concerns.

SEI was contracted by the US Fish and Wildlife Service (USFWS) to evaluate what constitutes the best available science concerning the ecology of the threatened Northern Spotted Owl. The review focused on several issues raised during the review of the Draft Northern Spotted Owl Recovery Plan (DRP) released in April 2007.

The goal of this effort is to provide a strong, understandable, and impartial scientific foundation for decision makers and stakeholders. All decision-making authority rests with USFWS. SEI panelists were charged solely with a scientific evaluation of the DRP and comments received on it. The panelists rigorously adhered to this guideline. In addition, SEI made clear to the panelists that they were in no way obligated to reach a consensus and that they should each express their separate opinions as necessary.

The review and workshop format was based on the SEI process. This is an open and transparent science review method pioneered by SEI in order to help managers use the best science available when making critical decisions for species and their habitats. The process has been used to resolve critical and controversial science based issues regarding endangered species, and the restoration and management of ecosystems. In 2004, SEI completed a critical review and synthesis of recent scientific information on the status of the Northern Spotted Owl (Courtney et al. 2004). This effort, which used the SEI process, also produced a final report and a peer reviewed scientific paper.

The hallmarks of this method are:

1. The Institute assembles a panel of scientists who collectively have the breadth of expertise necessary to address the issues at hand. The panel is specifically charged with addressing the underlying science and not to make policy.
2. SEI gathers relevant materials and engages with stakeholders to identify the critical issues and questions.
3. SEI believes that an open and public deliberation of science helps others to understand the scientific process. This is especially true when issues are controversial and complex. SEI convenes a public science forum. At that meeting, the panel listens to the presentations on available science, deliberates and debates the science, and subsequently issues its findings and conclusions. This open process allows all stakeholders to participate in the scientific process, to understand why certain conclusions have been reached, and to have a greater understanding of the quality and certainty around the current science. Meetings

are facilitated by a scientific translator. Further details can be found on the SEI website or by contacting SEI.

ORGANIZATION OF REVIEW

Overall project lead was Dr. Steven Courtney, Vice-President of SEI, who has expertise in endangered species research and management, and in the application of peer review processes to natural resource management issues. Lisa Sztukowski and Katie Fehring of SEI, and Kate Engel of Parametrix acted as sub-group leads. Lenny Young from Washington Department of Natural Resources facilitated information sharing with the Recovery Team.

SEI selected reviewers based on both the professional standing of scientists and whether they had potential conflicts of interest that might affect the actual or perceived impartiality of their review. Experts were drawn from a range of different academic backgrounds relevant to the review. Some reviewers served on the previous status review of the species providing continuity and current knowledge of the science available (Courtney et al. 2004). Additional reviewers were found using SEI's Conservation Science Network together with our larger network of professional contacts. In addition, we solicited input from appropriate members of the SEI Science Advisory Board, from previous panel members, and from relevant professional societies.

The panel consisted of four sub-groups, addressing particular subject areas and expertise; some panelists served in multiple sub-groups, acting as a bridge between groups, sharing information. Sub-groups were:

Owl Biology

Dr. Andy Carey, Pacific Northwest Research Station (former)

Prof. Martin Cody, University of California, Los Angeles

Prof. Jerry Franklin, University of Washington

Dr. Mark Fuller, U.S. Geological Survey

Prof. R. J. Gutiérrez, University of Minnesota

Dr. John Lehmkuhl, Wenatchee Forest Sciences Lab

Forest Ecology

Dr. Andy Carey, formerly Pacific Northwest Research Station

Prof. Jerry Franklin, University of Washington

Dr. Mark Fuller, U.S. Geological Survey

Dr. Miles Hemstrom, Pacific Northwest Research Station

Dr. Paul Hessburg, Pacific Northwest Research Station

Dr. John Lehmkuhl, Wenatchee Forest Sciences Lab

Prof. Scott Stephens, University of California, Berkeley

Habitat Fitness Potential

Prof. R. J. Gutiérrez, University of Minnesota

Dr. Jim Nichols, Patuxent Wildlife Research Center

Prof. Ken Pollock, North Carolina State University

Genetics

Prof. Andrew Bohonak, San Diego State University

Prof. Keith Crandall, Brigham Young University

Prof. R. J. Gutiérrez, University of Minnesota

Prof. Robert Zink, University of Minnesota

Information Reviewed

Panelists were provided all scientific reviewer comments, a list of issues raised created by USFWS, and all relevant documents associated with reviewers' comments. Panel members also collected and shared additional information they felt relevant to the review. Additional information was provided at two public forums. Some other information was sought directly from researchers and others.

The panel evaluated 15 sets of comments from 12 groups. These comments were selected by USFWS as containing substantive scientific comments. SEI provided some guidance to reviewers, differentiating science vs. policy and management issues, and identifying comments directed to specific sub-groups. As many of these reviews inter-mixed science and policy, SEI abstracted the scientific comments for each sub-group to assist the panel and focus the review on science.

Public Forums

SEI assembled the panel of experts, scientists whose work has contributed to our knowledge of the species and system, decision-makers and other interested stakeholders for two public forums. The first meeting focused on threats, Barred Owl impacts, owl response to fire, habitat fitness potential models, and population viability, and took place on January 8 - 9th, 2008 in Portland, Oregon. On February 11, 2008 in Bellevue, Washington, a second meeting concentrated on habitat issues, fire regimes and adaptive management. During these meetings, there was both formal presentation and discussion of scientific materials, and also structured debate on the best interpretation of these data. The goals of these meetings were to ensure that all scientific opinions were heard, and that the pros and cons of alternative viewpoints were vigorously and transparently debated.

Public forums are an important component of the SEI process. Agendas are a reflection of the substantive issues within the reviewer comments, and are directed by the panel. Presenters are selected through an open process with suggestions from the panel, interest groups, and stakeholders who have relevant scientific data to share. Presenters are instructed prior to the meeting to present on the science, not policy or management. Meetings are facilitated by a scientific translator who ensures participants adhere to the rules.

SCOPE OF THE REVIEW

SEI was tasked with evaluating reviewers' comments on the Northern Spotted Owl Draft Recovery Plan, preparing a list of the scientific questions raised, and recommending a process for answering these questions using the best available science. To evaluate the comments and the science we convened a panel of experts, conducted three days of public meetings, compiled a complete record of the processes, and produced a summary report with the panel's conclusions.

SEI selected the reviewers from a wide range of subject disciplines, so as to fully address the comments and reviews already obtained by the USFWS. In selecting reviewers, we carefully considered the strengths of different reviewers, and ensured that we obtained a wide range of scientific opinion, adequate to the many issues raised by commentators. Hence we included experts in forestry, fire ecology, owl ecology, statistics and genetics (among other areas). We also attempted to ensure multiple reviews on all important substantive issues. We followed NAS guidelines in selecting reviewers, so as to ensure adequate representation of scientific opinion.

Our goal was to address the issues raised by commentators in as far as they concerned issues of science. It was not our charge to consider issues or comments that concerned purely policy or values. Hence we did not address issues such as the ethics of Barred Owl control, or whether timber harvest is a worthwhile goal of forest management. These issues are appropriately considered by decision-makers, in USFWS and other agencies, but they are outside the scope of our scientific evaluation. On several issues however, reviewers entwined scientific comments with value-driven statements. In such cases we attempted to address the scientific content, but did not evaluate their other comments. For instance we specifically do not evaluate whether either Option 1 or Option 2 of the DRP is 'acceptable', although numerous scientists included recommendations on this topic in their reviews and comments. Federal decision-makers must use the best available science when making decisions on management of endangered species, but they must also balance many non-scientific factors in reaching such decisions on 'acceptability' (e.g. practicality, public opinion). Hence we cannot evaluate the 'acceptability' of any plan on purely scientific grounds. We can however determine whether such a plan uses the best available science, and uses it appropriately. We can also evaluate whether particular management prescriptions are likely to succeed or to have desired outcomes.

We found that many of the comments received from scientists interwove issues of science and policy. It is of course entirely appropriate that scientists submit their comments on policy, ethics etc., as is the right of any citizen. It is also important that USFWS consider these comments in the public comment process. However we did not consider such comments in our review. We do not regard 'statement by scientists' as being synonymous with 'scientific statements'. We attempted to fairly evaluate the scientific part of any argument, without passing comment on the accompanying sentiment or policy conclusion. Hence a statement such as:

> "…despite real reductions in logging on federal lands, there is strong evidence that demography of Northern Spotted Owls across their range remains insufficient to maintain stable populations. Further, owl habitat is continuing to decline at the rate of 2.1% per year on federal lands (Table 2.1, page 128). In light of these trends, I would argue that conservation efforts should be strengthened not weakened." (see comments of SCB)

would be evaluated in terms of the comments on logging levels, demography and habitat decline (and on the likely success of current conservation efforts), but not in terms of its policy recommendation.

A particularly fine distinction must be carefully drawn in the area of 'scientific opinion'. Scientific opinion can under some circumstances be appropriate for us to evaluate. When 'scientific opinion' is a statement on the probable validity and strength of an argument, and is based on experience with the system, or with similar systems, then it may be appropriate to include such opinion in our overall evaluation. For instance, when a statement is made by an acknowledged expert in fire ecology that:

> "The real experience of the last 15 years is that the threat of habitat loss is no longer just a threat. It is real and it is here. The 2007 Recovery Plan fails to place this reality into context" (comments of J. Agee)

then this statement is appropriate for us to consider. However such opinion has to be weighed with all the other evidence available. Statements of simple scientific opinion, although they have value (particularly when gleaned from a highly respected or qualified individual), are nevertheless relatively light in value, unless substantiated by further evidence. Of course if 'scientific opinion' is the only information available, then it is by definition the 'best available science'.

One of the comments received by USFWS was a letter signed by 112 scientists, some of them eminent scholars at well-respected universities. We found that although some of the issues raised were substantive (and mirrored concerns expressed by SCB, TWS and others), some other statements in this letter were value-based, and were 'statements by scientists' as opposed to 'scientific statements'. Such value-based statements were not considered in our evaluation, and are appropriately considered along with other public comments by USFWS. The statements in this letter however that could be described as scientific opinion (e.g. " though Barred Owls have emerged as a growing threat to Spotted Owls, the science is far from conclusive regarding how this biological invasion will affect the survival and recovery of the northern spotted owl") were included in materials sent to the panel for evaluation. We noted that many of the scientists who signed this letter were experts in fields other than forestry or owl biology (although some of the presumed primary authors, e.g. DellaSala, Carroll, Perry, Rosenberg, Olson do indeed have such experience). Hence the letter, although signed by many respected scientists, does not represent a consensus of experts in the particular fields of greatest relevance to Northern Spotted Owl conservation. By contrast, the more focused review of the Wildlife Society was highly pertinent and clearly prepared by experts in these fields, while the reviews provided by individual scientists such as Dugger, Franklin and Olson were by the most relevant experts on 'habitat fitness potential'. As it happened, all the scientific issues raised in the letter by the 112 scientists were also raised in other reviews and comments by acknowledged experts.

Our evaluation therefore had to consider the relative strengths of scientific arguments. The panel prepared an evaluation that weighed different lines of argument and data. When there was a clear consensus in the field, well substantiated with multiple publications on a topic, we had relatively high confidence in a conclusion. When there was only limited information on a topic, there was less confidence in the argument. In general, the conclusions reached in peer reviewed publications and reports are most likely to be sound and accurate. Less weight is accorded to un-reviewed material and papers, and even less to un-analyzed data and observations, or to 'scientific opinion'. The SEI panel process allowed opportunity for additional input of scientific material through the public meetings, where scientific presentations and discussions were heard. Although brief scientific talks do not allow for the detailed presentation in, say, a peer-reviewed paper with a full statistical analysis, the public format, and in particular the questioning of presenters by panelists, allows a different form of scrutiny. Such questioning allows panelists to probe arguments and data for flaws in a way that is unavailable in any other format. It also allows panelists and presenters to engage in scientific dialog that reaches new conclusions or consensus.

Hence the panel weighed evidence of many different sorts: papers, presentations, reports, written comments, scientific opinion, verbal replies to questioning, etc., as well as their own scientific experience and opinion. The panel reached their conclusions based on the relative strengths of all these lines of evidence. If the evidence was unclear, or the conclusions reached were tentative, then this is stated.

Of particular importance were issues where there was genuine scientific disagreement, or differences in scientific opinion. The panel considered many such issues, including: the relative importance of different threats to the Northern Spotted Owl; the ability of owls to survive and reproduce in burnt forests; the fitness of owls in heterogeneous landscapes. In cases where there were such differences between scientists, the panel determined which alternative was best supported by the suite of evidence. In some cases apparent differences in opinion were explicable by differences in experience (e.g. in different parts of the range of the owl).

Although the primary charge of the panel was to consider the DRP, and the comments received on it, we did not exclude any relevant information from our discussions. We saw our overall task as a full and complete assessment of the issues raised in the DRP. Hence we sought out and received data, papers and presentations on topics regarding Barred Owl management, genetics, population trends, modeling etc. that either were not available to USFWS at the time of drafting the DRP, or were not even developed at that point. Hence our review is more comprehensive and up-to-date. Some of the differences between our assessment and that in the DRP are therefore ascribable to the availability of this new information, as opposed to differences in interpretation. Nevertheless on some issues, the panel determined that the DRP did not represent the best use of available science, and we have provided instead the conclusions that appear best supported on available evidence.

RISKS AND UNCERTAINTY

When evaluating any scientific conclusion, it is often helpful to also evaluate the uncertainty associated with that conclusion. Such uncertainty can stem from many sources – the data for instance could be sparse or inadequately analyzed, or the study could be well-carried out, but limited to a small part of the range. It may also be that different studies yield different and inconsistent results. In such circumstances, there may be substantial uncertainty as to the extent that a conclusion is well-founded, or applicable throughout the range. Such uncertainty is normal to the scientific process, and is usually resolved by further observations and study. For instance Leskiw and Gutiérrez (1998) have recorded possible predation by Barred Owls on Spotted Owls. Although this observation accords with many other anecdotal observations of aggressive behavior by Barred Owls against Spotted Owls, and is logically consistent with other lines of evidence implicating Barred Owls in Spotted Owl declines, it is still only preliminary evidence for a direct effect of Barred Owls. Gutiérrez et al. (2007) and others (Buchanan et al. 2007) have argued persuasively that more information is needed to unequivocally determine the scale of any such effect.

However, the USFWS is always constrained to using the information and opinion that is 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. Hence the standard, as set by ESA, NEPA, DQA etc, is that the Service must use ‘best available science’. Nevertheless it is useful and important when making recovery decisions to distinguish between conclusions that are well substantiated, those that are preliminary, and those that are more speculative. Making such distinctions allows decision makers to weigh the probability that any particular action will ultimately be supported by the science. If a particular interpretation or conclusion (even if it is the only one supported by data) has only weak support, it may not ultimately be corroborated.

In preparing this report, we have recognized that the Service must use the 'best available science', even where this fails to reach the standards that would be applied e.g. in academia. We have considered all information, including unpublished manuscripts, un-reviewed manuscripts, verbal presentations, letters, etc., and have attempted to distinguish which conclusions are best supported by the available evidence. We have attempted to qualitatively assess such conclusions – making clear whether a particular position or conclusion is well-supported or more tentative. A significant issue here is 'sufficiency' to draw conclusions. We recognize that the appropriate standard for evaluating the DRP, as with other ESA issues, is 'best available' rather than 'sufficient'. Nevertheless we have indicated where conclusions appear weak.

A particular issue that arose repeatedly in our review of the DRP was 'limits of inference'. Throughout the DRP, the comments received, and this our report, there is reference to the significant geographic variability in the ecology of Northern Spotted Owls, their habitat, prey base, fire regime, etc. The panel has emphasized the importance of such variability, and the limited extent to which conclusions reached in one location could be extrapolated to another place. In species whose ecology varies little, it is more reasonable to expect that any particular study will accurately reflect the species as a whole, as opposed to species that vary greatly. A pertinent question is the degree to which conclusions from one area can be extrapolated elsewhere. For instance, at the time of drafting the DRP, two of three studies on 'habitat fitness potential' supported a conclusion that heterogeneous habitats (at territory scales) enhanced demographic performance. The DRP extrapolated from these two studies (both in the southern part of the range) throughout the range of the species. Such an extrapolation appeared to the panel unwarranted for two reasons: viz. the geographic extent of the studies was limited; not all studies supported the conclusion. Hence the panel attempted to set appropriate 'limits of inference'. In this case, given the observed high geographic variability, it was felt unlikely that a conclusion appropriate to northern California populations dependent on wood rats would apply equally well to Washington populations eating Flying Squirrels – indeed our expectation based on 'scientific opinion' was that it would not apply well.

A quite separate issue from 'uncertainty' is 'risk'. 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. As an example, there is some limited evidence that Spotted Owls reduce or cease calling in the presence of Barred Owls. If true, this may have important implications for survey design and population assessment – there may be more Spotted Owls in some areas than are currently detected. If such areas were to be cleared for harvest, based on presumed absence of Spotted Owls, then this would be based on a faulty conclusion. If those areas are permanently protected from harvest however, the faulty conclusion would not have any consequences for Spotted Owls. 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. Hence, throughout our report, we have attempted to clearly state the uncertainties surrounding any conclusion, as well as the risks associated with making an incorrect conclusion. We have avoided however drawing any conclusions as to whether a particular risk is acceptable. Hence we have made statements such as 'Factor X will (with high probability) increase risk of local extinction' but not statements such as 'Factor Y will increase risk of extinction to an unacceptable degree'. Science can only inform the decisions made in the Final Recovery Plan.

When faced with both uncertainties and risks, conservation biologists and others often invoke use of the Precautionary Principle. In essence this principle is a guide for managers, and suggests that avoiding unnecessary risks is sensible when faced with significant unknowns. Although this may be common-sensical, it is important to note that use of the Precautionary Principle is a policy decision, not a scientific issue. Scientists can only help managers determine the levels of uncertainties and risks. Whether or not to accept any particular level of risk remains the responsibility of the manager.

Use of the Precautionary Principle does not simply call for inaction in the face of uncertainty. Rather, the principle argues for avoidance of unnecessary risk – whether this constitutes inaction or action will depend on the circumstances. The authors of both the DRP and of many received comments all address 'appropriate' management of risk. The SEI panel (see below sections) show that in some circumstances possible management actions may increase risks to Spotted Owls. On other issues, proposed actions (even when not supported by extensive scientific information) will probably reduce such risks. Three issues have received particular attention: Barred Owls, large stand-replacement fires, and timber harvest. Given the risks associated with these threats, the precautionary approach would suggest action with regards to Barred Owls and fire, and inaction with respect to harvest. However, as stated above, whether or not to take action (e.g. institute Barred Owl control) is a policy decision, not a scientific one.

Another response to uncertainty and risk is to institute adaptive management. Again, this is a policy decision, not a scientific one. However scientists can be useful to those who must decide whether to adopt adaptive management. If there is a reasonable expectation that uncertainty can be reduced through research and monitoring, and that risks can therefore also be reduced, then the 'precautionary' approach may be to limit actions in scope, and to progressively modify these actions as more information becomes available. Throughout this report, the SEI panel has indicated where adaptive approaches will likely lead to improved decision-making and management. We have also discussed in some detail possible structures and scientific analyses that would be useful in refining management. However whether or not to institute adaptive management remains a policy decision, not a scientific one.

GENERAL EVALUATION OF RECOVERY PLAN

THREAT ASSESSMENTS

Perceived Threats at Time of the 1990 Northern Spotted Owl Listing
The Northern Spotted Owl was listed as "threatened" in 1990 based on its declining numbers; at that time the overriding threat to the owl's persistence was considered to be past and continuing habitat loss (USFWS 1990). It was recognized as dependent on LSOG (late successional/old growth) forest, which had declined in coverage some 60% from historic levels. In addition, much remaining LSOG was fragmented and variously degraded. The inadequacy of existing regulatory mechanisms to protect the Northern Spotted Owl and its habitat was also an element of listing because of the pace and extent of timber harvest leading to habitat loss. Other factors exacerbated habitat loss to timber harvest such as wildfire, volcanic eruptions, and windthrow. Predation threats from Great Horned Owl, and competition and hybridization threats from invasive Barred Owls were recognized, but only received passing notice.

A Draft Recovery Plan for Northern Spotted Owl was produced in 1992 (USFWS 1992), from which evolved the Northwest Forest Plan (NWFP) (USDA 1994a,b). The NWFP was generated, in part, to counter the major threat of habitat loss to Northern Spotted Owl; it was designed also to conserve habitat for other threatened and endangered species, and ecosystems. Through its implementation, timber harvest was dramatically curtailed, and with the establishment of late-successional reserves (LSR) under the NWFP, much of the remaining LSOG forest was conserved, with more forest projected to return to LSOG over time with protection and natural vegetation succession. With tree harvest slowed, much of the remaining LSOG forests protected, and a reserve system in place to ensure more LSOG developing over time, Northern Spotted Owl recovery was thought to be on a secure track.

Perceived Threats at Time of 2004 Northern Spotted Owl Status Evaluation Report
After a decade of protection under the NWFP, the status of the Northern Spotted Owl was re-evaluated by the USFWS. In support of this effort, SEI convened a scientific panel in 2004 to review and summarize current scientific information on the owl and its habitat (Courtney et al. 2004). Following this, USFWS found that the weight of evidence supported continued listing of the Northern Spotted Owl; indeed, a majority of the dozen or so most closely-studied populations had declined over the preceding decade, and Northern Spotted Owls had suffered steep declines and range curtailment in the north and northwest.

In reaching their conclusions on Northern Spotted Owl status, Courtney et al. (2004) examined threats to Northern Spotted Owls in detail. The report evaluated whether the original threats at the time of listing still existed, and if so whether they were stronger, unchanged, or less important than previously thought. Courtney et al. (2004) distinguished operational (current and ongoing) threats from potential threats; under the latter category were placed those factors thought to be currently of no major importance to Northern Spotted Owl population persistence but which might become so in the future, along with threats that might be currently important but evidence to support that classification was lacking.

Courtney et al. (2004) panelists confirmed the association of Northern Spotted Owls with LSOG forest and an overall relation between Northern Spotted Owl demographic performance and the availability of LSOG forest. The panel affirmed that because of the NWFP, the threat of “habitat loss from timber harvest on Federally-managed public lands….has clearly been substantially reduced since 1990” (Courtney et al. 2004, 6-4), but found it difficult to weigh the current effects and ramifications of past harvest that had resulted in extensive Northern Spotted Owl habitat removal. For example, there might be genetic repercussions in terms of allelic loss where small populations persisted in habitat fragments. However the panel found that the ongoing loss of habitat remains a significant threat.

The threat of habitat loss might eventually be offset in part by growth of forests, i.e. forest succession toward LSOG status, but the panel found no comprehensive studies of whether, or within what time frame and following what schedule, forest in the process of replacing timber harvest clearcuts or partial cuts ultimately would be suitable for breeding Northern Spotted Owls. Thus factoring ingrowth into the equation of habitat availability to quantify trends, and the possible amelioration of habitat loss to other factors by ingrowth, proved extremely difficult.

Northern Spotted Owl habitat loss to wildland fires was considered a major threat by Courtney et al. (2004), and range-wide this constituted a greater threat, in terms of area affected (>3%) than timber harvest. Fire is a potent agent of habitat alteration especially in southern and eastern parts of the Northern Spotted Owl range, such as the eastern Cascades and the Klamath region. Forest scientists talk of “stand-replacement fires” (SRF) of high or moderate intensity and extensive coverage (>100,000 ac), and ca. 75% of habitat loss due to natural disturbances is attributable to SRF (e.g. Tyee, Biscuit, Bar Complex, Megram/Onion Fires). It was noted that options to conduct forest management/modification to reduce the incidence of SRF in the drier forests were provided for in the NWFP, but few foresters had exercised these options. The threat of SRF in the southern areas of the Northern Spotted Owl range is likely, it was thought, to become more prevalent in the future, with the continued accumulation of forest floor and ladder fuels: “…Because more years of fire suppression have occurred during the time the owl has been listed there has been a concomitant increase in the accumulation of fuels in these forests, which makes these forests more susceptible to stand replacement fires, pests and pathogens. This significant threat will remain for some time.” (Courtney et al. 2004 p.6-4).

A factor mentioned in the original Northern Spotted Owl listing was competition from Barred Owl, a close relative of the Northern Spotted Owl and a species (then) recently invasive into the northern parts of the Northern Spotted Owl range. The threat to Northern Spotted Owls from Barred Owls was given little more than passing mention in 1990, reasonably so given the perceived overriding importance of habitat loss from timber harvest. However, concerns were raised, and "…continued examination is warranted of the role and impact of the Barred Owl as a congeneric intruder…" (USFWS 1990). At the time of Courtney et al. (2004) the threat from Barred Owls had assumed major proportions, as Barred Owls had continued their spread south from Washington and Oregon into California, and had become a conspicuous resident in habitat erstwhile occupied by Northern Spotted Owls. Accumulated evidence, mostly circumstantial, suggested that Barred Owl was a prominent factor in reducing habitat usage, occupancy, and/or suitability by the Northern Spotted Owl. A wide review of the literature, and of recent and ongoing studies that included Barred Owl involvement at Spotted Owl study sites, and a survey of the coexistence patterns of owl communities worldwide, supported an elevated level of concern for negative impacts of Barred Owls on Northern Spotted Owls; the risks, uncertainties, and options were examined in some detail.

Courtney et al. (2004) noted that there had been very little research to evaluate interspecific interactions between these two congeners, and the mechanism of the competition was understood very poorly. Many factors were implicated in the interaction, from predation on Northern Spotted Owls by Barred Owls, to resource competition for prey and nest sites, to direct aggressive encounters between the two that favored the larger Barred Owl and resulted in displacement of the smaller Northern Spotted Owls from suitable habitat. The status evaluation panel concluded that, because of the lack of both unequivocal data of owl numbers over time in shared habitat, and of definitive studies of behavioral and ecological aspects of the interspecific interaction, "…it is impossible to predict with a high level of accuracy or confidence the ultimate impact of the Barred Owl on the Spotted Owl in the Pacific Northwest." (Courtney et al. 2004: 7-4). Nine alternative hypotheses were listed with respect to the outcome of Barred Owl-Northern Spotted Owl contact and interaction, ranging from one extreme, Barred Owls replacing Northern Spotted Owls throughout its range, to some form of stable if not peaceful coexistence. The first-mentioned extreme was judged "clearly plausible" by the panel. It was pointed out in particular that a) the body size ratios, a near-universal index of coexistence potential in owls, of Barred Owls/ Northern Spotted Owls in the Pacific Northwest (PNW) are around 1.09-1.24 (larger Barred Owl mass/smaller Northern Spotted Owl mass, males-to-females), whereas these same two species where they coexist in south-central Mexico are much more disparate in body sizes (ratios 1.72-1.96); see Gutiérrez et al. 2007 for details of this argument, and its relevance to Northern Spotted Owl protection. Thus, the uncertainty surrounding the outcome notwithstanding, a majority of the Courtney et al. (2004) panelists saw evidence for "strong effects" at present of Barred Owls on Northern Spotted Owls in the northern parts of its range (British Columbia, Washington), decreasing present effects through Oregon to the south in the California Redwood and California Cascades/Sierra zones, but potentially strong effects in the southern part of the Northern Spotted Owl range "in the long-term future (50 years+)." Buchanan et al. (2007) outline approaches to a detailed and scientific examination of the Barred Owl- Northern Spotted Owl interaction that, if followed, could allay much of the present uncertainty.

Besides those present and ongoing issues, two potential threats were also considered in Courtney et al. (2004), West Nile Virus (WNV) and Sudden Oak Death (SOD). WNV was introduced into North America in 1999 in New York, and has subsequently spread coast to coast over the whole country (though it is still unrecorded in British Columbia, alone of the southern Canadian provinces). The primary agency of transmission of the virus is mosquito-bird-mosquito, and owls are included as "moderately competent hosts" in a systematic evaluation by Kilpatrick et al. (2007). While some avian families (Corvidae, Turdidae) are especially susceptible to infection and can suffer high mortality rates, there is currently no reason at present to believe that WNV is a potent threat to Northern Spotted Owl populations, given the landscape distribution and habitat preferences of the infectious vectors (Pecoraro et al. 2007).

Southernmost Northern Spotted Owl habitats include a proportion of oaks (*Quercus* spp.) in the predominantly coniferous vegetation, and the potential threat of habitat deterioration in e.g. the Klamath region via sudden oak death (SOD) following fungal infection by *Phytophthora ramorum* was raised (Courtney et al. 2004). However, recent evaluations of the extent of SOD in northern California show only sporadic incidence in Mendocino county and southern Humboldt county (California Oak Mortality Task Force 2006), and there seems no reason to elevate SOD above the level of a potential threat, subject to continued monitoring.

Apart from the specific threats discussed above, Courtney et al. (2004) mentioned predation, disease, and adverse genetic consequences of small and possible isolated populations, but none was thought a significant threat at that time.

Threat Assessment in 2007 DRP and Proposed Actions

Given that threats to Northern Spotted Owl persistence have shifted in kind and magnitude since the original listing, we summarize here how threats are perceived and how they are potentially countered in the 2007 DRP. Besides the DRP itself, the SEI Science Panel heard a presentation from K. Livezey at the January 8th meeting, reporting on a June 2006 workshop, which helped to forge the 'threats assessment' used in the DRP. At this 2006 meeting, USFWS panelists considered and ranked, by province, a total of 19 threats to the Northern Spotted Owl; level of uncertainty around a threat, and its potential consequences, were also evaluated. In summary, the three highest ranked threats were determined to be Barred Owl competition (level 9), past habitat loss and ongoing habitat loss (each level 8). The DRP cites three major threats that were discussed at length in Courtney et al. (2004), namely a) past and ongoing habitat loss to timber harvest; b) habitat loss to catastrophic wildfire, and c) Barred Owl competition, and summarizes the evaluation of these threats in each province of the Northern Spotted Owl range (PP. 17-18; Appendix C; threat assessment does not differ between Options 1 and 2 of the DRP). Minor threats, such as WNV, are mentioned in passing. The DRP raises Barred Owl impacts on Northern Spotted Owls to the single, most predominant threat, one that requires immediate action. The evidence to support this position is cited in the DRP, which concludes that the "…preponderance of evidence suggests that Barred Owls are exacerbating the Spotted Owl population decline", "there is no evidence that the increasing trend in Barred Owls has stabilized in any portion of the Spotted Owl's range," and "the threat from the Barred Owl …was the only threat whose actions received any priority 1s in the Plan" [i.e. DRP]. A strategy for experimental removed of

Barred Owls from Northern Spotted Owl habitat is described in Appendix G of the DRP, to be supervised by a proposed Barred Owl Working Group; implementation of the strategy "because of the pressing nature of the threat requires appropriate action as soon as possible" (DRP p.168). Such proposed action includes expediting permitting of Barred Owl control, experimental tests for the effects of Barred Owls on Northern Spotted Owls, and management of Barred Owl populations if negative effects on Spotted Owls are indicated.

Threats from past and ongoing Northern Spotted Owl habitat loss to timber harvest and threats of further habitat loss due to fire are summarized in the DRP. To ameliorate these threats, habitat conservation is proposed via establishment of MOCAs (Managed Owl Conservation Areas) and ancillary CSAs (Conservation Support Areas). The former align approximately with existing LSRs, the latter are outside of federal lands and assigned a supporting role in the recovery process. Option 1 stresses the need for "implementers and regulators" to modify MOCAs and CSAs as they see fit, to better accomplish recovery goals, while Option 2 identifies no formal conservation areas, but leaves management of suitable Northern Spotted Owl habitat entirely within the jurisdiction of local forest managers in various different agencies who are "urged to work closely and cooperatively" (DRP p. 25) to achieve the goals of the DRP.

Notably, the assessment of threats of the Northern Spotted Owl as represented in the DRP has received considerable adverse criticism, chiefly voicing two points of contention. Firstly, most critics regard the significant reduction in protected Northern Spotted Owl habitat under the DRP as a major reversal of conservation goals and, secondly, the rationale/evidence behind elevation of Barred Owl competition to sole top priority status is vigorously questioned. At the first panel meeting both of these points were raised and discussed. It was noted by K. Livezey that the 2006 threats assessment (see above) explicitly assumed that all existing regulatory mechanisms would continue unchanged, including maintenance of LSRs; hence, further loss of habitat to timber harvest was anticipated to be minor. Under the DRP, this assumption is not met, as additional timber harvest is feasible under both Options 1 and 2 (outside reserves in Option 1). However, with these Options now on the table, the threats assessment was not revisited by the USFWS; with a reduction in conserved habitat it is possible that a reordering of priorities might take place. Specifically, threats from past and especially ongoing habitat loss might assume more prominence.

The SEI Science Panel sees no reason to deviate from the findings of Courtney et al. (2004) on threat assessment, in terms of identity, magnitude, regional variation, uncertainty, and possible consequences. The major threats remain past and potential future habitat loss from timber harvest and fire, and competition from Barred Owls. While these threats appear not to have changed in nature, they are, in view of recent information on Northern Spotted Owl populations, simply more pressing. R. Anthony in his presentation to the panel at the January 9th SEI meeting, showed the most recent occupancy data from Washington and Oregon (through 2007). This indicated that Washington has continued to decline and now Oregon is showing a decline in the percentage of sites occupied by pairs. Acknowledging that the pace of timber harvest in

Northern Spotted Owl habitat on federal land has greatly declined 1990-2007, we view the continued conservation of LSOG forest to be paramount for Northern Spotted Owl recovery. Several reviewers stated that the MOCA strategy reserved significantly less habitat than did the NWFP, and that such reduction in owl habitat at this time was inadvisable. The presentation by C. Carroll directly addressed this point. However we remain unsure of the extent DRP provisions depart from the NWFP. We concur that increasing the harvest of occupied habitat would harm the species at a time when it appears to be in accelerated decline. However there remain ambiguities in the DRP with respect to habitat protection: 1) The NWFP includes reserves set aside for many species other than owls. Hence it is not clear the extent to which owl habitat is treated differently under the two plans. 2) The DRP states that "Cutting suitable habitat in areas that have higher habitat percentages than the listed percentages is not recommended, unless future research indicates otherwise (see recovery actions 32 and 33)." Given these observations, it is important, in order to evaluate the effectiveness of the Recovery Plan, to address the extent to which the proposed recovery options would lead to increased loss of occupied habitat. The extent to which such losses occur elevates threats to the species and diminishes recovery potential.

It remains debatable as to how the various threats to Northern Spotted Owl persistence are evaluated and compared. If the results of experimental research on Barred Owl-Northern Spotted Owl interactions were already in hand, we would have a much firmer grasp on the magnitude of the Barred Owl threat, and therefore what our options might be to counter this threat. Similarly, armed with detailed maps of the size and isolation of Northern Spotted Owl occupiable habitat and their current populations, a PVA analyst could make informed estimates of the persistence probabilities of the meta-population, and how those probabilities would change from NWFP to DRP's Option 1 and Option 2. Recent data (post-2004) from the 13 major demography study areas confirm and extrapolate the declines seen prior to 2004 (Anthony presentation). It should be possible to derive far more information from these studies than the ultimate data reduction statistic of finite rate of increase λ. Which conditions within the study sites are contributing to λs near or below 1, and how can those conditions be ameliorated? These details, many from areas of good habitat availability and absent Barred Owls, should be relevant to, even critical information for, a recovery plan.

CONSERVATION STRATEGY

Many factors must be weighed by the USFWS in developing the Final Recovery Plan. Policy decisions, such as which conservation strategy to adopt, must be informed by many issues, including science. Our goal here is to review the scientific underpinning of owl recovery, but not to comment on policy concerns, which remain within the purview of USFWS.

Overall we find that the threats to Northern Spotted Owls have not diminished since the last status review (USFWS 2004, Courtney et al. 2004). Although presentations and review comments suggested some evidence for newly increased threat levels, these indications are preliminary and unpublished. Hence we believe that the species is at risk, but not likely to become extinct in the near term. However the risks to the species remain substantial, and in some cases (e.g. with threats from Barred Owl, catastrophic fires) can be expected to increase, absent active management. Unless the Final Recovery Plan results in a concerted effort to take action on these threats, we foresee the situation progressively deteriorating.

The most important underlying principle of the ISC, FEMAT and NWFP analyses was that habitat protection was key to protecting and recovering the Spotted Owl. As a corollary, it was assumed that recovery actions could be focused on habitat as a surrogate, and that it would not (for instance) be necessary to know where all the Spotted Owls were, provided their presumed preferred habitat was protected and enhanced. This may have been a reasonable assumption at the time, but it led to the current situation, where we have little information on newly critical issues, such as the actual current distribution and abundance of the species in all areas. Now, the assumption no longer holds. The burgeoning populations of Barred Owls have apparently displaced Spotted Owls in some areas. Hence we can no longer use LSOG habitat as a surrogate for Spotted Owl well-being. Any conservation strategy for Spotted Owls therefore must deal with the need for information on owls, and with action directed at owls, rather than indirectly though habitat. This means, for instance, that for MOCAs (or other reserves) to protect currently living owls, they need to be placed where owls actually are. Note that we are in no way stating that the importance of habitat is diminished; protection of habitat is key.

Importantly, we note that there is substantial geographic variation in the threats faced by Northern Spotted Owl populations. Barred Owls, where present, are a significant issue – but not all parts of the range currently have large Barred Owl populations. Similarly catastrophic fires leading to mortality and loss of habitat may be disproportionately threatening in the eastern Cascades provinces compared to elsewhere. Hence a conservation strategy that explicitly addresses such variability in the local threats will perform more successfully than does one that adopts a global approach. This point is underscored by the large regional variation, noted repeatedly through this report, in the ecology of Spotted Owls (prey, habitat, territory size, effects of weather etc.). The DRP acknowledged some of this variability; the success of the Final Recovery Plan will probably depend in part on whether it adequately addresses geographic variability, and presents a workable framework for managing such complexity.

Regional differences in forest type (biotic community composition, developmental and successional processes, see Carey et al. 1999a, Franklin et al. 2002), forest ecology, disturbance regimes, history of management and disturbance, prey base, and local adaptation of Spotted Owl populations to these differences suggest that a bottom up (locality to region) approach would be more efficacious than a top down (region to locale) approach (Carey 2007). The importance of various factors in determining Spotted Owl viability will vary markedly across the region as should approaches to management for recovery.

The DRP presents two options. Forest habitat conservation under one of these is explicitly map-based; the other operates by rule sets. There was extensive criticism by many reviewers on both options, and particularly for the rule set option (Option 2) which was perceived by reviewers as substantially reducing the reserve network. The panel remains convinced that habitat is a significant issue for Spotted Owl populations, and agrees with many reviewers that any reduction in habitat protections will be detrimental to the owl at a time when it is under threat. On the other hand, we heard a presentation that suggested that under some circumstances an Option 2 strategy could actually increase habitat protection from current provisions of the NWFP (Gaines presentation). We found that many of the criticisms and reviews received were primarily about management of the options, and about lack of trust for the federal agencies. We have not addressed such comments. A priori, there is no reason why rule sets should not constitute a successful approach, provided there is adequate long-term protection of occupied and occupiable habitat. Indeed a rule set approach may be very useful when combined with a reserve network. For east-side fire-prone habitats we are convinced that a successful conservation strategy will have to explicitly recognize the dynamic nature of the landscape, and adjust to changes in it.

Whether to adopt a particular conservation strategy or option is largely an issue of risk management – evaluating risks is a science-based task; risk management is a policy decision. We have evaluated the risk to populations in east-side fire-prone habitats to be large and in this case, the evidence for the scale of the risk is quite evident. When considering other parts of the range, the panel debated longer, and had a wider diversity of opinion on the risk posed by fire. This illustrates an important general point for this species – there are few formalized means to evaluate risk, such as whether a particular strategy will have a high probability of success. The threats assessments carried out by the USFWS for the DRP were qualitative and at very large scales. Risk can be considered more systematically and quantitatively (and ultimately more usefully, e.g. in a Population Viability Analysis – see Noon in Courtney et al. 2004). However, it is important to recognize that some quantitative models (e.g. efforts under way by Marcot and Raphael) are not well-suited to evaluating risks – these are more heuristic in nature (e.g. in determining whether larger reserves afford 'more' protection). Absent a more appropriate quantitative model (which would require considerable effort to make it applicable to particular landscapes, and possess the capacity to account for the regional variation in conditions emphasized above), USFWS will continue to be constrained to using essentially qualitative risk assessments of conservation strategies.

Throughout the DRP, the USFWS identified issues that will require further resolution. Comments from reviewers and our own evaluation agree that there are many issues where integration of new scientific information will be key to successful implementation of any conservation strategy. Three examples are: the proposed Barred Owl removal experiment; the known distribution of Spotted Owls in east-side forests that will be aggressively managed for fire; the local fire and prey ecology of landscapes in Klamath provinces. Given the scale of these scientific efforts, and the magnitude of the decisions that will flow from them, integration and communication between science and managers will be an important element of a successful conservation strategy. Recovery Action 1 of the DRP discusses such a coordination group:

> "Implementation of a Recovery Plan with the breadth and scope of this Plan would greatly benefit from a working group to facilitate implementation of the numerous recovery actions necessary to carry out the Plan and recover the spotted owl. The NSO Work Group should be responsible for coordinating other necessary work groups, such as one to deal with barred owls"

We disagree with this statement only to the extent that it understates the importance of such a coordinating effort. Unless there is a high priority for integration of science into an adaptive conservation strategy, it is unlikely that new information will be available in the timeframe necessary for successful recovery of the owl. The workload of a NSO Work Group would be large, and entail evaluations of many issues on an ongoing basis.

Among the important early tasks of any recovery group will probably be efforts to evaluate the effectiveness of the reserve network. It may be necessary to adjust the location or boundaries of the MOCA or other reserves and this need for re-adjustment may continue. This will be important for several reasons: 1. The assumption that LSOG habitat is a sufficient surrogate for Spotted Owl presence no longer holds (due to displacement by Barred Owls). 2. It may be that important portions of the Spotted Owl population occur in matrix areas (Pearson and Livezey, 2003). 3. MOCAs will probably be lost as viable population centers (due to either Barred Owls or fire). Hence it will be necessary to regard the current reserve network as an interim strategy, to be enhanced as new information becomes available.

The SEI panel believes that only an adaptive Recovery Plan will be able to make the significant adjustments necessary to recover the Spotted Owl. The challenges are large, and the need for new information is pressing. Similarly a fully engaged Recovery Team, able to meet the significant demands for expertise and effort, will be necessary to make changes. We anticipate many such challenges and changes in the first few years (5+) of operation of this plan.

Assuming continuing implementation of the NWFP and its late-successional reserves, a strong multipronged strategy for the recovery of the Spotted Owl will still be necessary to ensure the viability of Spotted Owl populations in the Pacific Northwest. Such a plan could include ecosystem management approaches to recovery, or development, of Spotted Owl habitat; protection of existing Spotted Owl habitat; and evaluation of the impact of Barred Owls.

The following potential recovery actions are currently under-emphasized in the DRP:

Encourage and develop incentives for industrial landowners to manage forests in manner that promotes biocomplexity and produces multiple values.

On the Olympic Peninsula, on industrial lands adjacent to state and federal lands, where demographic support is lacking for owl populations in LSRs, current intensive management calls for clearcutting on rotations less than 40 years, intense site preparation, application of germination inhibitors, planting dense monocultures of genetically superior strains of trees, application of herbicides to reduce competition from non-crop species, precommercial thinning to promote growth of crop trees while inhibiting growth of non-crop species, pruning, and clearcutting again (Carey et al. 1999b, Carey 2007). These areas are likely to be devoid of prey and to lack roosting and nesting structures for Spotted Owls. Where benign neglect has furthered ecosystem recovery on industrial, state, and federal lands--where there are some biological legacies, wetlands, unintended multispecies regeneration, and persistence of hardwoods such as vine maple, big leaf maple, and alder-- Spotted Owls are persisting and sometimes breeding and producing young (Carey et al. 1999a, Carey 2000). Thus, there is potential for management for owls on lands managed for timber revenues. Similarly, in the redwood and Mixed Conifer/Mixed Evergreen types, minor changes in management can be very important. For example, precommercial thinning to stimulate the growth of crop trees can include control of hardwoods that destroys prey (Dusky-footed Woodrat) habitat or encourages the development and persistence of woodrat habitat (Carlson-Higley presentation).

Emphasize ecosystem recovery through active management, including ability to support Spotted Owls and their prey, in wet-mesic forests west of the Cascades in Washington.
Washington west-side forests are exhibiting poor demographic performance on the part of Spotted Owls with reduced recruitment from outside demographic study areas; these areas support large Barred Owl populations that will increasingly compete with Spotted Owls for habitat space. Active management can be used to accelerate development of biocomplexity (including prey, roosts, and nest trees) in i. second-growth forests (Carey 2003a) within late-successional reserves and, ii. more importantly in adaptive management areas on Forest Service lands, iii. in areas under habitat conservation plans on state lands and private lands, and iv. through incentives on lands being purchased and managed by non-profit and socially minded investment organizations (Carey et al. 1999b, Carey 2007). Prime areas for such active management include the Olympic National Forest, the Olympic Experimental State Forest, and various privately owned timber lands on the Olympic Peninsula; Fort Lewis in the Puget Trough; the Capitol State Forest, other state forests, forests now (and in the future) owned by conservation groups in southwestern Washington (Washington Coast Ranges) and protection of Spotted Owl special emphasis areas on industrial forest lands in southwestern Washington (Washington Coast Ranges). Active management of second-growth for biocomplexity might prove essential to the recovery of Spotted Owls and to enhanced landscape function in general (Carey 2003b, 2006). Other opportunities for collaborative recovery efforts exist on private lands recently acquired in and around Snoqualmie Pass and substantial acreages of cutover forests on National Forest lands south of Mt. Rainier. Multiple opportunities exist for such active management in the Oregon Cascades, Coast Ranges, and Klamath Mountains as well.

Consider the prey base in all strategies for recovery of the Spotted Owl.
Understanding prey distribution and abundance is crucial to understanding Spotted Owl ecology (Carey et al. 1992, Carey and Peeler 1995). Indeed, Spotted Owl habitat should be defined locally as a mosaic of biotic communities (Carey and Peeler 1995) that

maintains sufficient prey base and other elements of Spotted Owl habitat, such as roost and nest sites, as to support successful reproduction by a pair of Spotted Owls. As discussed above there is considerable variation in the prey base used by Spotted Owl. Key prey in Oregon, such as the Red Tree Vole and Dusky-footed Woodrat, do not occur north of the Columbia River (Carey et al. 1992, 1999c). The life history and ecology of the single-most important prey of the Spotted Owl, the Flying Squirrel, varies across the range of the Spotted Owl (Carey 2000, Lehmkuhl et al. 2006b).

The southern Oregon Coast Ranges, especially along the Umpqua River valley margins, offers the most complex prey base and perhaps the greatest overall biomass of prey within the Spotted Owl's range (Carey et al. 1992, 1999a), even though prey biomass may peak in late clearcut/sapling stands in the Mixed-conifer/Mixed Evergreen, redwood, and chaparral types where Dusky-footed Woodrats abound. Spotted Owls seem to be doing well demographically here. Maintaining existing Spotted Owl habitat in the southern Coast Ranges and adjacent Klamath Mountains may offer the best opportunity for ensuring the persistence of Spotted Owls in Oregon and Washington. In the Eastern Washington Cascades, Flying Squirrel and Bushy-tailed Woodrat abundance is high, even in open ponderosa pine forests not typically considered Spotted Owl habitat, and more similar to mixed-conifer forests of southern Oregon than the wet western hemlock and Douglas-fir forests of western Washington (Lehmkuhl et al. 2006a,b). It is important also to keep within-region variability clearly in mind. For example, in the area where the Western Hemlock Zone transitions to the Mixed Conifer Zone in southern Oregon Coast Ranges, Bushy-tailed Woodrats, Northern Flying Squirrels, and Red Tree Voles may be simultaneously in high abundance in complex, older forest and just a short distance away, in the Valley Margin forests, the Dusky-footed Woodrat joins the other 3 species in high abundance in old forests, a marked addition to prey variety and prey biomass. All these may be much reduced in abundance to absent in younger second-growth forest. Whereas the Dusky-footed Woodrat may be highly abundant in very young forest of northern California, occupancy of clearcuts and sapling stands is much more variable and uncertain just north in southern Oregon. In southern Oregon, Dusky-footed Woodrats can be present in relatively high numbers in mixed-conifer old-growth forest that have had a history of frequent moderate to high intensity fires that were very limited in area (hectares or less) or patchily and lightly distributed over large areas. In southern Oregon, early seral stage (clearcuts and sapling stages) may require Spotted Owls to traverse much larger areas to include some minimum amount of old growth in their home ranges; the cost of maintaining larger territories may be equivalent to eliminating a major prey species from the prey base (Carey and Peeler 1995). Thus, in discussing strategies for recovery of the Spotted Owl, clear communication and efficacy of management would be enhanced if these discussions were held in the context of particular biotic communities and their seral stages (Franklin et al. 2002 for natural forests and Carey 2003c, 2007 for managed forests). For example, Carey et al. (1992) concluded that in the Douglas-fir/western hemlock/Flying Squirrel/Bushy-tailed Woodrat communities in the southern Oregon Coast Ranges, 1,000 ha of old growth within a 2,000-ha area would produce a reasonably high expectation of a pair of Spotted Owls persisting for 1 year; in nearby mixed conifer/Flying Squirrel/Dusky-footed Woodrat/Bushy-tailed Woodrat/Red Tree Vole communities, 500 ha of old forest within a 2,000-ha range might prove sufficient for

1 year, and 650-700 ha/2000-ha range for 2 years. Where the minimum amounts of old growth are present, a Spotted Owl learns to monitor and use prey in other biotic communities on continuous, intermediate, and sporadic bases (Carey and Peeler 1995). Thus, maintenance of LSRs (as assumed under the DRP) and other areas of Spotted Owl habitat may prove adequate; timber harvests to increase "habitat heterogeneity" may be counterproductive.

OWL BIOLOGY

PROVINCE LEVEL APPROACH

Understanding the biotic communities and the ecologies of the species inhabiting them requires an appreciation of the effects of landform and complex environmental gradients (e.g., the large-scale moisture temperature gradient in the PNW) on plant communities (Franklin and Dyrness 1988), zoogeography (e.g., Carey 1995, Carey and Johnson 1995, Carey et al. 1992, 1999b), the processes underlying plant community succession and forest development (Franklin et al. 2002, Carey 2007), and how these processes influence biodiversity in general and keystone species in particular (Carey et al. 1999a). Physiographic provinces, then, provide a good starting point for design of conservation strategies and related research (e.g., Carey and Spies 1991). But it is important to next examine the array of biotic communities found within physiographic provinces and how these may differ in their capacity to support diversity in general and species of special interest in particular, how this capacity may vary with stage of development of biocomplexity, and how community development may differ from historic examples due to ever changing management and disturbance regimes (Carey 2007). Thus, a conservation strategy for a particular species like the Spotted Owl must consider how the owl is affected by zoogeography (prey base) and management influences (landscape character) e.g., Carey et al. (1992), and within landscapes by prey diversity and abundance, well-defined stages of community development, and local arrangement (patches) of biotic communities (e.g. Carey and Peeler 1995). All the research cited previously in this paragraph suggests that a conservation strategy must be carefully formulated by the bottom up (landscape to physiographic province to region), not the top down (the species range to the physiographic province).

Unfortunately, the DRP (Appendices A and B) takes a top-down approach, even to combining unlike physiographic provinces (Puget Trough with the Washington Coast Ranges) and not clearly discriminating among low-, moderate-, and high-elevation forested biotic communities in other provinces. Both seem eliminated from consideration, but the Puget Sound Trough includes the 78,000-acre Fort Lewis Military Reservations, much of which is covered with forests more than 80 years old and which have been managed to accelerate forest developmental processes. Large amounts of State forest span the boundaries of the Puget Trough and significant portions of the Southern Washington Cascades and the Washington Coast Range. The Washington Coast Range has become a focus of conservation of old-growth related species (including the Spotted Owl and the Marbled Murrelet) with formulations of Habitat Conservation Plans on State and private lands, acquisition of industrial lands by non-profit conservations groups, and placement of addition lands in wildlife refuges and natural resource conservation areas. The Spotted Owl is demonstrating markedly different demographic performance and faces markedly different threats in the various provinces and within provinces, ranging from catastrophic fire in its habitat in many east-side forests, to competition from the Barred Owl throughout Washington, to inadequate recruitment of subadults from outside demographic study areas on the Olympic Peninsula, to continuing habitat loss and lack of habitat recovery in the Washington Coast Ranges. Thus, strategies for the recovery of the Spotted Owl need to be locally specific.

Ambiguity engendered by references to the northern or southern parts of the Northern Spotted Owl's range or by defining its habitat grossly (and inaccurately) as forests older than 50 years vs. forests younger than 50 years will contribute to the likelihood of failure of a conservation plan. For example, there are marked differences in owl ecology where the Western Hemlock Zone in the southern Oregon Coast Range transitions to the Mixed-Conifer/Mixed Evergreen Zone in the Klamath Mountains and to the Mixed-Conifer Zone in the adjacent Umpqua Valley margins (Carey et al. 1992, Carey and Peeler 1995). In this area, owl populations seem to be the most robust of Washington and Oregon; here protection of habitat (ideally mosaics of old growth and niche-diversification stages of forests development with inevitable inclusions of other seral stages and biotic communities such as riparian forests characterized by a significant component of deciduous trees and shrubs) would seem integral to any overall conservation plan for the Spotted Owl. Further south, in the redwood forests, old growth seems less useful to the owl than some younger seral stages. In the Mixed Conifer/Mixed Evergreen forests of the Klamath, maintenance of the hard-leaved sclerophyll component of old forests through non-catastrophic fire leads to relatively high Dusky-footed Woodrat populations and small home ranges where old growth make up the bulk of the range. As the Evergreen component becomes predominant, the Dusky-footed Woodrat becomes the most important prey, and use of early seral stages may increase. Note, however, that the primary prey of the Northern Spotted Owl does differ with specific location within the Klamath (aspect, elevation, position on major temperature-moisture gradient, and the resultant biotic community). Specific descriptions of biotic communities, their seral stages, and their potential bases of prey for the Northern Spotted Owl can be readily constructed from regional wildlife-habitat relationships manuals (e.g., Johnson and O'Neil 2000), summaries of research conducted specifically for the purpose of describing the biotic communities in the Pacific Northwest (Ruggiero et al. 1991), new descriptions of the stages of development of natural forests (Franklin et al. 2002), new descriptions of stages of development of managed forests (Carey 2003, 2007), and a large literature now existing (e.g., Forsman et al. 1984, 1991, and others) on the prey bases of Northern Spotted Owls provides the necessary science for formulating bottom up approaches to maintaining viable populations of Northern Spotted Owls across their historic ranges in California, Oregon, and Washington.

POPULATION VIABILITY AND MODELS

The lack of population viability analysis (PVA) for DRP options was expressed variously in public comments and peer reviews: "no explicit analysis of risks for different DRP options", "population modeling was outdated", the "best available science was not used". Related issues concerning area, size, and spacing of reserves and their impact on population viability and recovery are addressed in the next section.

The DRP does not include an explicit PVA or any risk analysis of the options. It appears to rely solely on the scientific credibility of the ISC plan and the subsequent 1992 DRP that was based on ISC principles. The current DRP cites Courtney et al. (2004) to the effect that the ISC plan is based on sound scientific design principles, yet Courtney et al. make that statement solely in reference to the NWFP, not the ISC or 1992 DRP. As far as we can tell, the NWFP differs from the DRP in having larger reserves and more habitat protection in the matrix, so the two plans are not equivalent. Habitat is also protected in riparian reserves of the NWFP where dispersal habitat is provided. It has been conceded that the ISC and 1992 Recovery Plan were based on sound principles (e.g. Raphael 2006); but, where the current DRP perhaps differs is in the application (or details) of those principles using 1992 science vs. the best current science. Some issues related to those details are described in the next section.

The issue of risk analysis would seem to be a critical one given unexpected declines in Northern Spotted Owl populations throughout the range, especially in Washington (Anthony et al. 2006), recent suggestions of further declines in Oregon (Anthony presentation), lower levels of protected Northern Spotted Owl habitat in the DRP compared to the NWFP (Raphael viability presentation, Carroll presentation), known Barred Owl impacts, and other threats. The 1992 models were developed at a time when Barred Owl invasion was extensive and on-going; hence, the basic observed parameters used in the models probably already incorporated some Barred Owl effects. What has changed is (1) Our understanding of the probable role of Barred Owls in Northern Spotted Owl population dynamics and habitat use, and (2) The extent of these negative effects (e.g. more widespread than previously known).

The 1992 models used in the 2007 DRP simply apply some basic premises of conservation biology, viz: persistence is more likely with bigger reserves with smaller spaces between them, and when these are well distributed on the landscape. The models used cannot give explicit population projections tied to explicit landscapes, as in a PVA, but were useful in providing a general guide to policy decisions. The models were unable to provide sufficient detail to state, for instance, "in this actual landscape, in this habitat type, with this configuration, reduction in spacing of reserves by x% will give an increase in λ by y amount". The models used were simply useful general guides to conservation principles – they did not answer the most pertinent management question "what configuration of reserve design will maintain [Northern Spotted Owl]?" They did not set either the minimum habitat requirements for persistence, or the marginal increase in probability of persistence that would be gained by incremental increases in reserves. Only a detailed, geographically-explicit model would be capable of providing strong quantitative assessments of different reserve designs for Northern Spotted Owl recovery. Appendix 10 of Courtney et al. 2004, developed by B. Noon, called for exactly this sort of PVA approach.

Published sources that were not addressed in the current DRP indicate the ISC design, hence the current DRP design, results in less long-term certainty of viability outcomes (FEMAT 1993), and smaller long-term population size and lower range occupancy than the NWFP (Raphael et al. 1994, Raphael viability presentation). In the absence of a risk analysis of the current DRP options, a discussion of the published analyses cited above would provide some perspective on the comparative viability of the DRP design with respect to area of habitat, the size and configuration of reserves, and matrix management.

Note that the current modeling effort by Marcot and Raphael, admittedly heuristic, attempts to be somewhat realistic by use of parameters that approximate real-world conditions. An exception to this is that the model is based on vital rates that are predicted to support a net population growth rate, λ, of 1 (i.e. the population is stable). Marcot and Raphael's models are designed to illuminate whether a stable population would be supported by a particular configuration in their models. The procedure they followed to derive the values necessary for their model parameters was to take adult survival rates (averaged throughout the range) as reported by Anthony et al. (2006), and adjust them upwards, so that, when combined with actual reproductive and juvenile survival rates, the net result would be a λ of 1. Clearly this procedure further limits the applicability of these heuristic models in terms of a real-world population where λ is significantly less than 1.

CONNECTIVITY, SPACING AND ALTERATION TO SITE CENTERS

The primary issue from comments and reviews is that the size of reserves is based on the ISC and 1992 DRP design, which is said to be outdated. The size of reserves was based on modeling by Lamberson et al. (1994) that indicated population size stabilizing in hypothetical meta-populations when individual reserves supported 20-25 pairs of owls. Subsequent unpublished modeling using a spatially-explicit life-history model in real landscapes suggested that population stability is best achieved by individual reserves with 30-40 pairs of owls, and with a few large reserves (>100 pairs) (unpublished ms reported in Noon and McKelvey 1996). Some large reserves, in addition to more reserve and matrix habitat, is one potential reason for the relatively better predicted viability outcomes of the NWFP vs. the 1992 DRP (Raphael 2006). The 1992 DRP design was judged to be the minimum for reserve design that might ensure some level of long-term viability for Northern Spotted Owls (Raphael 2006). To date, no improved or alternative modeling effort with the most current demographic and ecological data has been completed, although new simulation modeling of reserve size and spacing in hypothetical landscapes is in progress (Raphael and Marcot presentations). Reserve spacing guidelines in the current DRP of 7 to 12 miles are consistent with recent information on median juvenile dispersal distances of 9 miles (males) to 15 miles (females) (Forsman et al. 2002).

Under these circumstances, we can make only general statements about the adequacy of the DRP reserve design. Theory predicts that bigger reserves, more closely spaced, provide better probability of persistence than do smaller reserves, further apart. Increasing reserve size, reserve number, or decreasing spacing will have some incremental increase in persistence. How big such an increase would be is unknown with current modeling capabilities. Also, effective reserve size, number, and spacing may vary by province depending on differences in the persistence of reserves in wet vs. dry provinces, where reserves may be lost or diminished by wildfires unless actively managed to restore stable fire regimes (Agee and Edmonds 1992). In dry provinces the number or size of reserves may need to be larger to account for future loss. At some point increasing reserve size and number may involve the majority of the landscape, so an alternative approach could be to manage the whole dry-forest landscape to maximize the persistence or recovery of Northern Spotted Owl habitat while minimizing the complexity of land-use allocations (i.e., reserves and matrix), and minimizing loss of habitat in the matrix. In areas without large numbers of Barred Owls, the existing strategy presumably can be considered as being as adequate (or inadequate) now as it was previously. In areas with extensive Barred Owl populations, reserves may not be performing as planned – but it is probable that Barred Owls will impact Northern Spotted Owls in such areas regardless of the existing reserve design. Barred Owls have and will continue to usurp some unknown proportion of Northern Spotted Owl habitat, in effect reducing the size of reserve available to the Northern Spotted Owl.

NEW DEMOGRAPHY INFORMATION

A summary of the latest science on the long-term demography of the Northern Spotted Owl (Anthony et al. 2006) is presented in Appendix A of the DRP. We regard this as a complete and accurate representation of current knowledge. This information, however, does not appear to have been used to inform reserve design, for tailoring DRP designs and recovery actions by province according to reported rates of change, or for risk analysis of DRP options.

GENETICS

The SEI Science Panel observed an oral presentation by Dr. Susan Haig on the evidence for genetic bottlenecks in Northern Spotted Owl populations. Subsequently, she provided two unpublished manuscripts (with co-authors) to the SEI Science Panel, which were sent by SEI to three genetics experts for review (Dr. Keith Crandall, Dr. Andrew Bohonak, and Dr. Robert Zink). These papers are current in review at two journals, use the same data, and discuss different elements of inference relative to the data. The oral presentation to the SEI Science Panel (and USFWS) was an amalgam of these two papers and some (but not all) of the ideas contained therein. The peer-reviewers of these papers state that the sample size and distribution of localities are good. In summary, she reported in her oral presentation (and the papers corroborate) that she used 11 microsatellite loci as genetic markers extracted from blood samples of 352 Spotted Owls taken from 16 "populations" from throughout the range of the Northern Spotted Owl as the basis for her (and the two papers') assessments. In her oral presentation, Dr. Haig emphasized that microsatellite markers represent a "recent" genetic signal and this inference is perpetuated in the papers. Using a computer program called "Bottleneck" she identified evidence of genetic bottlenecks at several spatial scales (individual "populations" [study areas], regions, and subspecies). Haig explicitly stated that she could not conclude that these bottlenecks were the cause (or related) for recently documented declines in Spotted Owl populations. Nevertheless, she implied that the bottlenecks and population declines were related simply by presenting a "cross-walk" table depicting the status of Northern Spotted Owl populations (studied by Anthony et al. 2006). Her conclusion from the cross-walk table was that a gross correlation existed between population status and the evidence for bottlenecks, which suggested that either the recent declines were the result of bottlenecks or that the declines were leading to bottlenecks (it was not clear which of these possibilities Dr. Haig favored). The manuscripts submitted to our team basically reflect this assessment although the reviewers discuss in greater detail the other analyses conducted on these data.

Based on our reading of the submitted, unpublished manuscripts, Dr. Haig's oral presentation, and the three peer-reviews of the two unpublished manuscripts (2 manuscripts by Funk et al.), the SEI Science Panel does not believe that this genetic information has direct bearing on the current revision of the Recovery Plan for the following reasons:

1) The information presented by Dr. Haig has not been published, but is being peer-reviewed by journals. However, the manuscripts submitted to the panel allowed us to solicit our own peer-reviews of the papers, which resulted in significant evaluation of the strengths of conclusions reached in the papers, given the data. The results of the journal's peer reviews are not available for evaluation at this time, but they would also make it easier for the scientific community to evaluate the results, inferences, and conclusions. At this point, the conclusions regarding the role of genetics in population declines, the effects of population declines on genetic diversity, and hence on population viability can be evaluated in a sufficient, but preliminary, manner for us to draw general conclusions about these potential threats to owls based on the manuscripts supporting Dr. Haig's oral presentation.

2) A priori, the theory of genetic bottlenecks appears inconsistent with recent demographic changes in Spotted Owl populations because genetic bottlenecks occur when populations are reduced to such a low level, and for a sufficiently long time (i.e., population reduction followed by a time lag) to allow purging of genetic variation from the population. This is a stochastic process and can, of course, theoretically occur over a relative short time periods if the reduction in population size is substantial and co-occurs with "sampling error" (Roughgarden 1979, Hartl and Clark 1989). If population size reduction is relatively smaller (but still substantial) changes in genetic structure would take much longer time periods for their manifestation as a "bottleneck." Such points were also noted by our solicited peer-reviews. We have no evidence that Spotted Owls have

declined to such low levels within the time frame of current conservation concern for the owl (i.e., they would be the cause of a bottleneck). We have no idea of past population levels of Spotted Owls. We also believe that populations experiencing present and recent declines have more parsimonious explanations for such declines (e.g., past and present habitat loss and impact by Barred Owls). It is possible that some rare alleles in a population might be lost due to "sampling error" during a severe short-term population decline in Spotted Owls, but the spatial distribution and relative abundance of extant Spotted Owl populations argues against this possibility.

3) Some of the populations in the Haig presentation/Funk et al. studies that were identified as having gone through a genetic bottleneck are in relatively close proximity, are linked by habitat to other owl populations, or are within the dispersal range of individuals. Thus, the possibility of gene flow among "bottlenecked" populations is inconsistent with "sampling error" of genetic material. This was noted by one reviewer.

4) The term "recent" in evolutionary terms (and with respect to microsatellite evolutionary rates) could mean something quite different than "recent" in common language usage. "Recent" in evolutionary time could be on a scale of hundreds if not thousands of years. Thus, a priori, any observed evidence for bottlenecks in Spotted Owl populations is unlikely to reflect population processes occurring during the most intense study of Spotted Owls (past 30 years). The reviewers also discuss bottleneck theory from other perspectives, and provide much reason to doubt that current population status (i.e., recent declines) has anything to do with historic genetic signatures. It is also highly likely that historic bottleneck signatures reflect time spans in tens if not thousands of generations, which would put any estimated bottleneck events well beyond modern time.

5) Even if genetic bottlenecks occurred in some (many) Spotted Owl populations at some time in the past, it is not clear if the recognition of these potential events has bearing on the adaptive potential of Spotted Owls based on this study of presumably neutral microsatellite markers. One reviewer (Crandall) noted that such a general result (loss of genetic diversity) for Spotted Owls, or any endangered species for that matter, is almost an expected result.

6) One reviewer (Zink) discusses at length the problem with confusing presumed decline in diversity of microsatellite loci as meaningful measure of loss of diversity with respect to adaptive traits. That is, loss of microsatellite diversity may not reflect loss of evolutionary potential, in the same way that allozymes were shown to be selectively neutral some years ago. From the perspective of the USFWS, this is a key issue because loss of diversity is a question relevant to adaptive potential and is of fundamental concern for conservation geneticists.

7) Although the panel saw no explicit analysis in the oral presentation, we believed the program ("Bottleneck") used to infer the occurrence of bottlenecks is sensitive to the mutation mechanism and this is poorly understood for microsatellites. The reviewers supported our initial assessments and provide more rigorous assessments of analyses supporting the papers.

8) One problem noted by two reviewers (Bohonak and Zink), and one that is fundamental to any analysis, is that the "populations" of interest in these studies are arbitrarily defined. There are various definitions of biological populations, but it is generally understood that they have generally have little genetic interchange (linkage) with other populations of the same species. By defining populations in an arbitrary manner, it is not known if these are truly biological distinct populations or simply samples of larger populations. From an analytical point of view this is critical because the limits of boundaries can have substantial influence on the results. Indeed, there is no basis for assuming such lack of gene flow occurs among a number of these "populations."

9) Although the reviewers state that the writing within the papers is good, all three discuss potential or real problems associated with microsatellite analysis for analysis and inference. These range from laboratory problems (scoring errors of microsatellite) to poorly known mutation rates of microsatellites (Bohonak, Zink). It was also pointed out by the all three reviewers in different ways that the implications of these problems on inference or analysis, the analysis itself, or the inferences drawn (some of which are internally contradictory within or between the manuscripts), suggest that the microsatellite approach may not be the most appropriate one to take for such an analysis. There also other equally plausible explanations for the results presented.

While we believe the study of genetics is important to the understanding of wildlife populations, particularly endangered species, and we encourage its continued study for Spotted Owls, we do not believe that data or results presented in either the oral presentation or the two manuscripts currently warrant re-evaluation of genetics concerns as threats. Observed bottlenecks are likely the result of population declines and not the cause of it, and they are signatures of something that occurred in the past.

It was noted by Dr. Haig that a Washington population had closed affinity with the almost extinct British Columbia population and that reintroduction of Spotted Owls may be a potential management avenue in the future for rescuing the failing British Columbia population. We recognize that reintroduction of owls is best accomplished by selecting populations that are most closely related genetically to the population that has been extirpated (for reasons of co-adaptation). In the case of the Spotted Owl, we believe it is not prudent to remove owls from U.S. populations that are undergoing severe decline as a reintroduction source for British Columbia. This is particularly true, when the root cause of the original declines in British Columbia have been neither identified nor eliminated.

In summary, we believe that a clear causal link between loss of genetic diversity and subsequent reduced population performance (loss of diversity that is clearly adaptive) has not been made by these data, and that such a link would have to be made before such information would warrant a change in our evaluation of this potential threat. The conclusion by Barrowclough and Coats (1985) is still appropriate here, which is that 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. Our conclusions might warrant re-consideration at some future point, in the context of explicit evidence linking reductions in genetic diversity to current conditions, and current or future population performance. The SEI panel recommends that the USFWS read the reviews of the genetics papers for their detailed explanations and the associated literature cited therein.

CURRENT APPROACH: HABITAT FITNESS POTENTIAL

The Draft Recovery Plan invested heavily in a theoretical concept, "habitat fitness potential," developed by Franklin et al. (2000). The DRP used habitat fitness potential as the template for managing habitat conditions across the range of the Northern Spotted Owl. The use of the habitat fitness potential model in this manner was criticized by most scientific reviewers including Franklin, Dugger and Olsen, who have used this method in exploratory analyses to assess the relationship between human-defined habitat metrics (e.g., edge between habitats, percentages of owl habitat and "other" habitats) within owl territories and fitness measures (reproductive output and survival) of owls occupying those territories. The SEI Science Panel heard an oral presentation by Dr. Gail Olsen on her use of habitat fitness potential metric including the way in which she estimated the metric. She articulated her criticism of the DRP's use of this metric as a landscape prescription or management strategy. Her presentation was an excellent overview of the methodology and issues of concern that resulted in criticism from a variety of sources. Finally, the SEI Science Panel requested independent reviews from Dr. James Nichols and Dr. Kenneth Pollock, both of whom are acknowledged authorities on vertebrate population dynamics and the use of these metrics ('habitat fitness potential').

The idea developed by Franklin et al. (2000) was novel because it attempted to link habitat characteristics at Spotted Owl territories with demographic performance of owls occupying those sites. Consequently, it should have been viewed as a hypothesis by the DRP about the potential influence of specific owl habitat characteristics on reproduction and survival of owls occupying individual territories. This is so for several reasons: 1) the habitat conditions described by the investigators are ones perceived by investigators to be relevant to owls, but it is unknown if any or all of them are relevant to owl biology (i.e., these habitat conditions, such as the amount of edge, are indicative of territory condition and might be correlated with owl higher survival, but higher survival might actually be caused by something else, which is correlated with edge); 2) in the original Franklin et al. (2000) study they were unable to define the nature of heterogeneity within owl territories, only that it occurred; 3) it is unknown if demographic performance of owls occupying sites with specific conditions is the result of the quality of the individual territorial owl or the quality of the habitat within a territory (i.e., owl quality and habitat quality are confounded); 4) the estimation of habitat fitness potential is made at the scale of an owl territory so it is unknown if (and likely not) it could be applied at a larger scale; and 5) the idea was developed within a limited geographic area, which precluded generalization to other parts of the owl's range.

The main criticisms the USFWS received on its use of habitat fitness potential were: 1) there was an assumption in the DRP that the positive attribute of heterogeneity was the result of past logging events [or could be replicated by logging]; 2) the application of the metric by the DRP was made to entire provinces (i.e., there is a mismatch between the scale of analysis and the scale of proposed application); and 3) the DRP extended the application (generalized) of habitat fitness potential throughout the range of the northern spotted owl (i.e., the potential for inference was much more limited than conceded by the DRP).

The reviews by Nichols and Pollock supported the criticism by scientists who had used this metric, that the use of habitat fitness in the DRP was inappropriate, for the above reasons. In addition, they pointed out that the modeling of habitat fitness potential often resulted in complex models (multiple factors were important to explaining variation in the data), which was explicitly ignored by the DRP through its focus on single factors as metrics of interest in setting habitat direction in the plan. They also point out an apparent confusion in the DRP between habitat fitness potential, λ_h, with λ, the population growth rate (a population metric) by indicating that $\lambda_h = 1$ indicated a stable population. Habitat fitness potential is not a population growth metric. Such problems were compounded, in their estimation, by a selective use of data from the papers written by the investigators using λ_h.

In conclusion, the SEI panel concurs with the evaluation of scientists (both scientists working on owls and the independent reviewers) that there were both inappropriate interpretations and inappropriate application of λ_h in the DRP. The original concept of habitat fitness potential was an important first step in the attempt to link some potentially important habitat characteristics within owl territories to the demographic performance of owls living in those territories, but clearly were not definitive regarding owl habitat relationships. Tests of this concept as a hypothesis may provide insight into characteristics of habitat that are important to owls at the territory scale, but they need to be replicated in many places to allow generalizations to the Northern Spotted Owl's range. Therefore, we agree that it is not appropriate to use this metric as a landscape scale prescription for owl habitat throughout its range.

The panel does support the use of relevant demographic and local habitat data in setting habitat goals, providing these reflect geographically appropriate scales. Some (but not all) recent studies have corroborated the basic findings of Franklin et al. (2000) regarding heterogeneous habitat conditions in territories (Diller and Carlson presentations). However it is neither clear how such results should be applied to forest management at larger scales, nor whether conclusions drawn from one region (e.g. northern California Klamath or Redwood) can be applied to other landscapes (even in the same region). Given such uncertainty, development of local or regional habitat goals would usefully include explicit statements of the risks and benefits from a particular proposed conservation or other forest management strategy.

RIPARIAN HABITAT

Some reviewers expressed concern about the lack of inclusion of riparian reserves in the Draft Recovery Plan, because, under the NWFP, riparian reserves were considered to facilitate juvenile Spotted Owl dispersal. However, management of riparian areas in a broader context has the potential to be helpful in the recovery of the Northern Spotted Owl in a more complex sense than just facilitating dispersal. What, then, can the role of riparian management be?

Management of riparian areas is mandated not only on federal lands but also on state and private lands, e.g., under the Washington Department of Natural Resources Habitat Conservation Plan, its Sustainable Harvest Calculation, Forest Practices Rules, and Timber-Fish-Wildlife Agreement. Several aspects of riparian, or aquatic, management strategies are important to keep in mind.

1) FEMAT/NWFP strategies required rather large buffers around fish-bearing streams; these buffers, in practice covered 30-40% or more of the landscape and constrained management on other areas by isolating them and making management infeasible (e.g., Carey 1999a). These riparian reserves could conceivably produce Spotted Owl habitat in a landscape that otherwise might be quite inhospitable to Spotted Owls (such as an industrial forest landscape in which stands are intensively managed on short rotations) or a landscape otherwise marginal for Spotted Owls ("matrix" federal lands), especially where management practices include protection of wetlands and variable retention harvests wherein 15% of the forest is retained during a regeneration harvest.

2) It is conceivable that riparian buffers might facilitate dispersal of juvenile Spotted Owls in landscapes dominated by clearcuts and shrub and sapling states of forest development. While these buffers seem too narrow in the context of clearcuts to be of much value to Spotted Owls and while the noise of running water may impede owl foraging, the streamside forest, even if a relatively narrow strip, may constitute substantial biological legacies in the longer term in developing forests and may help a forest move into a diversification stage much more quickly than a forest without legacies. In other words, over time, riparian buffers may speed recovery of Spotted Owl habitat and in the interim produce an environment favorable to dispersal and maintaining non-breeding subadult owls for demographic support of owl populations in reserves. Riparian hardwoods may support owl prey, like (a) the Northern Flying Squirrel, by providing dens in hardwoods and older conifers (Carey et al. 1997) and supplementary foods from catkin-, berry-, seed- and nut-bearing hardwoods (Thysell et al. 1997); indeed some of the highest densities of Flying Squirrels have been found in mixed conifer-hardwood stands (Carey 2000), (b) the Bushy-tailed Woodrat by providing habitat (Carey et al. 1999b), (c) the Dusky-footed Woodrat, by providing habitat and dispersal corridors (Carey et al. 1999b), and (d) in some areas, habitat for Snowshoe Hares, an important seasonal prey of the Spotted Owl. When the streamside forests are in the context of developing forest beyond the ecosystem reorganization stage, Flying Squirrels may leave dens in hardwoods or older trees in riparian areas and forage along 1-km foraging circuits (up to 5 km in a night) within second-growth conifers, which can produce substantial diversity

and biomass of the truffles that constitute the primary food of the squirrel, Carey 2000). In the range of the Dusky-footed Woodrat, woodrats may radiate out from riparian areas to colonize new early seral stages with hard-leaved sclerophylls like tanoak.

3) Many riparian strategies incorporate more than simple streamside set asides. Of particular importance is the protection given to unstable slopes, slopes with potential for rapid, shallow landslides, slopes with potential for deep-seated landslides, and areas of colluvial soil. Even where riparian buffers are relatively narrow, protection of unstable slopes, retention of green trees during harvests, limitations on harvest unit size, and extended (or alternating 70- and 130-year) rotations with thinnings to promote biocomplexity may lead to relatively quick development of new Spotted Owl habitat (Carey 1999a; these course is now being followed by the Washington Department of Natural Resources on their HCP lands).

4) Riparian strategies also may give protection to seeps, headwater streams, swamps, bogs, and the shores of ponds and lakes, providing for a further diversity of prey, roost sites, and nest sites.

It is not clear from the DRP whether the above benefits of reserved riparian habitat have been recognized, nor whether they are included as part of the conservation support strategy for Spotted Owls outside of MOCAs.

OWL RESPONSE TO FIRE

Fire can be considered a threat to Northern Spotted Owls because wildland fire can destroy or alter suitable owl habitat, and because fire and fuels management alters features of owl habitat. The extent of the threat of fire depends on several general factors and many local variables. Within the geographic distribution of Northern Spotted Owls there exists a range of climatic conditions, including "dry to wet" and the associated forest communities that are more or less prone to recurring fire. Fire behavior varies in association with these conditions, and characterizations of types of fire, such as catastrophic, stand replacing, high to low intensity or severity, and ground or crown, are associated with different effects on owl occupancy and demography in burned areas. Fire might be a minor threat in some wet forests in some areas, but a major threat to owls in dry forests. Historical forest management and especially historical and current planned fire and fuels management may have significant implications as threats to owls. Thus, we conclude that fire is an integral part of Northern Spotted Owl recovery planning, and we believe that recovery planning must be explicit in addressing factors such as geographic location, prevailing environmental conditions, forest conditions, prevailing disturbance regimes, forest succession, post-fire restoration, and management ability to promote desirable spatial patterning of Spotted Owl habitat.

Related to the topic of fire, we suspect that differences in the ways persons use and interpret terms leads to some confusion or misinterpretation about relationships among owl occurrence and demography, owl habitat, fire, and fire or fuels management. A revision of the plan would be helped by consistency of terms, reference standard definitions, and provide definitions of key words and phrases to allow ease of interpretation. Reviewers raised concerns that there are important distinctions associated with terms and phrases such as fire behavior, forest composition and structure, seral stages, and management methods. This led to criticisms such as 'the plan uses "habitat loss" in reference to effects of fire. The presumption of "habitat loss" is also central to some of the analyses. … Therefore, a wide range of conditions and spatial patterns created by fire may be included under sweeping generalizations about "habitat loss" due to fire.'

Furthermore, it seems that some statements are meant to apply across the entire range of the Northern Spotted Owl. Reviewers noted that important distinctions among factors were not addressed adequately. For example, there are differences in types of wildland fire, differences among fires that occur in different geographic regions and locales, and differences in fire due to forest composition and structure, seral stages, and management methods.

The entire issue about how to deal with fire and fuels management is difficult because after 30 years of Spotted Owl research we still have no clear ideas of the subtle effects of certain types of habitat alterations on Spotted Owls (e.g., thinning from below). This likely will continue to be an important area of uncertainty because fire management is integral to forest management. Any attempts to manage fire or fuels in the context of Northern Spotted Owl recovery should be considered under a rigorous framework of research and adaptive management with adequate safeguards to ensure that the framework is followed.

In addition to written materials, presentations and discussions at the public meetings convened by SEI in January and February 2008, there were follow-up inquiries from the panel to outside scientists. The section of this report under Ecosystem Ecology and Management deals specifically with ecological conditions and forest management relative to Northern Spotted Owl recovery. Below we provide information about owl associations with burned areas. This information is arranged around topics and reviewer comments related to the subject of fire in the DRP.

1) Importance of fire as a threat

- Overestimated or underestimated

Respondents offered a range of opinions from: "the plan underemphasizes the threat from fire" (*Comment TF1*) to, "the plan overemphasizes the threat from fire, and it is likely therefore that the recovery plan has overstated the threat from fire" (*Comment TF2*). These two comments underscore the uncertainty about the extent and nature of fire that is present even among knowledgeable persons. On the one hand, owls presumably evolved in fire-affected habitats so one would expect some adaptive response or mechanism to have evolved in the presence fire. However, the amount of habitat present and its distribution in past times (pre-hominid or at least pre-European) might have been sufficiently large that owls persisted because there were alternative habitats or because the total amount of habitat available within the bird's distribution was sufficient to buffer negative effects of fire. Those conditions do not exist currently.

The comments about emphasis on fire also indicate persons are thinking about the fire issue in two different ways, one from the perspective of the owl and the other from the perspective of anthropogenic effects such as forestry, or perhaps climate change. Fire ecologists also have differing opinions on this subject, particularly about what to do about fire. See the Ecosystem Ecology and Management section.

We recognize that some fires result in habitat loss; other fires cause various changes to habitat that affect owls in various ways. We believe that the emphasis on fire as a threat and fire management will vary with different prevailing conditions within the range of the Northern Spotted Owl. The Final Recovery Plan could profitably make clear distinctions among different types of wildland fire and methods of fire and fuels management in different parts of the Northern Spotted Owl range (e.g. dry or wet forest). See the Ecosystem Ecology and Management section.

- Current vs. future threats

The threat of destroyed habitat or diminished Northern Spotted Owl habitat quality is a current threat, because the owl population is declining and there are other threats with which fire contributes to cumulative effects. The DRP does not distinguish among types of fires and the immediate, short term, and long term effects on owl ecology and population biology. Historically, Northern Spotted Owls have persevered through various types of fires across the range, even very broad scale catastrophic fires, but that was when there was much more habitat supporting larger owl metapopulations, which provided the foundation for recolonization of redeveloped habitat. For recovery planning, current and future conditions are different than historical conditions. Fire likely will remain a potentially significant threat for at least 100 years.

- Is fire a threat or benefit to owls?

In January the panel saw 3 presentations that focused on fire, and each indicated an initial decrease in the occupancy of owls after wildfire in their study areas (Bond, Lee, Siegel, and Ward presentation, Clark and Anthony presentation, Irwin presentation). From these and some pertinent literature (e.g., Bond et al. 2002, Clark 2007, Franklin and Gutiérrez 2002, Lee and Irwin 2005) it is clear that fire can have an immediate negative impact on owls, especially in areas or under circumstances leading to broad scale catastrophic fires. Catastrophic fire in combination with other known and unknown risks might indeed pose a high risk to the owls. In a landscape of Northern Spotted Owl habitat, low to moderate intensity fires of a restricted spatial scale and pattern can contribute to landscape heterogeneity and different seral stages that may benefit owls, for example, by creating patches of habitat that support different kinds of prey species.

- Does fire equal habitat loss?

Fire does not equal habitat loss. Based on presentations and limited literature cited in the previous section, we have learned that after fires, owl occupancy, re-occupancy, or demography varied depending on the type of fire within the study area. Results from these studies are given below in **2) Owl use of areas that have experienced fire**. These studies suggest that Spotted Owl behavior and population biology in areas affected by fire can vary depending on the severity of fire, where the fire occurs, and the spatial scale. They suggest that owls' responses to fire can change from initial negative responses to other behavior and demography during post-fire succession. Fire might or might not result in habitat loss; it is dependent on the fire severity, extent etc. Previous estimates of "habitat loss" and hence of the extent of the threat in some regions (e.g. Courtney et al. 2004) are clearly inflated. An accurate assessment of the amount of habitat lost would require more detailed information on known owl fates. We concur with critics that "habitat affected by fire" should not be equated with "lost habitat". We also concur with critics who argue that in some circumstances owls may remain in or recolonize partially burned territories. Hence harvest (salvage) in such areas cannot be assumed a priori to have no impact on owls.

- Provincial differences

There are important differences among and within physiographic provinces relative to fire occurrence, fire management, and owl ecology. At a very broad scale, one can consider differences among the wet west-side forests, the dry east-side, and the Klamath region.

2) Owl use of areas that have experienced fire

Some reviewers of the draft plan, and authors (e.g. Hershey et al. 1998), cite a need to consider the role of fire and fire management (Everett et al. 1997) in creating the forest structures associated with owl presence. While some biologists have presented convincing evidence that large wildfires have a negative effect on Spotted Owls, there also is evidence that not all fire is detrimental, and in some cases, owls successfully use certain post-fire conditions. The few examples and studies that exist come from locales across the species distribution and include evidence from each subspecies and various landscapes.

- Effects of fire severity and configuration

The suitability of forests that have burned as habitat for Spotted Owls depends on the scale, intensity, completeness, and frequency of burning and varies with forest type and physiographic province.

Clark and Anthony (presentations) studied Northern Spotted Owls in southern Oregon at study sites in 1 unburned and 3 burned areas (Biscuit, Quartz, Timber Rock). Comparing Timber Rock to unburned areas, owl occupancy declined more rapidly in burned than in the unburned areas (5 of 20 owls emigrated), and survival decreased 64%. Thus, the burn had a negative effect on owls. After burns, based on all 3 burned study sites, owl core areas were colonized when larger portions of nesting roosting foraging (NRF) habitat had low severity burns. Core areas were abandoned in association with: 1) increasing fragmentation caused by fire, 2) high severity fire, 3) timber harvest prior to the fire, and 4) salvage after the fire. Clark's survival rates suggest some effect of fire on survival and so perhaps there is a short term negative effect that does not last that long, in terms of survival, assuming the owls still have suitable habitat available. Within a home range, owls selected low severity burn areas for NRF habitat, and moderate burns for RF habitat. At a landscape scale moderate and high severity burns were selected over early seral stands for NRF. Clark and Anthony recommend protecting low and moderately burned areas on a landscape scale and precluding clearcut salvage from high severity burn areas within 1.5km of nest centers.

D. Clark in an email to D. DellaSala (pers. comm.) stated that he "documented several owl pairs fledging young in post-fire landscapes and in general reproductive output was similar to unburned landscapes (but I may have lacked the precision to detect a difference). In general, if owls were still capable of occupying a territory they were capable of producing young. One pair of owls produced young multiple years in a stand of moderately burned forest that was immediately adjacent to a patch of high severity fire. So owls can likely produce in a variety of burn severities."

- Succession and other temporal effects – is long-term use of burned habitat supported?

Bond, Lee, Siegel, and Ward (presentation) studied California Spotted Owls 4 years after a burn in the Sierra Nevada. Owls selected low to moderate severity burn areas and selected against unburned habitat for foraging. Roosting and nesting were about equally distributed in low to moderate severity burn areas and in unburned habitat.

M. Bond, in an email to D. DellaSala (pers. comm.) stated, "The McNally Fire study [results] we presented at the Northern Spotted Owl Recovery Plan meeting was only investigating post-fire use of habitat by owls that remained. In conversations with the Sequoia National Forest biologist regarding occupancy in and directly adjacent to the McNally Fire (in which territories were impacted by the fire), I recall that there were an estimated 2 territories apparently abandoned after the fire, about 7 remained occupied, and one new territory became occupied. Our team personally conducted reproductive surveys in 7 of the territories in or directly adjacent to the burn (this was 4 years post-fire), and 2 of 6 pairs we located were reproductive 4 years after the fire (one of the pairs was unresponsive -- just heard one distant male hoot). Owls reproduced successfully in some of the burned territories in previous years, too, according to FS survey data. But we have to remember that the FS typically only conducts surveys for owls in conjunction with planned timber sales, so the surveys are not always consistent every year, nor are they conducted throughout the forest, so there is certainly missing information. However, I feel like there was pretty decent coverage of the McNally Fire area both before and after the fire. Theresa Benson and Wendy Rannals of the Sequoia NF did a good job with surveys in their district. I hope to have more information from our larger study which we will be happy to share. I do believe, however, that these concerns raised by the Northern Spotted Owl team are very good topics for additional research. One major problem is quality of surveys…"

A reviewer's comment is that the plan should not rely on in-growth of suitable habitat until in-growth forests have been verified to be of high quality. We are not sure if this comment applies specifically to dry forests or west-side wet forests. If dry forests, then we interpret this to mean that a consequence of fire suppression has been the development of multi-story canopies in forest types that historically had frequent fires and single-story canopies, and that those multi-story stands putatively have now become Northern Spotted Owl habitat. The comment indicates that one does not know that this is true (i.e., perhaps owls were in more fire dominated landscapes prior to modern era of fire exclusion). There is ample evidence that most of these "in-grown" stands in the mesic Douglas-fir and dry grand fir plant associations indeed are current Northern Spotted Owl habitat (Buchanan et al. 1993, Everett et al. 1997). In-grown stands in the driest ponderosa pine and Douglas-fir plant associations currently dominated by ponderosa pine in the over- and under-stories currently are not NRF habitat and likely will not be NRF habitat in the future.

- Interaction between the effects of fire and salvage

Salvage effects, as with fire effects, can vary by forest type, the severity of fire, and salvage methods (e.g., clear-cutting vs. partial removal, cutting large trees vs. cutting small trees, etc). It is conceivable that salvage could have either high or negligible impacts on Spotted Owl habitat or the long-term development of habitat, depending on post-fire conditions and harvest prescriptions. Salvage, or post-fire logging, issues are not black and white. For example, salvaging dead small–diameter trees ("in-growth") in high-intensity dry forest burns that have developed under fire suppression may have little impact on habitat values for Spotted Owls and may be consistent with thinning and fuel reduction objectives for restoring green dry forests. In contrast, clear-cutting or removal of all large trees from that same stand may have both short and long-term negative effects on Spotted Owl habitat and be inconsistent with dry forest restoration objectives. See the Ecosystem Ecology and Management section for a full discussion of salvage and post-fire logging.

- In dry forests current targets of 60% owl habitat preclude management actions

This comment brings up an important issue that largely is the result of confusing language in the DRP. Managing for a habitat threshold of 60% of the dry forest landscape, as suggested in Table F2 of the DRP (p. 147), would be unsustainable if not impossible given the patchiness and complexity of the landscape (Hessburg and Agee 2003). Such a high threshold might limit habitat protection (e.g. fuels reduction around habitat) or dry forest restoration actions, if habitat could not be treated. We interpret that habitat threshold, however, to be 60% of the "habitat capable acres", not of the entire landscape. As shown in Table F2, habitat capable acres are estimated to be 58% of the total acres in MOCAs in the Eastern Washington Cascades; 60% of 58% equates to 35% as the habitat maintenance threshold for the entire landscape. This closely agrees with recommendations in the Ecosystem Ecology and Management section for having 30-35% of the landscape as a maximum sustainable Spotted Owl habitat threshold, and would leave ample scope for management actions.

3) Fire and fuels management and impact on owl habitat

Fuels management and post-fire management options likely will affect how owls use an area, but there is relatively little information about this. Monitoring of owls responses to management will provide useful data for maximizing recovery. However, if the recovery plan incorporates the processes to promote restoration of ecosystems and landscape recovery, managers can make some fairly informed decisions about the array and intensities of treatments that can be applied and the probability of having short-term negative or positive results and long-term positive results (Carey 2007).

- Management within historic fire regimes

It is important to be clear that fire can cause significant loss of habitat for Spotted Owls (e.g., forests in eastern Washington), especially if fires are broad-scale, intense, catastrophic crown fires in forests that have deviated in their development from historical fire-prone and fire-resilient forests that historically were adapted to widespread, low-to-moderate intensity ground fires. Large scale fires in which high intensity crown fires occur in patches, with low intensity fires that produce no to scattered mortality in forests with species that are adapted to these kinds of fires will produce at least some habitat loss in the short term but can produce excellent quality habitat in the long term; this situation is not uncommon in the Klamath Mountains.

- Clear criteria to balance fuels reduction and owl habitat conservation

There needs to be explicit development of how to strive for this balance. Clark and Anthony (presentation) recommend reducing fire hazards in dry forests because fire reduces owl occupancy of an area, and they suggest research to determine if there are differences in owl use of areas after mechanical fuels reduction or prescribed fire.

More specifically there were comments such as the plan should recommend that federal agencies be prevented from doing habitat alteration within 500 meters of known, occupied Spotted Owl site-centers, but this depends on what is meant by habitat alteration. Our comments about specificity and clarity are appropriate here. If one is discussing trail clearing (a form of habitat alteration) versus clear cutting (also a form of habitat alteration) the alteration might be quite different relative to owl habitat quality. In contrast to west-side forests, not all the 500-m radius area adjacent to the nest is likely to be NRF habitat in dry forests, and fuels reduction might be considered for protecting site centers and other features of the birds' habitat if nest disturbance from human activities can be addressed (e.g., by winter logging). This comment goes back to one of the reasons there were Adaptive Management Areas established in the NWFP, which was to learn how owls and other attributes of forests responded to various "alterations of habitat."

Limited management within 500 meters of owl site centers is important, especially in Washington where there are substantial conflicts over what should or should not be done around Spotted Owl site centers, not only on federal land, but on state land (DNR has a HCP) and industrial forest land (under forest practice rules).

For example, fuels reduction can be considered for protecting site centers. The Final Recovery Plan can encourage carefully considered management so as not to undercut ongoing conservation efforts aimed at the Spotted Owl off of federal lands.

Another issue to consider in terms of balancing fuel treatments is that the extent of treatment that is likely to occur in a given watershed will be limited by logistics and efficiency. It is estimated for the eastern Cascades that perhaps a maximum of ~20% of dry forest landscape could be treated for fuels because of the mix of forest types, Northern Spotted Owl core areas that would not be treated, topography, access, and other constraints on treatment (Lehmkuhl et al. 2007). That figure is congruent with the modeling by Finney et al. (2007) and others to optimize the location and area of fuel treatments: most results are showing that maximum benefits are accrued with treatment of ~20 % of the landscape over a ~20 year period.

- Effects of fuel treatments are not neutral

Fuel treatments can have many effects in a biological community. For example, if trees are killed (by fire, by felling, by girdling, by insects) they stop supporting hypogeous fungi that produce truffles that are the primary food of the Flying Squirrel, a primary prey of the Spotted Owl. This will be a short-term effect. If the hard-leaved, fire-adapted sclerophylls burn up (as they easily do) and an intense fire also destroys the stick houses of Dusky-footed Woodrats then there will be at least a short-term effect on Dusky-footed Woodrat populations which are a primary prey of owls in some of the southern areas.

Bond et al. (2002: 1022) used available data from all 3 subspecies and concluded: "We hypothesize that wildfires may have little short-term impact on survival, site fidelity, mate fidelity, and reproductive success of Spotted Owls. Further, prescribed burning could be an effective tool in restoring habitat to natural conditions with minimal short-term impact on resident Spotted Owls. While we do not advocate wholesale prescribed burning in Spotted Owl territories at this time, we believe our observations justify large-scale experiments on effects of prescribed burning on Spotted Owls to corroborate our observations and to establish cause-and-effect relationships." However the panel notes that most of these fires were low intensity to moderate intensity fires not completely covering an owl's territory.

Lee and Irwin (2005) analyzed relationships of habitat structure and owl population data (California Spotted Owl) and concluded that mechanical thinning, in combination with other factors, need not degrade canopy conditions, and can contribute to reducing the likelihood of "uncharacteristic" wildfire that adversely affects owl populations (e.g., lowered carrying capacity; Irwin presentation).

Fuel treatments in theory (but not always in practice), are meant to mimic the impacts of low-severity fires; so, if low-severity fires are neutral or beneficial as described earlier, then we should conclude that fuel treatments that have the same effects most likely would be beneficial (Lehmkuhl et al. 2007). However, there needs to be a clear understanding of the types and frequency of fuel treatments. US Forest Service work shows that prescribed fire by itself has very low impact because prescribed burning conditions are strictly controlled to keep fire intensity low and controllable. Burning needs to be repeated regularly (5-10 year cycle). Thinning + burning (2nd year) have greater impacts and a faster rate of return to desired conditions (e.g. historical or fire resistant conditions). Thinning alone reduces canopy density and canopy fuel ladders, but does not reduce flame length, which could lead to crown fires. So, in terms of frequency of treatment, it may be good to thin and burn to minimize the initial time of disturbance, then maintain the stand by burning alone every 10 years or so. See the Ecosystem Ecology and Management section for full discussion of fuel treatment options and applications. Note that the benefits of fuel treatments need to be carefully weighed against any actual harm to owls. Maintaining adequate canopy cover is important.

- Effect of doing nothing/passive management

Active, scientifically based adaptive management is needed to understand how forest management options affect Northern Spotted Owls. Fire management also should consider the prey of Spotted Owls and interactions between Spotted Owls and Barred Owls. Owl response to fire requires additional study, and suggestions are provided by Franklin & Gutiérrez (2002) and in reviewers' comments about the DRP.

4) Salvage logging

See the Ecosystem Ecology and Management section.

5) Research

There is uncertainty related to many issues of Northern Spotted Owl recovery. Because there are several threats, the recovery effort is relatively complicated.

- Need recovery action to research fuel reduction impacts on owl habitat, prey, and Barred Owl/Spotted Owl interactions

The plan would profit from addressing the complexities and variability of fire behavior and effects on Northern Spotted Owl populations and habitat across the species' range, with the understanding that fire behavior is a function of weather, moisture, fuels, etc. In specific physiographic regions and with consideration of local forest conditions, fuels management methods should be attempted under controlled conditions.

We emphasize that after 30 years of research we do not understand the subtle effects of certain habitat alterations on Spotted Owls (e.g., thinning from below). Scientists have recommended such research since 1984 (Gutiérrez 1985 in Gutiérrez and Carey 1985) and we are now finally seeing some experiments on this question. Regardless, this is an area of uncertainty and all attempts to resolve it should be considered under a scientific and adaptive management framework. Scientific information or analyses should provide the underpinnings and framework of a recovery plan. Many of the comments and criticisms are asking for the scientific basis for inference, conclusions, proposals, strategies, etc., especially when there are recommendations that differ from existing management. For example, the idea of adaptive management is long-standing and has considerable merit as a concept. However, there is no clear scientific or organizational framework in the DRP for implementing adaptive management for topics like fuel management or restoration of stable fire disturbance regimes in dry forests, or Barred Owls. Furthermore, in order for adaptive management to succeed, it is important that there be appropriate safeguards and feedback loops that ensure completion of the adaptive management process.

- Research needed on succession and the amount of time burned areas become owl habitat

There is relatively little information about how fuel reduction management or post-fire logging, or restoration efforts affect owl ecology, but recovery planning should account for how owls respond to fire severity and post fire succession and management. Thus, research and adaptive management are integral to recovery

BARRED OWLS

The DRP identified the Barred Owl as a “significantly greater threat to Spotted Owl recovery than was envisioned at the time of listing” or than was discussed in the 2004 review of the bird’s status (USFWS 2004) or the status report (Courtney et al. 2004, USFWS 2007). We agree with the former assessment, and believe that the level of the Barred Owl threat described in Courtney et al. (2004) is as accurate now as it was several years ago, given a lack of further, substantial, or definitive evidence in the interim. Courtney et al. (2004) did recognize the significance of potential negative interaction of these species and outlined in some detail a variety of potential outcomes as a result of their interaction. Gutiérrez et al. (2007) noted the degree of uncertainty surrounding the data supporting the nature of those interactions, which precluded a definitive assessment of the ultimate consequences of the Barred Owl invasion on Spotted Owls. Limited subsequent research has provided additional insight into the potential interactions between the species (Crozier et al. 2006, Diller Report “Preliminary Observations of the Feasibility and Effectiveness of Doing Lethal Barred Owl Control” presented to both the USFWS’ Barred Owl workshop in Portland, Oregon [February 2007] and the SEI Scientific Review Panel [January 2008]). Thus, the Recovery Team and current SEI Science Panel draw their inferences from essentially the same information base (i.e., there were no data available to only the Recovery Team or the SEI panel). This base includes a previously unpublished paper since published (Livezey and Fleming 2007) and other existing information (Gutiérrez et al. 2007, Buchanan et al. 2007). We did hear one additional presentation on unpublished research (Singleton presentation) which provided much useful information on Barred Owl ecology in one landscape. Note that we also heard a presentation by Raphael, suggesting that observed declines in Northern Spotted Owls on demographic study areas correlated with increasing Barred Owl numbers, but not with changes in habitat.

The potential effects of Barred Owls on Spotted Owls were accorded predominance in the DRP. While this threat is important and its likely consequences are recognized, the strong emphasis drew criticism from several scientific reviewers. Our assessment is that a focus on the Barred Owl threat in the DRP is warranted, but not to the exclusion of other threats (such as habitat availability). Other criticisms of the DRP stemmed from the form of the proposed actions to counter the Barred Owl threat, and these criticisms in our opinion have some merit. Any recovery plan for the Northern Spotted Owl must take the potential Barred Owl threat seriously and offer strategies or actions that will effectively deal with these threats. On the other hand, an elevated concern about Barred Owl impacts does not warrant de-emphasis of other important factors (e.g. habitat loss), previously identified as threats to the Northern Spotted Owl.

Competition theory predicts that Barred Owls will compete with Spotted Owls because they are similar in size and have overlapping diet and habitat requirements (Gutiérrez et al. 2007). Limited experimental evidence (Crozier et al. 2006), a quasi-experiment (Diller Report, "Preliminary Observations of the Feasibility and Effectiveness of Doing Lethal Barred Owl Control"), correlational studies (Kelly 2001, Kelley et al. 2003, Olson et al. 2004, Dugger et al. 2005), and copious anecdotal information (Gutiérrez et al. 2007) all suggest a competition effect through reduction of site occupancy by Spotted Owls, potential interference competition, and possible predation. Yet, three fundamental uncertainties remain about Barred Owl-Spotted Owl interactions. First, are the steep declines in Spotted Owls in the more northern areas of its range due solely to the expansion of Barred Owls? Second, do steep declines in Spotted Owl numbers reflect any residual or lag effects of past or continuing habitat loss, or interactions between lag effects and Barred Owls or some other factor? Third, what is the mechanism(s) by which Barred Owls supplant Spotted Owls (assuming further evidence supports such a process)? These uncertainties moderate the pre-eminence given to the Barred Owl threat in the DRP, and support an approach that retains consideration of and concern for habitat loss and/or degradation. The DRP appears to adopt a lowered level of concern for Northern Spotted Owl habitat by its proposal to reduce direct habitat protection (e.g. in LSRs and riparian reserves) and allow perturbations to habitat, under the rubric of increased management flexibility.

We believe that there are really only two fundamental (and alternative) ways to address the on-going Barred Owl invasion of Northern Spotted Owl range and habitat. First, the case has been made, as noted above, that the Barred Owl has direct impacts on the Spotted Owl and, further, that the recent steep declines in Spotted Owl populations are correlated to these impacts. Well-designed removal experiments will help resolve this issue, but the scale of experiments suggested in the DRP is probably too limited to detect an effect of Barred Owl removal. Appendix G of the DRP outlines a general design for Barred Owl removal experiments. However, the design appears to be focused at the scale of the individual territory. Six to eight sites would be selected from within up to 18 study areas across the Northern Spotted Owl range (including, industrial timber land, public land, and tribal land) and in areas having different densities of Barred Owls. The recommended removal sites would be selected by priority ranking based on history of occupancy and reproduction and with a recommendation to select sites where owls were banded or radio-marked. We believe removal experiments should be conducted at the scale of landscapes because local recruitment of Barred Owls would probably negate the effect of removal. In addition, it is unknown whether Barred Owls may influence Spotted Owls from other territories (i.e., extra-territorial effects have been suggested to occur). We also think that the scale of removal should be large enough to produce a treatment effect that is detectable (changes in occupancy, reproduction, or survival of Spotted Owls), and where we can anticipate adequate statistical power. For these reasons, we think that removal experiments are best conducted on existing demographic study areas because 1) there is a wealth of existing demographic information on Spotted Owls, 2) it would be more efficient (locations of Barred Owls are likely known), and 3) response of Spotted Owls or treatment effects should be more easily calculated and monitored with existing protocols. Findings from such removal experiments could quickly be adapted and applied to other areas if they are deemed either necessary or feasible. Note that there must be enough Spotted Owls remaining in the study area for treatment effects to be readily detected (thus some study areas will be more suitable than others). We also think that the cost of such experiments, especially those conducted on existing Spotted Owl demographic study areas, will be much less expensive than envisioned by the DRP. The ad hoc quasi-experiment removal conducted by Diller ("Preliminary Observations of the Feasibility and Effectiveness of Doing Lethal Barred Owl Control") provides support for our assessment that removal experiments will be of low cost and logistically easy. Removal experiments are best implemented on existing study areas where there are preexisting data on Spotted Owls, and an accessible, testable hypothesis (Spotted Owl removal will stabilize or reverse declining estimates of lambda). However, the treatment effect must be large enough and last long enough such that a treatment response can be detected. To this end, removal experiment study designs should be formulated by and solicited from quantitative biologists reporting to the USFWS, as a guide to any Barred Owl removal actions recommended in a revised Recovery Plan. Design of removal experiments must include the development of Barred Owl survey methods incorporating the probability of detecting Barred Owls, estimating their abundance before removal, and monitoring the rate at which they re-occupy areas in which removal has been conducted. Re-occupancy rate is important for evaluating the efficacy of control as a recovery management option.

Closely linked to direct experimentation is a need to understand the nature of the dynamic interaction between the species. Addressing this interaction is best accomplished by observation studies and specific behavioral manipulations designed to investigate the nature of the interspecific interaction (e.g., Crozier et al. 2006), but these do not supplant the need for removal experiments. Removal experiments should relatively quickly reveal if the presence of Barred Owls precludes the use of areas by Northern Spotted Owls, or reduces their density, or affects their demography. Observation studies and specific behavioral manipulations can provide evidence of behavioral relationships (e.g., foraging behavior, habitat selection), but they might take many years to provide sufficient insight into the mechanism by which competition might be occurring. However, Diller's ("Preliminary Observations of the Feasibility and Effectiveness of Doing Lethal Barred Owl Control") observations suggest that if many Spotted Owls are located nearby, Northern Spotted Owl recolonization of historical (previously occupied) sites may be very rapid. If Barred Owls are causing a decline in Spotted Owls, their adverse effects will accumulate over time, arguing for early, rapid, and direct intervention; such control measures might be required and instigated before the details of behavioral and ecological relationships are fully studied and resolved. However, we do believe such field studies are important for understanding the mechanisms of competition and how this competition ultimately might be managed; the competition studies can be closely linked to removal experiments in ways that make use of Barred Owl removals and avoid confounding factors.

Research and monitoring of Barred Owls is important for other reasons. Barred Owls are now distributed from central Mexico to Southeast Alaska in numerous forest types, and they forage on a variety of prey including small mammals, birds, reptiles, amphibians, fish and invertebrates, and are described as an opportunistic predator (Mazur and James 2000). There is little information about the abundance of Barred Owls in the Northern Spotted Owl range, nor details about Barred Owl habitat selection or diet. However, it is clear that Barred Owls occur widely within Northern Spotted Owl range; therefore, recovery actions should consider the potential that management (e.g., habitat alteration) might benefit the Barred Owl as much or more than the Northern Spotted Owl. Note that the Barred Owl occurs over a much wider range in the Pacific Northwest than does the Spotted Owl, and utilizes forests on a much larger scale than the Northwest Forest Plan. Hence any management of this species will need to be addressed at such large scales.

The only other option in response to the Barred Owl threat would be to let the dynamic interaction between Spotted and Barred Owls proceed without intervention, and run its natural course. This alternative could be considered a "natural" experiment, but it could also be considered a "no action" response by agencies charged with Northern Spotted Owl recovery. This "no action" response has been viewed as untenable for resolving the Barred Owl-Spotted Owl question by Buchanan et al. (2007).

We note that the current assessment of the threat posed by Barred Owls is qualitative in nature, and based on correlative information rather than controlled experimentation. This is essentially a similar evaluation to that for the effects of habitat perturbation and loss on Spotted Owls (albeit with very strong correlative evidence). We know in a general way that Northern Spotted Owls require habitat above some poorly understood thresholds, that they cannot tolerate excessive habitat loss but do manage within some limits of habitat variability, contiguity, productivity. However, there is uncertainty about how much perturbation and of what kind they can tolerate. Nevertheless knowledge of owl habitat relationships has been evaluated as sufficient to indicate the need for habitat protections.

We regard the information available, on Barred Owls as a threat, as sufficient to warrant action in a conservation strategy. We evaluate two of the issues raised by reviewers, (namely cost of removal and need for continued control of Barred Owls) as significant but possibly not as expensive or extensive as perceived by some reviewers. The determination to engage in Barred Owl control would follow the results of removal experiments; if Barred Owl control is supported, Barred Owl would join the many other species for which removal is authorized by the USFWS.

In summary, we agree that the DRP is justified in placing high emphasis on addressing the impact of the Barred Owl on Northern Spotted Owl; however, there are other threats, and Barred Owl removal experiments or control experiments alone cannot serve as the corner stone to recovery of the owl. The original reasons for listing the Northern Spotted Owl, including loss of habitat, still remain threats. We believe that the DRP could seek and consider recommendations for various experimental designs for Barred Owl removal experiments. These would include estimates of effect sizes and degree of control needed to identify a Spotted Owl response to removal. The ad hoc experiment by Diller (op. cit.) suggests such experiments will be cost effective and easy to accomplish. The results will provide the necessary guidance for future direction in the management of Barred Owls, should that be necessary for Northern Spotted Owl recovery.

THREAT INTERACTIONS

Although not emphasized within the DRP, concerns have been raised within the comments and by USFWS through this review regarding interactions of threats. Comments included:

> "Rather, increased threats from Barred Owls and potential climate change effects justify protecting more habitat – not less – as a precautionary principle in the conservation and recovery of listed species that is clearly missing from the draft recovery plan." Owl scientist letter p. 2.
>
> "…Spotted Owls are likely vulnerable to competitors because they inhabit only a small proportion of their original range." AOU and SCB reviewers letter p. 12.
>
> "On pages 18 and 25 (Reasons for Listing and Assessment of Threats), climate change should receive more coverage than a potential and uncertain future event. Climate change likely will lead to changes in temperature, precipitation regimes, vegetation and forest structure, fire frequency and intensity, wildlife diseases, wildlife community structure including competitors and prey for Spotted Owls, etc. that could have substantial impacts on Spotted Owls. We realize that predictions of effects may currently lack specificity, but this topic should be more adequately addressed. At the very least, one of the recovery actions should call for more research on the topic." National Park Service Comment page 3.

It is generally thought that interaction among threats may affect the persistence and recovery of Spotted Owls, perhaps in a synergistic manner. These synergisms are logical and reasonable but remain essentially unproven at this time.

An interaction between habitat, weather, and owl demography is one exception. Franklin et al. (2000) demonstrated interactions between habitat quality and weather which affect survival, where higher habitat quality buffered owls against the effects of bad weather. [Dugger et al. (2005) did not find any association between survival and weather. Also weather explained little of the variation in models of reproduction or survival in the Hoopa study region (Carlson pers. comm.).] This study did not indicate the mechanism for this interaction; however an effect through prey availability, abundance and diversity is plausible as an explanation. Although both weather and habitat affect reproduction, the analysis did not show interaction between covariates (Franklin et al. 2000, Dugger et al. 2005, Olson et al. 2004).

Below are some examples of plausible but unproven interactions.

East-side habitat and Barred Owls

In the fire prone habitats of the east-side, Barred Owls may be displacing Spotted Owls into higher elevation sites. Singleton found that Barred Owls in the eastern Cascades may more readily use mesic forest types and areas lower on slope then did Spotted Owls (Gaines presentation). However these differences represent current locations found after Barred Owl presence in the area. Numerous studies show no difference in elevation between Spotted Owl sites and Barred Owl sites, though there may be an initial spread into lower elevation mesic habitats (see Courtney et al. 2004 for a summary of evidence on this point). A previous study in the eastern Cascades of Washington showed Spotted Owls positively associated with proximity to riparian habitat and negatively associated with elevation (Irwin et al. 2004). Displacement of Spotted Owls by Barred Owls is consistent with correlative data throughout the range (Courtney et al. 2004), but formal testing of this hypothesis and the mechanism has not been performed.

If displacement is forcing Spotted Owls out of lower slope, mesic areas such as riparian habitat into drier more fire prone areas, then this would increase the risk of fire directly affecting Spotted Owls. In addition, displacement may impact habitat quality available to Spotted Owls. Effects of increased fires and any future Barred Owl encroachment may require a flexible, adaptive approach to recovery and fire fuel management to accommodate changes in a dynamic system.

At a landscape level, the threat of fire may be increasing; this is not only due to increases in fire fuels and management, but also due to greater proportions of the population being found in more fire prone habitats as populations in mesic conditions (i.e., in the north) are reduced in size or disappear. Hence it is plausible that the effect of Barred Owls in some areas may be to increase the susceptibility of Spotted Owls to other threats (e.g. weather, fire) by forcing Spotted Owls into suboptimal habitat.

Olympic Peninsula habitat, Barred Owls, prey base, and climate

The interaction of marginal habitat, due to Barred Owls displacing Spotted Owls into higher elevation sites, may interact synergistically with severe weather reducing survival and reproduction. Productivity has been negatively correlated with Barred Owl occupancy and weakly correlated with precipitation, elevation and longitude (Raphael Presentation; Courtney et al. 2004). On the Olympic Peninsula, Spotted Owls may have been pushed into higher elevations sites by the spread of Barred Owls (Gremel in Courtney et al. 2004). These higher elevation sites may be marginal Spotted Owl habitat and impose increased energy costs associated with changes in prey base and availability, thermoregulation, and environmental changes.

Declines in Spotted Owl populations, and presumptive movements to sequentially higher elevations correspond to general Barred Owl increases within the Olympic National Park (Gremel in Courtney et al. 2004). Spotted Owls in the northern part of their range tend to have larger home ranges than elsewhere. This may be due to low prey densities, availability, or diversity in the diet (Carey et al. 1992, Zabel et al. 1995), or direct effects of temperature.

Changes in weather and snow cover associated with changes in elevation would not only affect the owls directly but could also affect prey type and availability, such as behavioral modifications (i.e., reduced activity and foraging strategies during severe weather) of Northern Flying Squirrels, a key prey species in the area. Temperature extremes may further increase maintenance metabolic costs of Spotted Owls. Considering that Spotted Owl home ranges tend to be larger in this part of the range, these changes may be resulting in reduced productivity and survival depending on weather and habitat quality; these results would be consistent with the Franklin et al. 2004 study.

The current evidence is that the Olympic Peninsula population of Northern Spotted Owls is declining over time. Its habitat is degraded because of past and present timber harvest in suitable habitat, and unharvested reserve areas are now fast being occupied by Barred Owls. There may also be synergistic effects, where loss of habitat combined with Barred Owls invasion might have more of an effect than either one by itself.

Barred Owls and the conclusions of previous studies

Barred Owls have been present in some areas since the late 1960s-early 1970s (Campbell 1973, Reichard 1974, but see Courtney et al. 2004 for more details). Many important studies on Spotted Owls have been carried out during the time since Barred Owls arrived and became numerous. Hence, it is possible that some of our conclusions regarding Spotted Owls may have been altered by the presence of Barred Owls. An example may be our understanding of habitat selection and home range size. Past researchers may not have recognized that presence of Barred Owls was a confounding effect on results of their research.

Uncertainty and risks regarding synergistic effects

As indicated above (Risks and Uncertainties section), it is important to assess both the uncertainties regarding any conclusions and the risks associated with potential unknowns.

Synergism among factors and threats is plausible and reasonable given current knowledge. However in most cases, the uncertainties associated with synergistic interactions are large.

On the Olympic Peninsula:

1. There is some evidence that Barred Owls are preferentially invading optimal Northern Spotted Owl habitat and appear to be pushing Spotted Owls into higher elevation sites. Spotted Owls did not use high elevation sites in the past; a priori the current high elevation sites likely constitute marginal habitat.
2. Our current knowledge of interactions between weather and habitat quality elsewhere suggests the potential for synergism (Franklin et al. 2000).
3. Weather severity may increase with elevation and climate change.
4. Prey base, availability and diversity may change with elevation. For example, Bushy-tailed Woodrats become more frequent with increasing elevation because rock outrcrops are more common on steep, high elevation slopes on along steeper stream channels than along rivers and in forests at lower elevations (Carey et al. 1999c); similarly, Snowshoe Hares may become more abundant with elevation (juvenile hares are important summer prey). Logging, and later, farming, on the Olympic Peninsula, began at lower elevations and along rivers. Most farmland, second-growth forest, and intensively managed state and industrial forests are at lower elevations with a majority of old-growth and complex natural forests at higher elevations; structurally and compositionally complex forests have a more diverse and abundant prey base than the second-growth forests, thus prey diversity and abundance generally increases with elevation as does the severity of weather and probability of snow that can influence prey availability (Carey and Harrington 2001). Furthermore, the biotic communities change rapidly with the rapidly increasing elevation on the Peninsula, with Sitka spruce and western hemlock dominated communities abundant in the lowlands and river valleys of the western Peninsula and Douglas-fir dominated and Pacific silver fir dominated communities occurring at higher elevations; the biotic communities with significant fir components seem to have more Flying Squirrels (the primary prey of the owl) that the spruce and spruce-hemlock dominated communities; second-growth hemlock communities seem almost devoid of prey (Carey 1995).

Hence a reasonable interpretation, based on in situ studies and extrapolation from elsewhere, is that synergisms among threats is likely occurring on the Olympic Peninsula.

In other areas, the risk posed by threat interactions are less well substantiated, so there is little justification for suggesting any elevated threat to owl persistence.

Untangling the intricacies of threat interactions will require years of data across the breadth of the range. Because recovery actions must move forward despite uncertainties using existing scientific knowledge, an adaptive framework could incorporate new data as they become available. These studies could include effects of restoration, fire management, climate change and knowledge of the prey base.

ECOSYSTEM ECOLOGY AND MANAGEMENT

IN-GROWTH AND HABITAT QUALITY

Only two of the scientific peer review comments primarily relate to habitat in-growth and quality:

1. Comment *TH16* states that habitat definitions in the DRP are "too vague."

Although this comment is broadly stated, it has merit. Habitat terminology in the DRP is not well defined or consistently used. For the Final Recovery Plan, all habitat terms should be explicitly defined, and care should be taken not to use similar terms interchangeably (e.g., "suitable Spotted Owl habitat", "high quality Spotted Owl habitat"). However, the reader should realize that the Final Recovery Plan does not intend to provide detailed, province-specific habitat definitions based on forest structure: in both DRP options, development of such definitions is directed by Recovery Action #17: “Using a collaborative process, standardize province-specific habitat definitions across the range of the Spotted Owl." p. 52.

2. Comment *TH24* states that the Final Recovery Plan "should not rely on in-growth of suitable habitat until those forests have been verified to be of high quality."

We agree with this comment. The DRP does not describe a process for determining when habitat targets are met. We recommend that the Final Recovery Plan includes such a process description. In our view, this process should include field examinations not just the application of remote sensing techniques and/or habitat modeling. Unless there is substantial uncertainty as to what constitutes Spotted Owl habitat in a particular area, we do not feel it is necessary to carry out radio telemetry studies of Spotted Owl habitat use to verify that newly created habitat is actually being used by owls. Needless to say, well-thought-out, appropriately scaled habitat definitions based on forest structure are a necessary precursor to any attempt at determining whether habitat targets have been met: the target must be clearly defined. This comment is relevant whether habitat targets continue to be expressed at the province level or in some other manner.

FIRE

FIRE MODELING AND CLIMATE CHANGE

Wildfire in Northern Spotted Owl habitat
Habitat loss by high severity wildfire is an important consideration related to the viability of the Northern Spotted Owl, particularly in the drier forest types in the Cascades and

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

Several recent analyses have investigated whether wildfire has become more common in US forests. Stephens (2005) analyzed USFS fire records from 1940-2000 for the entire US and found that wildfire area had significantly increased in the western US, with the exception of California and Alaska, where no change was detected. In a more recent paper by Westerling et al. (2006), they determined that wildfire area has increased since the mid 1980's in the western US, and changing climates are likely contributing to this change. Most recently Rhodes and Baker (2008) analyzed data from USFS burned area emergency rehabilitation reports (BAER) in the western US and argued that high severity wildfire was not as common in ponderosa pine forests as many have reported. Three recent papers have discussed the strengths and weaknesses of using BAER data in such an analysis (Odion and Hansen 2006, Safford et al. 2008, Odion and Hansen 2008). A new technique that analyzes remotely sensed data before and after wildfire (Collins et al. 2007) provides a more direct assessment of forest fire severity and the heterogeneity of fire effects. A similar analysis could be done in the Cascade and Klamath province to fully assess fire effects over the last 2 decades.

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

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

Regarding the disagreement (Rhodes and Baker 2008 versus Moeur et al. 2005, Haynes et al. 2006, Agee 2007) in the amount of forests burning by high severity wildfire--there are three issues to discuss. The first is the spatial scale of the analysis; the scale of analysis matters. Rhodes and Baker (2008) conduct their analysis at large spatial scales similar to that done by Stephens (2005) and Westerling et al. (2006). None of these analyzes at large spatial scales could answer questions at the Northern Spotted Owl province scale. The second issue concerns possible problems associated with estimating forest fire severity with BAER data versus a more direct assessment of remotely sensed data discussed above. Lastly, the analysis of Moeur et al. (2005) and Haynes et al. (2006) were targeted to Northern Spotted Owl provinces in California, Oregon, and Washington and are therefore the most appropriate for this assessment.

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

Adaptation Options

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

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

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

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

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

MANAGING FOR SUSTAINABLE NORTHERN SPOTTED OWL HABITAT IN DRY EASTERN CASCADES FORESTS OF THE INLAND NORTHWEST

BACKGROUND

According to the Draft Recovery Plan for the Northern Spotted Owl (USFWS 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 1). 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. 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 1). 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 1) that reflect major environmental and old forest differences.

Table 1. 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 1980
[6] Barrett 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 1). 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 1). 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 1). 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 10's 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. <u>Reduce surface fuels</u>—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. <u>Increase the height to live crowns</u>—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. <u>Decrease crown density</u>—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) <u>Local owl biologists should identify existing high quality Northern Spotted Owl habitat</u>. 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 PROVINCE

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 only two province-level findings: 1) that extensive new research would substantially reduce scientific uncertainties, and 2) that knowledge gained from studies of the eastern Cascades dry forests or wet coastal forests is not directly applicable to the Klamath Mountains forests.

The review panel also offers these more general comments, which may be useful in the next phase of planning for the Klamath provinces:

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. (1999b) 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) 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 2) 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 2. 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.

STRUCTURE OF ADAPTIVE MANAGEMENT

A common theme that emerged among many reviews of the Draft Recovery Plan was that scientific information or analyses of information should provide the underpinnings and framework of the plan. Many of the comments and criticisms asked for the scientific basis for inference, conclusions, proposals, strategies, etc. A clear exposition of the scientific basis for the Recovery Plan's proposed actions is important (especially since we know more about the owl than any other endangered species). This is particularly true when changes to the plan are contemplated.

For example, the idea of adaptive management is long-standing (early 1970s) and has considerable merit as a concept. Indeed the application of adaptive management is gaining momentum throughout federal agencies charged with managing public lands or public natural resources. Adaptive management is a process that calls for clear objectives, strategies, thresholds that trigger changes in management, and institutional and scientific feedback loops. A looming concern among many publics and scientists is that "adaptive management" is the "buzzword" of the day, and a surrogate for continuing action on the ground, but without the intent explicit in concept of "adaptive management." This problem is apparent in the DRP because there is no scientific or structural framework in the plan for guiding adaptive management in many critical areas such as fire management or Barred Owls. The SEI panel believes that if the Recovery Plan advocates adaptive management, that it is important to articulate the scientific feedback loops. We found this concern to be a common undercurrent embedded within discussions of adaptive management. We conclude that in order to satisfy such criticisms and concerns, any discussion of adaptive management would need to be formalized. A formal framework for adaptive management would include, but not be limited to the following: clear objectives (these would be realistic and relevant to the owl and other natural resources), expected results, an appropriate quasi-experimental or true experimental design (i.e., the design would be capable of providing the information necessary to answer the objectives), proper execution of the design, monitoring of treatments, a rigorous mechanism for oversight, clear assignment of responsibility at each level of the framework, and a clear feedback and adaptive response mechanism that is quickly capable of recognizing and mitigating errors or deficiencies of the framework or individual management treatments. We believe the explicit development of such a process is essential if adaptive management is to be a strong component of the plan. Developing and presenting recovery actions in an adaptive management framework requires considerable effort and cannot be accomplished in a short period, but we think the plan can adequately describe the concept of adaptive management and demonstrate its application to planning with a few examples (below we provide brief examples).

Example:

BARRED OWL

Learning as a process in science can be viewed as hierarchical with its most rudimentary being learning by trial and error and its most advance form being inferring cause and effect relationships derived from true experiments. Understanding cause and effect relationships is the goal of all science, but executing well designed experiments in ecology (natural resources) is more difficult than some fields of science (e.g., chemistry, physics) because are ability to control confounding factors is greatly limited by the complexity of natural systems (Romesburg 1981). Adaptive management is proposed mechanism to formalize learning in management systems (Walters and Holling 1990). Moreover, its goal is evaluate management actions and then curtail or modify them to correct failed or inappropriate action without destroying the capacity of the system to respond. Thus, adaptive management is a form of decision analysis that is predicated on acquired data and analysis specific to the problem of interest.

We present here a very brief, hypothetical scenario about the role of the Barred Owl in the conservation of the Spotted Owl. This is purely hypothetical and could easily be replaced with a well-considered plan. Indeed, our scenario is mostly a combination of conjecture and ideas that simply frames a thought process about the role of adaptive management in decision making about Barred Owls. Our scenario is presented as an outline with various points discussed within bracketed comments.

A. Stage 1 “The Broad Question”: How should the USFWS respond to the perceived threat of the Barred Owl to Spotted Owl viability?

1. Sub-questions
    a) Are the recent declines of Spotted Owl populations in demographic study areas solely or partially related to the invasion of Barred Owls?
    b) If Barred Owls are linked to Spotted Owl declines, by what mechanisms is the impact occurring (e.g., direct displacement from habitat, behavioral interference competition, predation, food competition)?
    c) If Barred Owls are a major threat, what is the appropriate and feasible response?
    d) Other questions possible

2. Preliminary assessment of information
    a) Review of status (Courtney et al. 2004)
    b) Review of peer-reviewed papers based on observational or experimental studies.
    c) Compilation of anecdotal information relevant to the issue.

d) Review of theoretical models designed to evaluate scenarios of Barred Owl invasion or patterns of diffusion.

e) Other assessments are possible (e.g., The Draft Recovery Plan).

B. Stage 2 "Strategic Response to Acquiring Reliable Knowledge" (sensu Romesburg 1981).

[The background for this stage has already been set, largely by the many actions under A.2.a-e, for answering question A.1.a. because there is a preponderance of anecdotal evidence, a growing number of observational studies, predictions based on theory, and a an experimental study that all suggest Barred Owls could be negatively affecting Spotted Owls, but it still is not clear how much an impact they are having on Spotted Owls (Gutiérrez et al. 2007). The demographic studies are the places where declines have been formally documented (Anthony et al. 2006), but declines apparently have occurred in other places such as Redwood National Park. So it is logical to assume that if Barred Owls are the root cause of the decline of owls in many of the demographic study areas then a formal prediction from removal experiments located on the demographic study areas is that owl populations will stabilize or increase. An adaptive management program on Barred Owls would require removal experiments because they will guide future actions and more importantly, the scale of such actions. They are necessary to demonstrate a cause and effect relationship between the Barred Owl invasion and the decline of the Spotted Owl because if this cannot be demonstrated through removal experiments it suggests the cause lies somewhere else, which means entering into a control program may be unwise or unnecessary. If cause and effect is established, well-designed removal experiments will help evaluation of such management considerations such as cost of removal, scale of removal, distribution of removal zones, and frequency of removal of Barred Owls from selected removal.]

1. Design and execute removal experiments in a classic Control/Treatment Design).

    a) Removal experiments have to be done at a large scale. [Removal of Barred Owls at the scale of individual Spotted Owl territories is not sufficient because Barred Owls are now relatively abundant in areas of concern, have strong dispersal abilities, and have the capability of quickly moving into vacant {removal} areas. Thus, as noted under our "Barred Owl" discussion, we recognize that scale of removal is an important consideration for detecting an effect because the experimental design should be such that it reduces immigration rates to study area, and hence colonization rates of individual territories.]

    b) The extensive population data on Spotted Owls in demographic study areas should allow a predicted response given a specific removal strategy. [This is one of the major benefits in reducing costs of such an experiment, all the parameters of interest for Spotted Owls are being estimated annually. The only element of additional cost that needs to be incorporated is the effective removal of Barred Owls from sufficiently large areas within, and perhaps beyond, the boundaries of demographic study areas to observe a treatment effect.]

c) Monitor and record the cost of Barred Owl removal, monitor and document recolonization patterns of Barred Owls from removal area, and monitor the response of Spotted Owls to Barred Owl removal. [These are key features that will guide an adaptive management strategy as well as provide the bases for informed decision making about the long-term strategy. We view this information as key to understanding the future of Barred Owl management strategies. If Barred Owls are demonstrated to be the root cause of Spotted Owl declines, and if the USFWS decides to control Barred Owls as it does with many other species that impact endangered species, this information will help guide an appropriate control strategy. For example, it has been stated that it will be a never ending control effort that will be very costly. The information in this segment may show that control needs only be a periodic endeavor and is logistically feasible and cost effective. The Diller presentation is convincing to the SEI panel that Barred Owl control, at the scale of demographic areas would be feasible and very cost effective. We predict from population dynamics theory that if control is effective and of a large enough scale, it may take some years for Barred Owls to recolonize removal areas, which would mean that removal could occur in periodic fashion.]

d) A design (or designs?) for removal experiments is being developed at this time by others (Buchannan presentation). Therefore, our simplistic discussion above should be considered as a possible framework for thinking about the value of removal experiments and the scale of a design to provide useful, reliable knowledge, to guide decision making. We expect the designs to be rigorous and meet the overall goals of informing management. We recommend that the USFWS have the designs peer-reviewed, not from philosophical viewpoints but from scientific viewpoints.

e) Although we do not know the design(s) being developed for Barred Owl removal experiments, our speculation is that such experiments would provide sufficient information regarding a Spotted Owl response within 4-6 years. We based this speculation on the approximate time between the first and second Northern Spotted Owl meta-analyses. This was a five year period and reflected the time period where a presumed response of owls to the reduction of timber harvest was observed (i.e., some of the populations in the southern part of their range went from a declining status to a stable status).

2. Design and execute key behavior studies, particularly interaction studies to assess the possible mechanisms of interaction between the two species including agonistic interactions, interference competition, food competition, space use, and fine scale habitat selection (many other valuable studies are possible as well).

[These can be synergistic to removal studies or separate because they are providing other information that might inform decision makers. For example, there is still much doubt about the habitat preference of Barred Owls, and such studies could provide information about those preferences relative to Spotted Owls. Another study could radio-mark Barred Owl chicks outside of removal areas and then estimate the rate of dispersal into removal areas. The number of possible studies is large and simply needs to be ranked by priority to provide the most pressing information to this problem.]

C. Stage 3 "Using reliable knowledge to form an adaptive response."

1. Decision to control based on results of removal experiments

2. Assuming a decision to control is made, the following questions should be guided by information acquired from both experiments and observational studies.
    a) Where should the control programs occur?
    b) How many control areas should there be?
    c) What should be the intensity of control?
    d) What should be the frequency of control?
    e) What should be the expected cost of control?

D. Stage 4. Engage in desired process.

1. Monitor all aspects of control from owl response to cost

2. Evaluate efficacy of decisions in C.2.a.

E. Stage 5. Evaluate control and make changes if necessary based on evaluation process and expectation based on predictions of research and effort.

F. Stage 6. Revise or continue plans depending on results of D. [This is a primary "feedback" loop that we alluded to above, but clearly feedback, and hence, adaptation should occur at each iterative stage.]

CONCLUSIONS

Our example portrays the adaptive management process in a simplistic manner. In reality, it is far more dynamic and complex depending on the goals of the adaptive management program. It is not a mostly linear hierarchy as we outlined, but rather a web of interactions and feedback mechanisms designed to acquire reliable knowledge that allows ample time for an agency to change direction if management is inappropriate. Therefore, adaptive management is an iterative process where a goal for management is defined, and is applied in a limited way such that the consequences of making mistakes are not irreversible. The SEI panel believes that if adaptive management is articulated as a goal in the revised recovery plan that it must be formalized, structured, and transparent to the public. Further, we recommend that the USFWS be part of any adaptive management process for Spotted Owls and provide external oversight to any adaptive management program. Although, we focused on the Barred Owl as our example, the same process can be envisioned for fire management, habitat management, or any other management action which is likely to affect owls or its habitat on a large scale.

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APPENDICES

A. Habitat Fitness Potential review by James D. Nichols and Kenneth H. Pollock
B. Review of Spotted Owl genetics studies by Funk et al.
C. Panel response to focus questions by USFWS
D: Northern Spotted Owl Questionnaire to SEI panel
E: List of Comments on the Draft Recovery Plan for the Northern Spotted Owl (*Strix occidentalis caurina*)

A. HABITAT FITNESS POTENTIAL REVIEW BY JAMES D. NICHOLS AND KENNETH H. POLLOCK, FEBRUARY 25, 2008.

We were asked to review the comments made by A. B. Franklin, G.S. Olson and K. Dugger, on the Draft Recovery Plan for the Northern Spotted Owl. Our first comment is that our review was probably unnecessary. The best scientists to comment on any limitations and extrapolations of study results are the scientists who produced those results in the first place.

Drs. Franklin, Olson and Dugger all were emphatic that their inferences (based on Franklin et al. 2000, Olson et al. 2004, Dugger et al. 2005) about habitat potential at the scale of the individual owl territory were simply not intended to be extrapolated to inferences about owl population growth rate at the landscape level. Habitat fitness potential, λ_h, was computed by Franklin et al. (2000), Olson et al. (2004) and Dugger et al. (2005) as a function of survival and fecundity estimates, without a full accounting of emigration and immigration. The latter movement parameters are needed to model rate of change at the population level. This is especially relevant to landscape inferences, as proximity and number of occupied potential neighbor territories, although irrelevant to computation of λ_h, is very relevant to owl population dynamics at the landscape scale. In addition, the λ_h were estimated for occupied territories only (hence the use of the terms "habitat fitness potential"). Unoccupied potential territories of similar habitat to those that were occupied did not receive $\lambda_h = 0$, again emphasizing that the potential habitat fitness metrics were not intended as surrogates for population growth rates of territory clusters or larger landscapes.

If estimates of λ_h had been relevant to owl populations at the landscape scale, extrapolation of results of analyses such as those of Franklin, Olson, Dugger and colleagues would require an assumption about the applicability of their results to a larger area that includes the spotted owl habitat of the Pacific northwest. The 3 cited studies were based on selected intensive study areas, and indeed such areas of intensive study are required for the kinds of inferences about owl survival and reproduction presented in the reports. However, extrapolation to the spotted owl range is not really appropriate. Ideally, such extrapolation would be based on studies conducted at probabilistically (e.g., perhaps randomly) selected study sites throughout the area to which inference is intended.

Appendix D of the Draft Recovery Plan includes 3 figures in which habitat fitness potential and survival are plotted against single habitat covariates (e.g., percent nesting habitat in Fig. D1). As noted by Franklin in his comments, the model selected by Franklin et al. (2000) for inference about λ_h included multiple covariates, whereas appendix D uses a single covariate for the plots. Model selection thus led to the inference that multiple covariates were relevant to λ_h, and the plots using a single covariate are potentially misleading (e.g., they imply that λ_h is determined by the single habitat variables in the plots). Similarly, habitat management based on a single covariate also runs the risk of leading to inappropriate conclusions about habitat adequacy.

The Draft Recovery Plan (e.g., p.38) emphasizes $\lambda_h = 1$ as a type of threshold for considering adequacy of spotted owl habitat. The Plan noted that $\lambda_h = 1$ indicated a "stable population", again confusing habitat potential at the territory level with spotted owl population growth rate. Even if the two λ 's could be equated (they cannot), any sort of management based on this threshold for adequacy should incorporate the uncertainty associated with estimated λ and with the influence of environmental variation on predicted λ. If the objective of management is to insure that owl populations maintain $\lambda \geq 1$, then optimal management would not focus on providing any habitat for which predicted $\lambda \geq 1$. Because of the uncertainty associated with any prediction of λ as a function of habitat covariates at territory or landscape levels, optimal management would focus on areas for which $\lambda \geq 1$ with relatively high certainty. Such areas would not include habitats that produced $\hat{\lambda} \approx 1$. This point brings up the suggestion to treat spotted owl habitat management as a structured decision problem, developing recommended actions that are optimal with respect to objectives and current state of knowledge, where state of knowledge includes the various sources of uncertainty. Note that this recommendation fits well with the recommendation by Franklin in his comments to use formal adaptive management to manage Northern Spotted Owls.

The various authors (Franklin, Olson, Dugger) also indicate a selective use of data producing a biased view of habitat needs. Indeed, the above-noted reliance of Appendix D figures on single covariates, rather than on all covariates judged to be relevant to λ_h, provides one example of selective use of data. Olson's comment about Fig. D2 being based on 6 sample points rather than on her entire data set is another example of selective use of data. This point about selective use of data is best made by the original authors, and here we simply note our agreement that this is a problem in the Draft Recovery Plan.

In summary, after reviewing the Draft Recovery Plan for the Northern Spotted Owl (primarily Appendix D) and the comments about this Draft Plan made by A. B. Franklin, G.S. Olson and K. Dugger, we find ourselves in agreement with Drs. Franklin, Olson and Dugger. In particular, we agree that their various inferences about habitat fitness potential at the level of the individual territory were not properly applied to develop habitat management objectives. Appropriate application of these results requires consideration of the topics discussed above, as well as of a number of other specific criticisms leveled by Franklin, Olson and Dugger. In fact a primary recommendation is that these biologists and selected colleagues and coauthors be a part of any future effort to develop recommendations about habitat conservation and management for Northern Spotted Owls.

B. REVIEW OF SPOTTED OWL GENETICS STUDIES BY FUNK ET AL.

REVIEW BY DR. ANDREW BOHONAK

19 February 2008
Dr. Andrew J. Bohonak's, Associate Professor, San Diego State University, review of two manuscripts currently in peer review that summarize patterns of genetic diversity in the Northern Spotted Owl: Genetics shows current decline … (Funk et al., in review at Proc. Roy. Soc. B) and Landscape features shape genetic structure … (authorship unknown, in review at Evolutionary Applications).

Summary
Overall, I have found the evidence for recent declines in genetic diversity to be convincing. Assuming no systematic bias in laboratory methods, the data and analyses are appropriate. By far, the most plausible cause for a genetic bottleneck would be a recent decline in effective population size Ne. This would be most easily interpreted as a recent decline in the census population size Nc, although these two population parameters are not identical. (For example, it is possible that Ne has declined more quickly than Nc due to factors such as increased variance in family size over time, increased departures from an equal sex ratio, etc.) Objectively, it is very difficult to define "recent" based on currently available methods. However, these declines are much more likely to be attributable to a time scale of tens or hundreds of generations, rather than thousands.

The analysis of barriers to gene flow is also thorough, incorporating some of the more recent statistical techniques. Across the spatial scale of the study (northern California to Washington), the degree of genetic structure is relatively small, but statistically significant. The general pattern is that of isolation by distance from north to south, with particularly high levels of divergence in the southern Cascades.

Importantly, very recent declines in genetic connectivity across space (< 100 generations) are unlikely to be detected (or underestimated if they are detected) using traditional analyses based on F-statistics/AMOVA. It is difficult to determine how much of the observed subdivision is due to very recent declines in gene flow, and how much was historic. Assuming that gene flow has in fact decreased from very high levels, there is a better likelihood of detecting statistically significant population subdivision if sample sizes are large (in terms of number of individuals and number of loci) and one of the various "assignment test" methods are used. GENELAND, which falls into this category, failed to find evidence for genetic subdivision.

Population subdivision clearly exists. However, one must place significant weight on non-genetic information to infer whether 1) populations have always been subdivided across the study area, or 2) a previously panmictic species has only recently become subdivided.

My only substantive criticism is that in the genetic structure manuscript, the authors dismiss the Columbia River as not acting as a barrier to gene flow. One of their analyses (the hierarchical AMOVA) finds statistically significant divergence across the river, but the authors dismiss this because the magnitude of the effect is small. In my opinion, there are fundamental differences between 1) statistical significance, 2) significance in terms of short-term (ecological) population viability effects, and 3) significance in terms of long-term genetic/evolutionary effects. One could make the case that these three are uncoupled for this specific example, but that has not been done in an effective way.

The short- and long-term consequences of decreased genetic variation in a subdivided species are, in some ways, less tangible than decreases in the number of individuals. Further, the relationships between neutral genetic variation and adaptive genetic variation are not always direct. Nonetheless, a continuously growing body of evidence suggests that decreased variation in markers such as microsatellites should raise an alarm for conservation biologists and resource managers.

1. Genetics shows current decline …

Theoretical Background

Population genetic variation is a function of the effective population size Ne and the mutation rate μ. Ne is often estimated from empirical data to look for changes over time, to provide an indirect method of assessing the census population size Nc, or for direct comparison with Nc when each can be estimated from different information. Differences between Ne estimated from genetic data and Nc estimated from surveys are often quite large. This information is useful for both ecological considerations (e.g., PVAs, Allee effects), and long- term evolutionary implications (e.g., potential for adaptive evolution).

Theory and conventional wisdom hold that the effects of population bottlenecks (declines in Ne) on genetic variation are generally weak, unless the bottleneck is strong (Ne < 50 for a diploid species, and likely < 30), and/or prolonged across many generations. Initially, rare alleles are expected to be lost although frequencies of common alleles will change little. Large variance in these changes can be expected over loci, even with large numbers of individuals sampled and no laboratory errors. Thus, multiple loci (>10) and large numbers of individuals provide increased statistical power when testing for bottlenecks.

Genetic bottlenecks have been found and studied in various organisms. As one might expect based on the above criteria, those studies that demonstrate very recent declines in genetic variation due to anthropogenic impacts (or very recent natural habitat fragmentation) tend to reflect dramatic changes in Ne and/or invertebrates with short generation times.

Methodological Summary

Although microsatellites are the marker of choice in most conservation genetics studies, they have more technical limitations than many people realize, including scoring artifacts, null alleles, large allele dropout, etc. The degree of technical limitations varies greatly across species, loci and laboratories. It is impossible to evaluate the accuracy or bias of any study based on a published paper, so ultimately one must trust that great attention to detail is present in all well- established laboratories. Verification from independent laboratories would be the only way to assure this, although it is rarely conducted.

A. BOTTLENECK analysis

The manuscript uses the BOTTLENECK program to test for recent genetic bottlenecks based on Cornuet and Luikart's (1996) method (note to authors: this citation does not appear in the manuscript's bibliography). This test has been used in many published studies and is widely accepted. It is often described (confusingly) as a test for "excess heterozygosity". In reality, the test compares two simple summary statistics for the allele frequency distribution within each locus: He (expected heterozygosity) and K (the number of unique alleles in the sample, sometimes called A). In a simple gene pool model of drift and mutation at equilibrium, the allele frequency distribution (histogram) should have a characteristic shape, with few common alleles and more rare alleles. The exact shape depends on the standard population genetic parameter $\theta = 4Ne\mu$. If there is a discrepancy between He and K, then a basic model assumption has been violated. If K is too small, then a reasonable assumption is that rare alleles have been recently lost due to a decline in Ne. The system is no longer in an equilibrium between drift and mutation. Changes in more common alleles will follow as a new equilibrium is reached, but this may take a much longer period of time.

The test is conducted by generating a null distribution for He from random data that are simulated to match the observed K. Observed He is compared to the null distribution. The mutation model may be an infinite allele model, or a stepwise mutation model. The authors do consider potential biases from varying the mutation model parameters (Table 1).

The model also assumes that only a single gene pool is being studied. If two or more gene pools are unknowingly combined for this analysis, it could bias results in either direction. In their manuscript, the authors acknowledge that gene flow into the study area could bring in rare alleles, biasing their results against a recent bottleneck. An alternative explanation that they do not discuss is that two divergent gene pools might coexist within the same spatial area, biasing results towards a recent bottleneck. Although I am not an expert in avian biology, it is reasonable to assume that the latter phenomenon is unlikely.

When such departures from drift-mutation equilibrium occur in a large number of markers from across the genome, the most parsimonious explanation would be a recent population bottleneck. Other explanations (e.g., a change in natural selection, or in mutation rates) are unlikely because they would need to simultaneously impact all genes being studies in a qualitatively similar manner. The authors found some aberrant patterns in one of the 11 loci studied, discussed possible interpretations, and then stated that qualitative conclusions do not change with exclusion of this locus. This is a reasonable approach.

B. Bayesian analyses

The authors also used two newer Bayesian methods for detecting changes in Ne over time. The method of Beaumont (1999) incorporates all information about the gene genealogy, rather than only summary statistics. Under a linear or exponential growth/decline model, it estimates 1) the current population parameter ⎝, 2) the ratio of current to ancestral population size, and 3) the time since the change in Ne began. A stepwise mutation model is assumed. Storz and Beaumont (2002) developed a similar model, which estimates 1) current Ne, 2) past Ne, 3) the time since the change in Ne began, and 4) the mutation rate. The more recent model also allows for variation among loci.

These Bayesian methods differ from the simple BOTTLENECK analysis as follows:
1) the Bayesian methods are expected to integrate over a much longer period of time, 2) they provide parameter estimates, rather than a simple hypothesis test, and 3) as with any Bayesian method, model estimates depend critically on the values chosen as priors. Thus, the priors must be biologically realistic. Other methods for detecting changes in Ne over time are available (e.g., Bayesian skyline plots), but most of these tend to be applicable to DNA sequence data, rather than microsatellites. One exception is the very recently published method of Tallmon et al. (2008).

2. Landscape features shape genetic structure …

Theoretical Background

A wide variety of methods are available for studying the genetic differences among populations. These can be divided broadly into categories such as 1) individual-based methods vs. those that require a priori designation of gene pools, 2) explicitly vs. implicitly spatial, 3) visualization methods vs. model-based methods, and 4) “assignment tests” that likely integrate over only a few generations vs. frequency-based methods that likely integrate over hundreds of generations or longer. As is fairly standard, the authors use a variety of methods that have different underlying assumptions, and look for common features in the results.

Methodological Summary

Frequency-based methods (pairwise FST, AMOVA, allelic differentiation tests) indicate low but statistically significant levels of divergence among populations. These are consistent with an isolation by distance apttern (Mantel Test). The spatial, individual-based clustering algorithm in GENELAND found only one gene pool for the entire data set, but the Monmonier algorithm found a genetic break in the southern Cascades. This break is also apparent in the individual-based AIS visualization. The AIS plot shows that the isolation by distance pattern is likely due to a latitudinal trend. My comment concerning the Columbia River interpretation is expressed above.

REVIEW BY DR. KEITH CRANDALL

Review of Spotted Owl Genetics studies by Funk et al. (Proc Royal Soc. B & Evolutionary Applications) by Keith Crandall.
14FEB08

Both studies provide novel data and analyses that provide insights into the population structure and history of the northern spotted owls (*Strix occidentalis caurina*). The first paper uses a data set of 11 microsatellite loci collected from 352 individuals to draw the conclusion that the owls have undergone a recent population bottleneck. The results also demonstrated a signature of Pleistocene expansion. Both signatures were strongest in Washington state. They conclude that the northern spotted owls have recently declined and further suggest that loss of genetic variation is an emerging threat to the subspecies' persistence. The second study uses nearly the same data to test for genetic substructure ("breaks") associated with landscape features. Despite finding no evidence for substructure and finding good evidence for extensive gene flow, the authors conclude that dry low elevation valleys and the Cascade and Olympic Mountains restrict gene flow. The stronger study of the two is clearly the Proceedings paper. I will take a detailed look at each one in turn and provide my views on the conclusions drawn from each study.

***Proceedings* study**: This is, in general, a well-done study with great sampling both in terms of individuals throughout the species range as well as in terms of the multiple genetic loci sampled. Both studies potentially suffer from sampling bias caused by using microsatellite loci developed in other species (in some cases from other genera!) (Vowles & Amos 2006). Nevertheless, the analyses performed are well-done and appropriate for the data. There are a few concerns, however, with the conclusions of the paper as well as some minor points on the presentation. Those are detailed below.

The conclusion of this paper is that the population has undergone a recent bottleneck. Yes, well, we already know that, don't we. Presumably, that is why the species is listed as an Endangered Species. So the conclusion is hardly surprising. What the authors fail to detail is the timeframe of this decline. What is actually meant by "recent"? They imply a decline since conservation action began, but present no evidence for this timeframe. It would have been nice if the authors had combined their new genetic findings with previous work for a more complete picture including ideas on timing etc. The fact that the field study found evidence for declines in survival and fecundity suggests that the population is, indeed, still in decline. Thus, the conclusion for future efforts in monitoring genetic diversity are very warranted as the decline of diversity will potentially lead to non-random mating (inbreeding) and then cause highly detrimental effects in the population.

Minor points –
How are the samples distributed across years? How does this impact subsequent analyses?

The authors conclude that mtDNA has lower power for indicating population bottlenecks. I would argue that the timeframe is simply different. The mtDNA is probably reflecting a much older history.

***Evolutionary Applications* study**: This study was more difficult for me to appreciate. The general premise is well laid out and reasonable, that is, that landscape features might influence population structure and levels of gene flow. The authors pretend that this is something new and novel ("landscape genetics"), but indeed what they are talking about is phylogeography and it has been around for a while, thanks to John Avise and others. Not to mention that the across species ideas (biogeography) have been around at least since Alfred Russell Wallace. In addition, there are often non-landscape features that lead to population structuring as well (life history differences, physiological differences, etc.) that the authors ignore. But the main issue of this paper is the fact that the authors test for population substructure, find none, conclude there is ample gene flow across the entire subspecies, and then proceed to discuss "landscape features" and their impact – the data suggest that have no impact, so there is no point in discussing them. Indeed, if they did have an impact, then these would be old (since the landscape features (e.g., mountains and rivers) are old) and you would have seen the impact in the mtDNA. But those studies conclude, as this one does, that there are no such barriers and that there is ample gene flow across the subspecies. Indeed, the introgression studies across subspecies (which are hard to keep track of because the authors don't use the scientific names) suggest that there is reasonable gene flow across subspecies as well. This is actually probably good in the long run because it will help the species maintain genetic diversity and keep it from suffering the genetic problems alluded to in the first paper. Nevertheless, the authors continue with statements like "Mountains also influenced the genetic structure of northern spotted owls" and "areas that appear to be isolated from the rest of the subspecies' range by mountains or valley include …" in the discussion after their results of "within northern spotted owls, only one population as inferred." The authors conclude by suggesting finer scale sampling to "allow dissection of the effects of specific landscape layers on genetic structure." BUT THERE IS NO GENENTIC STRUCTURE. The authors seem unwilling to believe their own conclusions. Despite the importance of gene flow in many of the arguments made in both papers, neither one actually measures gene flow. There is not one estimate of migration rate to be found.

Minor points –

The Fst values (pairwise) are never actually presented, only ranges are given. The authors also do not present Fis values, which are relevant here.

How was convergence determined in the MCMC analysis?

Summary: Together these studies provide useful data on the genetic structure of populations for the northern spotted owl. The sampling is very good with 352 individuals and 11 loci sampled. The data are very important in terms of providing a baseline genetic assessment for overall genetic diversity (which the authors did not calculate, but can be easily estimated from the data) to monitor the subspecies for future loss of genetic diversity. The data show convincingly that there is ample gene flow across the subspecies range and that the subspecies should probably be treated as a single ESU. The recommendation for future monitoring of genetic diversity to determine the impact of the current bottleneck on genetic diversity and species survival is also highly warranted.

REVIEWS BY DR. ROBERT ZINK

Review of "Genetics shows current decline and Pleistocene expansion in northern spotted owls" by Robert Zink.

This is a well written paper. The authors use variation at 11 microsatellite loci from 350 northern spotted owls (nso) to infer signatures of relatively ancient population expansion, and more recent bottlenecks. The two apparently antithetical conclusions are reconciled by assuming that they occurred at different times in history. They claim that the inference of bottlenecks has implications for conservation. I discuss the two conclusions separately.

Population expansion in the Pleistocene

This is a standard conclusion for north temperate birds, thought to be a result of population increases following glacial retreat. Typically it is inferred from quantitative analyses (Ramos-Onsins and Rozas 2002) or graphical portrayals (Rogers and Harpending 1992) of "mismatch distributions" based on sequence data. I don't know whether the inference is robust for microsatellites. The methods are, I think, relatively unproven.

Furthermore, the mtDNA sequence data (Barrowclough et al. 2005) do not support the notion of population expansions. This discrepancy ought to have been discussed. Nonetheless, it is not clear why this is even in the paper because the authors barely mention the implications or importance of a Pleistocene population increase in the Discussion. Perhaps it is considered novel to detect both expansions and bottlenecks in the same data set. But as I discuss in the Summary, I am not convinced by the analysis.

Recent Genetic Bottlenecks

This is clearly the most provocative piece of this paper. The authors conclude that there are detectable signatures of bottlenecks in nso microsatellite frequencies and that it is a result of population declines documented in recent recorded history. There are several points to make about this.

Theory. The authors assume that a reduction in allelic diversity at putatively neutral microsatellite loci will be a proxy for loci important in fitness (survival, reproduction). It was well established during the allozyme days, in papers by Chakraborty (1981, The distribution of the number of heterozygous loci in an individual in natural populations. Genetics 98:461-66), that heterozygosity at allozyme loci (single loci analogous to microsatellites) cannot be logically linked to heterozygosity in other sets of loci. Still there could be a general effect from a reduction in population size (and concomitantly in Ne) at fitness loci. However, fitness traits are most likely polygenic, and hence they lose genetic variation more slowly, and gain it more quickly, than single (microsatellite) loci. Therefore, loss of rare alleles at single neutral loci (microsatellites) has an unknown relationship to traits that might influence survival and fitness of populations.

Although "bottlenecks" are widely thought to lead to negative consequences, those that do so are really severe. The authors should review the paper by Nei et al. (1975, Evolution) that makes clear the required magnitude and duration of a bottleneck before it is really severe. The meaning of "bottleneck" is not the same as a small reduction in genetic variability. A population bottleneck means there are very few individuals for many generations. If there are still thousands of owls, it is not clear there is a major concern for genetic variation due to bottlenecks – it depends on Ne which will depend on the connectivity of the populations.

Data and analyses. Therefore it was surprising to see that the authors equate the loss of rare alleles at neutral loci with inbreeding depression and loss of adaptive genetic variation in nso. Nothing in their data supports this inference. Only if loss of variation at neutral loci also forecasts loss of variation at significant fitness traits could this correlation be interpreted in a causal manner.

Actual recorded population declines are relatively recent, and variation at nuclear loci contains information over much longer periods. There has to be a lag time before population reduction leads to reduced genetic variation, and the authors need to establish that microsatellite loci and population reductions are on the same time scale. It is not clear why the authors expect there to be a cause and effect relationship between very recent population declines and microsatellite variation, which contains information about far deeper in the past.

The authors note that the program they used (Bottleneck 1.2.02) detects bottlenecks by searching for losses of rare alleles. In reality, it takes advantage of the fact that allelic diversity is lost faster than heterozygosity (rare alleles don't contribute much to heterozygosity). The unit is group of individuals. In this study, samples were pooled arbitrarily into units, with boundaries of units often corresponding to potential geographic barriers. Yet, groups of individuals often span other potential geographic barriers. Thus, the results are dependent on how samples were pooled. However, in the companion paper, they showed that the entire nso was a single population unit. Hence, it is not clear why they used so many different sampling subunits. It would be interesting to know if the entire nso shows evidence of a bottleneck with this program, because Bottleneck requires closed populations.

The authors did not mention the result from Barrowclough et al. (2005) that there was considerable gene flow. The present authors state that gene flow would bias their analysis against finding bottlenecks. However, if gene flow was from leading edge expansion, it would not introduce rare alleles, only common ones and therefore not cause the effect they stated. Their explanation therefore is inconsistent.

The authors claim that Barrowclough et al. (2005) did not find a statistically significant signature of a bottleneck – in fact, these authors did not mention "genetic bottleneck" in their paper nor did they test for it. Actually I don't think there are any unambiguous tests for bottlenecks in single loci. Furthermore, the paper by Barrowclough et al. (2005) also shows a decline in nucleotide diversity to the north, as do the two papers using microsatellites, but it was not acknowledged.

Summary
In my opinion, the authors cannot determine if population declines led to decreased genetic variation (not genetic bottlenecks in the sense of Nei et al. 1975), or the reverse – genetic “bottlenecks” led to population declines (as the authors briefly allude to on pg. 12, line 1). They wish to favor the latter interpretation, but with only a correlation, it is not possible to know which explanation is correct.

Although I questioned the inclusion of the results for population increases above, they are actually relevant for considering the two papers in concert. In the companion paper, the authors inferred a northward range and population expansion as the explanation for the decrease in genetic diversity in the north. In that paper, the authors essentially invoked a sampling process to explain decreased genetic diversity in the north. In this paper, from the same data, they conclude that decreased genetic diversity in the north is due to a bottleneck. There is a discrepancy here. It could be that the northward range expansion simply mimics a bottleneck effect. In any event, the authors seem to have come up with two explanations for the same phenomenon, and it seems unlikely that they are both true.

This needs further study via a simulation (possibly in Mesquite). One often finds after a major population expansion a single “main” allele and lots of one-step-removed alleles (a “star phylogeny”). This is a classic signature of a population expansion. A bottleneck should remove these rare alleles, and indeed that is what the test they used is based on. Thus, the results are puzzling. Incidentally, these tests would be far more robust if the authors had sequenced 10 nuclear loci, rather than relying on microsatellites and frequency-based analyses.

It is not clear whether this paper has any management implications for nso, or that the authors claim it does. They point out that one might use their methodology for detecting reductions in genetic variability, and this could serve as a warning to managers. But I think this requires more thought before declines in rare alleles at neutral loci has management implications. If indeed the nso has undergone a reduction in genetic variation at loci affecting fitness, the solution is to have more owls. But I’m sure the authors would agree that this is scarcely controversial and requires nothing more than the demographic estimates already available.

Comments on "Landscape features shape genetic structure in threatened northern spotted owls (*Strix occidentalis caurina*)" by Zink.

This is a very well written paper that describes some interesting findings and makes some important points. However, I do not agree with the conservation implications that the authors advance. Nor do I think that the title reflects the results presented in the paper.

The study focuses on microsatellite variation in northern spotted owls (nso). 352 individuals were genotyped at 10 loci, with ca. 50 birds excluded because of possible mixed ancestry with other spotted owl taxa (California, Mexican). Samples were grouped into artificial units that had some logical topographic boundaries; the authors claim that their arbitrary groupings did not influence their results because most of their analyses were based on individuals, not groups.

The authors conclude that there are no significant genetic breaks in the range of nso. That is, the nso is a single genetic unit, at least north of the potential southern contact zone. However, the authors suggest that some, but by no means all, mountain ranges or dry valleys might be associated with slight differences in allelic frequencies (the so-called landscape effects) – hence my basis for claiming the paper is misleadingly titled. It is likely that any assortment of populations is going to show some differentiation if there are enough gaps in sampling. The interesting finding of an apparent decrease in genetic diversity to the north is consistent with a phenomenon called "leading edge expansion" although the authors do not use this terminology.

The authors do not interpret their findings very critically. The Fst values range from 0.001 to 0.061, and we are not given an average or standard errors. We are told that 61 of these Fst values are statistically significant. Given that there are no geographic breaks, this is of dubious biological significance. Let's say the average Fst was 3% - this means that 97% of the variance has nothing to do with geographic structure. This is later confirmed when the AMOVA returns a statistically significant value of 1% (in text, although Table 1 reports different, albeit trivial values). The fact that these values are statistically significant does not lead to the conclusion that they are biologically significant. The authors report a Mantel correlation of $r = 0.089$, which was statistically significant. I do not think that a value of this sort, which explains 0.79% of the variance, less than 1%, has biological significance. Even if it did, how would that mesh with Congressional direction to use the ESA "sparingly"? There could scarcely be less variation explained by geography, and probably every species would contain many units if statistical significance of Fst alone was the criterion.

Now granted, the authors are simply reporting the values, and the corresponding significance levels, that they obtained in their analyses. And, there is little or no guidance in the literature on how to interpret very low values of Fst that are nonetheless statistically significant. They rightly state that they "found no evidence for distinct genetic breaks in northern spotted owls", and this is indeed what their data clearly show. I was interested in the apparent conflict with the unpublished study that they cite – could the latter be biased by sampling gaps? Nonetheless, there is no basis for their conclusion (pg. 15) that there should be finer scale sampling. The result is clear in both mtDNA and nuclear loci and a geographic scale that is already sufficiently finely scaled (i.e., would we consider conserving 10 independent groups of nso if they existed?).

Of concern is their conclusion that their results provide a basis for conserving nso. It is striking that in one paragraph they go from stating (pg. 15, line 321) that the nso "represents one genetic population or deme" to "Maintaining this variation is important for persistence in the face of environmental change" (pg. 15, line 330-1). This latter conclusion does not come from *any* data in their paper and is speculation about potential adaptive differences unrelated to their study. Their data lead to one obvious conclusion, namely that the microsatellite data reveal no discrete genetic groups with independent histories that ought to be individually considered for preservation. Instead, one might conclude that their data suggest that in the face of dwindling habitat, effort should be made to preserve the largest most viable group of populations that can be sustained, hopefully without marked human intervention. Maybe this is the entire range, maybe it is select areas; their data are moot on this point.

General comments:
The authors could have anticipated their findings. The lack of mtDNA differences within nso leads to the obvious prediction that there will not be differentiation at the much more slowly coalescing microsatellite loci. Although the authors refer to microsatellites as "hypervariable", their coalescence time is in fact longer (by ca. 4 times) than a mtDNA gene because they are nuclear-encoded loci. Thus, the authors confuse the mutation rate (which adds branches to the tree) with the coalescence time (which is not a function of mutation rate).

For many reasons the authors ought to be using nuclear DNA sequences, so that more sophisticated coalescence analyses can be used. The clear direction of this field is away from vague markers like microsatellites, where homology is in doubt, genotypes are pooled, trees cannot be rooted, etc., and towards sequencing nuclear loci (see Carstens, and Knowles 2007 and Dolman and Moritz 2006). There are good reasons why we abandoned allozymes, and microsatellites suffer from the same basic problems; I predict an end to the microsatellite era quite soon.

The authors state that "landscape genetics" is a new field. I would argue that it is a new name for the old established field of microevolutionary pattern or more recently "phylogeography". They suggest that landscape genetics involves figuring out how geographic barriers affect genetic patterns. This is exactly what we have done for past three decades with allozymes, mtDNA restriction sites and sequences and now nuclear sequences. Plus, we have known for decades that some groups of animals, such as salamanders and pocket gophers, show major genetic breaks across the "landscape" whereas across the same region, birds and other vagile organisms do not.

The part of the discussion dealing with landscape genetics is too long for the new information it covers. There is too much speculation from a lack of clear pattern.

C. PANEL RESPONSE TO FOCUS QUESTIONS BY USFWS

Dear Paul:

Attached is SEI's initial response to the 6 questions that you recently posed us, in supplement to the larger report that we are working on. We are providing you these initial responses to the 6 questions in order to expedite your own progress on preparing the Final Recovery Plan. You should recognize that some of these issues are still being debated by the panel, and so it cannot be emphasized enough that these are interim responses. They represent the result of an initial round of discussions and debate - and the document certainly contains some points on which the panel have not completed their evaluation. Also you should note that since the 6 questions all address issues of owl biology, I have not pressed the 'habitat scientists' (Franklin, Stephens, Hessburg) for comments on this document, although one (Hemstrom) did send comments in; the current response is largely the work of Carey, Cody, Fuller, Gutiérrez, Lehmkuhl, and SEI staff.

It is possible that some of our conclusions in this initial response will be altered (or even reversed) in the larger, more detailed report that we are preparing. It is certainly our intention to provide far more detailed responses on these and other issues, and to give full context for our answers. As we proceed with our report, I will of course alert you to any substantial differences as they arise. We are committed to providing you the best scientific analysis in as timely a manner as possible.

Sincerely,
Steven Courtney

FOCUS QUESTIONS FOR USE BY CONTRACTOR

1. **Is there a way to manage or prioritize spotted owl habitat such that the theorized competitive effects of barred owls are reduced?**

2. **Does the presence of BDOW affect the size and spacing, or habitat condition of needed habitat blocks?**

3. **What is a reasonable, sustainable percentage of nesting habitat for each MOCA by province?**

4. **What is the evidence, if any, that indicates post-fire salvage logging is not compatible with maintaining NSO presence and reproduction?**

5. **Several reviews hypothesized synergistic effects on spotted owl from barred owl competition, timber harvest, and fire. In addition, we have heard new information concerning possible recent genetic bottlenecks, and**

unquantifiable but supposed effects from climate change. Further, the revised modeling currently shows adult survival rates are not sufficient to achieve a stable spotted owl population. Given these multiple threats, what would be the most effective way to increase adult survival in the near-term? Comments received include build MOCAs to support 15 owl pairs immediately and decrease the MOCA size in the future as habitat grows in; no harvest within 500 meters of all active and historic spotted owl centers, and all nest trees.

6. **Is persistence of spotted owl on the Olympic Peninsula population dependent upon connectivity to the rest of the range?**

Draft response by SEI

1. **Is there a way to manage or prioritize spotted owl habitat such that the theorized competitive effects of barred owls are reduced?**

This question conflates several issues, which are useful to consider separately. Firstly, whether NSO can be protected in situ by modifying occupied habitat in some way so as to reduce either the impact of BO on resident NSO, or to reduce rate of invasion by BO. A second issue is whether conservation actions can be better focused in some way as to reduce competition. A third issue is whether existing conservation actions (e.g. reserves) are placed in the most appropriate places to allow NSO to resist BO. Fourth, will adding habitat and expanding the available habitat space in terms of both variety and area help achieve niche partitioning and coexistence of the two species.

On issue 1, there is no evidence suggesting any habitat modifications would be successful at 'armoring' NSO sites against BO invasion. Although BO have a wider habitat preference than NSO, there is some preliminary evidence that BO preferentially invade optimal NSO habitat. The NSO niche (at least in moister forest types) may be fully enclosed within the BO niche (on the habitat dimension); only time will tell if the BO, in its rapid expansion and opportunistic phase can compete year after year with the NSO with its peculiar adaptation to relatively stable old forest environments and relatively scarce arboreal prey. In any case, it is unlikely that any habitat modification (e.g. harvest, thinning in old forests, etc.) would be successful at reducing use by BO; in fact the results would probably be quite the opposite. It is probable that, on a landscape level, reducing the amount of late successional forest would alter the competitive interaction in favor of BO over NSO because NSO potentially lose habitat rather than by increasing the amount available to BO. In addition, given the very large dispersal capabilities of BO, there appears to be no simple way to prevent BO invasion into any potential habitat without direct removal. Study of BO habitat associations and tests for selection of certain habitat features might provide guidance for forest management that favors NSO and is less attractive to BO. However such data are not yet available.

On issue 2, it is difficult to envision any conservation action (other than direct control of BO) that can halt or reverse potential effects of BO on NSO. Study of the impact of BO on NSO prey species will provide information about the hypothetical option of managing prey populations to reduce competition. Where the species are currently interacting, there does not appear to be any documented or scientifically supported way to manipulate habitat to favor NSO over BO, or to 'reduce competition'.

On issue 3, there is some evidence that existing late successional reserves are prime targets for BO invasion. BO appear to be occurring in great numbers in National Parks (Olympics, Redwoods) and LSRs (WA Cascades). This may stem from an initial settling of BO in moist forest types. As discussed in Courtney et al. (2004) this is probably a temporary phenomenon, and BO do now appear to be progressively invading drier sites in these locations and elsewhere. For now, it is possible that NSO may persist on given landscapes for longer periods in the higher, drier sites. Hence if a goal is to maximize the local persistence of NSO in the presence of BO, then higher, drier locations would be high conservation priorities. However it is by no means clear that such sites (e.g. at high elevations in the Olympics) are adequate for sustained conservation of the NSO. Long-term, NSO populations need to be reestablished and maintained in the most productive locations. Hence an appropriate conservation strategy would be, in the short term to protect NSO populations wherever they may be most resistant to BO, and in the long term to protect habitat necessary for recovery.

Surveys to quantify the abundance of BO relative to that of NSO in various parts of the NSO range might provide insight about areas and habitat conditions that favor one species over the other.

For issue 4, there exists some possibility that accelerating the development of NSO habitat, in forest too simple to provide such habitat (whether in LSRs, AMAs, matrix, and non federal lands) offers the opportunity to increase the amount and variety of habitat space—to provide diverse stages on which the evolutionary play of K-strategy on the part of the NSO and a r-type strategy on the part of invading BO can be acted out. To date, the very limited evidence shows BO eating diverse small prey potentially using active hunting strategies incorporating near ground and near water tactics, perhaps emphasizing both hearing and vision, and searching a wide variety of foraging patches; whereas the NSO, in the Western Hemlock Zone, at least, uses a sit-and-wait strategy to detect auditorially nearby prey, usually of medium size, and then moving to the prey; a second facet of the sit-and-wait strategy is determining relative occupancy of foraging patches and whether to invest time hunting there. A real hypothesis, here, is the NSO might do well in areas with relatively high arboreal and semi-arboreal prey (flying squirrels to woodrats) with relatively lesser amounts of smaller, terrestrial prey available; in such areas, BO may not find it profitable to forage in the long term. The situation is complex due to the interference competition provided the NSO by the BO (as opposed to simply competition for resources) and what kind of intraspecific spacing behavior and spacing the BO may exhibit upon reaching some level of more or less stable populations. The NSO has persisted in the face of the great horned owl; one wonders what will happen over time in the interactions between BO and great horned owls. The situation is complex, complexity helps lead to coexistence of congenerics. Hence habitat restoration in general may help NSO persist.

2. **Does the presence of BDOW affect the size and spacing, or habitat condition of needed habitat blocks?**

Under NWFP and other NSO conservation strategies, habitat blocks (including their size and spacing) were conserved on the basis of simple models. To date, there has been no improvement using nor alternative modeling effort done with more recent data. Moreover, the models that supported the first HCA plan was developed as a falsifiable hypothesis, which has not yet been falsified. This does not prove the models are correct but rather that they are robust given that no one has been able to provide a rational, scientifically-based (and now with much more data) alternative.

These models reinforce some basic premises of conservation biology, viz: persistence is more likely with bigger reserves with smaller spaces between them, and when these are well distributed on the landscape. The models used did not give explicit population projections tied to explicit landscapes, as in a population viability analysis, but were useful in providing a general guide to policy decisions. The models were unable to provide sufficient detail to state, for instance, 'in this actual landscape, in this habitat type, with this configuration, reduction in spacing of reserves by X% will give an increase in λ by Y amount'. The models used were simply useful general guides to conservation principles – they did not answer the most pertinent management question "what configuration of reserve design will maintain NSO?" They did not set either the minimum habitat requirements for persistence, or the marginal increase in probability of persistence that would be gained by incremental increases in reserves. Only a much more detailed, geographically explicit model would be capable of providing stronger quantitative assessment of different conservation options (reserve designs). Appendix 10 of Courtney et al. 2004, developed by Noon, called for exactly this sort of approach. Only a PVA of the detailed approach described by Noon would be able to provide the sort of detailed answers requested.

Note that the models were developed at a time when (we now know) BO invasion was extensive and on-going. Hence the basic observed parameters used in the models probably already incorporated some BO effects. What has changed is 1. Our understanding of the probable role of BO in NSO populations, and 2. The probable extent of these negative effects (e.g. more widespread).

Under all these circumstances, we can make only general statements about the adequacy of the existing reserve design. Firstly, theory predicts that bigger reserves, more closely spaced, provide better probability of persistence than do smaller reserves, further apart. Increasing reserve size or decreasing spacing will have some incremental increase in persistence. How big such an increase would be is unknown with current modeling capabilities. Secondly, whether the current Draft Recovery Plan design or any alternative is sufficient for persistence is also difficult to assess. More is better, but how much is enough? We cannot provide an estimate of the marginal increase in persistence that would be gained with increases in reserve size. Thirdly, in areas without large numbers of

BO, presumably the existing strategy can be considered as being as adequate now as it was previously. Fourthly, in areas with extensive BO populations, reserves may not be performing as planned – but it is probable that BO will impact NSO in such areas regardless of the existing reserve design. BO have and will continue to usurp some unknown proportion of NSO habitat, in effect reducing the size of reserve available to the NSO; an area already considered insufficient. In such areas, protection of existing NSO and their habitat will provide more conservation benefit than protection or expansion of reserves containing BO. Of the various options available to immediately protect NSO populations already in direct competition with BO, expansion of reserves is unlikely to provide as much benefit as direct control of BO.

We have not heard new information suggesting that inadequacies in the existing NWFP reserve configuration are responsible for the accelerating declines in NSO populations. However we do have correlative evidence that BO are driving such declines in some areas. It is prudent to at least maintain NSO habitat conservation while the threat from BO competition remains an elevated concern.

Given that reserve design is a policy decision that must weigh many considerations, not just scientific information (and its uncertainties), it is important to state that we do not have strong information supporting any particular amendment to the reserve design. We note that the NWFP reserves are set up for many species, not just NSO, and hence that the Recovery Plan is addressing just one part of the NWFP's objectives.

3. **What is a reasonable, sustainable percentage of nesting habitat for each MOCA by province?**

The analysis supporting the percentages shown in the Draft Recovery Plan, as shown in Appendix D, is deeply flawed, and cannot be used to credibly derive such values. However the intent behind this analysis, to set habitat goals that are reasonable and reflect local conditions, is appropriate and may benefit owl conservation. We lack sufficient information at this point to make other than general statements on how to achieve this.

Notably, it is probable that in some parts of the range (some but not all areas in California and southern Oregon), appropriately scaled heterogeneous habitats support higher demographic performance than do homogeneous habitats. This is very likely driven by the biology of the prey base in these areas. However, given the observed variability among the 5 studies that have directly addressed this issue (Franklin, Dugger, Olsen, Green Diamond, Hoopa), and the great within province and between site variability in habitat types, it is unlikely that, even at the province level, one single percentage prescription will adequately represent an 'optimal' condition.

In other parts of the range, all available evidence supports the notion that demographic performance is highest in landscapes with larger amounts of late successional forest. In such landscapes, maximizing the amount of such forests probably should enhance owl performance. In such areas, ‘reasonable’ habitat goals are likely to be driven more by issues of sustainability (fire resistance). Issues of policy will also obviously play a role (and are outside the scope of our comments).

Ideally, where there is substantive variability within a province, habitat goals would be crafted with knowledge of local conditions, perhaps at landscape scales below that of the province. A watershed approach may then be more able to capture appropriate habitat goals. Such local knowledge should include information on prey use, and demographic performance. Where such information is lacking for the area in question, it might be appropriate to extrapolate from other areas, but clear statements on the inherent assumptions and predictions must be made (it would also be appropriate to test these assumptions).

As for setting the particular habitat goals to be designated in the Recovery Plan, the strategy set out in recovery action 17: “using a collaborative process, standardize province-specific habitat definitions”, might be an appropriate way to proceed to incorporate knowledge and set goals. However such a process should give primacy to scientific information, rather than an expert opinion/Delphi process approach. The data on NSO habitat use are more numerous and of better quality than those for any other raptor. These data should be the basis for developing habitat guidelines that are scientifically defensible. This science-driven and transparent process may be seen as a high priority action item, given the need for management agencies to make decisions on these landscapes. Whether such agencies, and the Recovery Plan, should proceed with interim provisions until these analyses and scientifically based conclusions have occurred is a matter of policy. If interim provisions are put in place, then the Service might consider ways so as not to limit future options for owl conservation, because carefully evaluated results of management actions will shed new light on alternative conservation practices and recovery strategies. We note that, in this spirit, the Draft Recovery Plan states ‘Cutting suitable habitat in areas that have higher habitat percentages than the listed percentages is not recommended” (DRP at p. 33).

If interim goals are set in the Final Recovery Plan, then it is justifiable to use provisions that reflect regional and local differences (as the DRP does) provided the interim guidelines are scientifically defensible. The differences between some Californian sites and others further north are sufficient to argue for differences in habitat provisions. The actual percentage values used however will be important – and at this point it is not easy to justify any particular figure as ‘adequate’ for owl conservation. It may be useful here to acknowledge that even current habitat provisions have not led to the halt of the decline in owl populations. Interim habitat provisions under the Final Recovery Plan might therefore be appropriately set so as not to further reduce habitat protection. Under this approach the goals set on page 33 of the DRP would be seen as minima for habitat protection, rather than maxima, and would be accompanied by provisions suggesting no loss of any occupied habitat on federal lands.

Research, monitoring and adaptive management would be key to development of improved habitat goals, and these activities would need to be made a high priority in order to develop a scientific bases for improved goals.

The habitat goals given in the DRP (Percentage of Habitat-Capable Acres in suitable habitat) are stated as criteria for de-listing, not as management objectives which meet other criteria (late-successional reserves, timber harvest, etc.). It is stated that other factors (notably demographic performance) will be prime in determining whether de-listing should occur – this is appropriate given current concerns over NSO populations. There is currently no evidence based on occupancy and demographic studies of the NSO that there is any excess habitat for NSO in OR or WA.

4. **What is the evidence, if any, that indicates post-fire salvage logging is not compatible with maintaining NSO presence and reproduction?**

We have heard relatively little evidence for or against the direct effects of salvage on NSO survival and reproduction as opposed to restoration capacity of the habitat. We have however heard conflicting evidence on the effects of fire itself on owls. It is clear from this evidence, and from a priori considerations of forest and fire ecology, that there will be considerable variability in the effects of fire. In some landscapes, under major stand replacement events, few owls may be expected to survive and reproduce successfully. Under other circumstances, with lower intensity fires, owls may persist in the short-term, or may even perform well long-term post-fire. Hence the effects of any particular fire will need to be considered carefully. If owls remain in an area that has burned then clearly further reductions in habitat through salvage would probably be detrimental. When owls are no longer present, and cannot reasonably be projected as likely to re-colonize in the near future, then salvage will not materially harm owls in the short-term. However, currently there are few data with which to make predictions about re-occupancy. When considering situations where fire has affected only portions of an owl's home-range, in order to assess the potential effects of salvage, one would have to consider the potential for owl use of the burnt area.

If no owls are directly impacted by salvage, then assessing the effects of salvage may involve determining whether activities retard or accelerate the development of non-habitat (burnt) into habitat (e.g. late successional), as well as other risks to the owls on the landscape. A priori, it is to be expected that some of the activities that might be carried out under salvage could be negative, while others could be positive. Hence removal of green trees, and 'legacy elements' would clearly be likely to retard succession (as might soil compaction and perhaps fuels reduction, by reducing prey populations). On the other hand, removal of dead and dying trees that would probably fuel future catastrophic fires would perhaps enhance NSO persistence on the landscape. Strategic removal of dead or dying trees may also reduce the risk of disease and insect infestation of green trees and 'legacy elements'. Note that many other important aspects of biodiversity are represented in post fire conifer forest (eg. wood-boring beetles, several species of woodpecker, Tachycineta swallows, house wrens, mountain bluebirds and other cavity-nesting birds). The exact effects of any particular salvage proposal would therefore require very careful analysis at various spatial and temporal scales, and (to have any degree of accuracy) would involve considerable knowledge of local owl behavior and population status. Any salvage activity should be treated as an experiment, carefully designed to allow evaluation of key effects (e.g., occupancy, re-colonization, demography, and how the practice affects the use of the area by NSO and BO).

Under a NSO Recovery Plan, we see no need to consider the purely economic factors for or against salvage. There may be circumstances (as indeed envisioned by Appendix E of the DRP) where 'salvage' activities enhance restoration of the owl habitat. Under such conditions, the issue is the relative benefits and harms, short- and long-term, to the owl population. Restoration of owl habitat provides the context for assessing the relative benefits of action or inaction.

Post-fire salvage logging has proven to be too narrowly framed in many, if not most, cases to be of real use in maintenance or restoration of NSO habitat. If post-fire logging is to be done in areas in which a goal is to manage for the persistence of the NSO, then it must be done as part of a well-planned multi-faceted restoration effort as should other aspects of post-fire management often linked to salvage, such as planting trees and seeding.

5. **Several reviews hypothesized synergistic effects on spotted owl from barred owl competition, timber harvest, and fire. In addition, we have heard new information concerning possible recent genetic bottlenecks, and unquantifiable but supposed effects from climate change. Further, the revised modeling currently shows adult survival rates are not sufficient to achieve a stable spotted owl population. Given these multiple threats, what would be the most effective way to increase adult survival in the near-term? Comments received include build MOCAs to support 15 owl pairs immediately and decrease the MOCA size in the future as habitat grows in; no harvest within 500 meters of all active and historic spotted owl centers, and all nest trees.**

Our full report will consider the effects of BO, timber harvest, fire, genetics, climate change etc. (all acknowledged as potential threats), as well as synergism among factors, and also the evidence from modeling.

The question emphasizes the role of adult survival rates – this is indeed appropriate, because λ is sensitive to variation in adult survival rates and low survival rates are thought to underlie low estimates for λ. It is hard to see how some of the proposed actions (e.g. increasing the size of reserves) would alter adult survival within reserves in the short term – the birds have not survived well (in and out of reserves), and simply putting more habitat off-limits to harvest may not (short-term) elevate survivorship. [There is no evidence to support this proposition one way or another.] In the areas of the range where there is a stricter association with late successional habitat (e.g. Washington and parts of Oregon), then it is probable that any reduction in such habitat inside the home range of an owl would impact its survival (as well as reproduction) – hence protections around the nest there seem likely to enhance survival. (Based on central place foraging theory and energetic costs, reduction of harvest close to the nest would be helpful.)

BO competition and predation, a priori, might be expected to have significant impacts on survivorship of NSO. Hence it is plausible that much of the low survival in parts of the range are ascribable to BO effects. If this is the case, removal of BO might be predicted to foster better survivorship. Some of the panel are of the opinion that this effect would be relatively swift, and large in scope relative to other factors affecting survival.

Note that if reduction in habitat occurs while conducting experiments into BO removal, BO re-colonization might be enhanced. It is important that all assessments of BO effects on NSO, or attempts to manage to reduce competition are planned in a scientific framework.

6. Is persistence of spotted owl on the Olympic Peninsula population dependent upon connectivity to the rest of the range?

Connectivity between the Olympic Peninsula and the rest of the range is thought to have three functions:

a) maintenance of genetic diversity by movement of birds across the landscape
b) demographic support under a metapopulation structure, whereby areas are re-colonized following local extinction.
c) demographic support under a source-sink population structure, whereby areas of low performance are "subsidized"

Long-term, all these issues support the need for maintaining connectivity. However in the short-term these are minor issues compared with the pressing conservation needs of the species on the Peninsula. They are also easily addressed by other means. It is widely acknowledged for instance, that even low levels of immigration can maintain genetic diversity (work of Slatkin and others). One or two immigrants in every generation is usually sufficient to maintain most genes in a population (if necessary this could be carried out by transferring a few eggs between nests or translocating a few birds [but neither of these are important if there is insufficient habitat to support birds]). Demographic support is important in any metapopulation (and can again be addressed by translocation as a last resort). However for a 'rescue effect' to occur into unoccupied habitat there must be adequate habitat for the species to re-colonize. Demographic support under a source-sink dynamic might be relevant to the Olympic Peninsula but we currently have no information supporting this. The current evidence is that the Olympic Peninsula is deteriorating over time with respect to NSO. Not only has habitat been lost to harvest and current management practices on second-growth forests, but unharvested reserve areas are now fast being lost to BO occupation. Unless this trend is reversed, it is unlikely that there would be open habitat for NSO to re-colonize. In terms of short-term

(<100 years) persistence on the Olympic Peninsula, connectivity is a minor issue compared with the direct loss of habitat to harvest or BO.

D. NORTHERN SPOTTED OWL QUESTIONNAIRE TO SEI PANEL

Sustainable Ecosystems Institute

Northern Spotted Owl Questionnaire

The NSO questionnaire addresses many of the important issues considered during the Draft Recovery Plan review process. The individual panelists' responses will show the degree of unanimity or uncertainty on different topics. They will also show which data are considered most reliable, and why panelists have reached their individual conclusions.

In filling out this questionnaire, please take the opportunity to expand on your answers. We have found that such 'explanations' can be very useful. It is also a way that you may address uncertainties, alternate hypotheses, etc. Use this also as an opportunity to comment on ambiguities or qualifications. If you are filling in an electronic copy, simply add space as necessary. If working from a hard copy, use a separate sheet for expanded responses.

Key to respondents:

AC	Andrew Carey
JF	Jerry Franklin
JL	John Lehmkuhl
MC	Martin Cody
MF	Mark Fuller
MH	Miles Hemstrom
PH	Paul Hessburg
RG	Rocky Gutiérrez
SS	Scott Stephens

1. The major threats facing Northern Spotted Owls remain those identified at the time of the Status Review (2004), viz: loss of habitat to harvest and fire; Barred Owl competition.

Strongly Agree XXXXX
Agree XXXX
Disagree
Strongly Disagree
No Opinion

JF: Both are major threats.

MF: Loss of habitat is a major threat to a declining species, and is an especially key consideration when competition also is a threat. However, there might be other factors, as yet undetermined, that are affecting the population status of northern spotted owls, and there likely are synergistic or cumulative effects that affect the population dynamics of the species. Vigilance for other threats is required.

PH: One additional concern I have is that the Plan will attempt to recover the NSO by buying time on the east-side while the west-side habitats are regrown. Quite high levels of east-side LSOF will be attempted with uncertain outcomes; i.e., historically high levels occurred some of the time in some eastside landscapes, but high spatial variability in the broader regional landscape probably made this possible. Fire prone landscapes did not cultivate high levels of such habitat. Without that spatial variability in the broad regional east-side landscape, can this hang time be reasonably purchased with a strategy such at that recommended by our panel? I don't know.

RG: An equal threat is the potential for failure of existing regulatory mechanisms given the results proposed management actions. For example, adaptive management without structure and substance.

SS: Not much loss of habitat by harvest has occurred since 2004. Fire losses are occurring and will get worse with warming climates, particularly in the dry provinces.

2. There is considerable geographic variation in the ecology of Northern Spotted Owls and a successful conservation strategy will need to fully address these differences.

Strongly Agree XXXXXXX
Agree XX
Disagree
Strongly Disagree
No Opinion

AC: Much of this variation is reflected in the prey base and understanding the ecology of prey species and how management might affect them is key. Recovery of spotted owl habitat, in particular, means recovery of complex food webs in a biotic community and reducing this to "multi-storied" stands is overly reductionistic.

JF: This seems so obvious to me that it hurts! I did not understand how FWS failed to understand that habitat preferences in SW OR as well as in W WA and NW OR were related primarily to prey base. It also relates to why we have devised the strategy we have for the eastern Cascade Range (i.e., you need dense forest for the NSO prey base there, as well).

JL: Yes, this is particularly so for those provinces with dynamic disturbance regimes. They will require much more active management, i.e., a dynamic conservation strategy vs. a passive one (i.e., reserves). One could argues for managed reserves, but then what is the point if reserves are managed the same as the matrix re restoration and protection. Economic logging the matrix would require a different plan with reserves, perhaps. Also, the west-side areas with large private timberland holdings need a strong process for integrating state and private efforts at NSO conservation.

MF: The population dynamics of northern spotted owls and the relative magnitude of threats to the owls vary geographically, thus the extent and type of management best suited for recovery vary.

PH: Although unsatisfying, we don't know enough about the Klamath to make a difference there this go around. This must be remedied in the next decade. Too much is at stake.

SS: This is critical. The plan still comes up short in this area, particularly regarding the dry provinces of the Klamath and Cascades.

3. Even if Barred Owls are a major threat to Northern Spotted Owls, habitat remains a priority.

Strongly Agree XXXXXX
Agree XX
Disagree
Strongly Disagree
No Opinion X

JF: Absolutely no possibility of survival without sufficient habitat.

JL: Yes, if we managed to eliminate the barred owl factor, we would need habitat for the NSO. Not sure how one could envision a plan without strong habitat conservation, unless in the future some stable equilibrium (niche partitioning) between BO and NSO occurs and BO habitat could be managed separately.

MC: Yes, habitat remains **a** priority as, equally, Barred Owl remains a priority.

MF: Furthermore, habitat is especially important with barred owls as a major threat. To learn the extent and manner of the barred owl threat and to identify management options, it is important to understand barred owl habitat use and ecology.

PH: Agree, but not the only one.

4. Experimentation is needed to determine the effects of Barred Owls on Northern Spotted Owls and the efficacy of Barred Owl removal.

Strongly Agree XXXX
Agree XXXXX
Disagree
Strongly Disagree
No Opinion

JF: If this is going to be done, than it has to be preceded by a carefully controlled experiment. Doesn't have to be of long duration but it has to be a serious, defensible experiment.

JL: Yes. Information will only help reduce uncertainty, devise a stronger plan, and clarify options for management across the range of BO & NSO interactions.

MC: Experimentation is needed mainly to give credibility to a Barred Owl removal program, if or more likely when such a program is instigated. I.e. experimentation will lead, presumably, to undeniable and scientifically upheld conclusions that BO is a strong negative influence on NSO. The research to unequivocably establish this is required more for its PR value in a government-led BO extermination campaign than for establishing beyond reasonable doubt what we already know, that Barred Owls and Spotted Owls do not coexist over the longer term.

MF: Experimentation is a logical approach for readily and rigorously testing ideas about the ways and the extents that barred owls interact with northern spotted owls. Experimental removal of barred owls from areas where the two species occur can be very informative.

MH: Whether or not control/removal of barred owls is implemented on a wider scale, experimentation to determine efficacy seems necessary. Is the FWS prepared for the inevitable bad press?

5. Depending on the results of experimentation, control of Barred Owls may be the only available option to counter this threat.

Strongly Agree XX
Agree XX
Disagree XXX
Strongly Disagree
No Opinion XX

AC: This is a poorly worded question/poorly based question; I could easily say: no matter what the results of the experiment, a decision to control barred owls and a decision not to control barred owls could both be equally defended.

JF: Not quite as clear on this but I think that this is likely.

JL: Odd question. I can't say if control may be the "only" option, because I cannot foretell the results of experimentation – "depending" on what outcome?. I doubt control will be an effective, cost-effective, & long-term option over the range of the NSO. I am not sure how one might carry out such a program for the long term over the entire range of the owl. Incentives for industry would be not to control BO, and conservation groups are unlikely to go out and kill owls. Give the job to APHIS? Many lawsuits will result.

MC: Yes, if we want PNW forests with NSO rather than BO as occupants, then we have to control BO via a removal program.

MF: The distribution and abundance of barred owls relative to northern spotted owls has not been thoroughly established, and studies of the "response" of northern spotted owls to the presence of barred owls have begun only recently. Range expansion by a species does not necessarily cause the extirpation of another; the two species might adapt and coexist. However, a "wait and see" approach is not an option because of the comparatively rapid recent decline of the northern spotted owl in some geographic areas and because it is an historically reduced population. Removal experiments can be informative, but they must be accompanied by study of relationships among the two species in different geographic areas and in settings where barred owl presence has occurred for longer and for shorter periods. Furthermore, the response of each owl species to "experiments" with features of their habitats (e.g., ground cover and understory, canopy) should be carefully monitored. In the meantime, control of barred owls might be an option.

MH: While ESA may seem to require conservation of a threatened species against an invading species, I have doubts about the ultimate success of controlling barred owls and about the propriety of a control policy. Species have always migrated and, consequently, one species invades and occupies territory held by another. Surely Spotted Owls themselves have not always existed in the area. While the argument that humans facilitated the migration of barred owls from elsewhere may be true, it's also true that species may facilitate the migration and disappearance of others in general. In addition, I doubt the ultimate success of a control policy. Barred owls seem to be fully capable of reproducing, migrating through a mountainous, difficult terrain, and displacing Spotted Owls. How would a control policy be effective in that setting? A third concern is public outcry against shooting barred owls. Surely dead owl pictures will show up in the newspapers and the costs for each dead tallied alongside.

PH: Let's wait and see what the experiments tell us, hmm?

SS: This may be true but I think it is infeasible. You will never get them all removed and the public outcry would be so large it would shut down the program.

6. Some conservation strategies assume that managing habitat can be used as an indirect surrogate for direct monitoring and conservation of owls. In light of Barred Owl threats, this assumption is no longer valid.

Strongly Agree XXXXXX
Agree XX
Disagree
Strongly Disagree
No Opinion X

AC: Agree, but a decision to encourage recovery of spotted owl habitat/production of spotted owl habitat in a managed forest environment could involve monitoring the developing forest and/or owl prey without monitoring owls which would not be expected to present for decades.

JF: The direct monitoring and conservation of owls is imperative in this case.

JL: Yes. If habitat was a good surrogate, then we would have expected to see stable populations of NSO during the last 10 years, assuming lag effects are discounted.

MC: No longer valid, because appropriate habitat alone in insufficient for NSO survival; it also has to be free of BO.

MF: "Habitat" management largely is restricted to manipulation of very few of the components or resources that are required to conserve a species. Similarly, monitoring is restricted, but monitoring the resource of interest - owls - is the priority.

PH: I am not sure I understand your question. Try it another way. If you asking whether I think that NSO and BO monitoring should be done at a high level, then yes, for certain.

RG: I am not sure it is valid even without Barred Owl threats given failure of existing regulatory mechanisms and our uncertainty about ecological features.

SS: Habitat is clearly not enough. Fire, Barred owls, and climate change all will have a large effect on the owl even if 'appropriate habitat' is available in sufficient quantity and distribution.

7. Poor demographic performance is being driven by low adult survivorship.

Strongly Agree X
Agree XX
Disagree XX
Strongly Disagree
No Opinion XXXX

AC: This statement seems too broad; I recall statement during the presentations that immigration from outside demographic study areas was insufficient as well. Similarly, if reproductive attainment was higher, wouldn't that also substitute for some low adult survivorship; I haven't studied the reports on this in depth, so you could also count me as "no opinion."

JF: Not an owl specialist but it looks that way to me, based on the data.

JL: That seems to be the results of the demographic studies, but I have not studied them carefully.

MC: Survivorship is only one part of either finite rate of population growth l or intrinsic rate of increase r (n.b. $l = e^r$), the other being production of young. If $l<1$, then and acting in conjunction either higher birth rates or lower death rates might serve to increase l such that $l>1$.

MF: "Estimates of apparent survival from individual study areas indicated that there were differences among age classes with adults generally having higher survival than 1- and 2-year-olds" Anthony et al. 2006.

8. Given that modeling efforts are largely heuristic, reserve design (size, spacing etc.) must be based on qualitative guidelines.

Strongly Agree X
Agree XXXX
Disagree XX
Strongly Disagree X
No Opinion X

AC: Agree, but would also include common sense; and it would be commonsense to include management for multiple values outside the reserves to support the reserves (Carey 2007).

JF: Absolutely agree. Also, would like to see this done by a single expert ID team.

JL: Not sure that "qualitative" is the best word here. Guidelines would qualitative in the sense that the real system has not been modeled; but, it seems they can be quantitative in the sense that modeling might show that a certain numbers of pairs, demographic rates, distance between reserves, etc. might be relatively more viable. Such guidelines remain as untested hypotheses without monitoring or a PVA, which itself would be an hypothesis, albeit much more specific and "quantitative".

MC: Agreed, but increased efforts could be put into modeling such that a more quantitative array of potential outcomes relative to potential inputs can result, i.e. they could be taken beyond the heuristic if it were deemed useful to generate a better FRP.

MF: Design that maximizes suitable habitat based on current general understanding and further inquiry into local knowledge of owl and forest ecology can be implemented then revaluated with forthcoming information about the distribution and abundance of northern spotted owls, their occupancy of existing habitat, and their interactions with barred owls.

PH: I think our historical reconstructions (100s) give us ample quantitative evidence for LSOF abundance and networking that is sustainable in fire prone forests of the Cascades. That is not the problem. What may be the problem is that more is being asked of east-side OR and WA fire prone landscapes, in terms of LSOF abundance and networking than evidence suggests was ever sustainable under native fire regimes. Now, add over the top of that, current landscape structure and fuel considerations.

RG: There is much quantitative information which could be used for advanced generation modeling, that may prove useful for evaluating hypothetical strategies of reserve design, which would then need to be tested.

9. The approach of the DRP for designating habitat goals based on habitat fitness potential is deeply flawed.

Strongly Agree XXXX
Agree XX
Disagree
Strongly Disagree
No Opinion XXX

JF: AMEN to that!

JL: Based on the scientists who did the research and the expert reviews I would say it is flawed. I agree with the statement in the report. Saying deeply flawed bothers me, however, because it sets the managers up to be suspicious of ever using research results.

I suppose a manager reading the report would conclude, "what is the value of the research if there are so many caveats and limitations" (as detailed in the report); i.e. if there is so much uncertainty about the research then it has little value for conservation. I suppose our statements at the end provide some options for using the research as one piece, not the primary piece, to devise a Plan. This aspect of the plan would be yet another one for validation by adaptive management or research.

MC: I agree, but **how** deeply flawed, you ask? Habitat fitness potential is the readout in terms of adult survival + chick production of a given owl pair at a given site in a given season. Given that a) habitat varies across the map, and b) the owls vary (with age, experience, also genetics) and c) year-to-year variation occurs in several factors that affect owl survival and production, then this argues against an easy application of an otherwise useful idea, without a lot more basic info.

PH: Not my area.

10. Fire intensity and geographic location result in a wide range of effects on Northern Spotted Owls.

Strongly Agree XXXXX
Agree XXXX
Disagree
Strongly Disagree
No Opinion

JF: I think that effects are highly situational.

JL: Yes, I agree to certain extent. This would be best answered by a fire ecologist, but I am not sure anyone has quantified this variability throughout the range of the NSO. My guess is that many of the interactive effects would be similar under similar environmental conditions at different geographic locations. For example, I would guess that fire effects in terms of stand and landscape patterns might be similar in the eastern Oregon and Washington Cascades, and perhaps in the Sierras. I am basically a lumper vs. a splitter.

MC: Better to say that fire intensity varies, and some of this variation covaries with geography, but owls everywhere would be susceptible to the adverse effects of high-intensity fire, but not much affected by low-intensity fire.

11. It is important to recognize variation in the effects of fire on Northern Spotted Owls when developing a conservation strategy.

Strongly Agree XXXXXXX
Agree XX
Disagree
Strongly Disagree
No Opinion

JF: Again, this seems obvious to me.

JL: Yes, in terms of fire effect differences caused by different fire severities and how they vary in proportion and spatial pattern across the range of the NSO.

SS: This is critical. The range of the owl includes many different forest types and geographical settings. Those forests that once experienced frequent, low-moderate intensity fire regimes are now at high risk to burning at high severity over large spatial scales. Management actions must be taken to reduce the fire risks in these forest types. If this does not occur the northern spotted owl will continue to decline in these areas, particularly the Klamath and Cascades.

12. The threat from wildfire is underestimated in the DRP for the dry forest provinces, and is inadequately addressed.

Strongly Agree XXXXXX
Agree XXX
Disagree
Strongly Disagree
No Opinion

JF: Absolutely agree—I don't understand, in fact, how they could have been so blasé about this.

MC: Inasmuch as there exist forest management options that favor low intensity and short return time fires and disfavor stand-replacement fires.

MF: The threat from wildfire and post fire salvage management includes loss of large and very large trees.

PH: We wrote a little bit on that.

RG: Strongly agree to the latter and agree to the form parts of the statement.

SS: The wildfire threat was underestimated for the dry provinces and this must be addressed during revision.

13. In east-side habitats of the Washington and Oregon Cascades, the only viable conservation strategy will be to actively manage fire-prone forests and landscapes to sustain Northern Spotted Owl habitat.

Strongly Agree XXXXX
Agree XXX
Disagree X
Strongly Disagree
No Opinion

AC: Agree, I hardly ever agree to “only” or “never” or “always” statements.

JF: Can’t disagree with my own proposal!

JL: Yes, I think the literature has firmly established this statement, interests groups concur, and agencies have been acting on it for the last 10 years or more. It may be true that stand-replacement fires did occur in the dry forest of the PNW, but I think the supporting presentation by Baker that we heard was flawed in using inappropriate data (BAER), which overestimated high-intensity effects. Stephens reviewed it well in the report. Because we have not successfully treated large areas, however, we don't know how well this strategy will work, except through modeling which is always an imperfect tool.

MC: Management for NSO habitat may be necessary but not sufficient in east-side habitats and alone might result in a non-viable conservation strategy.

MF: Current conditions require a broad scale approach.

PH: I just hope they’ll go far enough…

RG: Agree with the caveat that active management does not do more harm to owls than good.

SS: It could be that the actual owl PAC’s or other relatively small areas don’t need to be treated but lands surrounding them must be treated. Changing climates will only make fire risks worse. Active management including prescribed fire, thinning of small-moderate trees with and without prescribed fire, wildland fire use, and appropriate management response suppression fire will all be needed to reduce fire hazards and increase resiliency in these forest types. The spatial scale of the problem is huge and all tools will be needed to address this problem.

14. The Klamath region should be treated with a management plan similar to that detailed for the Eastern Cascades.

Strongly Agree X
Agree XXX
Disagree XXXX
Strongly Disagree X
No Opinion

AC: Disagree, it should be one developed specifically to the Klamath and built landscape up**.**

JF: I don't think that you can take our eastern Cascade strategy and apply it to the Klamath. Just that fact that the prey base is very different in the two regions ought to put you on guard against trying to do that. Then, when you consider the incredible topographic and vegetational complexity of the Klamath, I see no one with an obvious and high probability solution. Furthermore, I think that the whole firebreak and splat type of strategy may be flawed at its theoretical roots and that this is going to emerge in the peer-reviewed literature this year.

JL: Yes. I don't know the area well, but it is telling that the scientist most knowledgeable with the ecology of the area (and recently well published) would argue for a similar plan. The plan may not be the exact same as the eastern Cascades, but I think the outlines of the Cascades plan is general enough that the principles apply. It seems to me that one sticking point is the insistence from some that the whole landscape will need to be treated in the Cascades, and that is not appropriate for the Klamath, hence don't suggest a similar plan. I agree with some others that treating the whole landscape is an entirely impractical suggestion – pipe dream – that will never be feasible no matter how many times we say it as scientists. If we discard that as a guideline for the Cascades, then we can apply the general dry forest plan to all dry forests and plan on variations among provinces depending on conditions. I would agree with Skinner and others who argued that a similar plan could be advised on general principles for the Klamath and that we start with trying to optimize in some sense the strategic locations for fuels treatments in all dry forests. We do know enough to do this, and we hopefully will learn by adaptive management. The alternative seems to be keeping a reserve plan for the Klamath, which seems less viable that active management.

MC: The Klamath appears to differ from the E Cascades in several important respects, including climate, seasonality, dominant or co-dominant trees, and forest structure. It is unlikely that the same conservation or management plan would be optimal for both regions.

MF: The Klamath region is complex, exhibiting some features similar to west-side forests and other features like east-side forests. The area should be studied to develop a habitat management that addresses local conditions.

MH: While I agree with this statement, it is too general. Portions of the Klamath region should be treated similarly to the East Cascades. However, the specifics may differ from those used on the east-side due to climatic, topographic, and vegetation differences. In addition, the more mesic and western portions of the Klamath seem amenable to a west-side approach. Could the recovery plan indicate that this topic came up late in the process and requires additional work, perhaps as part of implementation, for fine-tuning the approach in a complex environment?

PH: I wrote a little bit on that.

SS: The plan would largely be similar but would have some differences based on different topography and fire regimes. However the premise will be the same, active management of the landscape will be needed to reduce fire risk. This of course will have to continue indefinitely into the future to maintain low fire hazards and produce resilient forests for the coming decades.

15. Post-fire habitat modifications should focus on habitat restoration and conserving habitat elements that take the most time to develop or recover.

Strongly Agree XXXXXX
Agree XXX
Disagree
Strongly Disagree
No Opinion

AC: Strongly Agree, but I would emphasize ecosystem recovery with criteria like those of the Society for Ecological Restoration.

JF: AMEN! And before habitat restoration happens there needs to be some very serious discussion about what that means. I seriously doubt a careful analysis will favor rapid reestablishment of dense, pure, coniferous plantations. I am confident that it will not support any significant salvage logging. THIS NEEDS SOME MEANINGFUL AND OBJECTIVE ATTENTION BY RESOURCE PROFESSIONALS!! There has not been significant thoughtful consideration of post-disturbance activities and far too much of the traditional foresters' approach to any loss of forest cover.

JL: Yes. We cannot go on thinking differently about ecosystem management objectives for green vs. burned forests. We would not think of managing green forests these days purely for economic value (i.e., give extracting economic value as the "purpose and need" in an EIS) while ignoring ecological management, so why toss all that away and managed burned forests for salvage of economic value. The term salvage should be stricken from our forest ecosystem management lexicon – let it remain for private lands that manage both green and burned forests of economic value.

16. Current mechanisms to implement adaptive management programs are adequate to deal with current and anticipated issues.

Strongly Agree
Agree
Disagree XXXX
Strongly Disagree XXXX
No Opinion X

AC: Strongly Disagree, and recently published analyses from the NWFP demonstrate inadequate institutional capability for adaptive management.

JF: Mechanisms may exist but the will and the funding to implement adaptive management programs are NOT evident.

JL: Yes, totally, and except for parts of the NWFP a complete failure as an operational goal. No agency will, infrastructure, or incentives to line officers or staff to do adaptive management. Actually seems to be disincentives to learn from management: "too complicated", "not a target", "no mandate from above" etc.

MC: Since I have a poor perception and understanding of what the current mechanisms are, I'll have to skip this.

MF: To date, adaptive management apparently has not been used thoroughly because opportunities were missed to exercise management options to achieve specific objectives and monitor to assess the outcome of the manipulations and evaluate and apply the results for improved conservation of northern spotted owls.

MH: I haven't seen evidence that current adaptive management programs accomplish much at all.

PH: Not even close. Management actions ought to be embraced as experimental in nature, with adequate designs, power in replication, and follow up monitoring at near and long term intervals. Without such an approach, managers will continue to fool themselves about the predictability of outcomes and the certainty of management methods in what are semi-predictable systems, at best.

RG: Adaptive management is being used as a buzz word and there is little evidence for substantive implementation of such a concept.

SS: Successful adaptive management has never happened regarding the management of the northern spotted owl, particularly on how restoration/fire hazard reduction treatments impact the owl and its prey base, particularly at large spatial scales. I suggest an independent 3rd party system where a group is established to monitor and report on adaptive management outcomes. Funding for this effort will not be easy to obtain but it is critical for the success of the program. It will take a commitment of at least 10 years to address the critical questions.

E. LIST OF COMMENTS ON THE DRAFT RECOVERY PLAN FOR THE NORTHERN SPOTTED OWL (*STRIX OCCIDENTALIS CAURINA*)

This list was provided to SEI by USFWS as a summary of the comments received by the Service. SEI also received the complete letters and comments for substantive scientific issues.

In this appendix we indicate whether the comment was reviewed by the SEI panel, and (if so) where our response may be found in this document.

Key:

N/A Not a scientific comment; not reviewed
N/R Not reviewed
R Reviewed (with section of report)

PROCESS

Comment *P1:* The Recovery Team did not include the appropriate or adequate scientists; it did not contain any recognized owl experts.
N/A

Comment *P2:* The plan needs to be peer reviewed.
N/A

Comment *P3:* There was inappropriate political interference.
N/A

Comment P4: There was insufficient time for public comments.
N/A

Comment *P5:* There was insufficient time for the whole process.
N/A

Comment *P6:* There was too much accommodation for timber interests.
N/A

Comment *P7:* Forest managers of the BLM and FS should not be allowed to modify reserve boundaries or entire reserves.
N/A

Comment *P8:* Reconvene a Recovery Team and rewrite the plan.
N/A

Comment *P9:* The range of options was too narrow; Option 1 was too much like Option 2. N/A

Comment *P10:* There was too much accommodation for plan revisions by BLM and FS. N/A

STRATEGY

Comment *ST1*: The plan should include a captive-breeding program.
N/R

(We deleted ST2.)

Comment *ST3:* Reduce or eliminate incidental take of spotted owls on Federal and/or private lands.
N/A

Comment ST4: The plan needs a population goal
N/R.

Comment ST5: The plan needs a population viability analysis.
R – see section Population Viability and Models

Comment ST6: The plan needs an analysis of how implementing the plan would recover the spotted owl.
R – see sections on Population Viability and Models, and Demography

Comment ST7: The Recovery Plan needs a presentation of the roles of CSAs, the criteria used to select CSAs, and the proposed management of CSAs.
N/R

Comment ST8: The plan should provide province-specific assessments of threats and means to address them.
R – see sections on Threats Assessment and Province level approach

Comment ST9: Satisfactory implementation of relocating habitat blocks in BLM and FS lands in Option 2 is impossible due to declining budgets and personnel, insufficient expertise, and necessary coordination among BLM and FS districts.
N/A

Comment *ST10:* The recovery potential of the many outcomes of Option 2 has not been tested or modeled; the plan needs to explain how Option 2 would achieve recovery.
R – see sections on Population Viability and Models and on Conservation Strategy

***Comment** ST11:* The plan needs to describe whether any other recovery plans have effectively used a strategy similar to that in Option 2.
N/A

***Comment** ST12:* For Option 2, the plan should include detail concerning the schedule of the designation of habitat blocks, how federal agencies would cooperate in the designations, how boundaries would change over time, how the public may have input into this process, and the oversight role of the FWS in adjustments made to boundaries of habitat blocks by BLM and FS.
N/A

Comment ST13: The plan should include meaningful incentives for private land managers to develop habitat. Regulations may have the unintended negative consequence of causing private landowners to remove habitat before it becomes suitable and occupied by spotted owls. A knowledgeable group could address the policy disincentives to promote spotted owl recovery. This group would need a variety of expertise including the expertise of industrial and non-industrial forest landowners, lawyers knowledgeable in ESA issues and conservation agreements, and State and Service personnel.
R – see section on Conservation Strategy

***Comment** ST14*: The Plan needs to describe how it differs (*e.g.,* amount and distribution of habitat; provisions for dispersal habitat; residual pair areas between habitat clusters; additional prescriptions to support clusters of spotted owls in high fire-risk areas; clusters of spotted owls in nonfederal lands; contributions of nonfederal land, especially in northwest Oregon) from the previous plans upon which it is based (*e.g.,* NWFP, 1992 Recovery Plan).
R – see section on Conservation Strategy

***Comment** ST15*: The plan should fully describe why the Western Washington Lowland, Willamette Valley, and California Cascades were excluded from Recovery Criterion 2, and what role they play in spotted owl recovery. Rather than exclude these areas from the conservation strategy, an evaluation of the potential future importance of these areas should be conducted. If this evaluation indicates a benefit from establishment of populations of spotted owls in those provinces, then this would provide incentive for voluntary, collaborative efforts to recruit or maintain spotted owls on Federal, State, and private lands.
R – see section on Conservation Strategy

***Comment** ST16:* Option 2 appears to allow flexibility, but, due to the few areas with large-enough acreages of suitable habitat that contain spotted owls, there are few options in identifying the locations of large-habitat blocks (especially in northern Washington).
N/A

***Comment** ST17:* The small habitat blocks allow for having only one pair of spotted owls, which is not biologically tenable.
N/R

Comment *ST18:* Many areas mapped as MOCAs do not meet the definition of suitable spotted owl habitat, and should be removed (listed in FS letter of October 24, 2007).
N/R

Comment ST19: The plan should include risk analyses for both options.
R – see sections on Conservation Strategy and Population Viability Analysis

Comment *ST20:* Private lands should not be included in the conservation strategy.
N/A

Comment *ST21:* The plan states that protection of federally owned lands are sufficient for the conservation of spotted owls, so only federally owned lands should be included in total acres shown for Option 2.
N/A

Comment *ST22:* The plan should clearly describe how MOCAs or habitat blocks and CSAs are to be managed.
R – see section on Conservation Strategy

Comment *ST23*: The plan should explain why tribal lands are not considered Federal lands for the purposes of this plan and why tribal lands are not necessary for the recovery of the spotted owl.
N/A

Comment *ST24:* The plan should prioritize the placement of reserves on FS lands over BLM O&C/CBWR lands since FS lands have no direction to make timber production the dominant use.
N/A

Comment *ST25:* The plan should address the risk that population declines of spotted owls may lag behind protection of habitat and may continue regardless of protection of habitat.
R – see section on Threats Assessment

Comment *ST26:* The plan needs to describe how recovery can be met in southwestern Oregon while allowing the BLM to fulfill its responsibilities for timber production under the O&C Act.
N/A

Comment *ST27:* Option 2 does not comply with two key components of recovery plans, which are a description of site-specific management and objective, measurable criteria.
N/A

Comment *ST28:* Eliminating existing protection of habitat in Federal lands as presented in both options could subvert existing conservation measures such as those in Habitat Conservation Plans and State forest practice rules.
N/A

Comment *ST29* (combined with *Comment ST15*)

Comment *ST30:* The plan should encourage the establishment of a collaborative program of spotted owl conservation with British Columbia.
N/A

Comment *ST31:* The overall number of pairs of spotted owls needed reach recovery is overly influenced by the number of MOCA 1s delineated. For example, adding one small area to an existing MOCA would not increase the number of pairs needed for recovery, but making that new area a MOCA 1 would add 15 pairs.
N/R

Comment *ST32:* The plan needs to describe the rationale for its estimated date of recovery as 2037 for both options.
N/A

Comment *ST33:* The plan should recommend recovery actions that would address the lack of regulatory mechanisms if the spotted owl were delisted.
N/A

SCIENCE

Comment *S1:* The plan does not include or is not based upon the best available science.
R – see sections on Threats Assessment, Conservation Strategy, Habitat Fitness Potential, Barred Owls, Fire etc.

Comment *S2:* The plan omits certain scientific information.
R – see sections on Threats Assessment, Conservation Strategy, Habitat Fitness Potential, Barred Owls, Fire etc.

Comment *S3:* The plan misinterprets certain scientific information.
R – see sections on Threats Assessment, Conservation Strategy, Habitat Fitness Potential, Barred Owls, Fire etc.

Comment *S4*: The plan relies on outdated population modeling.
R – see sections on Conservation Strategy, Population Viability Analysis

THREATS

Habitat

Comment *TH1:* The plan should be based on the NWFP and should protect at least as much habitat as the NWFP does; the plan needs to describe how protection of less spotted owl habitat than that in the NWFP would recover the spotted owl.

R – see sections on Threats Assessment, Conservation Strategy

Comment *TH2:* The plan does not preserve enough habitat to recover the NSO.
R – see sections on Threats Assessment, Conservation Strategy, Habitat Fitness Potential, Barred Owls, Fire etc.

Comment *TH3:* Option 1 is insufficient to recover the NSO.
R – see sections on Threats Assessment, Conservation Strategy, Habitat Fitness Potential, Barred Owls, Fire etc.

Comment *TH4:* Option 1 is a politically motivated option.
N/A

Comment *TH5:* Option 2 is insufficient to recover the NSO.
R – see sections on Threats Assessment, Conservation Strategy, Habitat Fitness Potential, Barred Owls, Fire etc.

Comment *TH6:* Option 2 is a politically motivated option.
N/A

Comment *TH7:* Option 2 has inadequate regulatory oversight.
N/A

Comment *TH8:* Protect all suitable habitat; protect all old-growth forests.
N/A

Comment *TH9:* Protect forests in all public/federal lands or prevent further habitat loss.
N/A

Comment TH10: State-owned land and other public lands need to take key roles/contribute to protections. The plan should include a recovery action concerning how State-owned lands and other public lands can contribute to the recovery of spotted owls while enabling those lands to continue to be managed consistent with their mandated purposes.
N/R

Comment *TH11:* Option 1 does not adequately protect forests from habitat changes including catastrophic fire.
R – see sections on Fire

(We deleted TH12.)

Comment *TH13:* The plan should support connectivity with Olympic Peninsula. At a minimum, there should be a re-analysis of the stability of this population and its role in recovery of the species before reductions in areas protected as is proposed in Option 2 be adopted.

R – see memo response to ‘six focus questions’

Comment *TH14:* The plan should be ecosystem-based, not spotted owl-based.
R – see sections on Threats Assessment, Conservation Strategy, Fire etc.

Comment *TH15:* The plan underemphasizes the threat from habitat loss.
R – see sections on Threats Assessment, Conservation Strategy, Fire etc.

Comment *TH16:* Habitat definitions are too vague (*e.g.,* it is impossible to know when targets are met; low-quality habitat could count for high-quality habitat; old forests could be logged as young forests become 80 years old; no definition of dispersal habitat), too inclusive (*e.g.,* they include open, old-growth, eastside Ponderosa pine forests), confusing (*e.g.,* Recovery Criterion 4 with “listed percentage of high-quality habitat” whereas the table for that criterion lists “percentage of habitat-capable acres in suitable habitat), or inaccurate (*e.g.,* high-quality habitat as defined in plan really defines suitable habitat).
R – see sections on Ingrowth and Habitat quality

Comment *TH17:* The plan overemphasizes the value of HCPs. Recovery Actions that are based on assistance from HCPs should be removed from the plan.
N/A

Comment *TH18:* The plan should evaluate how HCPs contribute to the recovery of spotted owls.
N/A

Comment *TH19:* The plan should address the inadequacy of regulatory mechanisms. For example, it should include an analysis of harvest of spotted owl habitat in non-Federal lands and an analysis of inconsistencies between State rules in Washington, Oregon, and California and Federal guidelines.
N/A

Comment *TH20:* The plan should provide for dispersal habitat or describe why it does not; if it does not, then the Plan should explain why NWFP riparian reserves are no longer needed.
R – see section on Riparian Habitat

Comment *TH21:* Option 2 would allow BLM to escape its responsibility to conserve the spotted owl via the Western Oregon Plan Revisions.
N/A

Comment *TH22:* The plan should encourage use of variable density thinning in matrix and reserves.
R – see sections on Habitat Restoration and Salvage

Comment *TH23:* The plan should encourage managing for decadence.
N/R

Comment *TH24:* The plan should not rely on in-growth of suitable habitat until those forests have been verified to be of high quality.
R – see section on Ingrowth and habitat Quality

Comment *TH25:* Option 2 should not allow currently suitable habitat to be logged in habitat blocks if habitat-capable forest is included in its place.
N/A

Comment *TH26:* Option 2 makes regulatory mechanisms inadequate because local BLM and FS districts can decide on the locations of habitat blocks without regional perspectives, and these decisions can be influenced by timber interests.\ N/A

Comment *TH27:* The size, spacing, and location of reserves should be modified to ensure spotted owls will persist in the presence of barred owls.
R – see sections on Threats Assessment, Conservation Strategy, Threats Interactions Barred Owls, Fire etc.

Comment *TH28:* There should be no logging in reserves.
N/A

Comment *TH29:* Purchase conservation easements from private landowners to develop habitat.
N/A

Comment *TH30:* The options should provide scientific analyses connecting performance of spotted owl populations and habitat-management actions to allow a comparison of whether the management approaches have high, medium, low, or no probability of meeting the recovery criteria.
R – see sections on Population Viability Analyses, Monitoring of Treatments, Adaptive Management

Comment *TH31:* The plan should include site-specific management actions; both options have vague and shifting management guidelines and fail to provide site-specific management actions, especially in Option 1 habitat blocks; the plan should put more emphasis on efforts to restore and enhance suitable habitat.
R – see sections on Regional Differences, Conservation Strategy, Fire, Habitat Restoration etc.

Comment *TH32:* The plan should recommend protecting all Federal land in which there are active, reproducing spotted owl sites.
N/A

Comment *TH33:* The plan should recommend that Federal agencies be prevented from habitat alteration within 500 meters of known, occupied spotted owl site-centers.
R – see sections on Owl response to fire, and Fire Management

Comment *TH34:* The recovery criterion should include reproductive output (not just total numbers) of spotted owls in the reserves
N/R

Comment *TH35:* The plan recommends conducting silvicultural treatments to help restore spotted owl habitat and accelerate its development. It also needs to recommend monitoring of stands in which such work has been done to evaluate whether spotted owls are establishing territories there.
R – see sections on Monitoring of treatments and Adaptive Management

Comment *TH36:* The plan inappropriately estimated percentages of suitable habitat needed by province (Recovery Criterion 4) by misinterpreting scale, lambda (h), and overall approach used in certain publications (i.e., Franklin *et al.* 2000, Olson *et al.* 2004, Dugger *et al.* 2005).
R – see section on Habitat Fitness Potential

Comment TH37: More information is needed concerning the meaning of "habitat-capable." It is unclear why, if they are capable of supporting 15 or more pairs, they are not currently inhabited by 15 or more pairs. If they are not inhabited by 15 or more pairs, it is questionable whether they are in fact capable of supporting that number of owls.
N/R

Comment TH38: Habitat blocks that are not currently capable of supporting 15 or more pairs of spotted owls should be enlarged so that they currently include enough habitat to support 15 or more pairs. These blocks could be decreased in size in the future; such decreases should maximize the numbers and distribution of spotted owls at that time.
N/A

<u>Barred Owl</u>

Comment *TB1:* The plan underemphasizes the barred owl threat.
R – see sections on Threats Assessment, Barred Owls

Comment *TB2:* The plan overemphasizes the barred owl threat.
R – see sections on Threats Assessment, Barred Owls

Comment *TB3:* Do not shoot barred owls; shooting barred owls will not be successful.
R – see sections on Threats Assessment, Barred Owls

Comment *TB4:* The plan needs a contingency plan for the barred owl.
R – see sections on Threats Assessment, Barred Owls

Comment *TB5:* Barred owls are part of the natural system and so should not be controlled; it is survival of the fittest.
N/A

Comment *TB6:* The plan should provide some incentives to pursue controlling of barred owls.
N/A

Comment *TB7:* Portions of the plan should be reworded to show that a causal link has not been established showing that barred owls negatively affect spotted owls. Consequently, specific prescriptions relative to control of barred owls (e.g., Recovery Action 6, Appendix G) should be removed from the plan.
R – see sections on Threats Assessment, Barred Owls

<u>Fire</u>

Comment *TF1:* The plan underemphasizes the threat from fire; for example, wildfire has accounted for more habitat loss (3.03%) in the past 10 years than has timber harvest (2.11%; Lint et al. 2005).
R – see sections on Owl responses to Fire, Fire modeling, and Climate Change

Comment *TF2:* The plan overemphasizes the threat from fire.
R – see sections on Owl responses to Fire, Fire modeling, and Climate Change

Comment *TF3:* Salvage logging should be banned, or not encouraged, especially in reserves.
R – see sections on Habitat Restoration and Salvage

Comment *TF4:* The plan should not standardize salvage prescriptions, and should not include such site-specific considerations such as limiting the use of shaded fuels breaks (in Recovery Action 25).
R – see sections on Habitat Restoration and Salvage

Comment *TF5:* The plan should encourage managing forests within historic fire regimes.
R – see sections on Owl responses to Fire, Fire modeling, and Climate Change

Comment *TF6:* The plan should develop clear criteria to balance fuels reduction and conservation of spotted owl habitat.
R – see sections on Owl responses to Fire, Fire modeling, and Climate Change

Comment *TF7:* There should be more reserves or larger reserves to compensate for forests lost to fires and other disturbances.
R – see sections on Conservation Strategy, Owl responses to Fire, Fire modeling, and Climate Change

Comment *TF8:* Fuels reduction in reserves should rely on non-commercial, thin-from-below management.
R – see section on Fire Management

Comment *TF9:* The plan should suggest specific objectives and desired outcomes for management of forests to reduce fire risk that are stratified by forest type and fire regime.
R – see sections on Conservation Strategy, Owl responses to Fire, Fire modeling, Klamath, and Climate Change

Comment *TF10:* The plan has higher expectations for percentages of suitable habitat than does FS LSR Assessments (*e.g.,* those in the Eastern Washington Cascades); many dry forests cannot support 60% spotted owl habitat, so such a requirement would severely restrict possible management; the plan should not recommend against management in fire-prone forests.
R – see sections on Owl responses to Fire, Fire modeling, and Climate Change

Comment *TF11:* The plan should include a Recovery Action to monitor/research how fuels-reduction treatments affect: (1) the risk of loss of spotted owl habitat; use of forests by spotted owls; prey of spotted owls; and interactions between spotted owls and barred owls.
R – see sections Monitoring of Treatments

Comment *TF12:* Recovery Action 21 (use of best-available scientific information relative to salvage activities) should be priority 1, not 3.
N/A

Climate

Comment *TC1:* The plan underemphasizes the threat from climate change.
R – see sections on Owl responses to Fire, Fire modeling, and Climate Change

Comment *TC2:* The plan overemphasizes the threat from climate change.
R – see sections on Owl responses to Fire, Fire modeling, and Climate Change

Comment *TC3:* Reserves should be larger to accommodate climate change.
R – see sections on Owl responses to Fire, Fire modeling, and Climate Change

Comment *TC4:* There should be a Recovery Action to address possible effects from climate change.
N/A

Disturbance

Comment *TD1:* The plan does not address disturbance to spotted owls in reserves.
N/A

Disease

***Comment** TDI1:* The plan should include accommodation for effects from West Nile Virus.
R – see section on Threats

***Comment** TDI2:* The plan should include a description of the effects from Sudden Oak Death and accommodation in reserves for habitat lost to it.
R – see section on Threats

MONITORING

***Comment** M1*: Recovery Criterion 3 states: "..within a period of 5 consecutive years, in each State at least 80 percent of [MOCA 1s][large habitat blocks] contain at least 15 occupied spotted owl sites." The plan should explicitly state which agency is responsible for monitoring of many hundreds of spotted owl sites; land-management agencies should not be responsible for this.
N/A

Comment M2: The current monitoring approach using well-distributed demographic study areas is yielding crucial information. This data set exceeds 20 years and provides detailed information on the population dynamics of the species that would no longer be obtained using methods based only on monitoring occupancy (presence or absence) of sites by owls, as is being considered. Additional monitoring approaches should complement the current approach, not replace it.
N/R

COSTS

***Comment** C1:* The plan should include costs and benefits from additional timber harvest facilitated by the plan.
N/A

***Comment** C2:* The plan should include total costs, not leave many as "TBD" (to be determined).
N/A

***Comment** C3:* The plan should include costs associated with coordination needed among agencies (BLM, FS, and FWS), among BLM districts, and among FW districts to identify Option 2 habitat blocks
N/A

Comment *C4:* The plan underestimates costs (*e.g.,* relative costs of fuels reductions attributable to spotted owls; habitat inventories, aerial photographs, and mapping; managing habitat-capable acres).
N/A

Comment *C5:* The plan should include estimates of the loss of timber revenues due to carrying out the plan.
N/A